PROGRAM INSTALLATION

The Pathloss program is supplied on a CD-ROM and requires a USB hardware key in order to operate. The USB hardware key must be connected to the computer before starting the program and remain connected during the program operation. The program uses the Borland database engine (BDE Version 5.0) for interference calculations and the site database. Other programs such as Word Perfect and Paradox use the same database engine and this may already be installed on your computer. The installation will automatically detect BDE and only carry out the installation if it does not exist or an earlier version is installed. BDE is supplied as a Borland redistributable product.

HARDWARE REQUIREMENTS

The recommended operating system is Windows 2000/XP. The program will not run on Windows 95 or Windows NT 3.51/4.0. The following are the recommended hardware requirements

- PC with 300 megahertz or higher processor clock speed recommended; 233 MHz minimum required (single or dual processor system);* Intel Pentium/Celeron family, or AMD K6/Athlon/Duron family, or compatible processor recommended

- 128 megabytes (MB) of RAM or higher recommended (64 MB minimum supported; may limit performance and some features)

- 1.5 gigabytes (GB) of available hard disk space

- Super VGA (800 x 600) or higher-resolution video adapter and monitor

- CD-ROM or DVD drive

- Keyboard and wheel mouse is recommended or other compatible pointing device

- Available USB port

INSTALLATION

The installation uses InstallShield for the basic Pathloss program and BDE. This is a common commercially available installation program. The setup program runs automatically when you insert the CD-ROM in your drive. If it does not start, click *Start - Run* and enter D:\SETUP assuming that the CD-ROM drive is D and click OK. The installation program will guide you through the process.

Uninstalling the Pathloss Program

The removal of all files and registry entries is carried out with the Windows Add /Remove Programs procedure. Click Start - Settings - Control Panel and select Add /Remove Programs. Select Pathloss from the list of software that can be automatically removed and click the Remove button.

Pathloss Program Files

The basic Pathloss program consists of the following files:

Table 1: Pathloss Program Files

PLW40.EXE	Pathloss executable file	These files are supplied with a maintenance update as a self extracting executable file. Refer to the Maintenance Update section for details.
PLW40DBS.DLL	Terrain database dynamic link library	
PLW40LIB.DLL	Pathloss dynamic link library	
*.HLP	Pathloss help files	
ENGLISH.MNU	Language support files. The file *.MNU and *.LNG contain all text in the program. Refer to the Language Support section.	
ENGLISH. LNG		
MENUDEFS.RH		
BDS52F.DLL	Borland dynamic link library files. These files have been modified and must not be replaced with other Borland libraries.	These files are supplied with the original shipment and are not part of the maintenance update.
CW3230.DLL		
OWL52F.DLL		
PASSIVE.BIN	Binary data files for rectangular passive repeaters, datums and coordinate transformation data. The TIMEVARB.BIN file contains the digitized time variability curves. These are read only files.	
PL_DATUM.BIN		
PL_REGNS.BIN		
PL_ELIPS.BIN		
TIMEVARB.BIN		
PLW_LOGO.EMF	Default program logo	

With the exception of the logo, all of the above files must be present in the Pathloss program directory to start the program. If the BDE database engine cannot be initialized, all menu items which require BDE will be disabled.

Option Files

The Pathloss program uses two options files:

PLW40.OPT   This is a general option file which saves all user settings on exit. By default, this file is saved in the Pathloss program directory. On a network, the program will check the environment variable PLW40DIR to determine if there is a private directory to save the option file in.

PLW40DBS.OPT   This file contains all terrain database options and settings. It is always saved in the Pathloss program directory.

MAINTENANCE UPDATE

The version number of the Pathloss program does not change. It is always 4.0. The releases are identified by the program build date. Click Help - About on the Pathloss menu bar to display the program release status.

The Pathloss program is maintained from the CTE web site http://www.pathloss.com. The maintenance update consists of a single file - PLW40HMU.EXE. This is a self extracting executable WinZip file which contains only the required maintenance update files shown in Table 1. Download this file to a temporary directory on your computer. Follow the steps below to upgrade your current program.

- Ensure that the Pathloss program is not running.

- Make a note of the Pathloss program directory.

- Select Start - Run and then browse for the file PLW40HMU.EXE.

- The Overwrite Files Without Prompting option must be checked.

- If necessary, change the Unzip to Folder entry to the Pathloss program directory.

- Click the Unzip button. This will extract the required files.

The updated Pathloss program is now ready to run.

The options files PLW40.OPT and PLW40DBS.OPT may change in subsequent program builds. These files contain the program options and user settings. The maintenance update will always overwrite these files with default values.

If the program is installed on a network, the options file PLW40.OPT is located on the users' hard disks. In this case it will be necessary to delete this file on the remote terminals before using the updated program.

PROGRAM UPGRADE

The Pathloss program is offered with the Microwave Interference and Area Coverage features as options which can be added at a later date. The documentation for these options are always included in the original shipment.

A program upgrade is supplied as a single file, either as an Email attachment or on disk. The file name is derived from the serial number of your Pathloss program (e.g. 010A-110.E2D). In the Pathloss program,
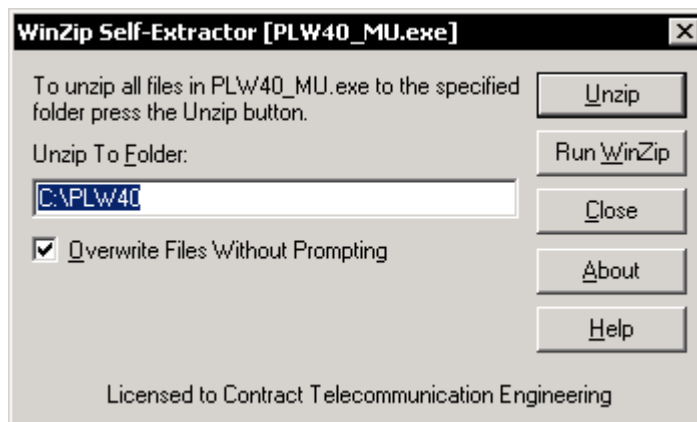
select Configure - Program - Upgrade and load the upgrade file. When the upgrade operation is complete, it is necessary to close and restart the Pathloss program to access the new features.

GENERAL PROGRAM OPERATION

PROGRAM ORGANIZATION

The program is organized into 10 modules. These are accessed from the Module menu. The format of the Summary, Antenna Heights and Worksheet modules will depend on the application (Microwave or VHF-UHF). The basic functions of these modules are summarized below.

Table 2: Pathloss Program Modules

Summary	This is the default startup module. It provides a central data entry display for the site data and application specific options. The Summary module is the interface to the site database. Interference calculations using the site database are made in this module.
Terrain Data	The Terrain Data module is used to create / edit a path profile using manual data entry, a digitizing table or a terrain database.
Antenna Heights	The Antenna Heights module calculates the antenna heights which satisfy a set of clearance criteria.
Worksheets	Two worksheet formats are provided for microwave and VHF-UHF applications. The selection is made in the Summary module under Application. The worksheet provides detailed data entry forms for equipment and path parameters required for transmission calculations. Multipath propagation reliability and rain attenuation are calculated in the microwave worksheet.
Diffraction	The diffraction module is used to calculate diffraction and tropospheric scatter loss on transmission and interference paths. Diffraction loss as a function of antenna heights, frequency and earth radius factor can also be calculated here.
Reflection	The Reflection module analyzes the effects of a single specular reflection on a path. The analysis is based on a user defined reflective plane.
Multipath	The Multipath module employs ray tracing techniques to determine the reflective characteristics of a path using either a constant or variable refractivity gradient.
Print Profile	Profile printing using a variety of formats is carried out in this module.
Network Map Grid	The Network and Map Grid modules provides a graphical representation of a network of sites. Each link in the network contains a reference to its Pathloss data file. Any of the design modules can be accessed for the selected path from the Network module. Intra system interference calculations are made in the network module. Map Grid is available as part of the Microwave Interference or Area Coverage module.
Coverage	Signal and line of sight coverage displays are calculated in this module. These can be imported into the network module for multi site analysis.

A terrain profile must exist to access the Antenna Heights, Diffraction, Reflection and Multipath modules.

DATA ENTRY

Two data entry forms are used throughout the program for data entry. This paragraph describes the basic features in each form.

Standard Data Entry Form

The standard data entry form is shown at the right. Move the hilited bar to the desired field using the mouse or cursor keys. The value is entered at the bottom of the display in response to the prompt. Press the Enter, Tab or one of the cursor keys to enter the value. Changing fields with the mouse will not enter the value.

Fields which cannot be accessed are shown in blue letters. This may be a calculated field or not editable for some reason.

Inverse Coordinates (Clarke 1866)

OK   Cancel   Help

	Brownvale	Peace River
Latitude	56 04 24.00 N	56 14 11.00 N
Longitude	117 52 47.00 W	117 15 45.00 W
True azimuth (°)	64.4145	244.9271
Distance (km)	42.4371	
Easting (km)	445.2364	483.7279
Northing (km)	6214.3764	6232.2069
UTM zone	11N	11N

Brownvale Latitude : |

- Select the OK menu item to accept the data entry. If Cancel is selected, the data will change back to the original values.

- To erase an entry, select the field and press the F3 key. Note that some data entries are mandatory and cannot be erased.

- To edit an existing entry, select the field and press the F2 key.

- In the Worksheet module only, a data entry can be copied from one site to another. Select the field to copy to and press the F4 key.

Grid Data Entry Display

Site List

Import   Edit   Update Files   Reports   View   Transform Coords.   Help

	Layer	Site Name	Type	Sector number	Call Sign	Latitude	Longitude	Elevation (m
1	Site Layer 1	Beaverlodge	point to point		CHW611	55 12 50.10 N	119 16 08.10 V	30
2	Site Layer 1	Brownvale	point to point		CHW615	56 04 24.00 N	117 52 47.00 V	20
3	Site Layer 1	Fairview	point to point		CHW614	55 50 14.00 N	118 35 48.00 V	574
4	Site Layer 1	Grande Prairie	point to point		VBC888	55 12 21.80 N	118 44 26.90 V	22
5	Site Layer 1	Peace River	point to point		CHW616	56 14 11.00 N	117 15 45.00 V	17
6	Site Layer 1	Woking	point to point		CHW613	55 28 47.00 N	118 44 50.00 V	925

The grid data entry display is used when a variable number of entries is required such as the site list in the Network module or in a lookup table. The following data types are used: numeric, text, boolean (e.g horizontal or vertical polarization) and drop down lists.

Existing fields can be edited directly on the display. First select the field and proceed as described below for the specific data type:

boolean   Double click the left mouse button on the field or press the Enter key.

drop down list	Double click the left mouse button on the field or press the Enter key to display the drop down list. Then select the item from the list with the mouse or the cursor keys followed by the Enter key.
text - numeric	Activate the edit mode for the selected field by pressing the Enter key or space bar or double click on the field. Make the required changes and then cancel the edit mode with the Enter, tab or up - down cursor keys.

To add a new record or edit an existing record, the Add - Edit menu must be used. Each grid display has a specific menu for its own purpose; however, a Edit menu selection is included except on read only lists.

To edit an existing record, first select the record and then select Edit - Edit from the menu bar to access the Edit Item form. Note that only the numeric and text fields appear in this form. Select OK on the menu bar to accept the changes or Cancel to ignore the changes.

To add a new record, select Edit - Add from the menu bar to access a blank Add Item form. The OK menu item will remain disabled until the mandatory data entries for that form are complete. Press the Enter key after completing the last field to enable the OK menu item.

Edit Item 2	
OK Cancel	
Site Name	Brownvale
Sector number	
Call Sign	CHW615
Latitude	56 04 24.00 N
Longitude	117 52 47.00 W
Elevation (m)	20.00
Structure Height (m AMSL)	
Easting (km)	445.236
Northing (km)	6214.376
UTM zone	11N

Often a new record is required which is only slightly different from an existing record. Click the left mouse button on the item number in the left side column. The item number will change to red text. Then select Edit - Add from the menu. The Add Item form will be initialized with the fields of the selected record.

Select OK on the menu bar to add the new record or Cancel to ignore the new record. A duplicate record is not allowed and will be rejected.

The records in some grid displays can be sorted. Click the left mouse button on a column header to sort the data in an ascending order based on that column.

Add Item	
OK Cancel	
Description	Andrew UHX10-56
Antenna model	UHX10-56 (L)
Gain (dBi)	42.90
Code	A1637C
BW	1.10
Antenna diameter (m)	3.05
Rad loss (dB)	
Freq Lo (MHz)	5600.00
Freq Hi (MHz)	6200.00

PROFILE DISPLAYS

Profile displays are used in most design modules. The basic operation of these displays is described below. The above display used to define a reflective plane in the Reflections module is a typical example of a profile display.

The terrain profile is preconditioned so that the minimum distance between profile points is one percent of the path length. Points are inserted to meet this requirement using linear interpolation. Most displays show the flat earth profile with a diagonal fill pattern and a second profile above which represents the effects of earth curvature. The earth radius factor (K) will either be displayed on the status bar or as a selection in a drop down list on the control bar. The latter case is illustrated in the above profile display example.

Profile displays use a cursor for various operations. The cursor is positioned on the display using the cursor keys or by clicking the left mouse button on the display. The cursor style and movement are described below:

Cursor Style
The default cursor style is a red arrow. Press the letter 'A' to change between an arrow and lines to the antenna. The latter is useful in assessing the clearance from some point to the antennas. The cursor style is also shown on the status bar as 'A' of 'L'. Alternately, click the left mouse button on this letter to change the cursor style.

Cursor Movement

Three cursor movement methods are used in the profile display:

P   The cursor can be positioned on any point of the terrain profile.

S   The cursor can only be positioned on peaks of the profile.

C   The cursor can be positioned anywhere on the display.

The letters P, S or C appear on the status bar. The continuous mode is only implemented in the Diffraction module. To change the cursor movement press the letter for that movement or click the left mouse button on the letter in the status bar.

Selecting a Segment of the Profile

Many calculations involve the selecting a segment of a terrain profile. Several examples are:

• Defining the end points of a reflective plane.

• Terrain roughness calculations.

• Inhibiting reflections over a portion of the profile.

• Manual diffraction loss calculations.

The basic procedure, in all cases, is as follows:

• Place the cursor at one end of the segment and press the F1 key or click the right mouse button. The cursor will change color to indicate that it has been selected.

• To cancel the first point selection, press the F8 key or click the reset button on the display.

• Move the cursor to the opposite end of the segment and press the F1 key again or click the right mouse button.

Terrain Data Point Information

Press the Ins key for information on the point at the cursor location. The format will vary depending on the design module. Alternately, click the left mouse button on the cursor location box on the status bar.

Status Bar Functions

The status bar, on most displays, includes short cut operations to commonly used functions. For example, in the above profile display, the method used to define the reflective plane can be selected by clicking the right mouse button on the method box on the status bar.

Click on each box in the status bar to determine if additional functionality has been implemented.

Terrain Data Point	
Distance (km)	3.54
Elevation (m)	442.79
Frequency (MHz)	5800.00
Earth Radius Factor K	1.33
Earth Bulge (m)	0.75
Clearance (m)	39.61
First Fresnel Zone (F1) (m)	9.60
Clearance /F1 (%)	412.47
Left Side Angles (°)	-0.532 0.508
Right Side Angles (°)	0.762 -0.786

Fresnel Zone Reference

Fresnel zone reference area is an essential part of any terrain profile analysis. In profile displays, the Fresnel zone dialog is accessed from the menu bar or with the F2 key.

The Fresnel zone reference can be expressed as a percentage of the first Fresnel zone reference or as a Fresnel number (e.g. F2 = 1.414 F1).
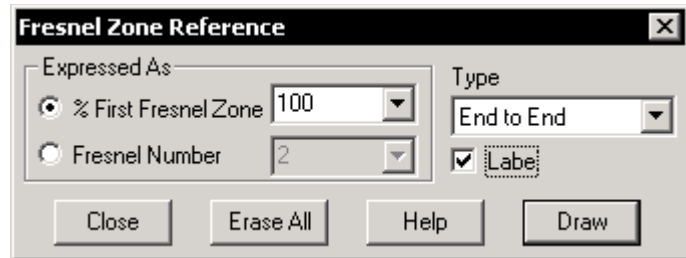
Several types of Fresnel zone references are available. On line of sight paths the Fresnel zone references are always drawn from end to end. On obstructed paths, a more meaningful representation is achieved by drawing the Fresnel zones between the horizons.

If a reflective plane has been defined, the Fresnel zones can be drawn to the reflection point. This provides a visual representation of the area along the profile required to support a specular reflection.

If the label box is checked, the Fresnel zones reference will be written at the mid point.

There is no limit to the number of Fresnel zone references. Each design display maintains its own list of Fresnel zone references and these are saved with the data file.
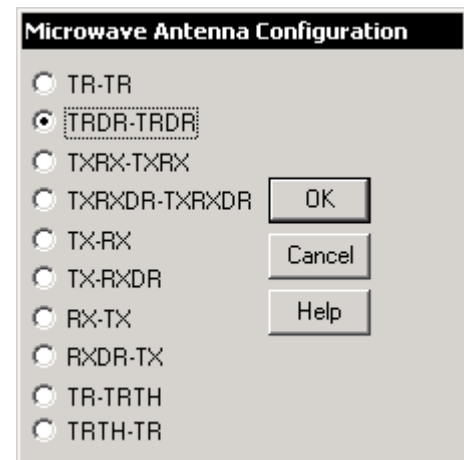
CONFIGURATION MENU

The Configuration menu selection contains program options and settings which are common to several modules in the program.

Antenna Configuration

All calculations and analysis in the program are based on an antenna configuration. The following terminology describes the antenna usage in microwave applications.

TR   the antenna is used to transmit and receive

TX   the antenna is used to transmit only

RX   the antenna is used to receive only

DR   the antenna is used to receive only in a space diversity configuration

TH   the antenna is used to transmit and receive in a hybrid diversity configuration

In VHF- UHF applications, the antenna usage is limited to TR, TX and RX.

These antenna types are combined into antenna configurations as shown in the following two tables.

Table 3: Antenna Configurations

| Two Way Antenna Configurations - Microwave Applications	
TR-TR	A single antenna is used at each site to transmit and receive.
TRDR-TRDR	Two antennas are used at each site in a space diversity configuration. The TR antenna is used to transmit and receive. The DR antenna is the diversity receive only antenna.
TXRX-TXRX	Two antennas are used at each site to transmit (TX) and receive (RX).
TXRXDR-TXRXDR	Three antennas are used at each site to transmit (TX), receive (RX) and space diversity receive (DR).
TR-TRTH TRTH-TR	This is a hybrid diversity configuration which uses frequency diversity in both directions and space diversity at one end of the path only. At the space diversity end, the TR antenna and TH antenna each transmit and receive one pair of the frequencies. The two configurations determine which site is equipped with space diversity.
One Way Antenna Configurations - Microwave Applications	
TX-RX RX-TX	Transmit at one site and receive at the other. The two configurations identify the transmit and receive sites.
TX-RXDR RXDR-TX	Transmit at one site and diversity receive at the other. The two configurations identify the transmit and receive sites.

Antenna Configurations - VHF-UHF Applications	
TR-TR	A single antenna is used at each site to transmit and receive.
TR-TXRX	A single antenna is used at Site 1 to transmit and receive. Separate antennas are used at site 2 to transmit and receive.
TXRX-TR	This is the reverse configuration of the above TR-TXRX configuration.
TXRX-TXRX	Two antennas are used at each site to transmit (TX) and receive (RX).

Select Configure - Antenna Configuration from the Pathloss menu bar to change the antenna configuration. If the antenna configuration is displayed on the status bar, you can also click the left mouse button on the configuration box.
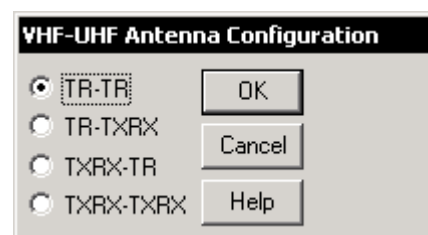
Antenna Combinations

Diversity and separate transmit and receive antenna configurations have several antenna combinations. Each combination must be analyzed separately. Select Configure - Antenna Configuration on the menu bar. Alternately, if the current antenna configuration is displayed on the status bar, click the left mouse button on the antenna combination in the status bar to select a new combination. The selection will be formatted for the current application setting (microwave or VHF-UHF).
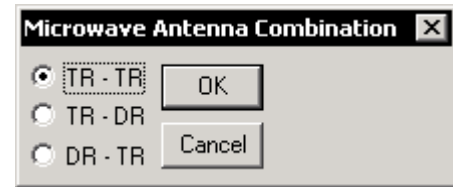
Antenna Heights

The antenna heights can be set in any design module in the program. Select Configure - Antenna Heights to access the data entry form. This will be formatted for the selected application (microwave or VHF-UHF) and for the antenna configuration. The tower height and minimum antenna heights are used as the default values in calculations which vary the antenna height.

	Woking	Fairview
TR Antenna Height (m)	79.20	55.20
Tower Height (m)	108.00	108.00
Minimum Antenna Height (m)	5.00	5.00
True azimuth (°)	13.33	193.45

Fairview Minimum Antenna Height (m) :

The true azimuth is determined from the geographic coordinates and is for information purposes only.

Geographic Defaults

Select Configure - Geographic Defaults from the Pathloss menu bar to access the Geographic Defaults dialog box.

Use Datum or Ellipsoid

An ellipsoid is defined by its major and minor axis. These are used to calculate distance and azimuths from the geographic coordinates and to convert geographic coordinates to grid coordinates such as UTM. A datum defines the horizontal measurement plan. Each datum is based on an ellipsoid, and contains measured correction factors to allow geographic coordinates defined in one datum to be transformed to another.

In most cases, the "Use Datum" option should be selected. This will allow coordinate transformation between datums (e.g. NAD-27 ⟺ NAD-83). This is important when using terrain databases with a horizontal datum different from the topographic maps. A typical example is a DTED terrain database which uses the WGS-84 datum and site coordinates referenced to the NAD-27

datum. If the user has specified the NAD-27 datum, then the site coordinates will be automatically transformed to WGS-84 to generate the profile.

The "Use Ellipsoid" option is required to handle specialized regional mapping. An example of this is Switzerland, which generally uses the European Datum of 1950. This datum uses the International (1924) ellipsoid. The Swiss grid coordinate system on the other hand uses the Bessel 1841 ellipsoid. In this case, the "Use Ellipsoid" option should be used.

Datum Selection
First select the datum and then select the specific region for the datum. The requirement for the region selection is necessary because there is no general equation to transform coordinates from one datum to another. The transformation uses data to determine the new coordinates. The breakdown of regions within a datum is a compromise between the transformation accuracy and the number of regions. Note that a datum selection automatically defines the ellipsoid.

Ellipsoid Selection
If the "Use Ellipsoid" option has been checked, select the specific ellipsoid from the drop down list.

Latitude Formats
If the latitude is set to the northern hemisphere, a minus sign must immediately precede the latitude degrees entry to specify a southern latitude. If the southern hemisphere is selected, the opposite is true. The letters 'N' and 'S' can be used to specify a northern or southern latitude respectively. In UTM coordinates, the northing entry must be a negative number for a southern latitude.

Northern Hemisphere SelectedSouthern Hemisphere Selected

Data Entry	Result	Data Entry	Result
49 32 24	49 32 24.0 N	49 32 24	49 32 24.0 S
-49 32 24	49 32 24.0 S	-49 32 24	49 32 24.0 N
49 32 24 S	49 32 24.0 S	49 32 24 N	49 32 24.0 N

Longitude Formats
If the longitude is set to the western hemisphere, a minus sign must immediately precede the longitude degrees entry to specify an eastern longitude. If the eastern hemisphere is selected, the opposite is true.

The letters 'E' and 'W' can be used to specify a eastern or western longitude respectively.

Western Hemisphere SelectedEastern Hemisphere Selected

Data Entry	Result	Data Entry	Result
115 32 24	115 32 24.0 W	115 32 24	115 32 24.0 E
-115 32 24	115 32 24.0 E	-115 32 24	115 32 24.0 W
115 32 24 E	115 32 24.0 E	115 32 24 W	115 32 24.0 W

Precision
Geographic coordinates can be formatted to the nearest second, nearest 0.1 second or the nearest 0.01 second. This does not affect the calculations, because the coordinates are saved as double precision numbers.

Grid Coordinate System

A grid coordinate system represents the simplest method of taking coordinates from a topographic map and guarantees a high degree of repeatability. The following grid coordinate systems are currently supported:

UTM (Universal Transverse Mercator)	Irish National grid
Gauss conformal (South Africa)	UK National grid
New Zealand grid	Swiss Grid
Irish Grid	WGS-84 to MG1 Austria
Gauss Kruger (user defined format)	WGS-84 to HGRS87 Greece

The data entry forms for inverse and forward coordinates will be formatted for the selected grid coordinate system.

Edit K List

Some profile displays provide an earth radius factor (K) selection in the drop down list in the control bar. The drop down list contains commonly used values of K. To add or edit this list, select Configure - Edit K List from menu bar. A maximum of 10 different values of K can be entered. This list of K values is saved in the Pathloss data file and becomes the default list each time the program is started.

Fonts

Select Configure - Fonts to change the attributes of the axis and titles fonts. The axis font is used on all profile and chart displays and for the map grid in the network module. The titles font is used for the titles in chart displays and the print profile module.

Edit K List

	K Values
1	0.66
2	0.80
3	1.00
4	1.33
5	2.00
6	5.00
7	10.00
8	1000.00
9	
10	
1:	

Display Options

Select Configure - Display Options to set the program display options.

Colors

Click on the color box associated with a color selection. The color can be changed by clicking on one of the predefined colors or by using the Red - Green - Blue scroll bars. The profile can be drawn using a solid or hatched fill.

Line Widths

Click on the line width box associated with a line width selection. Change the line width using the up down control or type in the value directly.

Logo

An optional company logo can be displayed in the Summary module and in reports. The logo must be a windows enhanced metafile and can be created with any vector type drawing program. The image should be cropped before saving.
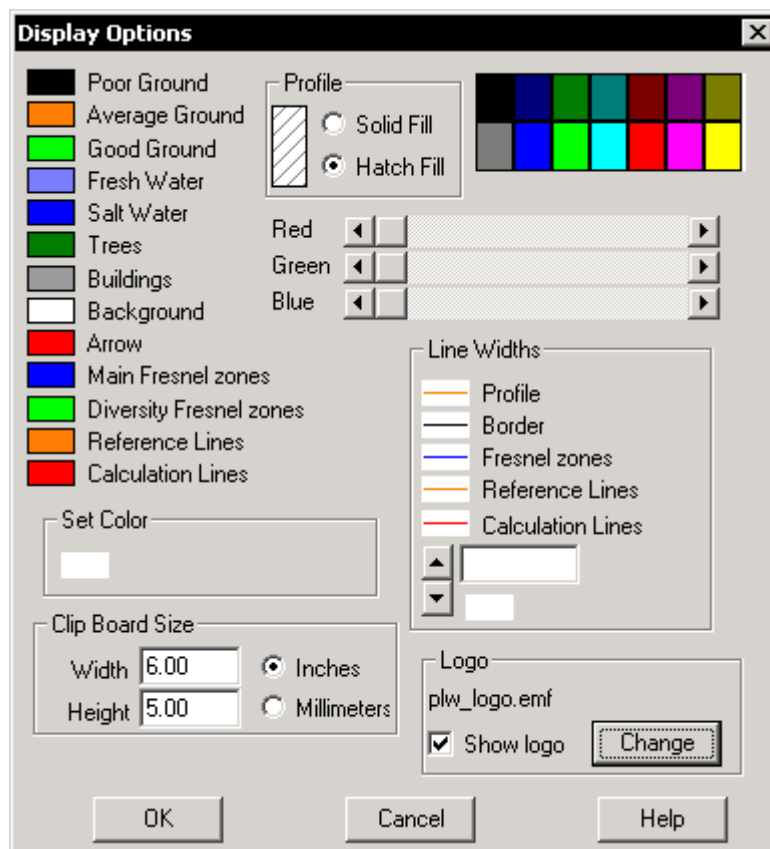
Clipboard Size

This option simply sets the default dimensions of all graphic displays which are copied. The image can always be rescaled after being pasted into another document.
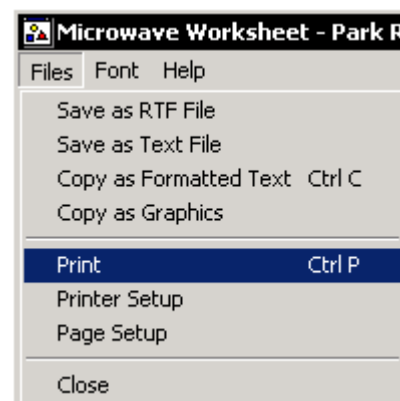
REPORTS

Each report in the program provides the following print options:

Save as RTF File

The report is saved as a Rich Text Format file and retains all formatting. Reports can be appended to the file which will allow you to transfer multiple reports to your word processor. The divider lines on worksheets will not be printed.

Save as Text File

The report is saved as an ASCII text file. The report is first generated using a fixed pitch Courier font to determine the format. Reports can be appended to each other in the same file. The divider lines on worksheet reports will not be saved.

Copy as Formatted Text

The report is copied as an RTF file. Most word processors accept this clipboard format. In your word processor, the report is pasted with the Ctrl V key combination. This is equivalent to saving the report as an RTF file and then loading the file into your word processor. The divider lines on worksheets will not be copied.

Copy as Graphics

The report is copied as a graphics image. This is the only way to copy the worksheet divider lines. The report cannot be edited as conventional text in your word processor.

Page Setup

The Page Setup dialog sets the format and options for direct report printing. The options include the margins, page orientation, and a report header. The current logo can be printed on the header.

Worksheets and interference reports retain their options. All other reports share the same options. The contents of the Pathloss note pad can be appended to a report. This option does not apply to interference reports.

Font

The same font face is used in all reports. Worksheets and interference reports retain their point size settings. All other text reports use the same point size.
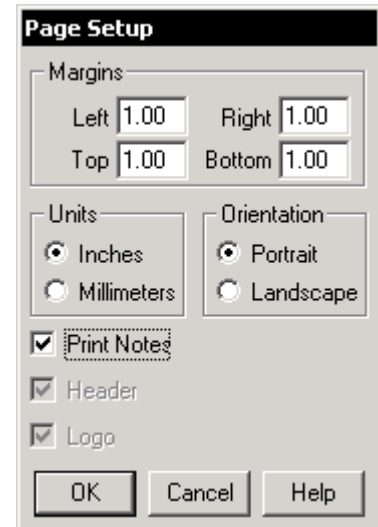
PATHLOSS NOTEPAD

A Pathloss data file provides for general notes and comments in the form of a note pad. Select Module - Notes from the menu bar. The notes only apply to the current Pathloss data file; and therefore, notes cannot be accessed from the Network or Coverage Modules. The note pad uses a standard Windows edit control and includes the copy and paste functions. Notes can be appended to any of the text reports.

PRINT PROFILE

Three profile formats are available in the Print Profile module under the Format menu selection. The color selection and line widths are set under Configure - Display Options. In space diversity microwave applications, different colors are available for main and diversity Fresnel zone references. This is also set in the Display Options.

The font face and size is set under Configure - Fonts - Axis / Titles. The titles font is used for the site names, the horizontal and vertical labels and the title block. The axis font is used for the axis and all site data.

The following profile formats are available in the Print Profile module.

Flat Earth

The lower filled profile at the bottom of the display represents the flat earth profile (K = ∞). Additional profiles are drawn above this for each specified earth radius factors (K). Up to four different values of K can be specified. Four different Fresnel zone references can also be specified. In microwave applications, the these can be drawn between the main antennas or the main - diversity antenna combinations.
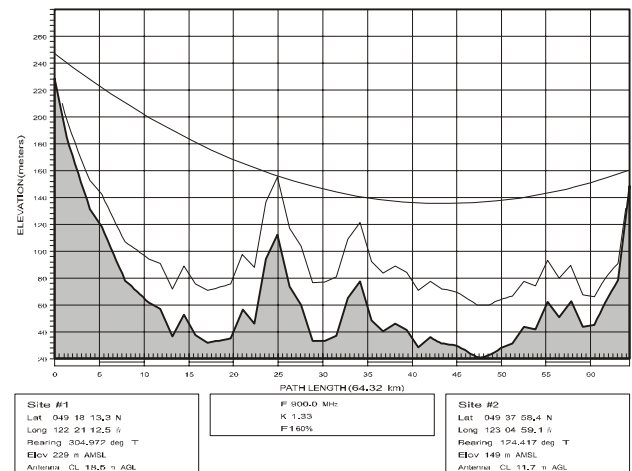
The Fresnel zones can be expressed as a percentage of the first Fresnel zone or as a Fresnel number. These can either be drawn from end to end or between the horizons if the path is obstructed.

In microwave applications, the clearance criteria can be used to define the values of K, Fresnel zone references and the antenna combinations.

Two options common to all profile formats are:

Draw Grid   This option controls the vertical and horizontal grid lines.

Draw Rays   The rays are the straight lines between the site 1 and site 2 antennas.

Curved Earth - Straight Axis

The curved earth - straight axis format is limited to a single value of the effective earth radius factor (K). All other format options are identical to the flat earth format.
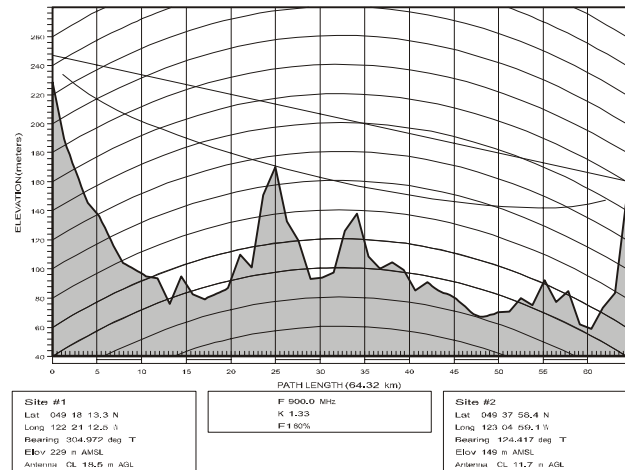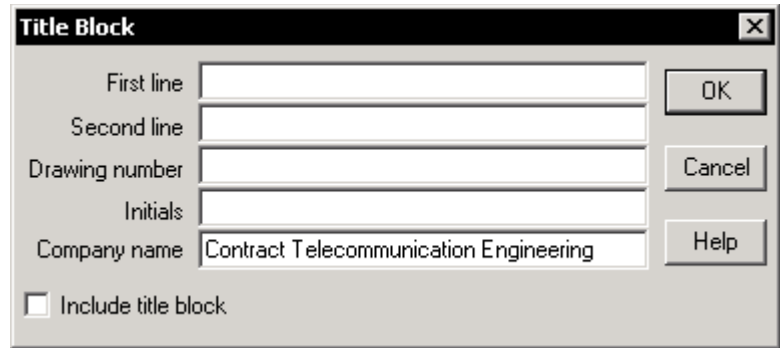
Curved Earth - Curved Axis

The display options for this format are identical to the curved earth - straight axis format.
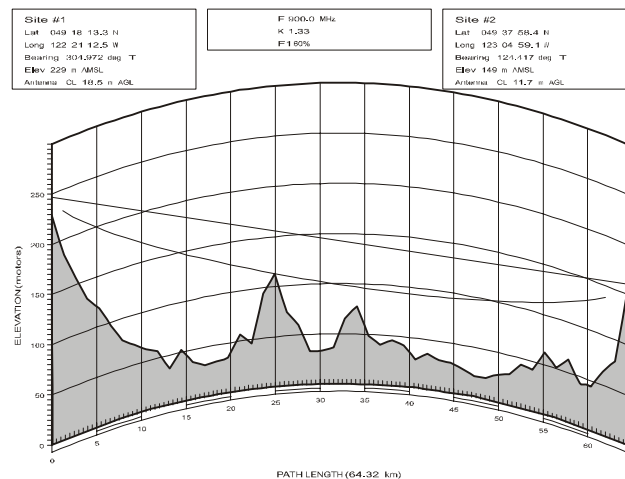
Title Block

An optional title block is available. The first line, second line, drawing number and initials are saved in the Pathloss data file. The file name is used as the default drawing number. There are no defaults for the other fields.

The company name will be used as a default for all drawings.

Title Block	✕
First line [ ]	OK
Second line [ ]	
Drawing number [ ]	Cancel
Initials [ ]	
Company name [Contract Telecommunication Engineering]	Help
☐ Include title block	

Batch Print

A multi select file open dialog box is used for batch printing profiles. The current page settings are used. Selections are limited to a single directory.

TERRAIN VIEW

Overview

A three dimensional terrain display is available in the Terrain Data and Network Modules. This utility uses the Sun Microsystems OPENGL libraries supplied with Windows NT / 98 and later versions of Windows 95. The user defines a rectangular area based on the geographic coordinates and the X and Y extents of the desired display. A terrain database must be configured to use this utility.
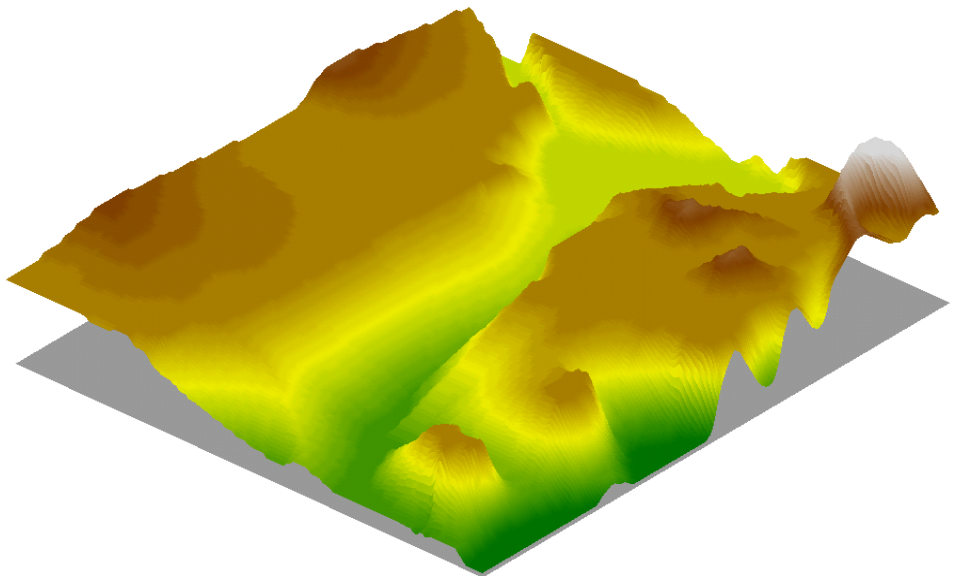
Operation

To access the Terrain View dialog in the Terrain Data module, select Operations - Terrain View from the menu bar. In the Network module, hold down the shift key and move the mouse to one corner of the area to be displayed. Hold down the left mouse button and drag the mouse to the opposite corner.

The primary and secondary terrain databases are displayed along with the selected datum. Note that if a datum and region has been selected, the coordinates will be automatically transformed to the datum used in the terrain database. In the example shown below, the USGS 7.5 minute database files may correspond to either a NAD83 datum or a NAD27 datum. The transformation, in this case, will only be made if the specific files are in NAD83. The Micropath 3 second database is always in WGS84; and therefore, the coordinates are always transformed.

In the Network module, the latitude, longitude are completely determined by the area selected by the user. In the Terrain Data module, this information must be entered along with a reference corner.

The program will generate a rectangular array of elevations expressed as floating point numbers spaces at the specified grid size. If the array size is less than 1 Mb, memory will be used; otherwise, the elevations will be saved in the file terrview.dat in the pathloss directory.

Provision is made to show the effects of earth curvature by specifying a value for K (effective earth radius).

The terrain view display uses a fixed color ramp to display the relative elevations of the display. The lowest elevations are a light brown color and vary through shades of green to a cyan color at the highest elevations. The maximum and minimum elevations on the display are shown on the status bar along with the extents of the drawing.

If the required database files cannot be located, the elevation is assigned a value of -100 and is displayed in a grey color. A sea level elevation is shown in blue. This produces a sharp transition with the terrain coloring scheme and it will be necessary to use a relatively small grid spacing to achieve a smooth coastline.

The terrain is displayed using an orthographic projection. This initial display shows a normal projection viewed from the Z axis. You can rotate the display on any axis designated Xa, Ya and Za using the up-down controls or by typing the required rotation angle. If a value is entered, press the ↵ key for the change to take effect.

The vertical scale of the drawing (Zs) can also be set with the up-down control or by manually entering the scale.

The terrain view display cannot be directly printed. Click the copy button, and paste the display into your word processor. This operation transfers the display as a Window bitmap using the current size of the Terrain View window.

If the terrain view was invoked from the network module, any sites within the display area will be shown on the initial normal display.

Adding a New Site

A new site can be added to the network module using the terrain view utility. With the display in the normal mode (all rotation angles set to 0), click the + button. The cursor changes to a cross hair and is positioned in the center of the display. Select the new location, click the left mouse

button and enter the name of the site. There is no visible indication that the new site has been added. Click the √ button to add the site to the network display.

LANGUAGE SUPPORT

The Pathloss program screen displays can be configured for the English, French and Spanish languages. The user can create an additional translation using one of the above languages as a template. Select Configure - Language from the menu bar and select the desired language. All text in the screen displays and reports will be changed to the new language selection. This section describes the requirements to modify an existing language and to create a new translation.

Language Files

All program text is contained in two external text files. The file names are the language name with the suffixes LNG and MNU. Three sets of language files are supplied with the program (ENGLISH, FRENCH and SPANISH). A fourth file name USERLANG is reserved for a user translation. Both the LNG and MNU files must be available in the Pathloss directory to start the program.

LNG

This file contains all program text exclusive of the program menus. The first line of the file contains the identifier PLW40_STR followed by the total number of entries. The following lines contain the entry number followed by a comma and the text. The entry numbers are numerically ascending but not necessarily sequential. This is to allow for future insertion. The file may contain blank lines and comments starting with the characters '//'.

Only the text can be edited. The entry numbering cannot be changed and new entries cannot be added.

This file is loaded during program startup. Any syntax errors will terminate the program immediately.

MNU

This file contains the text for all menus in the program. Each menu item line contains a mnemonic which is defined in the file MENUDEFS.RH. During program startup the MNU file is loaded and compiled into standard windows menus. Any syntax errors will terminate the program immediately. The following rules govern changes to MNU files:

- Only the menu text can be edited.

- All Menu entries contain the character &. This character precedes the letter in the menu text which will be underlined on the menu and can be accessed by the Alt key and letter sequence. No duplicate & and character sequences in a menu list are allowed.

- New menu items cannot be added.

- The mnemonic associated with a menu cannot be changed.

- Pop up menu numbers cannot be changed.

- The file MENUDEFS.RH cannot be changed.

Considerations for Maintenance Updates

Each maintenance update contains new language files. New menu items may have been added. The maintenance update procedure effectively overwrites the existing language files; and therefore, any changes that were made to the existing files will be lost. If a new translation was made, the menu structure in the new release may be different than the previous. The only solution to this problem is to advise CTE of the changes you have made and these changes will be incorporated into the new release. If a new translation is made, send in the translation and it will be incorporated as a new standard language.

All language change notifications should be sent by Email to cte@pathloss.com

FILE CONVERSION - VERSION 3.0 TO 4.0

Version 4.0 employs a binary data file format. This change was necessary to incorporate the new features in this release. In particular, the interference analysis requires random access to various components in the file. A severe performance penalty would result in a sequential read of an ASCII file to extract the required information.

The File - Open menu selection accepts either version 3.0 or 4.0 files; however, in other areas such as worksheet templates and importing pathloss files into the network, only version 4.0 files are accepted. A batch file conversion utility under Configure - Convert - Pathloss Version 3.0 files is available. If a single file is selected, you will be prompted for the new file name. If multiple files are selected, this prompt is not issued. The file will be saved with the same file name and the suffix pl4.

Files can be saved in the version 3.0 format; however, some loss of information is inherently possible with the different file formats.

In some areas the new file structure does not have a one to one correspondence with version 3.0 files. This section summarizes the resultant ambiguities and the rules used for converting version 3.0 to version 4.0 files.

Antenna Heights

If a building was entered at the end of the path, the antenna heights were measured from the top of this building in version 3.0. In version 4.0, antenna heights are always measured from ground level. The antenna heights are automatically corrected when the version 3.0 file is loaded.

Local Variables

The version 3.0 file data included a main antenna height and a diversity antenna height. If the diversity antenna height was specified, space diversity was assumed. Space diversity was specifically selected in the microwave worksheet.

The version 3.0 microwave worksheet used local variables for frequency, path length and antenna heights. The intent was to allow a certain degree of flexibility in analyzing a path. The worksheet included a warning if the value of any of these parameters were different than the corresponding values outside the worksheet.

This has been discontinued in version 4.0. When a version 3.0 file is loaded, the assignments will depend on whether the file contains a path profile, as shown in the table below.

Table 4: Local Variables

	Path Profile		No Path Profile	
	worksheet value	global value	worksheet value	global value
Frequency	ignored	used	used	ignored
Path Length	ignored	used	used	N/A
Main Antenna Height	ignored	used	used	ignored
Diversity Antenna Height	used if the global value is not specified and space diversity is specified in the worksheet	used if the global value is specified	used if space diversity is specified	ignored

The expanded header lines in the microwave worksheet are interpreted as follows:

line 1　　　　　　　　Site Code

line 2　　　　　　　　Site Call sign

The transmit frequency assignment is interpreted as follows:

CH 6 5912.375

SUMMARY MODULE

OVERVIEW

The start-up display in the Pathloss program is referred to as Summary module and serves the following purposes:

- provides a central location for the entry of path data parameters. Path calculations are carried out down to the receive signal level. Some items such as the site names and call signs can only be entered in this module. Other entries, such as antenna heights, can be changed in any design module in the program. Coordinates can be entered in both geographic and grid formats in the Terrain Data module.

- provides the interface to the Pathloss site database for data entry and interference analysis. Interference calculation details are given in the Site Database section.

- sets the application type as either microwave or VHF-UHF

APPLICATION

Select Application on the Summary menu bar to bring up the Application dialog box. Alternately, click the left mouse button on the application box on the status bar. The following options are provided in this dialog:

Measurement System

Select either kilometers-meters or miles-feet as the measurement system. Alternately, click the left mouse button on the measurement system box on the status bar to change the system.

The measurement system can be changed in the Summary, Terrain Data, Worksheet and Antenna Heights modules.

Application

This selection determines if the worksheet format is for a microwave or VHF-UHF application. An interference analysis only uses microwave applications.

Link Type

Microwave applications are classed as either point to point or point to multipoint. If the point to multipoint option is selected, the hub site must be identified as either site 1 or 2 and a sector number must be assigned. The sector number determines which remote stations operate with a point to multipoint site. The sector numbering is arbitrary as long as a different number is used for each point to multipoint sector at a site. This identification is required for interference analysis so that sites in the same sector do not interfere with each other or their hub site.

STATUS BAR

The status bar provides alternate access to several common dialog boxes and displays interference validations status of the data as an ✖ or ✓.

- Click on the units box to change the measurement system.
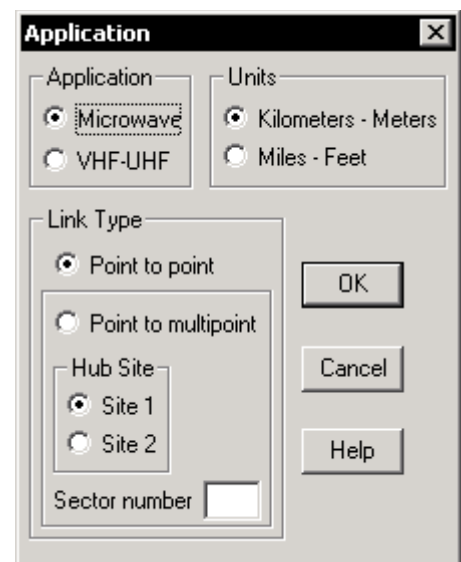
- Click on the antenna configuration box to select an new antenna configuration.

- Click on the application box to change the application type.

- The data must meet certain criteria to be imported into a Site Database or to run an interference calculation. The following items are checked:

  - a microwave application must be specified

  - each site must have a unique call sign

  - coordinates must be entered for each site

  - antenna codes must be specified for each antenna

  - data entry must be complete to the point where a receive signal is calculated

  - transmit channel assignments must be entered

If all of these criteria are met, the status is displayed on the status bar as a green ✓. If the status is shown as a red ✘, click the left mouse button on the ✘ to display the missing entry.

DATA ENTRY

The table below describes the data entry fields in the Summary module.

Table 1: Data Entry Fields in the Sumary Module

Field	Description
Site Name Call Sign Station Code State	These entries can only be made in the summary module. A unique call sign for each station is required to carry out interference analysis. The Site Code and State entries are optional.
Owner Code Company Code	The owner and company codes are fields used in the site database. The fields are used in the Summary module to facilitate transfer to the site database.
Latitude Longitude True Azimuth	The geographic coordinates can be entered in the Summary or Terrain Data modules. In the Terrain Data module, the coordinates can also be entered in several common rectangular grid formats. The reference ellipsoid defined in the selected datum is used to calculate the true azimuth. If the path contains a passive repeater, the azimuths shown are from the sites to the passive repeater.
Calculated Distance Profile Distance	The calculated distance is determined from the coordinates and the reference ellipsoid defined in the datum. The profile distance is the distance of the last point on the profile. Ideally, these should be the same. Both are displayed to help identify a potential error in the data entry.
Datum	This entry will be formatted as a datum or ellipsoid depending on the geographic defaults settings. The calculated distance and azimuths are based on the associated ellipsoid. Select Configure - Geographic Defaults to change the datum / ellipsoid.

Table 1: Data Entry Fields in the Sumary Module

Field	Description
Elevation	If a terrain profile exists, the elevations are taken from the first and last points of the profile and cannot be edited. Otherwise, the elevations can be entered but these will be overwritten when a terrain profile is created.
Tower Height	The tower height is used as the default upper limit in calculations which vary an antenna height. The Diffraction, Reflection and Multipath modules use the tower height as the default upper limit when a calculation varies the height of an antenna.
The Summary module display is formatted for the selected antenna configuration. Normally, the antenna data will be entered in the Worksheet module; however, the data can be entered in the Summary module in terms of the height, code and the transmit and receive loss as applicable. This information is sufficient to analyze interference against the Pathloss site database.	
Antenna Height	The antenna height is <u>always</u> measured from ground level. This is true, even if a building has been entered at the start or end of the profile.
Antenna Code	The antenna code is a reference to a file containing all specifications and the radiation patterns for the antenna. You can enter the code directly or use an Antenna Index. Double click the left mouse button on the entry or select Equipment - Antenna Index from the Summary menu bar to bring up the Antenna Index dialog box. All antenna specifications (model, gain and 3dB bandwidth) will be entered into the program.
TX - RX Loss	The TX - RX loss is the sum of all losses measured from the transmitter or receiver output to the antenna output and includes all branching network and transmission line losses. This loss is normally calculated in the Worksheet. The values can be directly entered in the Summary module; however, if the worksheet module is selected, these entries will be replaced with the calculated values. A prompt is issued to this effect.
Normally, the radio data will be entered in the Worksheet module; however, the data can be entered in the Summary module in terms of the height, code and the transmit and receive loss as applicable. This information is sufficient to analyze interference against the Pathloss site database.	
Radio Model	Information only entry.
Radio Code	The radio code is a reference to a file containing all radio specifications and associated T/I, RX selectivity and TX emission versus frequency curves. You can enter the code directly or use the Radio Index. Double click the left mouse button on the entry or select Equipment - Radio Index from the Summary menu bar to bring up the Radio Index dialog box. All radio specifications will be entered into the program.
Emission Designator	Optional entry.

Table 1: Data Entry Fields in the Sumary Module

Field	Description
Traffic Code	This term consists of the digital capacity and the modulation. It is used in interference calculations to identify similar radio types. The traffic code is automatically generated when the data is entered through a radio code.
TX Power	This is the design power used to calculate receive signals, fade margins and propagation reliability. This power can be modified for a specific TX channel.
Frequency	This is the design frequency. All performance parameters are based on this frequency. Interference calculations use the actual channel frequency assignments.
Polarization	This is the design polarization and is used in rain attenuation and reflection coefficient calculations. Interference calculations use the polarization specified for the channel assignments. Double click the left mouse button on the polarization to change between horizontal and vertical polarization. Alternately press the Enter key.
Free Space Loss EIRP ERP RX Signal	Calculated values.

TX CHANNEL ASSIGNMENTS

Select Equipment - TX Channels. The data entry form contains the following fields for each site:

Channel ID   The channel identifier is used to determine if a high - low violation exists at a site. To accomplish this, the last letter of the channel identifier must be an H (high) or L (low). The test for a high - low violation is carried out in the Network module under the Interference menu item.

TX Frequency   The transmit center frequency expressed in MHz.

ATPC Range   The automatic transmit power control range in dB. This is only used in an interference calculation as described below.

Power Reduction The transmit power used in an interference calculation can be reduced from the design power for an individual channel.

Polarization   Press Enter or double click on the polarization cell to change between horizontal polarization. If the site 1 polarization is changed, the site 2 polarization and the design polarization are both automatically changed to the site 1 polarization. Changing the site 2 polarization does <u>not</u> have the equivalent effect. In most cases the site 1 and site 2 polarization will be the same; however, in some frequency plans and links using back to back antennas as a passive repeater, opposite polarizations will be used at each site.

The fields, ATPC range and power reduction, determine the transmit power to be used in an interference calculation. The transmit power used to calculate the interfering signal level is given by:

design power - ATPC range - power reduction

Transmit Channel Lookup Table

Lookup tables are available for the transmit channel assignments. These use a standard grid data entry form. Refer to the General Program Operation section in this manual for details on the use of this form. The last used TX Channel lookup file is automatically loaded when the lookup table is accessed.

The menu items Site 1 Hi and Site 2 Hi load the channel assignment of the selected item into the TX Channel data entry form. The Up and Down menu items move the hilite bar in the TX Channel data entry form to facilitate multiple channel entries.

The Hi-Lo menu item sets the difference between the high and low frequencies. This is used when a lookup table is created. When the TX Hi frequency is entered, the TX Lo frequency is automatically assigned a value given by TX Hi spacing. Entering a value for the TX Lo frequency does not have an equivalent effect. To disable this feature, erase the frequency spacing.

Import - Export Frequency Plan

Select File - Import on the Lookup table menu bar to access the Import Frequency plan dialog.

- specify the field numbers.

- identify the frequency units.

- specify the delimiter and text qualifier.

- check the add high - low identifier to the channel ID. This is used to determine if a high low violation exists as part of the interference analysis. Remember the maximum number of characters in a channel ID is 7 including this identifier.

- Click Import and load the text file.

SITE DATABASE (SDB)

OVERVIEW

The Pathloss site database consists of a set of Paradox database tables located in the same directory. The database is given a descriptive name which is sometimes referred to as an alias. The alias is simply a cross reference to the directory which contains the tables. There can be any number of databases; however, each must be in its own directory and only one database can be active at any time.

The database includes the following tables:

PL40COMP.DB	owners and operators
PL40SITE.DB	site records
PL40STAT.DB	station records
PL40LINK.DB	link records
PL40TXCH.DB	transmit channel records
PL40PTMP.DB	point to multipoint records
PL40PRRC.DB	passive repeater records
PL40SATL.DB	satellite records
PL40XREF.DB	cross reference table for computer generated fields
PL40COMP.PX	owner - operator table index
PL40SITE.PX	site table index file
PL40STAT.PX	station table index
PL40LINK.PX	link table index
PL40PRRC.PX	passive repeater table index
PL40TXCH.PX	transmit channel table index

Database operations are accessed from the Summary module under the SDB menu. The Network module also accesses the site database to import sites, stations and links. A detailed description of each table format is given at the end of this section.

Basic Operation

The primary use of the pathloss site database is for interference calculations; however, it also serves as a convenient storage for radio site locations.

Note that separate tables are used for sites and stations. This allows several users to be co-located at the same location. A site represents the physical location of the tower as determined by its geographical coordinates; therefore, two sites cannot have the same geographical coordinates. A station represents the identity of the operator as specified by the call sign. Duplicate call signs are not allowed.

DATABASE SELECTION

Select Configure - Open Site Database from the menu bar. A list of the available databases is displayed. Each database name is an alias name which cross references the directory containing the tables. A database is identified as a Pathloss site database if the correct tables are located in the corresponding directory.

Select the database and click the open button. If the tables do not exist in the directory, you will be prompted to have the tables automatically created.
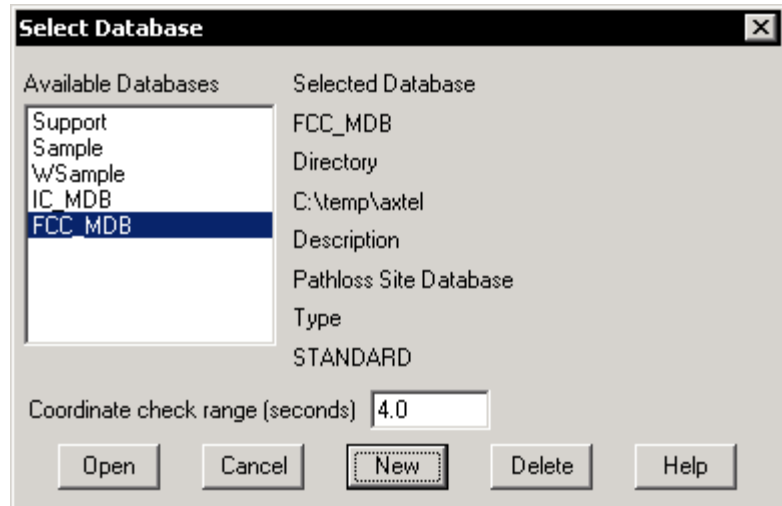
Coordinate Check Range

The Select Database dialog box includes one optional parameter - the coordinate check range expressed in arc seconds. A site is uniquely identified by its geographic coordinates. These are stored as a double precision number rounded to the nearest one hundredth of a second. When a site is added to the database from a Pathloss file, the program will first check for a site with exactly the same coordinates. If a match is found, the existing site will be selected. Otherwise, the program will generate a list of sites which are within the coordinate check range tolerance of the site to be added. The user has the option of selecting one of the existing sites or creating a new site in the database.

Delete

The delete button simply deletes the database name. The directory and all database files are unaffected.

Creating a New Database

Click the New button in the Select Database dialog. You must specify a database name and a directory. If the directory exists, you can click the Browse button and select the directory; otherwise, type in the directory name. If the directory does not exist, it will be created. The database files will be generated when you click the OK button in the Select Database dialog.
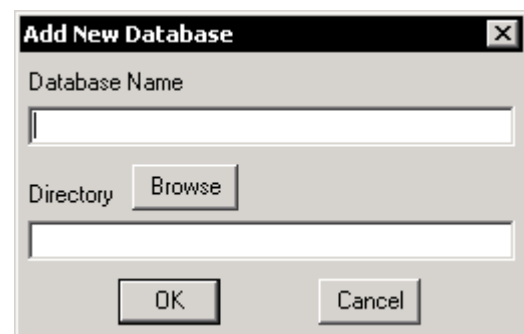
SITE DATABASE MODIFICATIONS

All additions and changes to the site database are made in the Summary module. Click SDB - Add Edit and then select the specific entry (Sites-Stations, Links or Owner-Operator). Changes are not automatically transferred to the database. You must click the Add-Modify button to make the change. If you move to another record, you will be prompted to make the changes.

OWNER - OPERATORS

A common table is used for owners and operators. The owner-operator ID's are referenced in the Site tables as the owner ID and in the Station table as the Operator ID. The first step in creating a new database is to compile a list of the owners and operators which will be used in the database. The Owner-Operator Code cannot be entered in the Site and Station table. These are selected from a drop down list which is created from the Owner-Operator table. In the Summary module, click SDB, Add Edit, Owner- Operator. There are only two required entries in this table - Code and Name. The Code must be a unique identifier in the table.

A situation arises where two entries have been made for the same company but with different codes. If you attempt to change one of the Codes to be the same as the other, the prompt "Code is already used - Use this Code?" is issued. If you click Yes, the current record will be deleted and all Sites and Stations which used this code will be changed to the other Code. Note that this only works if you click the Add-Modify button. If you move to another record, a Key Violation error will occur.

New - Cancel
If there are no Owner-Operator records in the database, the first record is added by typing in the entries and clicking the Add-Modify button. Successive records are added by clicking the New button, entering the data and then clicking the Add-Modify button. The Cancel button cancels the addition of a new record.

Reset
The Reset button, will undo any changes made to the record. Once the Add-Modify button is clicked, the changes are permanent and the reset button has no effect.

Delete
An Owner-Operator record cannot be deleted if it is referenced in any Site or Station table. The error message "Cannot delete - Record is referenced in other tables" will be issued.

Filter
Moving through the Owner-Operator records is accomplished with the First record, Prior record, Next record and Last record buttons. An incremental search is available for the Code and Name. The search is case insensitive. Type in the first few letters of the selected field. Only the matching records will be displayed. The search only works on sequential characters from the start of the Name or Code.

ADDING - EDITING SITES AND STATIONS

Select SDB - Add Edit, Sites-Stations from the menu bar to bring up the Sites - Stations dialog box. This dialog box combines the Site and Station tables.

A new site and station can be added in one operation.

A new site can be added without a station.

A new station can only be added to an existing site.

The display is divided into three sections: site related, station related and common functions.

The required entries in the site section are the site name, latitude and longitude. The latitude and longitude must be unique to the nearest one hundredth of a second. All other entries are optional. The units (feet or meters) for elevation and tower height correspond to the current program setting. Internally, all data is stored in Metric units.

The only required entry in the station section is the call sign. The call sign is always in upper case. This must be unique. All other entries are optional.

Filters

The First, Prior, Next and Last site buttons are used to move through the Site table. If more than one station exists at a site, then the First, Prior, Next and Last station buttons will be activated and you can step through the stations for that site.

An incremental search is available for the Site name. Just type in the first few letters of the site name. The search is case insensitive.

A similar search facility is provided in the station section for the Call Sign and Station Code. If a filter is active on either the Call Sign or the Station Code, the site name filter will be cancelled and the First station, Prior station, Next Station and Last station buttons now control movement through the database. Only sites and stations which match the station filter are displayed.

If you click a site movement button, the station filter is cancelled and the movement reverts to the default site sequence.

Reset

The Reset buttons in the site and station sections restore any changes to their original value. Once the Add-Modify button is clicked, the changes are permanent.

Delete

The Delete buttons will attempt to delete the site or station. A site cannot be deleted if it contains any stations. A station cannot be deleted if it is referenced in the Link table.

Adding New Sites and Stations

If the site table is empty, then the screen will be blank. Type in the site name, coordinates and any other available information. If you click the Add-Modify button without making any station entries, only the site will be added to the database. The station data must have a unique call sign to be added. To add additional sites, it is necessary to click the New button in the site section.

If the station section is blank, add the call sign and then click the Add-Modify button. To add a new station to an existing site, click the New button in the station section.

If you change an existing station call sign, all link records which reference the call sign will be automatically updated to the new call sign.

Adding Sites and Stations from the Summary Module

When the New button in the site section has been clicked or there are no existing sites, the Import group box is enabled. The Site 1 and Site 2 buttons will also be enabled if the data in the Summary module contains site names and coordinates as a minimum. In this case, you can import the data for the sites. Add any additional information available and click the Add Modify button.

The coordinates of the site in the Summary module are checked against the sites in the database. If a match is found to the nearest one hundredth of a second, the site will not be added and the display will switch to the existing site. A secondary check is made using the Coordinate Check Range specified in the Open Site Database dialog. If the coordinates in the Summary module are outside this tolerance, then a new site will be added to the display. Otherwise, the user will be presented with a list of all sites in the database which are within the Coordinate Check Range. The user has the option to "Add a New Site" or to use one of the existing sites. If the latter is selected, a further option of changing the coordinates of the existing site is available. If you elect to use an existing site and change the coordinates to the site in the Summary module, the change will be immediately made to the database and the display will show the modified site.

If you choose to add a new site, you must click the Add-Modify button to actually add the site to the database. The Cancel button will cancel the import operation, in this case.
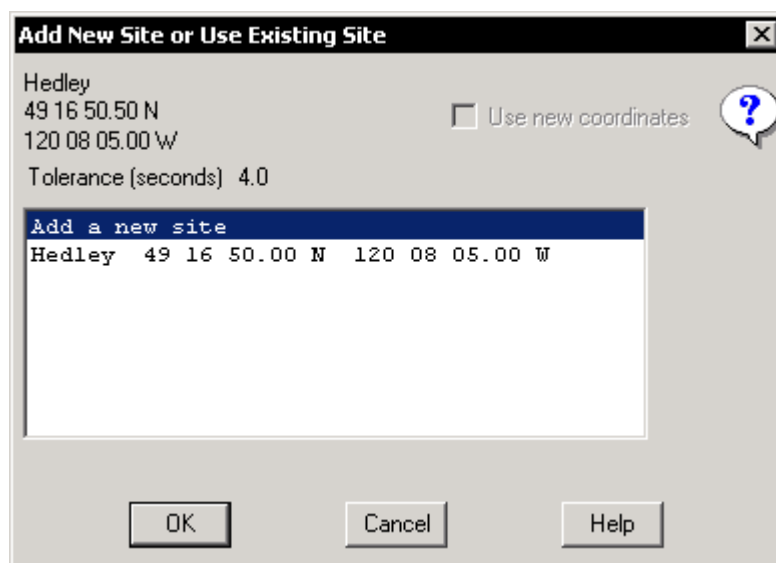
ADDING - EDITING LINKS

Select SDB, Add Edit, Links from the Summary module menu bar to bring up the Link display dialog box. This display shows the two sides of the link. Each side is an individual link record in the link table. A link record contains the following information:

- Link ID and the reverse link ID. If the site is a hub site in a point to multipoint application, the reverse link ID is blank and the link ID's of the associated remote sites are contained in the point to multipoint table.

- Link class. The classes are point to point, point to multipoint, point from multipoint and earth station.

- Sector number. This is applicable to point to multipoint and point from multipoint stations.

- Call sign of the associated station.

- Antenna azimuth. The azimuth is assumed to be the same for all antennas.

- Antenna vertical angle. The vertical angle is assumed to be the same for all antennas.

- Antenna configuration. The link antenna configuration must conform to one of the standard antenna configurations.

- Three antenna records to allow for the TXRXDR-TXRXDR antenna configuration. If the antenna record is not used in the antenna configuration, it will be blank. An antenna record contains the following parameters.

model	code
height	gain
tx loss	rx loss

- Number of passive repeaters on the link and the ID's of each passive repeater. A link can include a maximum of three passive repeaters. The term passive repeater includes back to back antennas, single and double rectangular passives and back to back antennas with rf amplification.

The display only shows the antenna records and the transmit channel records. The channel records are con-

tained in a separate table and include a field which identifies the Link ID. A transmit channel record in-
cludes the following parameters:

transmit frequency	channel identifier
transmit power	apc range
polarization	radio model
radio code	traffic code
emission designator	status
transmit link ID	receive link ID

A new link must be added from the Summary module. Within the Link display dialog box only the follow-
ing operations are possible:

* delete an existing link

* change any of the antenna parameters. the antenna model, code, gain, height, tx loss, rx loss and verti-
  cal angle. The antenna azimuth can only be changed on the hub site of a point to multipoint link.

* add or delete a transmit channel

* edit any of the transmit channel parameters

Changes involving a different antenna configuration cannot be carried out in the Link display. The following steps are required for this type of change:

- Import the link into the Summary module
- Make all the required changes in the Pathloss program
- Open the Link display dialog box
- Delete the link from the database
- Add the new link from the Summary Module
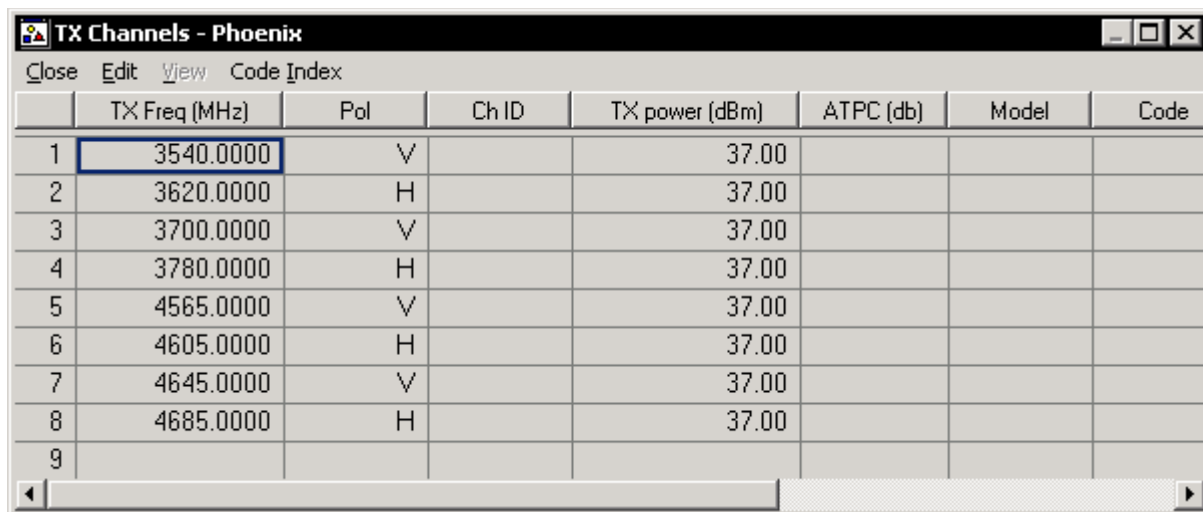
Editing Antenna Parameters

Click the button on the right side of the antenna data display. This will bring up the standard data entry form for the antenna. The antenna azimuth and vertical angle are the same for all antennas on that side of the link. The antenna azimuth can only be edited for a hub site on a point to multipoint application. You can view the radiation pattern envelope for the antenna with the View menu selection or change the antenna with the Code Index menu selection. Click OK on the menu to update the Link display. Note that the changes are not immediately transferred to the database. You must click the Add-Modify button. If you change to a different link, you will be prompted to make or discard any changes. Refer to the section on General program operation for information on the data entry forms used in the Pathloss program.

TR - Phoenix	
OK Cancel Code Index View Help	
Antenna model	KS-15676
Code	K15676_4
Antenna gain (dBi)	39.40
Antenna height (ft)	59.06
Antenna Azimuth (°)	100.20
Vertical angle (°)	0.00
TX loss (dB)	1.60
RX loss (dB)	1.60
Antenna model :	

Editing Transmit Channel Parameters

Click the button on the right side of the TX channel data display. This will bring up a standard grid data display form. You can edit, add or delete a transmit channel. You can view the radio specifications with the View menu item or change the radio type with the Code Index menu item. Note that this does not change the transmit power. Only the model, code, traffic code and emission designator are affected. A transmit channel can be added or deleted in this display. Refer to the General Program Operation for information on the grid data display.

	TX Freq (MHz)	Pol	Ch ID	TX power (dBm)	ATPC (db)	Model	Code
1	3540.0000	V		37.00			
2	3620.0000	H		37.00			
3	3700.0000	V		37.00			
4	3780.0000	H		37.00			
5	4565.0000	V		37.00			
6	4605.0000	H		37.00			
7	4645.0000	V		37.00			
8	4685.0000	H		37.00			
9							

Reset

The reset button restores any changes made to the antenna and transmit channel data to their original values on entry. This works if a new transmit channel has been added or an existing one has been deleted. Once the Add-Modify button is clicked, the reset button has no effect until further changes are made.

Filter

The site name, call sign, station code, coordinates, and the operator code are displayed for each side of the link. The First, Prior, Next and Last link buttons on the left side of the display step through the links in the database. The sequence will only show the link in one direction. Station A to Station B will not be repeated as Station B to Station A.

Filters are provided to simplify the search for a particular link. You can restrict the display to show only the links for one company code. You can search for a link using the site name, call sign or station code as a filter. Select the search method and type in the first few letters of the name. The filter is case insensitive. When a filter is active, the left side of the link display is restricted to the filter. The right side shows the associated link.

The First, Prior, Next and Last buttons on the right side of the display are inhibited on point to point links. If a point to multipoint link is displayed, the hub site will always be on the left side of the display. If there is more than one remote site associated with this hub site, the right side buttons will be activated and you can step through all of the remote sites for this hub site. The sector number of the point to multipoint link is displayed in this state.

Delete

A link can always be deleted. If this is a point to point link, the link records for both sides of the link will be deleted. If this is a point to multipoint link, the remote site will always be deleted. The hub site will be deleted if there is only one remote site for the hub site. The associated site and station records are unaffected by deleting a link.

All transmit channel records associated with the link will be deleted. Once a link has been deleted, it cannot be recovered.

ADDING A NEW LINK

The new link must be first be created in the Pathloss program and displayed in the Summary module. A path profile is not necessary. If the red ✖ mark is displayed on the status bar, the link is not valid and cannot be added. Click on the red ✖ to display the missing information. The following data is a prerequisite for a new link.

- This must be a microwave application. No provision is made for VHF-UHF links.

- Call signs must exist for both sites.

- Coordinates must exist for both sites.

- The design frequency must be specified.

- The antenna code must be specified for each antenna used.

- The data entry in the Summary or Microwave worksheet module must be complete to the point of a receive signal calculation.

- The transmit channels must be specified.

Open the Link display dialog box and click the new button. The sequence of operations are as follow:

The two sites are first added to the database. In the Pathloss program, there is no distinction between a site and a station; however, the Site database uses separate tables for sites and stations. The operation is similar to importing a site from the summary module and involves the following operations.

The site coordinates are first checked against the site table records. If the two sets of coordinates match to within a tolerance of one hundreth of a second, the existing site will be used. If an exact match is not found, the program will compile a list of all sites whose coordinates are within the Coordinate Check Range of the new site. The list is displayed and the user has the option of using an existing site or creating a new one. An option is also provided to change the existing site coordinates to the new ones.

If the call sign is used at a station for the site, then that station will be used. Otherwise, the call sign is checked for a duplicate in the station table. If the same call sign is found, then the operation terminates with an error message.

If a new site or station is to be added, the user is given an opportunity to verify the data entries before the additions are made to the database.
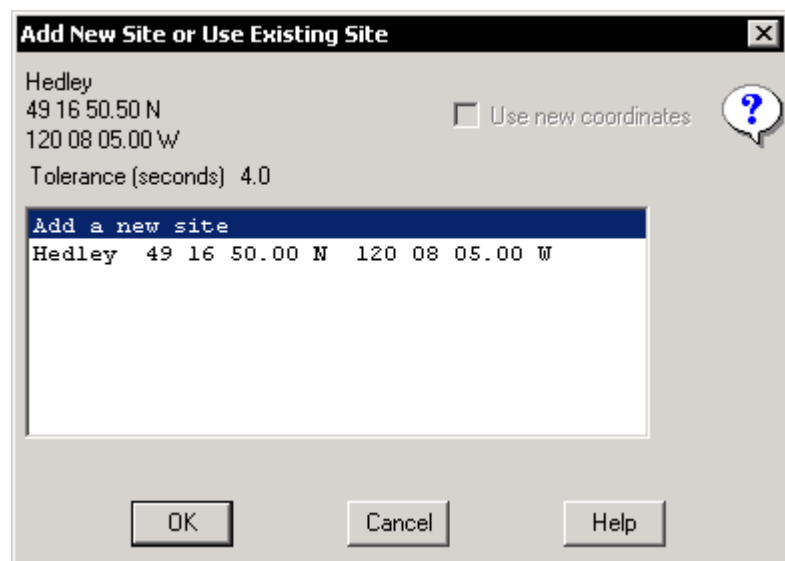
If the new link is using existing sites in the database, a further check is required to determine if the links already exists. On point to point links, the antenna configuration and antenna heights are criteria used to identify an existing link. On point to multipoint the criteria is the sector number.

If a link is determined to exist, the display simply switches to the link. The existing data will not be changed.

Verify Site and Station Data

Sites:
- Site Name: Phoenix
- Latitude: 49 05 24.00 N
- Longitude: 118 36 32.00 W
- Address:
- City:
- State: BC
- Owner Code:
- Elevation (ft): 17006.98
- Tower Height (ft): 2391.98
- Tower type:

Stations:
- Call Sign CFW310
- Station Code:
- License:
- Operator Code:

⚠ Verify Site and Station Data

OK

Cancel

SITE DATABASE TABLE DESCRIPTION

The tables are related to each other by design and contain computer generated fields. If a table becomes corrupted, then the entire database may be lost. You cannot arbitrarily add new records or restructure a table with a database program. The database integrity will be lost. If a table associated with one database is moved into the directory of another database, the database will be corrupted.

A description of each table is given below:

Field	Field Name	Format	Description
Table 2: Owner - Operator Table (PL40COMP.DB)			
1	Code	CHAR[16]	A unique owner or operator identity
2	Name	CHAR[32]	Owner or Operator name
3	Address-1	CHAR[32]	Address - line 1
4	Address-2	CHAR[32]	Address - line 2
5	City	CHAR[32]	City
6	State	CHAR[16]	State or Province
7	Zip	CHAR[16]	Zip or Postal Code
8	Contact	CHAR[32]	Contact Name
9	Title	CHAR[32]	Contact's position or title
10	Tel	CHAR[32]	Telephone number
11	FAX	CHAR[32]	FAX number

Table 2: Owner - Operator Table (PL40COMP.DB)			
12	Email	CHAR[32]	Email address

Table 3: Site Table (PL40SITE.DB)			
Field	Field Name	Format	Description
1	Site ID	INT32	Site Identifier - Computer Generated
2	Latitude	DOUBLE	Latitude rounded to 1/100 second
3	Longitude	DOUBLE	Longitude rounded to 1/100 second
4	Datum	INT16	Reserved for future use
5	Elevation	DOUBLE	Site elevation in meters
6	Name	CHAR[32]	Site Name
7	Address	CHAR[32]	Address
8	City	CHAR[32]	City
9	State	CHAR[16]	State
10	Owner Code	CHAR[16]	Owner Code
11	Tower Type	INT16	Tower type
12	Tower Height	DOUBLE	Tower height in meters

Table 4: Station Table (PL40STAT.DB)			
Field	Field Name	Format	Description
1	Call Sign	CHAR[16]	Call sign - key field
2	Site ID	INT32	Reference to Site Table
3	Operator Code	CHAR[16]	Operator Code
4	Station Code	CHAR[16]	Optional Station Identifier
5	Station License	CHAR[32]	Station License

Table 5: Link Table (PL40LINK.DB)			
Field	Field Name	Format	Description

Table 5: Link Table (PL40LINK.DB)			
1	ID	INT32	Link Identifier - Computer Generated
2	REVID	INT32	Reverse Link ID
3	CLASS	INT16	Point to Point / Multipoint - Earth Station
4	SECTORNO	INT16	Sector Number on Point to Multipoint Links
5	SATID	INT32	Satellite ID
6	CALLSIGN	CHAR[16]	Station Call Sign
7	ANTCNFG	INT16	Antenna Configuration
8	AZIMUTH	DOUBLE	Azimuth (degrees)
9	ELEVANG	DOUBLE	Elevation Angle (degrees)
10	ANTUSAG1	INT16	#1 Antenna Usage (TR, TX, ..)
11	ANTMODL1	CHAR[24]	#1 Antenna Model
12	ANTGAIN1	DOUBLE	#1 Antenna Gain
13	ANTHGHT1	DOUBLE	#1 Antenna Height (meters)
14	ANTCODE1	CHAR[16]	#1 Antenna Code
15	TXLOSS1	DOUBLE	#1 Transmit Loss
16	RXLOSS1	DOUBLE	#1 Receive Loss
17	ANTUSAG2	INT16	#2 Antenna Usage (TR, TX, ..)
18	ANTMODL2	CHAR[24]	#2 Antenna Model
19	ANTGAIN2	DOUBLE	#2 Antenna Gain
20	ANTHGHT2	DOUBLE	#2 Antenna Height (meters)
21	ANTCODE2	CHAR[16]	#2 Antenna Code
22	TXLOSS2	DOUBLE	#2 Transmit Loss
23	RXLOSS2	DOUBLE	#2 Receive Loss
24	ANTUSAG3	INT16	#3 Antenna Usage (TR, TX, ..)
25	ANTMODL3	CHAR[24]	#3 Antenna Model
26	ANTGAIN3	DOUBLE	#3 Antenna Gain
27	ANTHGHT3	DOUBLE	#3 Antenna Height (meters)
28	ANTCODE3	CHAR[16]	#3 Antenna Code

	Table 5: Link Table (PL40LINK.DB)		
29	TXLOSS3	DOUBLE	#3 Transmit Loss
30	RXLOSS3	DOUBLE	#3 Receive Loss
31	NUMPASS	INT16	Number of Passive Repeaters
32	PASSID1	INT32	Passive Repeater #1 ID
33	PASSID2	INT32	Passive Repeater #2 ID
34	PASSID3	INT32	Passive Repeater #3 ID

	Table 6: Point to Multipoint Table (PL40PTMP.DB)		
Field	Field Name	Format	Description
1	HUBLINKID	INT32	Hub Link ID
2	LINKID	INT32	Multipoint Link ID

	Table 7: Passive Repeater Table (PL40PRRC.DB)		
Field	Field Name	Format	Description
1	ID	INT32	Passive Repeater ID - key field
2	CALLSIGN	CHAR[16]	Call Sign
3	PR_TYPE	CHAR[16]	Passive Repeater Type
4	AZIMUTH1	DOUBLE	#1 Azimuth
5	AZIMUTH2	DOUBLE	#2 Azimuth
6	ANTMODL1	CHAR[24]	#1 Antenna Model (back to back antennas)
7	ANTGAIN1	DOUBLE	#1 Antenna Gain (dBi)
8	ANTHGHT1	DOUBLE	#1 Antenna Height (meters)
9	ANTCODE1	CHAR[16]	#1 Antenna Code
10	ANTMODL2	CHAR[24]	#2 Antenna Model (back to back antennas)
11	ANTGAIN2	DOUBLE	#2 Antenna Gain (dBi)
12	ANTGHGT2	DOUBLE	#2 Antenna Height (meters)
13	ANTCODE2	CHAR[16]	#2 Antenna Code

Table 7: Passive Repeater Table (PL40PRRC.DB)			
14	TXL_LOSS	DOUBLE	Antenna Transmission Line Loss (dB)
15	AMPGAIN12	DOUBLE	Amplifier Gain 1→2
16	AMPGAIN21	DOUBLE	Amplifier Gain 2←1
17	WIDTH1	DOUBLE	#1 Passive Width (meters)
18	HEIGHT1	DOUBLE	#1 Passive Height (meters)
19	WIDTH2	DOUBLE	#2 Passive Width (meters)
20	HEIGHT2	DOUBLE	#2 Passive Height (meters)
21	SPACING	DOUBLE	Spacing between double passive (meters)
22	PRGAIN	DOUBLE	Passive Repeater Gain

Table 8: TX Channel Table (PL40TXCH.DB)			
Field	Field Name	Format	Description
1	ID	INT32	Key field
2	FREQ_MHZ	DOUBLE	Transmit frequency in MHZ
3	BAND	CHAR[8]	Channel Number
4	TXPOWER	DOUBLE	Transmit Power (dBm)
5	APCRANGE	DOUBLE	Automatic Power Control Range (dB)
6	POLARIZE	INT16	Polarization 0-H 1-V
7	RADIOMODEL	CHAR[24]	Radio Model
8	RADIOCODE	CHAR[16]	Radio Code
9	TRAFFCODE	CHAR[16]	Traffic Code
10	STATUS	CHAR[32]	Status Information
11	EMDESIG	CHAR[16]	Emission Designator
12	TXLINKID	INT32	Transmit Link ID
13	RXLINKID	INT32	Receive Link ID

The cross reference table maintains the computer generated identifiers for the site, link, TX channel records, passive repeater and satellite records. This table contains only one record. The appropriate field is

updated when a corresponding record is added. The ID's in the cross reference table are the next available ID to be used. This table also contains the current version numbers of all tables in the site database.

Field	Field Name	Format	Description
Table 9: Cross Reference Table (PL40XREF.DB)			
1	SITECNT	INT32	Site Record ID
2	LINKCNT	INT32	Link Record ID
3	PRRECCNT	INT32	Passive Repeater Record ID
4	TXCHCNT	INT32	Transmit Channel Record ID
5	SATRECCNT	INT32	Satellite Record ID
6	COMPVER	INT16	Company Table Version
7	SITEVER	INT16	Site Table Version
8	STATVER	INT16	Station Table Version
9	LINKVER	INT16	Link Table Version
10	PTMPVER	INT16	Point to Multipoint Table Version
11	PRRECVER	INT16	Passive Repeater Records Table Version
12	TXCHVER	INT16	Transmit Channel Table Version
13	STATRECVER	INT16	Satellite Record Table Version
14	TMPCALLS	CHAR[16]	Temporary Call Sign

TERRAIN DATA

OVERVIEW

A terrain profile consists of a table of distances and elevations along the great circle arc between two sites. On most practical paths less than 150 kilometers, the difference between a straight line and the great circle arc is negligible. The Terrain Data module is used to create a terrain profile using any of the following methods:

- manual entry of distances and elevations taken from topographic maps.

- direct entry of distance - elevation data from topographic maps using a digitizing tablet.

- conversion of distance - elevation data in text files from other sources.

- direct entry of distance - elevation data from a terrain data base.

Optional structures and ranges can be added to the path. The Terrain Data display shows the terrain data entry form at the top and the profile display at the bottom. Once the second point has been entered, the profile will be drawn and will be continually updated as the data entry proceeds.

To move to a specific point on the profile, click on the profile display. The first point past the mouse cursor will be selected. Alternately, you can click on a line in the terrain data entry form.

The Home, End, PgUp, PgDn keys, the up and down cursor keys and the vertical scroll bar are used to move through the profile.

MANUAL DATA ENTRY

Type in the entries as requested by the prompt. The left, right, up and down cursor keys and the Enter key will register the data in the form. If the numeric key pad is used with the Enter key, the hilited bar will automatically advance to the next distance or elevation field. This is the fastest method for manual data entry.

To edit an existing entry, place the hilited bar on the item and press the F2 key. Alternately, you can double click on the item.

Distance entries can only be edited within the range of the previous and next distances. There are no restrictions on elevations.

To insert a point, the distance-elevation must be entered as the last point in the form. The new point will be inserted at the correct location in the terrain data entry form.

To delete a point, place the hilited bar on the line, hold down the Ctrl key and press the letter 'Y'.

SITE COORDINATES

Site coordinates can be entered in either a geographic or grid coordinate format. The choice of grid coordinates is made in the Geographic Defaults dialog box.

Geographic Defaults
Select Configure - Geographic Defaults from
the Pathloss menu bar to access the Geographic
Defaults dialog box.

Use Datum or Ellipsoid
An ellipsoid is defined by its major and minor
axis. These are used to calculate distance and az-
imuths from the geographic coordinates and to
convert geographic coordinates to grid coordi-
nates such as UTM. A datum defines the hori-
zontal measurement plan. Each datum is based
on an ellipsoid, and contains measured correc-
tion factors to allow geographic coordinates de-
fined in one datum to be transformed to another.

In most cases, the "Use Datum" option should be
selected. This will allow coordinate transforma-
tion between datums. (e.g. NAD-27 ⇔ NAD-
83). This is important when using terrain data-
bases with a horizontal datum different from the
topographic maps. A typical example is a DTED
terrain database which uses the WGS-84 datum
and site coordinates referenced to the NAD-27
datum. If the user has specified the NAD-27 datum, then the site coordinates will be automatically trans-
formed to WGS-84 to generate the profile.

The "Use Ellipsoid" option is required to handle specialized regional mapping. An example of this is Swit-
zerland, which generally uses the European Datum of 1950. This datum uses the International (1924) ellip-
soid. The Swiss grid coordinate system on the other hand uses the Bessel 1841 ellipsoid. In this case, the
"Use Ellipsoid" option should be used.

Datum Selection
First select the datum and then select the specific region for the datum. The requirement for the region se-
lection is necessary because there is no general equation to transform coordinates from one datum to an-
other. The transformation uses data to determine the new coordinates. The breakdown of regions within a
datum is a compromise between the transformation accuracy and the number of regions. Note that a datum
selection automatically defines the ellipsoid.

Ellipsoid Selection
If the "Use Ellipsoid" option has been checked, select the specific ellipsoid from the drop down list.

Latitude Formats
If the latitude format is set to the northern hemisphere, a minus sign before the degrees will change the
entry to a southern latitude. If the southern hemisphere is selected, the opposite is true. Alternately, the let-
ters 'N' and 'S' can be used to specify a northern or southern latitude respectively. In UTM coordinates,
the northing entry must be a negative number for a southern latitude.

Northern Hemisphere Selected   Southern Hemisphere Selected

Data Entry	Result	Data Entry	Result
49 32 24	49 32 24.0 N	49 32 24	49 32 24.0 S
-49 32 24	49 32 24.0 S	-49 32 24	49 32 24.0 N
49 32 24 S	49 32 24.0 S	49 32 24 N	49 32 24.0 N

Longitude Formats
If the longitude is set to the western hemisphere, a minus sign before the degrees will change the entry to an eastern longitude. If the eastern hemisphere is selected, the opposite is true. Alternately the letters 'E' and 'W' can be used to specify a eastern or western longitudes respectively.

Western Hemisphere Selected   Eastern Hemisphere Selected

Data Entry	Result	Data Entry	Result
115 32 24	115 32 24.0 W	115 32 24	115 32 24.0 E
-115 32 24	115 32 24.0 E	-115 32 24	115 32 24.0 W
115 32 24 E	115 32 24.0 E	115 32 24 W	115 32 24.0 W

Precision
Geographic coordinates can be formatted to the nearest second, nearest 0.1 second or the nearest 0.01 second. This does not affect the calculations, because the coordinates are saved as double precision numbers.

Grid Coordinate System
A grid coordinate system represents the simplest method of taking coordinates from a topographic map and guarantees a high degree of repeatability. The following grid coordinate systems are currently supported:

Universal Transverse Mercator	Gauss conformal (South Africa)
New Zealand grid	UK grid
Swiss Grid	Irish grid
Gauss Kruger	WGS-84 to MGI Austria
WGS-84 to HGRS87 Greece	

The data entry forms for inverse and forward coordinates will be formatted for the selected grid coordinate system.

UTM Coordinates
The UTM coordinate system divides the world into 60 zones, each zone covering 6 degrees of longitude. The zone numbers increase eastwards, starting at the international date line. The central meridian of each zone is the backbone of the system for that zone. Along the central meridian, the Y coordinate or northing of a point, is the distance from the equator in kilometers.

East-west grid lines are attached to the central meridian at right angles and follow great circle paths away from it. These are lines of constant northing and do not follow parallels of latitude, since parallels of latitude are not great circles. The X coordinate or easting is measured along these grid lines relative to the central meridian, which by definition has an easting of 500.000 kilometers. Finally, the north-south grids are drawn as lines of constant easting.

If UTM coordinates outside the above definition are entered, they will be converted to the standard definition. If the "Allow non standard UTM zones" option is checked, the original data entry will be preserved.

Geographic Coordinates Format

Latitudes and longitudes are entered in degrees, minutes and seconds separated by a space, or in decimal format or any combination of these two methods. The following examples illustrate the format:

Data Entry	Format	Geographic Defaults Settings
Latitude		
49	049 00 00.00 N	northern hemisphere - nearest 0.01 second
49.5	049 30 00 S	southern hemisphere - nearest second
49 30 01	049 30 01.0 N	northern hemisphere - nearest 0.1 second
49 30.5	049 30 30.00 S	southern hemisphere - nearest 0.01 second
-49	049 00 00.00 S	northern hemisphere - nearest 0.01 second
-49.5	049 30 00.00 N	southern hemisphere - nearest 0.01 second
Longitude		
122	122 00 00.00 W	western hemisphere - nearest 0.01 second
122.5	122 00 00 E	eastern hemisphere - nearest second
122 12 02	122 12 02.0 W	western hemisphere - nearest 0.1 second
-122 14.5	122 14 30.00 E	western hemisphere - nearest 0.01 second

The format defaults to the hemisphere setting in the Geographic Defaults dialog box. A negative sign must precede the degrees to format the entry for the opposite hemisphere. The number of decimal places of the seconds is also set in the Geographic Defaults dialog box. This has no effect on the accuracy, because coordinates are saved as double precision numbers.

Inverse Coordinates

Select Coordinates - Inverse from the Terrain Data menu bar. Coordinates for both sites are entered in the inverse coordinates data entry form. The path distance and the azimuths are calculated. Coordinates may be entered in either geographic or the selected grid format. The program automatically converts between the two systems.

Forward Coordinates

The Site 1 coordinates, azimuth and path length are entered in the forward coordinates data entry form. The Site 2 coordinates are calculated. The Site 1 coordinates can be entered in either geographic or the selected grid format. The program will convert between the two systems. Distance is entered in either miles or kilometers depending on the measurement system. The azimuth is entered in degrees from true north.

Coordinate Transformation

Select Coordinates - Transform from the Terrain Data menu bar to access the coordinate transformation dialog box.

Select the new datum and region and click the Transform button. Click the Accept button to use the transformed coordinates. The datum will also be changed.

NADCON

The Pathloss program uses the NADCON data to transform latitudes and longitudes between the North American Datum of 1927 (NAD27) and the North American Datum of 1983 (NAD83). The transformation is only valid in the United States territorial limits. NADCON is the United States Federal standard for NAD27 to NAD83 datum transformations.

The following operations are affected:

- Coordinate transformation between the NAD27 and NAD83 datums in the Coordinates - Transform procedure in the Terrain Data module.

- All terrain database operations using the USGS 7.5 minute - 30 meter DEMS including:

    - single profile generation
    - radial profiles generation in the Coverage Module
    - network backgrounds
    - terrain view

If the NAD83 datum has been specified, then a copy of the user's coordinates will be automatically transformed to the NAD27 datum to read the database.

Transformation Procedure

To transform coordinates between the NAD27 and NAD83 datums, the following settings must be made in the Geographic Defaults dialog box:

"Use Datum" must be checked in the Use Datum or Ellipsoid dialog box.

Either the NAD27 or NAD83 datum must be selected.

Select the NADCON region.

In the case of the NAD27 datum, the NADCON region is an all encompassing term and includes the following specific datums and regions:

CONUS (lower 48 states)	North American datum of 1927
Hawaii	Old Hawaiian datum
Puerto Rico and Virgin Islands	Puerto Rico datum
St. Laurence Island, Alaska	Old Island datum within Alaska
St. George Island, Alaska	Old Island datum within Alaska
St. Paul Island, Alaska	Old Island datum within Alaska
Alaska	North American datum of 1927

The transformation data is contained in seven files. The program will automatically select the correct file based on the coordinates.

Coordinate Transformation

Coordinate Transformation is carried out in the Terrain Data module. Select Coordinates - Transform. To access this procedure, a datum must be selected and coordinates for at least one site must be entered.

Set the "To Datum" to either NAD27 or NAD83 and then select the NADCON region.

Click the Transform button to carry out the coordinate transformation.

The Accept button changes the site coordinates to the transformed coordinates.

NADCON and the USGS 7.5 minute (30 meter) Terrain Database.

When the USGS 7.5 minute quad (30 meter) terrain database has been selected, and the input coordinates

are in the NAD83 datum, the coordinates will be transformed to NAD27 for the specific database operation. This transformation will always be carried out for any of the region selections available under the NAD83 datum.

Primary and Secondary Terrain Database Operation
Given the situation below:

- User coordinates are in NAD83.

- The primary terrain database is set to USGS 7.5 minute (30 meter).

- The secondary terrain database is set to the USGS 3 second compressed, GTOPO30 or any of the DTED selections. These are all referenced to the WGS84 datum.

- Due to incomplete coverage of the USGS 7.5 minute database, the secondary database will be used for part of the profile.

What region should be selected for the NAD83 datum?

The NADCON region should not be selected. Instead use the specific region (i.e. CONUS, Hawaii, Alaska excluding Aleutian Is or the Aleutian Islands). When the program reads the USGS 7.5 minute database, the coordinates will be automatically transformed to NAD27 using NADCON. When the program reads the secondary database, the transformation to WGS 84 will be carried out for the specified region.

NADCON Description
In addition to the Conterminous United States, the NADCON data is also used to transform data originally expressed in old island datums that exist in Alaska, Hawaii, Puerto Rico and the Virgin Islands into data referenced to NAD 83. However all datums, including these, are referred to as NAD 27. The procedure automatically chooses the proper transformation; the user does not need to know the specific name of the original datums.

Transformation Accuracy
At the 67 percent confidence level, the transformation introduces the following uncertainties:

- approximately 0.15 meter uncertainty within the conterminous United States (CONUS)

- 0.50 meter uncertainty within Alaska

- 0.20 meter uncertainty within Hawaii

- 0.05 meter uncertainty within Puerto Rico and the Virgin Islands.

In areas of sparse geodetic data coverage NADCON may yield less accurate results, but seldom in excess of 1.0 meter.

In near offshore regions, results will be less accurate but seldom in excess of 5.0 meters. Farther offshore NAD 27 was undefined.

Area	File	Latitude	Longitude	Grid-deg
Conterminous US (lower 48 states)	conus.ncd	20N - 50NW	63W - 131W	0.25

Area	File	Latitude	Longitude	Grid-deg
Alaska including the Aleutian Islands	alaska.ncd	46N - 77N	128W - 194 W	0.125
St. Lawrence Is., Alaska - Old Island Datum within Alaska	stlrnc.ncd	62N - 64N	168W - 172W	0.05
St. George Is., Alaska - Old Island Datum within Alaska	stgeorge.ncd	56N - 5N	169W - 171W	0.01667
St. Paul Is., Alaska - Old Island Datum within Alaska	stpaul.ncd	57N - 58N	169W - 171W	0.05
Puerto Rico and the Virgin Islands	prvi.ncd	17N - 19N	64W - 68W	0.05
Hawaiian Islands	hawaii.ncd	18N - 23N	154W - 161W	0.025

St. George Island and St. Paul Island are part of a region known as the Pribilof Islands. There were two separate datums, one for each island, before NAD 83. The old island datums differ significantly from NAD 27. Data input into NADCON must be consistent with the identified transformation data sets. The transformation of misidentified data can result in very large errors (as much as hundreds of meters).

The CONUS file covers an area from 20 to 50 degrees north latitude and from 63 to 131 degrees west longitude. The Alaskan file covers an area from 46 to 77 degrees north latitude and from 128 to 194 degrees west longitude. The CONUS and Alaskan files overlap between 46 to 50 degrees north latitude and 128 to 131 degrees west longitude. In this area, the CONUS and Alaskan files agree within 2 centimeters. For those cases requiring precision greater than this, the CONUS file is considered correct. In this overlapping region the CONUS file will always be used in the Pathloss program. Transformations based on NADCON data should be used only within the U.S. territorial limits.

OPERATIONS

The following functions are implemented in the Operations menu selection:

Measurements

Select Operations - Measurements from the Terrain Data menu bar to access the Measurements dialog box. Alternately, press the F4 key.

System

Select either kilometers-meters or miles-feet as the units of measure. The measurement system can be changed at any time. All data in the program is automatically converted to the new system. The measurement system can also be changed using the F5 key or by clicking the left mouse button on the units box in the status bar.
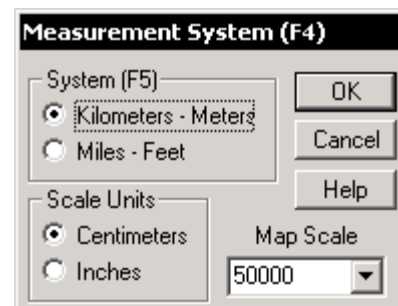
Scale Units - Map Scale

The scale units and map scale set the conversion between the scale distance and path distance. As an example, using centimeter units and a map scale of 50000 (1:50,000), a one centimeter entry in the scale column is converted to 0.500 kilometers in the distance column.

These settings are critical when a digitizing tablet is used to enter terrain data and whenever distances are taken from a map in inches or centimeters.

Delete Points

The following terrain point deletion options are provided:

Selected Point Only

This selection deletes the current point only. Alternately, hold down the Ctrl key and press the letter 'Y' to delete the current point.
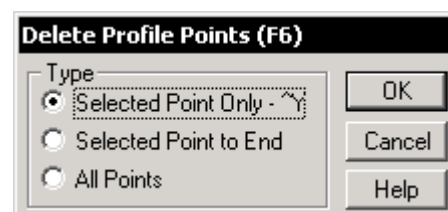
Selected Point to End

This selection deletes all points after the selected point. The selected point will become the last point in the terrain data entry form.

All Points

All terrain points are deleted. Note that all other parameters, including site names, coordinates and the worksheet data are unchanged.

Reverse Profile

Select Operations - Reverse Profile from the Terrain Data menu bar. The profile is reversed from left to right. All data including the site names, antenna heights, coordinates and the worksheet is also reversed.

Match End Point

Select Operations - Match End Point from the Terrain Data menu bar. This is used to compare the path length calculated from the coordinates with the path profile length. The path profile length is the distance of the last point on the profile.

The profile length can changed to the calculated length by simply changing the distance of the last point in the profile or by proportionally changing the distance of each point in the profile. The difference between the calculated and actual length must be less than five percent of the actual length to make the change. If the end point distance is to be changed, the calculated path length must be greater than the distance of the second last point in the profile.
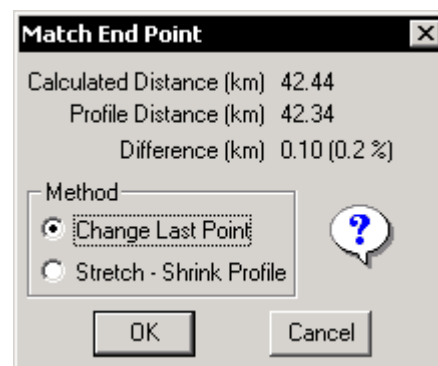
Survey Angles

The survey angles data entry form calculates the eleva-
tion difference derived from the measured and calcu-
lated vertical angles from Site 1 to a point on the
profile. Select Operations - Survey Angles from the
Terrain Data menu bar. The cursor must not be posi-
tioned at Site 1.

The following entries are required:

- The height of the instrument above ground level.
  The default height is 1.6 meters.

- The value of K for light. The default value for opti-
  cal K is 7/6.

- The vertical angle measured from the zenith. This can be entered in degrees minutes seconds or as a
  decimal.

Vertical Angle at 42.34 km	
OK Cancel Help	
Latitude	56 14 09.73 N
Longitude	117 15 54.73 W
K for Light	1.167
Instrument Height (m)	1.60
Calculated Angle (d-m-s)	090 16 58.73
Measured Angle (d-m-s)	090 12 00.00
Elevation Difference (m)	61.32
Measured Angle (d-m-s) :	

The data entry form shows the calculated latitude and longitude of the selected point, the calculated vertical
angle and the elevation difference derived from the measured vertical angle.

Strip Redundant Points

Calculation times and memory requirements increase when there are more than 500 terrain data points.
Many of the intermediate points do not improve the overall accuracy of the calculations. Profiles generated
from a terrain data base can have over 1000 points. If the path crosses over water, there will always be a
series of points with identical elevations.

Select Operations - Strip Redundant Points from the Terrain Data menu bar. The user is prompted to enter
a percent tolerance which is denoted by *P*. The points are removed from the profile according to the fol-
lowing algorithm:

The maximum and minimum elevations on the profile are determined as E_{max} and E_{min}. An elevation tol-
erance, *E*, is defined as:

$$E = P \cdot \frac{E_{max} - E_{min}}{100}$$ (1)

Peaks, valleys and points with a structure are always retained. The algorithm scans the profile, examining
three successive points in turn with elevations *E1, E2* and *E3*. If *E3 - E2* and *E2 - E1* are less than *E*, then
the central point will be marked in red for deletion.

To actually remove these points from the profile, select Operations - Accept-Reject from the Terrain Data
menu bar.

The default tolerance is 0 percent which will remove a point if its elevation is exactly equal to those of the
adjacent points. A tolerance of 5 percent is considered extreme.

Expand Flat Terrain

Terrain profiles developed from topographic maps often have flat top hills and valleys. This effect occurs when the profile crosses the last closed contour. The result may be a lack of clearance or lower values of diffraction loss depending on the application. Additional points can be added in these areas using the expand flat terrain feature. Select Operations - Expand Flat Terrain from the Terrain Data menu bar. The user is prompted to enter a percent of the contour interval. This determines the elevation of the new points.

The profile is first scanned to determine the contour interval. If several maps with different contour intervals were used to generate the profile, each section will be expanded using that contour interval.

Whenever two successive equal elevations are encountered in the profile, a central point is added.

The elevation of the central point is increased (or decreased) by the minimum of the specified percent of the contour interval or the value determined by the slope of the hillside.

The new point is marked in red for insertion.

If the ground type of the first point has been identified as salt or fresh water, the point addition will not take place.
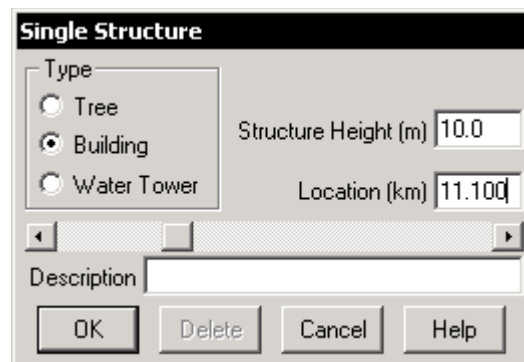
To insert these points permanently into the profile, select Operations - Accept-Reject Changes from the Terrain Data menu bar.

STRUCTURES AND GROUND TYPES

Single Structure

Single trees, buildings and water towers can be added to the terrain profile. Only buildings are allowed at the ends of the path. If a tree or water tower is added, it will be removed when the Terrain Data module is closed.

Place the hilited bar on the structure field at the desired point and press Enter or double click on the structure field. Select Single to open the Single Structure dialog box.

Select either tree, building or water tower as the structure type.

The location field is the distance in kilometers or miles from Site 1. The default value is the distance of the currently selected point; however, any distance can be specified. If required, the program will insert a new point in the profile using linear interpolation. Using this feature it is possible to move an existing structure.

Enter the structure height. The height can also be entered or changed directly in the height column of the terrain data entry form. An optional description of the structure can also be entered.

To delete a single structure, click the delete button or enter a zero in the height column of the terrain data entry form.

This procedure can be bypassed to enter trees only. Enter the tree height in the height column and the structure will default to a tree.

Structure Range

A continuous range of structures along the path can be specified. Overlapping ranges are not allowed; however, a single or off path structure can be located within a range.
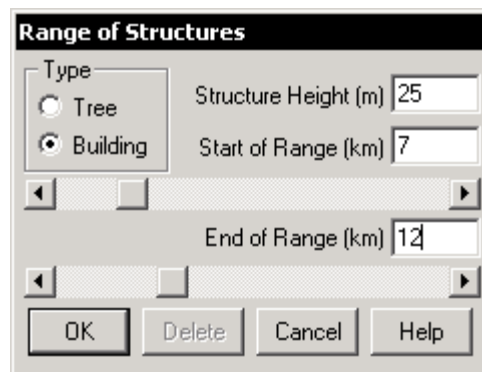
Place the hilited bar on any structure field and press Enter. Alternately, double click on any structure field. Select Range to bring up the Structure Range dialog box. Two arrows appear on the profile, marking the start and end of the range.

Select either a tree or building as the structure type.

Enter the start and end distances of the range or use the horizontal scroll bars to position the arrows at the desired point. The start and end points of an existing range can be edited in the same manner.

Enter the height of the range. The height can also be entered or changed directly in the height column at the start of the range (SR).

To delete a range, click the delete button or enter a zero in the height column at the start of the range (SR). Entering a zero at the end of the range (ER) has no effect.
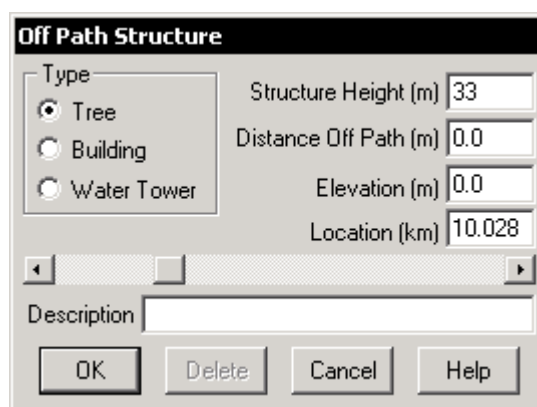
Off Path Structure

Off path trees, buildings or water towers can be added to the terrain profile. An off path structure cannot be located at the ends of the path. The clearance report in the Antenna Heights module calculates the horizontal clearance to the off path structure.

Place the hilited bar on the structure cell at the desired point and press Enter or double click on the structure cell. Select Off Path to open the Off Path Structure dialog box.

Select either a tree, building or water tower as the structure type.

The location field is the distance in kilometers or miles along the path. The default value is the distance of the currently selected point; however, any distance can be specified. If required, the program will insert a new point in the profile using linear interpolation. Using this feature it is possible to move an existing off path structure.

Enter the off path structure height in feet or meters. The height can also be entered or changed directly in the height column of the terrain data entry form.

Enter the off path distance in feet or meters. This is a mandatory entry.

The remaining two entries, the ground elevation at the off path structure and the description are optional and are for information purposes only.

To delete an off path structure, click the delete button or enter a zero in the height column of the terrain data entry form.

Ground Type

Ground types are classified as poor, average, good, salt water or fresh water. The terms, poor, average and good refer to the agricultural properties of the ground. Rocky terrain or desert conditions are classed as poor ground while fertile soil is characteristic of good ground. These classifications set the surface conductivity and the relative dielectric constant for the terrain. These parameters are used to calculate the theoretical reflection coefficient.

The default ground type is the same as the last point. In a new file, the default ground type is average.

Place the hilited bar on the ground field at the desired point. Press the Enter key or double click on the ground field and select the ground type. The ground type of all succeeding points will be changed to the selected type.

FILE CONVERSION

Convert Text File

A text file containing a listing of distances and elevations can be converted to a Pathloss data file provided that the file does not contain multiple distances and elevations on the same line. The size of the file must be less than 12 kilobytes. Select Text File from the Convert menu on the Terrain Data menu bar. The procedure is given in the following steps:

1. Load the required text file. The file can be edited in the display; however, the changes cannot be saved; and therefore, the original file will always be retained.

2. Determine if the distances and elevations are in kilometers-meters or in miles-feet. If necessary, change the measurement system to match the file units.

3. Define the columns for the distance and elevation. The maximum column number is 6. If a comma is used to separate the entries, then check the comma delimited box.

4. The conversion stops when either a blank line or the end of the file is reached. If necessary, add several blank lines after the last line containing distance - elevation data.

5. Place the caret (text cursor) at the start of the first line in the file containing the distance - elevation data. This is the point that the conversion will start.

6. Select Convert on the menu bar to convert the file.

7. The site names, coordinates and any other data in the text file can be transferred to the appropriate data entry form using the Windows copy and paste commands (Ctrl C and Ctrl V).
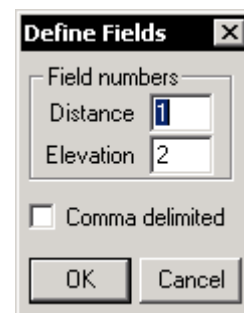
DIGITIZER OPERATION

Terrain profile can be generated using a digitizing tablet compatible with the GTCO Digi-Pad 5 series. A digitizing tablet completely eliminates manual data entry and will improve overall accuracy. Note that the digitizer must be enabled and the comm port set to access the digitizer in the Terrain Data module. Select Operations - Setup Digitizer from the Terrain Data menu bar. The default communications parameters settings correspond to the digitizing table default parameters.

Digitizer Buttons

The following descriptions apply to a four button digitizing cursor. The functions of these buttons cannot be changed. The additional features of a 16 button cursor are given later in this section. In the following descriptions, buttons will be referred to as SET REF, SAME, UP and DOWN. The action of these buttons are described in the following paragraphs.
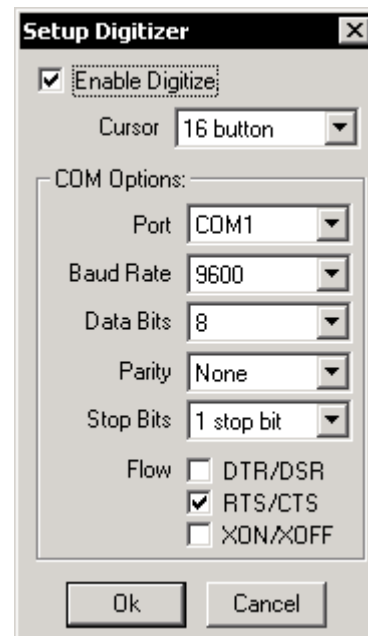
SET REF **(Button 4 - Set Reference Point)**

This button establishes a reference location on the tablet. This is always the first step in entering terrain data. All distances will be relative to this point. Unless the reference location has been selected, data entry cannot proceed. The reference location can be changed at any time. There is no data entry associated with this button press.

UP **(Button 1 - Go Up One Contour)**

If the last elevation is an exact multiple of the contour interval, the UP button enters a terrain point using the last elevation plus the contour interval. Otherwise, the elevation will be the nearest contour greater than the last elevation.

Example - Contour Interval = 50 meters

    Last Elevation   1500 meters (1500 is exactly divisible by 50)

    New Elevation   1550 meters

Example - Contour Interval = 50 meters

    Last Elevation   1521 meters (1521 is not exactly divisible by 50)

    New Elevation   1550 meters

DOWN **(Button 3 - Go Down One Contour)**

If the last elevation is an exact multiple of the contour interval, the DOWN button enters a terrain point using the last elevation minus the contour interval. Otherwise, the elevation will be the nearest contour less than the last elevation.

Example - Contour Interval = 50 meters

    Last Elevation   1500 meters (1500 is exactly divisible by 50)

    New Elevation   1450 meters

Example - Contour Interval = 50 meters

    Last Elevation   1521 meters (1521 is not exactly divisible by 50)

    New Elevation   1500 meters

SAME   **(Button 2 - Use Last Elevation)**

The SAME button always enters a terrain point using the same elevation as the last point. This is true even if the previous elevation is not exactly divisible by the contour interval.

Example - Contour Interval = 50 meters

    Last Elevation   1500 meters (1500 is exactly divisible by 50)

    New Elevation   1500 meters

Example - Contour Interval = 50 meters

    Last Elevation   1521 meters (1521 is not exactly divisible by 50)

    New Elevation   1521 meters

Initial Preparations

Verify the following settings in the measurements dialog box:

System   select the same units (miles-feet or km-meters) as the contours on the topographic map which will be used to digitize the profile.

Scale Units   select the same units (inches or centimeters) that were used to configure the digitizing tablet.

Map Scale   select the scale of the topographic map which will be used to digitize the profile.

Any errors in the above settings will result in a terrain profile with wrong distances or elevations. This can only be corrected by totally redigitizing the profile.

Locate the sites and draw a pencil line between the two sites to mark the path profile. Note that the profile can span any number of maps.

Attach the topographic map to the digitizing tablet using removable tape.

Digitizing Procedure

- Enter the first elevation in the terrain data entry form. This is the ground elevation above sea level at Site 1. This elevation must be taken from the map.

- Press the F9 key to enable the digitizer. You will be prompted to enter the contour interval.

- Place the cursor on the starting point (Site 1) and press the SET REF button. All distances will be referenced to this point.

- Move the cursor to the first contour interval and press the UP, DOWN or SAME button as applicable. The distance-elevation is automatically entered into the terrain data entry form. Continue this process until the end of the profile is reached. After the second point has been entered, the profile will be displayed as data entry proceeds.

- Press the F9 key to exit the digitizing mode and return to normal data entry and editing. If you return to the digitizing mode, the same reference point will be in effect.

Note that the reference point can be changed at any time during the digitizing process. If the terrain profile traverses several topographic maps, it will be necessary to re-establish a new reference point at the start of each map.

Sixteen Button Cursor

The following additional button functions are available using a sixteen button digitizing cursor.

Button	Function
5	UP_1/2 - up one half contour interval
6	SAME - same as last contour
7	DOWN_1/2 - down one half contour interval
8	Set the ground type of the last point to fresh water
12	Set the ground type of the last point to salt water
13	Enter a spot elevation
14	Enter the last spot elevation

Button 16 toggles the digitizing mode between the point /line mode and the continuous mode. The program must operate in the point /line mode and this toggle action cannot be disabled. Therefore, button 16 must not be pressed while digitizing a profile.

Switch Settings

This section lists the switch settings required to operate the program with a GTCO Digi-Pad 5 compatible digitizing tablet. The shaded areas represent the required switch settings.

Table 1: Switch 1 Settings (GTCO Digi-Pad 5)

	BAUD RATE					
	300	600	1200	2400	4800	9600
Switch S1-1	OFF	ON	ON	ON	OFF	OFF
Switch S1-2	OFF	OFF	ON	OFF	OFF	OFF
Switch S1-3	ON	ON	ON	OFF	OFF	ON
Switch S1-4	OFF	OFF	OFF	ON	ON	ON
	Switch OFF			Switch ON		
Switch S1-5	Parity Off			Parity On		
Switch S1-6	Parity Odd			Parity Even		
Switch S1-7	1 Stop Bit			2 Stop Bits		
Switch S1-8	7 Data Bits			8 Data Bits		

Table 2: Switch 2 Settings (GTCO Digi-Pad 5)

	Switch OFF		Switch ON	
Switch S2-1	No Pushbutton Code		Include Pushbutton Code	
Switch S2-2	No Space		Include Space (ASCII)	
Switch S2-3	No Carriage Return		Include Carriage Return (ASCII)	
Switch S2-4	No Line Feed		Include Line Feed (ASCII)	
Switch S2-5	Low Res ASCII if S3-7 is OFF Low Res Binary if S3-7 is ON		High Res ASCII if S3-7 is OFF High Res Binary if S3-7 is ON	
	Active Serial Port			GPIB PORT
	A and B	A Only	B Only	
Switch S2-6	OFF	ON	OFF	ON
Switch S2-7	OFF	OFF	ON	ON
	Switch OFF		Switch ON	
Switch S2-8	Alarm Disabled		Alarm Enabled	

Table 3: Switch 3 Settings (GTCO Digi-Pad 5)

	Switch OFF		Switch ON	
Switch S3-1	Not Used		Not Unsed	
	Rate - Coordinates / Second			Incremental Mode
	12	100	200	
Switch S3-2	OFF	ON	OFF	ON
Switch S3-3	OFF	OFF	ON	ON
	Switch OFF		Switch ON	
Switch S3-4	Point - Line Mode		Continuous Mode	
Switch S3-5	Stylus 4B or 5B Cursor		16 Button Cursor	
Switch S3-6	Inch Scale		Metric Scale	
Switch S3-7	ASCII Formats		Binary Formats	
Switch S3-8	No Hardware Flow Control		Hardware Flow Enabled	

TERRAIN DATABASES

OVERVIEW

The Pathloss program supports a number of raster type terrain databases. In essence, these consist of a two dimensional array of elevations expressed as 2 byte integers. The descriptions below refer to this array as rows and columns for both rectangular grid and geographic databases. The computer file may be written as sequential rows or sequential columns starting at any corner of the database. The following additional parameters are required to use the database:

- The number of rows and columns.

- The order of the rows and columns in the computer file.

- The spacing between the rows and columns. This may be expressed as a geographic spacing in arc seconds or as a rectangular grid spacing in meters depending on the type of database. The spacing and the number of rows and columns define the extents of the database file.

- A geographic reference of one corner of the array. Again, this may be the geographic coordinates or the grid coordinates (UTM, Gauss conformal...) of one corner. This reference allows the users coordinates to be mapped into the elevation array.

- The horizontal datum.

The above information allows a profile to span several database files. The information may be available in the file header, in a separate index or can be implicitly defined by the database type and the file name as described below:

File Naming Convention

The file name identifies the reference corner. All other information is implicitly defined by the data base type. Some databases also employ a directory naming structure.

Index Databases

A separate index file is maintained which stores the file name and all other required information. All files must be located in the same directory in this system.

File Header

This method is only used in the GTOPO30 global 3 arc second database. The program first determines the required file name then reads the header file.

All of these methods are used in various terrain databases supported by the Pathloss program.

Primary and Secondary Databases

The Pathloss program supports a primary and secondary database. This allows a high resolution database with partial coverage to be supplemented with a second database of lower resolution, but with complete coverage. An example of this situation is the USGS 1 degree and 7.5 minute digital elevation models in the United States. The 1 degree DEM has a spacing of 3 arc seconds between rows and columns for latitudes less than 50 and has complete coverage. The 7.5 minute DEM has a spacing of 30 meters. The coverage of the latter is not complete. One could specify the 7.5 minute DEM as the primary database and the 1 degree DEM as the secondary. A terrain profile would be generated from the 7.5 minute data, where it is avail-

able, and default to the 1 degree data if the required files are not available. The program creates a report on the primary and secondary file usage over the profile.

Datums

The datum used in a terrain database may be different from the datum used to specify the site coordinates. In Canada, the NAD27 and NAD83 datums are currently used on different scale topographic maps. A common database is the 1 degree DEM based on the WGS84 datum. The program will automatically transform the NAD27 or NAD83 coordinates to WGS84 coordinates to generate the terrain profile. Both the datum and the region must be selected in the Geographic Defaults dialog box for this transformation to take place.

Some regional grid coordinate systems do not conform to any of the standard datum definitions. An example is the Swiss grid coordinate system. In such cases it will be necessary to use an ellipsoid definition instead of a datum. The ellipsoid would be the same as that used in the grid coordinate system.

Database Operations

A terrain database is required for the following operations:

- To generate a terrain profile in the Terrain Data module.

- To calculate over the horizon loss (OHLOSS) when analyzing an interference case.

- To generate radial profiles in the Area Coverage module.

- To create a 3D terrain view in the Terrain Data and Network modules.

BASIC PROCEDURE TO CREATE A TERRAIN PROFILE

The following procedure is used to generate a terrain profile from any terrain database. Note that each database has a specific setup procedure as described later in this section. Single profiles area created in the Terrain Data module.
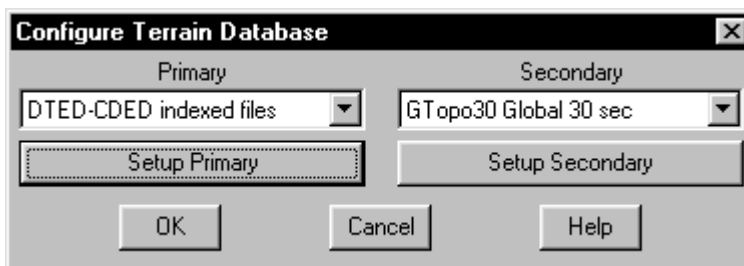
- Select Configure - Terrain Database from the menu bar to bring up the Configure Terrain Database dialog box.

- Select the primary and secondary databases. Use the "No Selection" for the secondary database if this will not be used. There is a performance penalty in interrogating two databases.

- Click the Setup button and carry out the setup procedures for the selected database. These procedures are described later in this section.

- Click the OK button to accept the terrain database selection. The configuration will automatically be saved.

- Enter the coordinates of both sites using either the inverse or forward coordinate data entry forms. Verify that the coordinates correspond to the selected datum.

- Click Operations - Generate Profile to access the Generate Profile dialog box.

- Specify the distance increment. The profile starts at Site 1 and generates points at the specified distance increment until Site 2 is reached.

- Click the Generate button.

Profile Generation

If the selected datum is different from the database datum, the coordinates will be transformed to the database datum if applicable.

The profile will follow the great circle arc between the two sites starting at site 1. At each point, along the profile, a new set of coordinates is determined and the corresponding elevation is read. The process continues until site 2 is reached. An elevation is determined by reading the elevations at the four points in the database which bound the required point. The elevation of the point is the weighted average of these four elevations. The relative location of the point, with respect to the four corners points, is used to determine the weighting.

A status report is created, on completion. The report lists the primary and secondary files that were used to generate the profile and the segment of the profile which they were used. The results can be copied to the Pathloss notepad or to another document.

Span Missing Files

The file corresponding to the Site 1 coordinates must be available to start the profile generation. If the database is indexed, the program has no way of knowing the required file name. If the database uses a file naming convention, the missing file name will be reported.

Normally, the profile generation terminates if the required file is missing. If the "Span missing files" option is checked, the program will continue on to Site 2 and generate a report of all of the missing file names. The database must use a file naming convention in order to generate this report. You can use this feature to determine the required primary and secondary files, as illustrated in the sample report below. In this case, the primary database was set to USGS 7.5 minute files in a single directory. The secondary database is DTED using a PL4 directory structure.

```
    Files Missing
    Primary           C:\DIG_MAPS\USGS_75\36090a1.30m
```
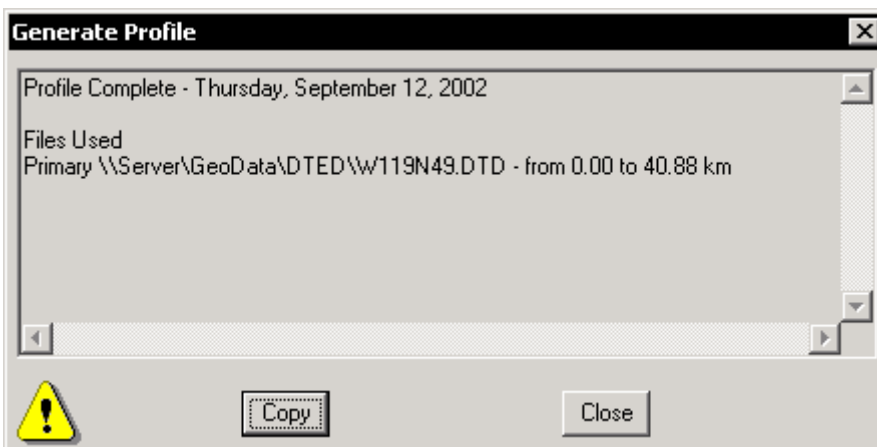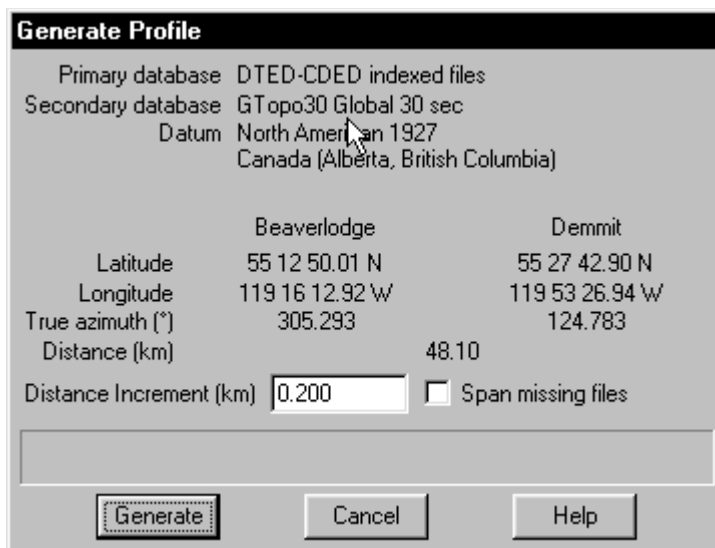
```
Secondary        C:\DIG_MAPS\W091\W091N36.DTD
Primary          C:\DIG_MAPS\USGS_75\36089a8.30m
Secondary        C:\DIG_MAPS\W090\W090N36.DTD
Primary          C:\DIG_MAPS\USGS_75\36089a7.30m
Primary          C:\DIG_MAPS\USGS_75\36089b7.30m
Primary          C:\DIG_MAPS\USGS_75\36089b6.30m
Primary          C:\DIG_MAPS\USGS_75\36089c6.30m
Primary          C:\DIG_MAPS\USGS_75\36089c5.30m
```

If a file read error is encountered, the profile generation always terminates.

DTED TERRAIN DATA

DTED (Digital Terrain Elevation Data) is the US Defense Mapping Agency binary terrain data format. The data is written in columns starting in the south west corner. The extents of the file and the latitude longitude increment is determined from the file header. A check sum value is appended to each column of data to verify the file integrity. DTED files are referenced to the WGS84 horizontal datum. Coordinates will be automatically transformed to this datum if necessary

The DTED file format is supported in three directory structures using a file naming convention and as indexed files. Any of these can be used as a primary or secondary database.

USGS 1:250,000 DEM files are supported by converting these files to the DTED format. Canadian CDED ASCII files can also be converted to the DTED format.

DTED 3 sec Indexed Files Setup

Directory
All files must be located in the same directory. Click the Set Directory button and point to the directory containing the DTED files.

File Index
The program uses an index file to detmine the correct file name to use for a given set of coordinates. The entire index is examined to ensure that the file with the highest resolution is used. Click the Index button to access the grid data entry form. Refer to General Program Operation section for details on the use of this form. When the grid data entry form is closed, the index is automatically saved in the file DTED.DTA in the Pathloss directory.

The ASCII to binary file conversion process automatically adds the newly converted file to the index. The index data can be entered manually into the data entry form or can be read from the DTED files. Select File
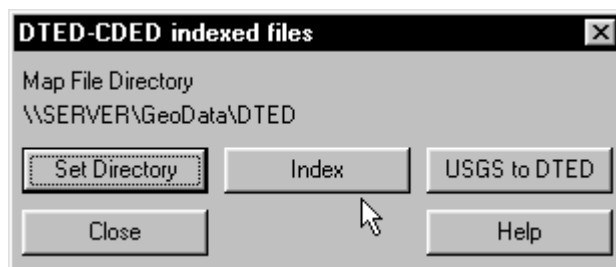
- File Index on the menu bar to access the multi-select file open dialog box. Select the files and click Open to create an index. DTED Level 1 and 2 can be entered. The index contains the following fields:

	Map Name	File Name	West edge (°)	East ed...	South ed...	North ed...	Lat Inc (")	Lng Inc...
1	092G02demw	092G02_0101_demw.dtd	123.00	122.75	49.00	49.25	0.75	0.75
2	092G02deme	092G02_0101_deme.dtd	122.75	122.50	49.00	49.25	0.75	0.75
3	072fdeme	w109n49.dtd	109.00	108.00	49.00	50.00	3.00	3.00
4								

Map Name

This is an optional descriptive term for the users reference and is not used by the program.

File Name

There are no rules for file names in an indexed database. The default file name is the ASCII DEM file name with the suffix dtd. For a one degree by one degree 3 arc second file, the naming convention shown below was previously used:

• The first letter is either 'W' or 'E' for western or eastern longitudes, respectively.

• The next three numbers represent the longitude of the south west corner, using a zero prefix if the longitude is less than 100 degrees.

• The fifth letter is either 'N' or 'S' for northern or southern latitudes, respectively.

• The next two numbers are the latitude of the south west corner.

• The file suffix is "DTD".

File Edges

The bounding edges of the file must be specified in degrees as follows:

west edge - longitude of the SW or NW corner. A negative value must be used in the eastern hemisphere.
east edge - longitude of the SE or NE corner. A negative value must be used in the eastern hemisphere.
south edge - latitude of the SW or SE corner. A negative value must be used in the souhern hemisphere.
north edge - latitude of the NW or NE corner. A negative value must be used in the souhern hemisphere.

Latitude and Longitude Increment

The latitude and longitude increment must be specified in seconds. For latitudes higher than 50 degrees the longitude increment may be greater than the latitude increment. The DTED level 1 tthe is always 3 seconds. The longitude increment normally depends on the latitude as shown below; however, there are many regional exceptions.

Latitude	Spacing	Columns
0 to 50 deg	3 sec	1201

|		
50 to 70 deg	6 sec	601
70 to 75 deg	9 sec	401
75 to 80 deg	12 sec	301
80 to 90 deg	18 sec	201

DTED Directory Structures and File Naming Conventions

US DMA Directory Structure
The files are organized by the longitude of the south west corner of the map. The directory structure is shown on the right. Note that there must be a leading zero for longitudes less than 100 degrees. Click the Set Directory button and select the root directory (DTED for the example) . The directory structure must be created by the user. The files are named by latitude only as follows:
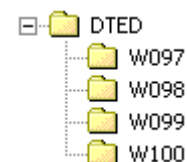
- The first letter is either 'N' or 'S' for northern or southern latitudes respectively.

- The next two numbers represent the latitude of the south edge of the file.

- The file suffix is "DT1" for level 1 and "DT2" for level 2.
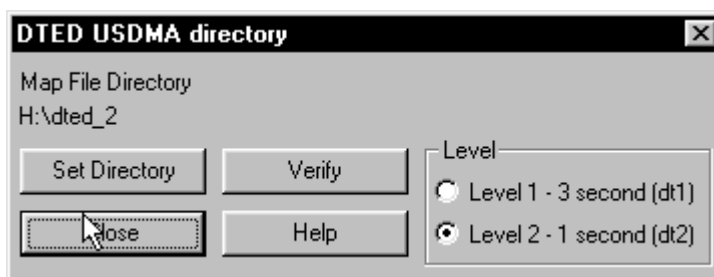
Note that the overall file identification depends on both the directory name and the file name. The same file names will occur in different directories.

Canadian Directory Structure
An example of the Canadian DTED directory structure is shown on the right. The format is similar to the US DMA structure with four zeros added to the directory and file names. Click the Set Directory button and select the root directory (DTED for the example) . The directory structure must be created by the user. The files are named by latitude only as follows:

- The first letter is either 'N' or 'S' for northern or southern latitudes respectively.

- The next two numbers represent the latitude of the south edge of the file.

- The next four numbers are zeros.

- The file suffix is "DT1".

Note that the overall file identification depends on both the directory name and the file name. The same file names will occur in different directories.

PLW40 Directory Structure
The files are organized by the longitude of the south west corner of the map. A typical directory tree for DTED files is shown on the right. Note that there must be a leading zero for longitudes less than 100 degrees. Click the Set Directory button and select the root directory (DTED for the example) . The directory structure must be created by the user. The files must be named as follows:

- The first letter is either 'W' or 'E' for western or eastern longitudes, respectively.
- The next three numbers represent the longitude of the south west corner using a zero prefix if the longitude is less than 100 degrees.
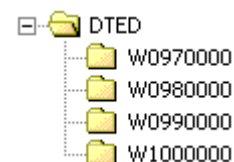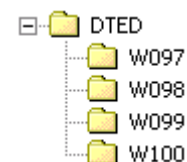- The fifth letter is either 'N' or 'S' for northern or southern latitudes, respectively.
- The next two numbers are the latitude of the south west corner.
- The file suffix is "DTD".

USGS to DTED File Conversion

USGS 1:250,000 DEM files are available from the USGS and also from various on-line vendors. The utility program GZIP is required to unzip these files. The USGS DEM files are approximately 9.8 Mbs and cover a one degree by one degree area. These files must be converted to the DTED format. This is carried out in the DTED - USGS Files dialog box. Click the USGS to DTED button and specify the USGS file to be converted. This is a multi-select file open file dialog box. If a single file is selected, a save file dialog box will open up, prompting for the name of the DTED file. The default file name will depend on the selected directory structure, as described in the preceding paragraph. If multiple files are selected, the save file dialog box does not appear and an existing file will be overwritten. Any error will terminate the file conversion.

If the file conversion is carried out in the DTED 3 sec Indexed Files setup, the converted file will be automatically added to the index.

Digital Terrain Elevation Data (DTED) Format

The DTED format is the US Defense Mapping Agency's standard format for the exchange of terrain elevation data. Each file consists of terrain data for an area of one degree in latitude by one degree in longitude. Two files are required to cover the area of a 1:250,000 scale topographic map.

Each file starts with general header information. The length of this header may vary depending on the source of the data. The elevations are represented by 2 byte integers with the high and low bytes reversed compared to the personal computer format. The elevations are stored in columns starting at the south west corner and ordered from south to north. There are 1201 elevations in each column, every 3 seconds of latitude. An eight byte column identifier is placed at the start of each column. The first character in the column identifier is hex AA. A four byte checksum is placed at the end of each column. This checksum is derived from the algebraic sum of the column elevation data and identifier.

The number of columns in the file depends on the latitude as shown below:

Latitude	Spacing	Columns
0 to 50 deg	3 sec	1201
50 to 70 deg	6 sec	601
70 to 75 deg	9 sec	401
75 to 80 deg	12 sec	301
80 to 90 deg	18 sec	201

Elevations are referenced to mean sea level and the horizontal datum is the World Geodetic System of 1984 (WGS84).

DTED File Verification

DTED files contain a checksum at the end of each column of elevations. A file verification sequentially reads each column in the file and calculates the sum of the individual bytes. This sum is compared with the checksum.

For a DTED 3 sec Indexed database, the verification is carried out in the index grid data entry form. Place the hilited bar on the required line and select Verify on the Index menu bar.

If a file naming convention option has been selected for a DTED database, click the Verify button in the Setup dialog and select the file to be verified.

GTOPO30 GLOBAL 30 ARC SECOND DATABASE

GTopo30 is a global digital elevation model with a horizontal grid spacing of 30 arc seconds. A total of 27 files cover the world excluding Antarctica. Each file covers an area 40 degrees in longitude by 50 degrees in latitude. This terrain database is supplied with the Pathloss program under the following organization.

Table 1: GTOPO30 CD-ROM Contents

GTOPO30 Disk 1 North & South America					GTOPO30 Disk 2 Europe Asia & Africa				
File Name	NW Lat	NW Long	SE Lat	SE Long	File Name	NW Lat	NW Long	SE Lat	SE Long
E140N90	90 N	140 E	40 N	180	W020N90	90 N	20 W	40 N	20 E
W180N90	90 N	180	40 N	140 W	E020N90	90 N	20 E	40 N	60 E
W140N90	90 N	140 W	40 N	100 W	E060N90	90 N	60 E	40 N	100 E
W100N90	90 N	100 W	40 N	60 W	E100N90	90 N	100 E	40 N	140 E
W060N90	90 N	60 W	40 N	20 W	W020N40	40 N	20 W	10 S	20 E
E140N40	40 N	140 E	10 S	180	E020N40	40 N	20 E	10 S	60 E
W140N40	40 N	140 W	10 S	100 W	E060N40	40 N	60 E	10 S	100 E
W100N40	40 N	100 W	10 S	60 W	E100N40	40 N	100 E	10 S	140 E
W060N40	40 N	60 W	10 S	20 W	W020S10	10 S	20 W	60 S	20 E
W100S10	10 S	100 W	60 S	60 W	E020S10	10 S	20 E	60 S	60 E
W060S10	10 S	60 W	60 S	20 W	E060S10	10 S	60 E	60 S	100 E

Table 1: GTOPO30 CD-ROM Contents

Program Disk - GTOPO303 - Australia					The GTopo30 database uses a file naming convention based on the coordinates of the north-west corner.
File Name	NW Lat	NW Long	SE Lat	SE Long	
W180N40	40 N	180	10 S	140 W	A header file and a digital elevation model file are supplied for each region. The corresponding file name suffixes are hdr and dem
W180S10	10 S	180	60 S	140 W	
W140S10	10 S	140 W	60 S	100 W	
E100S10	10 S	100 E	60 S	140 E	
E140S10	10 S	140 E	60 S	180	

Each USGS GTOPO30 image file is accompanied by five ancillary files (header file, world file, statistics file, coordinate file and the data descriptor record). Of these, only the header file (hdr) and the image file (dem) are supplied with the Pathloss program. In order for a profile to span two GTOPO30 files, the files must be located in the same directory. With the CD-ROM file organization this will cause problems in certain parts of the world such as Iceland. The solution is to copy the required dem and hdr files to the same directory on your computer's hard drive. The size of the dem files are exactly 57.6 Mbs.

The setup consists of identifying the location of the files.

Elevations in the Gtopo30 database represent the average elevation in the area bounded by a 30 second cell and is defined at the center of the cell. The following points should be noted:

- There is no information available on the maximum or minimum elevations in the file.

- There are no spot elevations.

Two possible approaches can be taken to develop a terrain profile from this database:

- If a point falls anywhere in a cell, the elevation is taken to be the average value in that cell. This will produce a profile with a series of steps.

- The elevation can be taken as the weighted average of the four elevations which bound the point. This method produces a smooth continuous profile.

The latter method is used in the Pathloss program. The horizontal datum is WGS84. Site coordinates are transformed to this data to generate a terrain profile.

USGS 7.5 MINUTE (30 METER) TERRAIN DATABASE

The USGS 7.5 minute terrain database uses a file naming convention. Each file contains elevation data for a 7.5 minute 1:24000 scale map quadrangle. The elevations have been determined by overlaying a square UTM 30 meter grid onto the quadrangle. Since the UTM grid system is not orthogonal to the latitude - longitude system that defines the map quadrangle, a skewing effect occurs. All columns do not contain the same number of elevation points and the first elevation in each column does not necessarily correspond to the same northing for all columns. For example, columns of data near the east or west edges of the quad-

rangle may be partially outside of the vertical boundaries defined by lines of longitude, and only the points within the quadrangle boundaries are included in the file.

The USGS 7.5 minute files are supplied in ASCII format and are available directly through the USGS or can be purchased from terrain data distributors. These ASCII files must be converted to the Micropath / SoftWright binary format in the Pathloss program. The format and content of the ASCII files are described in National Mapping Program Technical Instructions, Data Users Guide 5, "Digital Elevation Models".
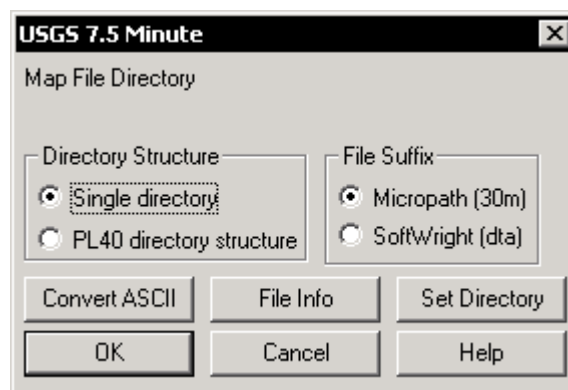
The setup procedure for the USGS 7.5 minute database is described in the following paragraphs.

Directory Structure

Two directory structure options are provided:

Single Directory

All files must be located in the same directory. Click the Set Directory button and select the directory containing the terrain data files.

PL40 Directory Structure

The files are organized by the longitude of the south east corner of the map. A typical directory tree for USGS 7.5 minute files is shown on the right. Note that there must be a leading zero for longitudes less than 100 degrees. Click the Set Directory button and select the root directory (USGS_75 for the example).

The directory structure must be created by the user.
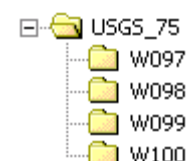
File Naming Convention

The program determines the required file based on the file names. The USGS file naming convention has the format "nnwwwNW" where:

nn	is the two digit northern latitude degree value, including leading zeros, of the southeast corner of the one degree block containing the quadrangle.
www	represents the three digit western longitude degree value, including leading zeros, of the southeast corner of the one degree block containing the quadrangle.
N	a single letter (A to H) designator defining the band of latitude north of the bottom (southern) edge of the one degree block.

A	0' to 7½'	E	30' to 37½'
B	7½' to 15'	F	37½' to 45'
C	15' to 22½'	G	45' to 52½'
D	22½' to 30'	H	52½' to 60'

W   a single number designator (1 to 8) defining the band of longitude west of the right (eastern) edge of the one degree block:

1	0' to 7½'	5	30' to 37½'
2	7½' to 15'	6	37½' to 45'
3	15' to 22½'	7	45' to 52½'
4	22½' to 30'	8	52½' to 60'

The letter C precedes the file name in the SoftWright binary file naming convention. The following file name suffixes are used:

USGS ASCII files	DEM
SoftWright Binary Files	DTA
Micropath Binary Files	30M

Binary File Format

The USGS ASCII files must first be converted into a binary format. The file consists of a fixed record length for each column of elevation data; however, the record length may vary from file to file. The first record in each file is a header containing the following information:

Bytes	Data type	Description
1-2	none	reserved
3-4	2-byte integer	Record length
5-6	2-byte integer	Number of columns
7-8	2-byte integer	Number of rows
9-12	4-byte integer	Minimum northing (meters)
13-16	4-byte integer	Maximum northing (meters)
17-20	4-byte integer	Minimum easting (meters)
21-24	4-byte integer	Maximum easting (meters)
25-64	ASCII	USGS map name.
65-75	ASCII	Datum (NAD-27, NAD-83,)
76	ASCII	DEM level (1,2,3)
77-78	2-byte integer	Minimum elevation (meters)
79-80	2-byte integer	Maximum elevation (meters)
81-120	ASCII	Data Source
121-122	2-byte integer	UTM zone (1-60)

The remaining records in the file contain the elevation data - one record for each column. The columns run from west to east. The elevations in each column run from south to north. The first entry in each column is

the easting (4 byte integer) of all elevations in the column. The next entry is the northing (4 byte integer) of the first elevation in the column. The remaining entries are the elevations in a 2 byte integer format. The northing of each successive column entry is obtained by adding 30 meters to the northing of the previous point. Since the binary file uses a fixed record length, some elevation points will be outside the boundaries of the map quadrangle. These elevations are set to the value -32000.

Binary File Conversion

Select either the Micropath or SoftWright file naming convention. The binary file format is identical in both cases. The program will use the selected convention to determine the correct file.
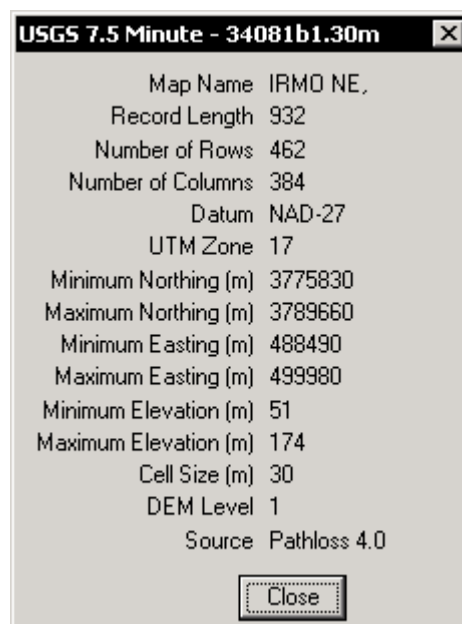
Click the Convert ASCII button, to select the ASCII files to be converted. This is a multi select open file dialog box. If a single file is selected, a save file dialog box is used to identify the location for the binary file. If multiple files are selected, the save file dialog box is not used and the converted files are saved in the specified directory structure. Existing files will be overwritten without warning.

The following anomalies are handled in the USGS 7.5 minute digital terrain data:

- elevations multiplied by a factor of 10

- 10 meter grid spacing (the default grid spacing is 30 meters)

- 1.5 minute longitude offset for the island of Oahu

- 5 minute latitude and longitude offset for the Maui island group

File Info

To view the header information of a binary file, click the File Info button and then select the binary file name. The header shows the extents of the file in UTM coordinates and the horizontal datum.

USGS 7.5 Minute – 34081b1.30m	
Map Name	IRMO NE,
Record Length	932
Number of Rows	462
Number of Columns	384
Datum	NAD-27
UTM Zone	17
Minimum Northing (m)	3775830
Maximum Northing (m)	3789660
Minimum Easting (m)	488490
Maximum Easting (m)	499980
Minimum Elevation (m)	51
Maximum Elevation (m)	174
Cell Size (m)	30
DEM Level	1
Source	Pathloss 4.0

ODYSSEY - PLANET TERRAIN DATABASES

The following Odyssey and Planet terrain data formats are supported:

- a general format based on a UTM projection

- regional format based on the Swiss National map projection system

- regional format based on the UK National grid system

- regional format based on the Irish grid system

- generalized Gaus Kruger projections

- New Zealand map grid

- Austrian MGI Lambert Conformal projection

These are indexed databases and the user must create an index as part of the database setup procedure. Any of these formats can be used as a primary or secondary database. The setup procedure is similar for all types and is described below:

Set Directory

All files must be located in the same directory. Click the Set Directory button and select the directory containing the database files.

Embedded building data

Normally an elevation is interpolated from the nearest four elevations to the point of interest. If the terrain data contains embedded building or canopy data, check the "Embedded building data" option. The cell elevations will be used in this case.
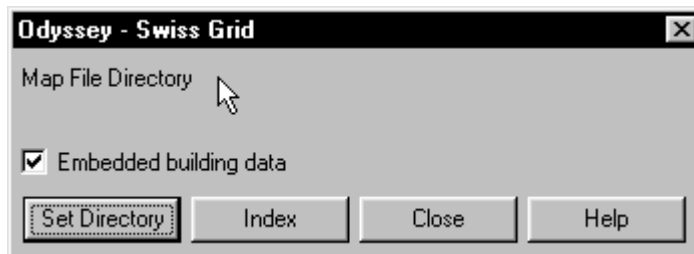
Index

The index uses a standard grid display. Refer to the General Operation section of this manual for details on the grid display. The index can be read from an external text file provided that the format is in the form shown below:

HEIGHT_FILE s1heights001 484825.00 253275.00 510425.00 278875.00 25.00 1 SPARC

	Map Name	Bytes /pixel	Bottom up	Byte order	Cell size (m)	West edge (km)	South edge (km)
1	s1heights001	2	True	SPARC	25.0	484.8250	253.2750
2	s1heights002	2	True	SPARC	25.0	510.4250	253.2750
3	s1heights003	2	True	SPARC	25.0	536.0250	253.2750
4	s1heights004	2	True	SPARC	25.0	561.6250	253.2750
5	s1heights005	2	True	SPARC	25.0	587.2250	253.2750
6	s1heights006	2	True	SPARC	25.0	612.8250	253.2750
7	s1heights007	2	True	SPARC	25.0	638.4250	253.2750
8	s1heights008	2	True	SPARC	25.0	664.0250	253.2750

Select File - Import List from the Index menu bar and select the list to convert. If a UTM projection is used, the user must enter the UTM zone for each item manually. The index is automatically saved in the Pathloss program directory using the following file names:

ODY_UTM.DAT   UTM formats

ODY_SNG.DAT   Swiss grid format

ODY_UKG.DAT   UK grid format

ODY_IRG.DAT   Irish grid format

ODY_GKR.DAT   Generalized Gauss Kruger

ODY_MGI.DAT   Austrian MGI Lambert Conformal

ODY_NZG.DAT   New Zealand Grid

The units are always in metric. The following fields are required:

Table 2:

Map Name	The file name of the map file. Enter the file name only. The full path is derived from the directory set in the previous step and the file name.
Bytes per Pixel	The elevations are stored as two byte integers in the database. Some implementations may contain an additional byte. Specify either 2 or 3 bytes.
Bottom Up	The file is written as sequential rows. If "bottom up" is true, the file starts at the upper left (north-west) corner. If "bottom up" is false, the file starts at the lower left (south-west) corner. Double click the left mouse button on the entry to change between the two formats. Alternately, press the Enter key.
Byte Order	The elevations are two byte integers. The byte order can be in either the SPARC or INTEL format. If the SPARC byte order is specified, the program will reverse the order of the bytes. If the profile is generated with random extreme positive and negative elevation, the byte order is wrong. Double click the left mouse button on the entry to change between the two formats. Alternately, press the Enter key.
Cell Size	This is the resolution of the database (spacing between the rows and columns) and is assumed to be the same in the north-south and east-west direction. Specify the resolution in meters.
West Edge	The western edge of the database file in kilometers. This is the minimum easting.
East Edge	The eastern edge of the database file in kilometers. This is the maximum easting.
South Edge	The southern edge of the database file in kilometers. This is the minimum northing.
North Edge	The northern edge of the database file in kilometers. This is the maximum northing.
UTM Zone	Specify the UTM zone for this database file. In this implementation, a database file cannot span several UTM zones. This field is only used for the UTM projection

Import Text File Index

Select Files - Import to define the fields for the import. All fields are delimited by one of more spaces. This is a generalized text import feature with default settings for Odyssey and Planet terrain databases.

Note that the "Byte order" and "Bottom up" options may have to be experimentally determined.

In UTM projections, enter the UTM zone N or S suffix and check "Zone number". Planet or Odyssey indexes do not include the UTM zone number. If the UTM zone is included in the index file, enter the field number for the UTM zone and check the "Field number" option.

The "Bytes per pixel setting is always 2 and the Edge units are always meters for Planet and Odyssey.

Click OK and load the index file.

Regional Grid Systems and Geographic Default Settings

Coordinate transformation is not used with any of the Odyssey terrain database formats. It is the user's responsibility to select the appropriate datum or ellipsoid. The following points should be noted:

- the conversion between geographic coordinates and Swiss, UK, Irish, New Zealand, and MGI grid coordinates is completely determined. The ellipsoid and scale factors are hard coded in the program.

- the conversion between geographic coordinates and UTM or Gauss Kruger coordinates will always use the current ellipsoid definition. This selection is set under Configure - Geographic Defaults on the main menu bar. If the "Use Datum" option is selected, then the ellipsoid associated with the datum is used. If the "Use Ellipsoid" option is selected, then the selected ellipsoid will be used.

- the calculation of distance and azimuth from geographic coordinates will always use the current ellipsoid definition.

For UTM databases, the same datum should be used as specified for the datum. You could also specify the ellipsoid directly. For example if the terrain data is reference to the European datum of 1950, you could select this datum and one of the region. Alternately you could specify the International 1924 ellipsoid directly.

In the Swiss, UK and Irish grid terrain data implementations, there is no corresponding datum. An ellipsoid must be specified as follows:

Swiss grid   Bessel 1841

UK grid   Airy (1830)

Irish grid   Modified Airy

Odyssey Gauss Kruger

The parameters for the Gauss Kruger projection must be specified. This can be accessed from The Odyssey - Gaus Kruger setup dialog or the Geographic Defaults.

Gauss Kruger - Transverse Mercator Definition

Latitude Origin (deg)	00 00 00.00
Longitude Origin (deg)	015 48 29.80 E
False easting (m)	1500000.00
False northing (m)	0.00
Scale factor	1.00000

OK   Cancel   Help   Swedish Grid

Odyssey UTM Projection

In many cases, terrain data is supplied in a single file. The east and west edges may extend outside of the standard UTM zone boudaries. In these cases, the UTM zone must be specified by either of the following two methods:

Check the "Use specified index file" option and then select the file from the dropdown list. The UTM zone associated with the selected file will be used and only the selected file will be used even if the index contains multiple files.

Odyssey - UTM

Map File Directory
C:\UTM - USGS

UTM zone
- Use standard UTM zones in index
- Use specified index file
- Use specified UTM zone 10N

☑ Embedded building data

Set Directory   Index   Close   Help

Check the "Use specified UTM zone" and enter the zone number suffixed by N or S. If N or S is not specified the zone will default to the northern hemisphere. The S suffix must be specified for the southern hemisphere.

In all other cases use the "Use standard UTM zones in index" option.

Equatorial Considerations for UTM Projections

Terrain databases which span the equator require special consideration. Two index files are shown below. Both of these consists of four terrain data files covering an area of 20 kilometers by 20 kilometers. Two of these files extend 20 kilometers above the equator and the other two files extend 20 kilometers below the equator.

The first index is referenced to the northern hemisphere. The map edge northings are +20,000 meters, 0 and -20,000 meters. In this case, a northern hemisphere UTM zone must be specified in both the index and the UTM zone method.

+20,000   10,020,000

20_1   20_2

0   Equator   10,000,000

20_3   20_4

-20,000   9,980,000
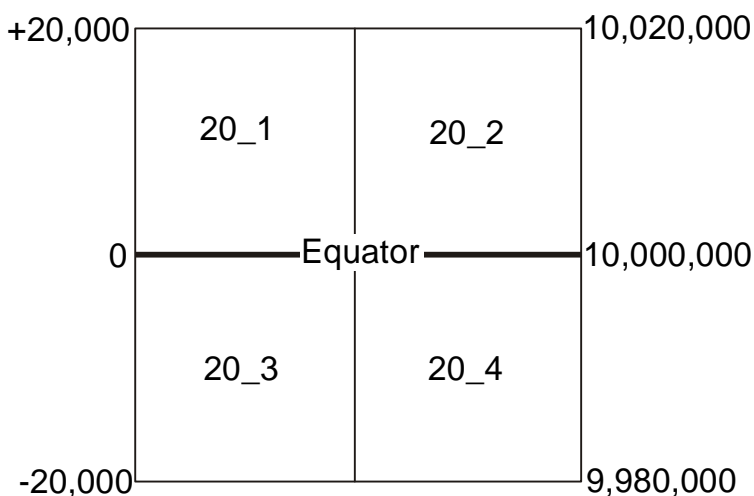
Northern Hemisphere Reference

```
20_1.height 565000 585000   0 20000 20

20_2.height 585000 605000   0 20000 20

20_3.height 565000 585000 -20000 0 20

20_4.height 585000 605000 -20000 0 20
```

The second index is referenced to the southern hemisphere. The northing of the equator is 10,000,000 meters.The map edge northings are 9,980,000 meters, 10,000,000 meters and 10,020,000 meters. In this case, a southern hemisphere UTM zone must be specified in both the index and the UTM zone method.

Southern Hemisphere Reference

```
20_1.height 565000 585000 10000000 10020000 20

20_2.height 585000 605000 10000000 10020000 20

20_3.height 565000 585000  9980000 10000000 20

20_4.height 585000 605000  9980000 10000000 20
```

Possible Problems

The background is not generated
- The file names in the index file are not the same as the actual database files. The extensions may be missing or different.
- The UTM zones in the index file are not correct or the N-S suffix is missing.
- The UTM method is wrong. The zone is incorrectly specified or the N-S suffix is missing.
- The SPARC - INTEL setting is wrong.
- The map file directory is incorrectly set.
- The file contains "no data" elevations. These values are usually 9999 and the program will ignore these.

The elevations are not correct or the display is incomplete
- The SPARC - INTEL setting is wrong

The display is upside down.
The bottom - up setting in the index is wrong This will be very apparent if the database has several vertical tiles.

MICROPATH 3 SECOND TERRAIN DATABASE

Micropath 3 second terrain data is derived from the USGS 1:250,000 3 second digital elevation model and is available from the Micropath Corporation (Golden Colorado). Each file includes elevation data for a one degree by one degree block. This database uses a file naming convention based on the coordinates of the south east corner. The format is YYXXX.3CD where YY is the latitude and XXX is the longitude with a leading zero for longitudes less than 100º. The data is arranged in columns starting at the south west corner and running from south to north. This database is supported as individual files or as the 6 set of CD-ROMS in uncompressed format.
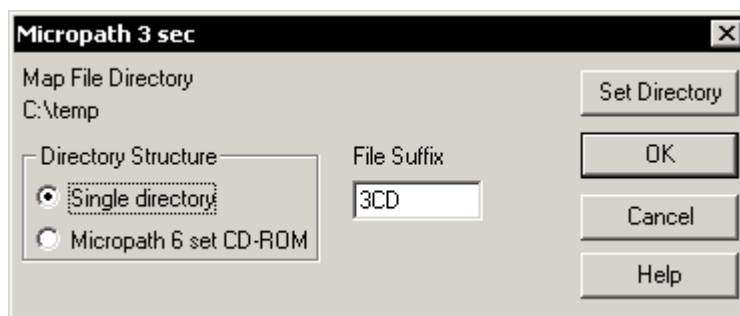
Directory Structure

The files can be located in a single directory or in the multiple directory format used on the 6 set of CD-ROMS. Refer to the Micropath documentation on this directory structure. For the single directory option, click the Set Directory button and point to the directory containing the files. If the CD-ROM structure is used, select the CD-ROM drive.

File Suffix

The default file suffix is 3CD. Older versions may use a different file suffix.

ESRI GRID ASCII TERRAIN DATABASE

This database is created by the ARC/INFO software package by Environmental Systems Research Institute (ESRI). The output file is referred to as GRID ASCII and can be referenced to either geographic coordinates or a UTM grid. This ASCII file must be converted to a binary format in the Pathloss program. The GRID/ASCII data base is supported as indexed files which allows a profile to span multiple files.

GRID ASCII File Format

The GRID ASCII file consists of a header followed by rows of data. The header format is shown below. The header is identical for the geographic and UTM reference. This is an ASCII file with a file format illustrated by the file fragment taken from SJ55.GRD for Melbourne:

Header example for a geographic reference

ncols 2492	number of columns of data
nrows 1411	number of rows of data
xllcorner 144.0000	longitude of the south west corner (positive east)
yllcorner -39.5275	latitude of the south west corner (positive north)
cellsize 0.0025	cell size in degrees (9 seconds)
NODATA_value -9999	no data value

Header example for a UTM reference

|	
ncols 398	number of columns of data
nrows 468	number of rows of data
xllcorner 652245	easting of the south west corner in meters
yllcorner 3610695	northing of the south west corner in meters
cellsize 30	cell size in meters
NODATA_value -9999	no data value

Note that the header for a UTM reference does not contain a UTM zone. This is stored in a separate file. The user will be prompted to enter the UTM zone number during binary file conversion.

The NODATA_value occurs where data does not exist. In most cases, this value is assigned to sea level. The Pathloss program uses a zero elevation when the NODATA_value is encountered.

The elevations are arranged in rows starting at the north west corner and moving from west to east. Each row consists of ncols of elevations. An elevation represents the average elevation of the area bounded by a cell and is defined at the center of the cell.

GRID ASCII Database Setup

Select Configure - Terrain Database and se-
lect either the ESRI GRIDASCII GEO or
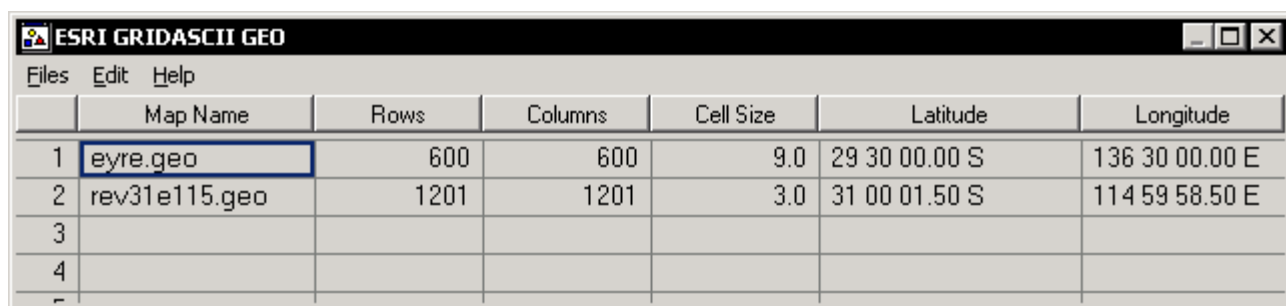UTM format as the primary or secondary da-
tabase.
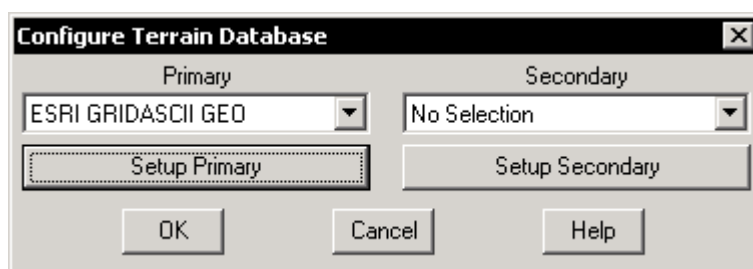
Click the Setup button and then the Set Di-
rectory button. Point to the directory containing the
GRID ASCII files. All files must be located in the same
directory.

Binary File Conversion

By default, binary names use the ASCII file names with the suffix "geo"
and "utm" for geographic and UTM references respectively. The names
are unimportant as this database uses an index to determine the required
file name. Click Convert ASCII to access the multi-select file open dia-
log box. If a single file is selected, a save file dialog box will open up,
prompting for the name of the binary file. If the file exists, a prompt is
issued to overwrite the file. Otherwise, the default binary file names will

be used. If this is a UTM reference, then a prompt is issued to enter the UTM zone. An index is automat-
ically created when an ASCII file is converted.
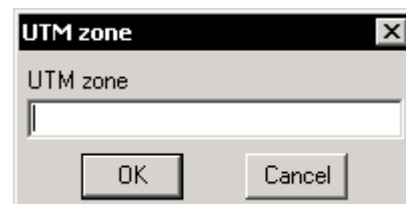
Index

	Map Name	Rows	Columns	Cell Size	Latitude	Longitude
1	eyre.geo	600	600	9.0	29 30 00.00 S	136 30 00.00 E
2	rev31e115.geo	1201	1201	3.0	31 00 01.50 S	114 59 58.50 E
3						
4						

The index uses the standard grid data display. Details on this display are given in the General Program Operation section. The index serves primarily as a reference.

It is unlikely that entries will be made directly into this form. As noted earlier, an index entry is automatically made when a file is converted. If binary files are being transferred from another computer, the index can be obtained directly from the file. Select Files - Index and select the required files. This is a multi select file open dialog box.

Terrain Profile Generation

Two possible approaches can be taken to develop a terrain profile from this database.

* If a point falls anywhere in a cell, the elevation is taken to be the average value in that cell. This will produce a profile with a series of steps.

* The elevation can be taken as the weighted average of the four elevations which bound the point. This method produces a smooth continuous profile.

The latter method is used in the Pathloss program. Be sure that the datum - ellipsoid setting corresponds to the database. Coordinate transformation is not used with this database.

PHOENIX 3 SECOND DATABASE

Phoenix is an Air Touch Cellular proprietary terrain data base. Each file represents a one degree by one degree block divided on full degree boundaries. Elevations are spaced 3 arc seconds apart, which produces a file of 1201 rows and 1201 columns. Elevations are saved as 2 byte integers. The file contains a 2402 byte header, which is not used by the program. Each subsequent 2402 bytes represent a column of data. The total file size is 2887204 bytes.

The data is organized in vertical columns. Within each column, the elevations are ordered from south to north. The order of columns is from west to east.

File Naming Convention

The Phoenix database uses a file naming convention. All files must be located in the same directory. The files are named: XXnYYYw.ter.

where   XX is the latitude with leading zeros

n can be either north or south

YYY is the longitude with leading zeros

w can be either east or west

Phoenix Database Setup

Select Configure - Terrain Database and se-
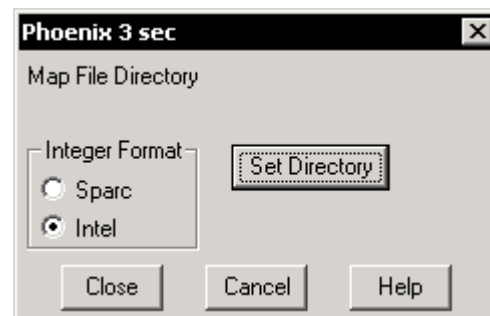lect Phoenix as the primary or secondary da-
tabase.

Click the Setup button and then the Set Di-
rectory button. Point to the directory con-
taining the Phoenix files. All files must be
located in the same directory.

An option is provided to set the integer format; however, this will
always be the Intel byte ordering for integers.
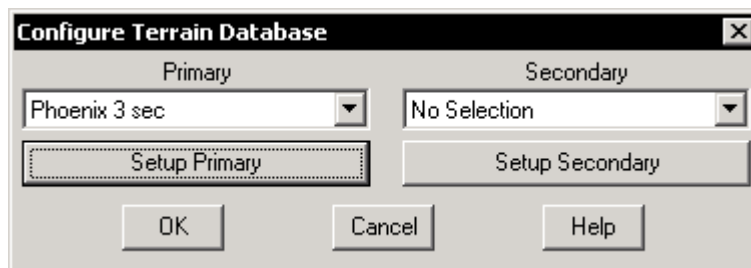
AUSLIG 3 SECOND DATABASE

The Australian AUSLIG terrain data base is a 3 second data base
in ASCII format. Each line of the file consists of the latitude and
longitude of the point in seconds and the elevation. The file covers
an area of 30 minutes x 30 minutes (0.5 degree x 0.5 degree). The
file is organized in rows and columns. Both the row and column
spacing is 3 seconds; and therefore, there are 601 rows and 601 columns. The first column starts in the south
west corner and all columns run from south to north. The file size is approximately 9.8 Mbs and must be
first converted to a binary format to be used. An example of the file format is shown below. Note that the
latitude and longitude are positive for the southern and eastern hemispheres.

```
543600.0   122400.0   200

543600.0   122397.0   167

543600.0   122394.0   135

543600.0   122391.0   111

543600.0   122388.0    95

543600.0   122385.0    84
```

AUSLIG 3 second database is supported as indexed files and all files must be located in the same directory.
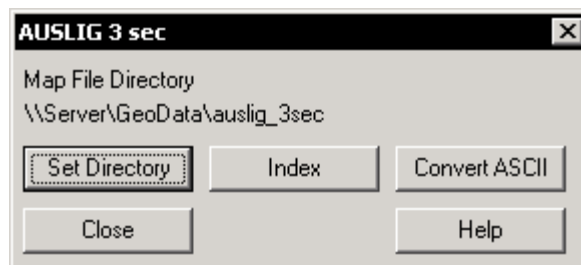
AUSLIG 3 SECOND DATABASE SETUP

Select Configure - Terrain Database and se-
lect the AUSLIG 3 second database as the
primary or secondary database.

Click the Setup button and then the Set Di-
rectory button. Point to the directory con-
taining the AUSLIG 3 second files. All files must be located in the same directory.
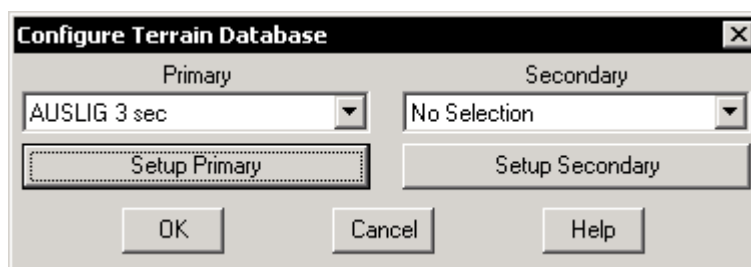
Binary File Conversion

By default, binary names use the ASCII file names with the suffix "bin". The names are unimportant as this database uses an index to determine the required file name. Click Convert ASCII to access the multi-select file open dialog box. If a single file is selected, a save file dialog box will open up, prompting for the name of the binary file. If the file exists, a prompt is issued to overwrite the file. Otherwise, the default binary file names will be used. An index is automatically created when an ASCII file is converted.

Index

The index uses the standard grid data display. Details on this display are given in the General Program Operation section. The index fields are described below:

Map name	The map name is for reference purposes only and must be entered by the user.
File name	The binary file name.
SW latitude	Latitude of the south west corner. This is a positive number in this index.
SW longitude	Longitude of the south west corner. This is a positive number in this index.
Latitude increment	Always 3 seconds.
Longitude increment	Always 3 seconds.

Other than the map name, it is unlikely that entries will be made directly in this form. As noted earlier, an index entry is automatically made when a file is converted. If binary files are being transferred from another computer, the index can be obtained directly from the file. Select Files - Index and select the required files. This is a multi select file open dialog box.

SOUTH AFRICA NATIONAL EXCHANGE STANDARD DATABASE

Each data base file consists of a rectangular grid of ASCII data organized in uniform rows and columns. The grid coordinates use the Gauss Conformal projection. The data is arranged in columns from south to north. The first column starts at the south west corner of the grid. The ASCII data must first be converted into a binary format to be used. The conversion program generates an index of the binary files. This index is used to determine the correct map file when generating a profile. If several map files span the same point, the map file with the closest spacing between data points will be selected.

SA NES Setup

Set Directory
Click the Set Directory button and point to the directory containing the SA NES files. All files must be located in the same directory.

ASCII to Binary Conversion
Click the Convert ASCII button to access the multi-select file open dialog box. Select the NES files to be converted. If a single file has been selected, a save file dialog box will open up, prompting for the name of the binary file. The default file name is the same as the ASCII file with the suffix "bin". If the binary file exists, you will be prompted to overwrite the existing file. If multiple files are selected, the default binary file names will be used and existing files will be overwritten without warning. The file conversion first reads the header and determines the following information:

> standard meridian
>
> Gauss Conformal coordinates of the south west corner
>
> number of data points in the X and Y directions
>
> the spacing between points in the X and Y directions

The elevations are then read and saved in binary form using the same row-column format as the ASCII file. An index of the converted files is automatically generated and saved as SA_NES.DTA in the Pathloss directory.

Index

Click the Index button in the SA NES setup dialog. It is unlikely that entries will be made directly in this form. As noted earlier, an index entry is automatically made when a file is converted to the binary format. If the file was converted using Pathloss Version 4.0, the index data is appended to the end of the binary file and can be read into the index. Click Files - File Index and select the binary files to create an index. This is a multi-select file open dialog box. The index entries are given below for reference:

File Name   The binary file name. The program adds this name to the path specified with the Set Directory button.

Ysw, Xsw (km)   Gauss conformal coordinates of the south west corner. Note that Y refers to the east - west direction and X refers to the north south direction.

Yne, Xne (km)   Gauss conformal coordinates of the south west corner.

Y cell (m)   Cell size in the east - west direction in meters.

X cell (m)   Cell size in the north - south direction in meters.

Rows   Number of rows of elevations.

Columns   Number of columns of elevations.

Standard meridian   The standard meridian of the above X - Y coordinates.

No data   The no data value (9999).

The index is saved in the file SA_NES.DTA in the Pathloss directory.

MDT DIGITAL TERRAIN MODEL - SPAIN

File Format
MDT digital terrain data for Spain is supplied in ASCII files. The elevations are reference to a UTM grid with cell sizes of 200 (MDT200) and 25 (MDT25) meters. The extents of the file are defined by the UTM coordinates of the south - west and north - east corners. These are denoted by (Xmin, Ymin) and (Xmax, Ymax) respectively in the following description.

The elevation data starts in the south west corner and is written in rows in the west to east direction using the cell size spacing between elevations. Successive rows of elevations start at the west edge with the northing incremented by the cell size.

In the MDT25 series, the file contains a header which specifies the extents of the data. In the MDT200 series, this information is contained in a separate file.

The MDT terrain database is supported as indexed files. All files must be located in the same directory. The files must first be converted to a binary format.

Setup Procedure
Click Configure - Terrain Database and select MDT Spain from the list of available databases.
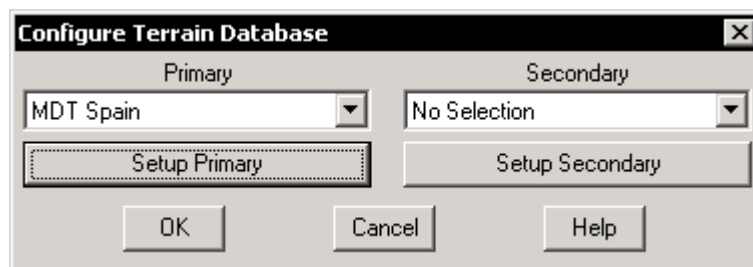
The setup procedure consists of identifying the directory containing the MDT files and provides the ASCII to binary conversion and file index utilities.
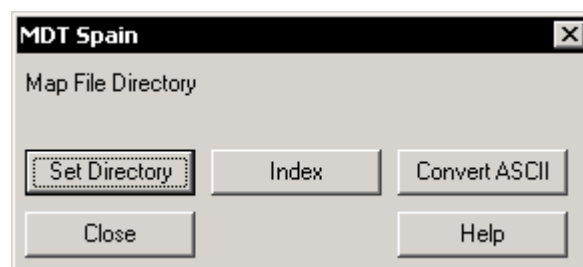
ASCII to Binary File Conversion

Click the Convert ASCII button and open the MDT ASCII file.

The Convert ASCII dialog box requires the following information:

Map Name	the map name is an optional entry
Xmin (meters)	the easting of the west edge of the file
Ymin (meters)	the northing of the south edge of the file
Xmax (meters)	the easting of the east edge of the file
Ymax (meters)	the northing of the north edge of the file
UTM Zone	the UTM zone for the above easting and northings
Cell Size (meters)	the cell size
No data value	no data elevation value. The default is -999

The first part of the file is displayed. If this is an MDT25 file, the header will be shown and the required entries can be made by copying the values from this display. Otherwise, use the values in the external text file.
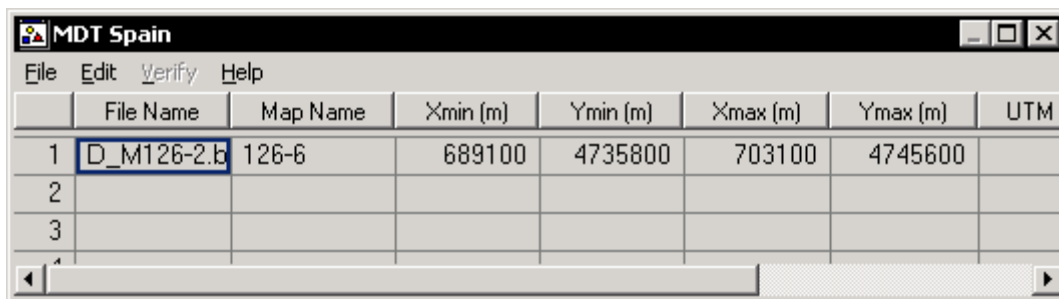
Note that the UTM coordinates must be entered in meters. The values in an MDT25 file are given in meters; however the MDT200 file uses kilometers.

When the entries are complete, move the horizontal scroll bar to the extreme left and place the cursor on the first elevation in the file. This is important as the conversion will start at this point.

Click the convert button and enter the name of the binary file. The default is the ASCII name with the file suffix "bin".

The conversion process will automatically create an index entry for the converted file.

File Index

The program uses the file index to determine which files to use.

The file with the smallest cell size will always be used if two files cover the same area. The index uses the standard grid display. Refer to the General Operation section of the manual for details. Although it is possible to enter values directly into this display, this is not recommended. An index entry is automatically created when the file is converted to binary. To create an index for an exiting binary file, select Files - File Index and open the required file. This is a multi-select open file dialog box.

The Verify menu item is not used in this index.

Using the MDT Terrain Database

Once the required binary files have been converted, the profile generation, area coverage and terrain view features are available. The MDT database does not use datum translation, therefore, it is important to specify a datum or ellipsoid corresponding to the data base. The UTM conversion uses International 1924 ellipsoid. This is set under Configure - Geographic Defaults under the main menu. The European datum of 1950 (Spain - Portugal) or 1979 uses this ellipsoid. Alternately the ellipsoid can be directly specified.

USA 3 ARC SECOND COMPRESSED TERRAIN DATA

Three arc second terrain data for the United States in a compressed format is available for use with the Pathloss program. This data has been taken directly from the USGS 1:250,000 ASCII DEMs. The elevations in these files are in meters relative to mean sea level. Spacing of the elevations between rows and between each column is 3 arc-seconds with 1,201 elevations per column. The only exception are DEMs in Alaska, where the spacing and number of elevations per column varies depending on the latitude of the DEM. Latitudes between 50 and 70 degrees north have spacings at 6 arc-seconds with 601 elevations per column and latitudes greater than 70 degrees north have spacings at 9 arc-seconds with 401 elevations per column.

The error checking on these files consisted of the following verifications.

- Each elevation must be within the range specified for both the entire file and the specific column.

- The absolute value of all elevations including the maximum and minimum values must be less than 10000 meters.

A total of 29 files did not pass this criteria and these were edited. The majority of errors involved the maximum elevation in the file. Other errors included extreme elevations (-32467) at the end of columns. These files have all been edited. None of the changes involved interpolating elevations. Most of the errors occurred at sea level.

USA 3 Second CD-ROM

All files are contained on a single CD-ROM and are organized in directories based on longitude under a main directory 3SEC_USA. The directory names are based on the longitude of the southwest corner of file e.g. W095. The file names are based on the longitude and latitude of the southwest corner. At latitudes less than 50º, the files have been split into two halves at the central longitude of the file. The letter L (left) or R(right) is appended to the file name. The file suffix is always cte (compressed terrain elevations). As an example, the file W095N44R.CTE represents the western half of the one degree block whose southwest corner is located at 44º north and 95º west. The file is located in the directory 3SEC_USA\W095 on the CD-ROM.
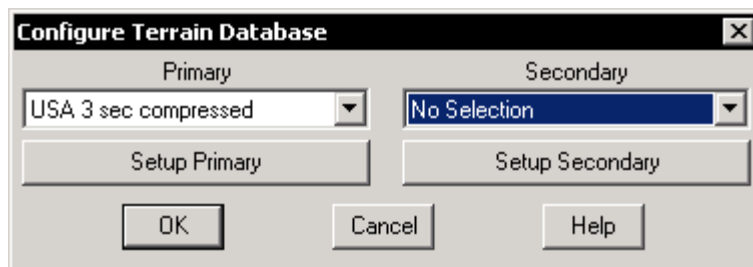
Setup Procedure

Click Configure - Terrain Database and select USA 3 second compressed from the list of available databases. The setup procedure consists of identifying the directory containing the compressed files. The correct directory is the root containing all of the directories (i.e. D:\3sec_usa)
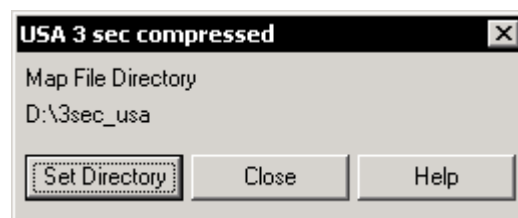
Profile Generation

When a single profile is generated, the program determines the required file and uncompresses it in memory. If the profile spans more than one file, each file is deleted when it is no longer required. In an area coverage calculation or when using the terrain view feature, all required files are retained in memory until the data acquisition is complete. For this reason, the large files with 1201 rows and columns have been split into two halves to conserve on memory. If one was to attempt a terrain view over a large area, a memory problem can occur.

Compression Algorithm

The compression algorithm first reads the USGS 1:250,000 DEM file into memory. The elevation data is arranged in a row - column matrix. The elevations are written in columns running from south to north starting at the south west corner. The spacing between rows and columns is three arc seconds. There are always 1201 rows. The number of columns is 1201 at latitudes below 50º and decreases with latitude as shown below:

Latitude	Spacing	Columns
0 to 50 deg	3 sec	1201
50 to 70 deg	6 sec	601
70 to 75 deg	9 sec	401
75 to 80 deg	12 sec	301
80 to 90 deg	18 sec	201

Each elevation is represented as a two byte integer. The difference between successive elevations in the file is usually less than ±127 meters which allows a differential elevation to be stored in a single byte; thereby

realizing an immediate file size reduction of 50%. In rugged terrain, exceptions will occur, and this is handled by creating a table of exceptions.

Huffman coding is used to compress the one byte differential elevations. The Huffman coding and compression algorithm is taken directly from the reference:

Numerical Recipes in C

The Art of Scientific Computing - Second Edition Cambridge University Press

William H. Press - Saul A. Teukolsky - William T. Vetterling - Brian P. Flannery

MICROWAVE ANTENNA HEIGHTS

OVERVIEW

The antenna heights module is implemented in two versions to handle the specific requirements of microwave and VHF- UHF applications. This section deals with microwave applications.

The antenna heights module is used to calculate antenna heights to meet a set of clearance criteria. A clearance criteria consists of three components:

- the earth bulge for a specified value of the earth radius factor (K)
- a specified percentage of the first Fresnel zone radius
- an arbitrary fixed height

Antenna heights based on clearance criteria alone, are not sufficient to ensure a reliable design under all conditions. This is only the first step in the overall design. Many path performance problems are the result of excess clearance due to over-design. Antenna height selection is definitely not a case of more being better. The final antenna heights will be a compromise based on the following additional analysis:

- Determine the minimum antenna heights which will result in an acceptable diffraction loss at the lowest expected value of K (Diffraction module).
- Determine the reflective characteristics and height gain characteristics of the path (Multipath module).
- Determine the receive signal variations as a function of K to ensure that a signal null does not occur at the median value of K (Reflection module).
- When a space diversity antenna configuration is used on a reflective path, determine the antenna spacing to avoid simultaneous signal nulls on the main and diversity antennas (Reflections module).

Antenna height calculations are based on the selected antenna configuration. Setting the antenna configuration is the first step in a design. If space diversity is an option, then start with the space diversity configuration and calculate the main and diversity heights. You can switch to the non diversity configuration later, if required.

Two sets of clearance criteria may be specified for both the main and diversity antenna combinations. In this case, the calculations use the greater of the two clearance criteria. Note that each set of criteria may control the clearance over different ranges of the profile.

Antenna heights are always measured from ground level even if a building has been specified at the end of a path. Note that in previous versions, antenna heights were measured from the top of the building.

BASIC OPERATION

Status Bar

The status bar provides information on the current program settings and is also used as an alternative access to the controls available in the Antenna Heights module. Starting from the left side of the status bar, status and controls are described below:

Site 1 Name   Information only

Main-Diversity	Active on space diversity antenna configurations. Click the left mouse button on this box to toggle between the main and diversity antennas. The display is automatically reformatted for the main or diversity clearance criteria.
Antenna Configuration	Displays the current antenna configuration. Click the left mouse button on this box to change the configuration.
Measurement System	Displays the current units (kilometers-meters or miles-feet). Click the left mouse button to change between the two systems.
Arrow Location	Displays the current location of the arrow (distance-elevation). The elevation is the flat earth (diagonal fill) profile. Click the left mouse button on this box to bring up the excess clearance display.
Auto-Manual Mode	Displays the current antenna height calculation mode. Left click on this box to toggle the mode between auto and manual. This is active only for a main antenna height calculation.
Height Increment	Displays the current height increment in meters or feet. Click the left mouse button to increase the increment and the right button to decrease it.
Site 2 Name	Information only.

Tool Bar

The tool bar displays the calculated antenna heights and the antenna name in a separate box for each antenna. This will vary from two boxes for single antenna configurations to six boxes for the TXRXDR_TXRXDR combination. Click the left mouse button on any box to bring up the antenna heights data entry form. An up-down control is located on the left side of the active antennas. Two additional controls are located on the tool bar:

 Optimizes the antennas heights

 Sets the design antenna heights to the displayed antenna heights

Changing Antenna Heights

The screen display shows the flat earth profile with a diagonal fill. The profile above this is derived by adding the composite clearance criteria to the flat earth profile. Structures are only shown on the upper profile. In this representation, any line which is entirely above the upper profile and any structures, represents a combination of antenna heights which satisfy the clearance criteria.

The tool bar displays the antenna heights for the selected antenna configuration. An up-down control is positioned on the left side of the active antenna for each site.

The heights are changed in fixed increments. The increment is shown on the status bar. Click the left or right mouse button on this height increment box to increase or decrease the increment. Alternately, the + and - keys can be used.

The site 1 antenna height is changed with its up-down control or with the Home and End keys. The site 2 antenna height is changed with its up-down control or with the PgUp - PgDn keys.

There are two calculation modes for changing antenna heights - Auto and Manual. The current selection is displayed on the status bar. The mode is changed by any of the following commands:

- Click the left mouse button on the status bar mode box.
- Select Operations - Auto-Manual on the menu bar.
- Press the F4 key.

In the Auto mode, the antenna height at the opposite site is automatically recalculated when an antenna height is changed.

In the Manual mode, the antenna height at the opposite site does not change.

On diversity antenna configurations, the display is switched between main and diversity by any of the following methods:

- click the left mouse button on the status bar main-diversity box.
- select Operations - Main-Diversity on the menu bar.
- press the F7 key.

The display is automatically formatted for the main or diversity clearance criteria.

In space diversity applications, only the Manual mode is available when a diversity antenna combination is selected.

A special case arises for the antenna configurations TXRX_TXRX and TXRXDR_TXRXDR where separate antennas are used for transmit and receive. Both the TX - RX and RX - TX antenna combinations are simultaneously displayed. Only one combination is active at any time. The active combination is drawn in red and the inactive in blue. To switch between the two, double click the left mouse button on the inactive line. Note that the tool bar up-down controls are repositioned for the active combination.

The antenna heights displayed on the screen and the tool bar are temporary variables. To reset the antenna heights to their initial values, select Configure - Antenna Heights on the menu bar to bring up the antenna heights data entry form and then select OK. If Cancel is selected the displayed antenna heights do not change.

The temporary display antenna heights are set to the design values by either of the following:

- Click the wrench button on the tool bar.
- Press the F1 key.

You will be prompted to revise the antenna heights when you leave the Antenna Heights module if there have been any changes.

Setting Antenna Heights

Select Configure - Antenna Heights to bring up the antenna heights data entry form. This form is formatted for the selected antenna combination. The minimum antenna height simply means that if a calculated antenna height is less than the specified minimum value, then the antenna height is set to the minimum value.

Set Microwave Antenna Heights	Fairview	Brownvale
OK Cancel Help		
TR Antenna Height (m)	259.84	279.53
DR Antenna Height (m)	200.79	200.79
Tower Height (m)	354.33	354.33
Minimum Antenna Height (m)	16.40	16.40
True azimuth (°)	59.29	239.88
Fairview TR Antenna Height (m) :		

If an antenna height exceeds the tower height a warning message is issued and the value is displayed in red on the tool bar. The height is **not** limited to the tower height.

Several modules (Diffraction, Reflection and Multipath) provide calculations as a function of antenna height. The default range is the minimum height and the tower height. These should be entered to facilitate these calculations. A default minimum antenna height of 5 meters is used.

Select OK on the menu bar to reset the display antenna heights to the values in the data entry form. Select Cancel to ignore any changes.

Optimizing Antenna Heights

An algorithm is provided to optimize the **main** antenna heights by determining the minimum value of the sum of the squares of the antenna heights. This definition of optimum assumes that tower costs are proportional to the square of the tower height. This optimization algorithm is invoked by either of the following methods:

- Click the calculator button on the tool bar.
- Press the F9 key.

The algorithm may terminate if the antenna heights are controlled by more than one critical point or an antenna height is limited by its minimum value.

If a diversity antenna combination is selected, the optimization simply calculates the minimum diversity antenna heights based on the terrain.

Display Zoom Feature

Any portion of the antenna height display can be selected as a full screen display. This zoom feature is only implemented in the antenna heights and diffraction modules. This is particularly useful on profiles which contain "near in" obstructions or buildings.

Move the mouse cursor to one corner of the area to be selected. Hold down the Ctrl key and press the left mouse button. Drag the cursor to the opposite corner. Release the mouse button and the selected area will be scaled to fill the window.

To reset the display, hold down the Ctrl key and click the right mouse button.

Setting Clearance Criteria

Select Operations - Set Clearance Criteria to bring up the clearance criteria data entry form.

Clearance criteria is expressed as the sum of the following components:

- earth curvature for a specified value of K

- percent of the first Fresnel zone radius

- an arbitrary fixed height

The minimum clearance criteria for free space loss conditions is 60% F1 at K=4/3.

Set Clearance Criteria

OK   Cancel   Help

	Main	Diversity
1st Criteria - K	1.330	1.330
1st Criteria - %F1	100.00	60.00
1st Criteria - Fixed Height (m)		
2nd Criteria - K		
2nd Criteria - %F1		
2nd Criteria - Fixed Height (m)		
Frequency (MHz)	5882.50	

Main 1st Criteria - K :

If two sets of clearance criteria are specified, the clearance is taken as the greater of the two criteria. Note that each set of criteria may control the clearance over different ranges of the profile.

Second Fresnel zone (F2) clearance at the median value of K can result under certain conditions. If the terrain is reflective, the addition of the main and reflected signals will produce a signal null. The Diffraction module can be used to check for this condition. Several conditions which can result in second Fresnel zone clearance are given below:

- F2 clearance can occur when two sets of clearance criteria are specified. In particular, the classic heavy route criteria, 100% F1 at K = 4/3 and 30% F1 at K = 2/3, can produce F2 clearance on longer paths where the 30% F1 at K = 2/3 criteria controls the clearance in the central part of the profile.

- Using the fixed height to account for future development or tree growth.

- The addition of trees on the profile as a safety factor; when in fact, the actual tree cover does not exist or is sufficiently sparse to be transparent.

Calculating Clearance Criteria

When analyzing an existing path, you can determine the clearance criteria used in the design. Select Operations - Calculate Clearance Criteria from the menu bar. If the antenna configuration supports more than one antenna combination, you will be prompted to select an antenna combination. The heights used in the calculations are displayed on the caption.

259.8 - Calculate Clearance Criteria - 279.5

OK   Cancel   Help

Earth Radius Factor K	0.230
% First Fresnel Zone Radius	115.23
Fixed Height (m)	
Frequency (MHz)	5882.50

Earth Radius Factor K :

If a %F1 entry is made, the earth radius factor (K) will be calculated. For all other entries (K, fixed height and frequency), the %F1 is calculated.

Clearance at a Point

To view the clearance at a point on the display, move the arrow to the point and then bring up the excess clearance display with any of the following commands:

- Press the Ins key.

- Left mouse button click in the status bar location box.

- Right mouse button click anywhere on the display.

The display shows the three components of the controlling clearance criteria at the selected point. If there is an off path structure at the point, the display also shows the horizontal clearance as a percent of the first Fresnel zone radius. The excess clearance is defined as:

excess clearance = ray elevation - (ground elevation + structure height + criteria total)

Excess Clearance	
Latitude	55 55 38.63 N
Longitude	118 19 31.36 W
Easting (km)	417.184
Northing (km)	6198.578
UTM zone	11N
Distance (km)	19.73
Elevation (m)	441.96
Controlling Criteria (Main - 1)	
Frequency (MHz)	5882.50
K = 1.33 (m)	37.46
%F1 = 100.0 (m)	24.95
Fixed Height (m)	
Criteria Total (m)	62.40
Ray Elevation (m)	856.09
Excess Clearance (m)	351.72

Adding or Editing a Structure

Structures are normally added to the profile in the Terrain Data module; however, the location of the critical points is not always evident in this module. You can add, edit or move a structure in the antenna heights module. The procedure is limited to a single structure. Ranges and off path structures are not allowed here.

Single Structure

Type
- Tree
- Building
- Water Tower

Structure Height (m) 10.0
Location (km) 18.686

Description

OK   Delete   Cancel   Help

To edit or move an existing structure, place the arrow on the structure and select Operations - Edit Structure on the menu bar. You can move the structure with the scroll bar or type in the new location and height.

To add a new structure, the arrow must not be located on an existing structure when Operations - Edit Structure is selected.

REPORTS

Clearance Report

The clearance report provides a listing of all points on the profile whose clearance is within a specified tolerance of the clearance criteria. When the clearance report is selected from the report menu, the user enters a tolerance in meters or feet, depending on the measurement system in effect.

At each point on the profile, the elevation difference between the upper profile and the line between the antennas is calculated. If this value is less than the specified tolerance, the value is printed. Since the upper

profile represents the clearance criteria on top of the flat earth profile, the elevation difference indicates how close the point is to the clearance criteria.

A zero value means that the point exactly meets the clearance criteria. A positive value means that the point is above the clearance criteria and a negative value means the point does not meet the clearance criteria.

The clearance report also calculates the horizontal clearance to any off path structures on the profile. This clearance is expressed as a clearance to first Fresnel zone ratio.

	Beaverlodge	Demmit
Latitude	55 12 50.10 N	55 27 43.00 N
Longitude	119 16 08.10 W	119 53 22.00 W
Elevation (m)	928.60	835.00
Distance (km)	48.09	
Frequency (MHz)	5882.50	
Clearance tolerance (m)	20.0	

Beaverlodge TR Antenna Height	60.00 m
Demmit TR Antenna Height	55.20 m

Clearance criteria - Main

1st Criteria - K	1.33
1st Criteria - %F1	100.00

Dist (km)	Elev (m)	Struct (m)	Clear (m)	K (m)	%F1 (m)	FH (m)	Crit
1.59	945.8	15	11.3	4.4	8.8		1

Off Path Building at 1.160 km - Canadian Hunter

Distance Off Path (km)	11.8
Ground Elevation (m)	949.4
Structure Height (m)	36.5
Clearance /F1 (%)	155.1

Orientation Report

The orientation report lists the horizontal and vertical angles required for antenna orientation. The report also lists the vertical orientation angle errors that occur at extreme values of K.

	Beaverlodge	Demmit
Latitude	55 12 50.10 N	55 27 43.00 N
Longitude	119 16 08.10 W	119 53 22.00 W
True Azimuth (°)	305.29	124.78
Elevation (m)	928.60	835.00
Antenna Height (m)	60.00	55.20

Tower Height (m)	100.00	60.00
Distance (km)	48.09	
Frequency (MHz)	5882.50	
Antenna Orientation K	1.33	
Vertical Angle (°)	-0.28 -	0.05
Error at K = 2/3 (°)	0.16	0.16
Error at K = 1 (°)	0.05	0.05
Error at K = 100 (°)	-0.16	-0.16

Antenna Height Tradeoff Report

This report varies one antenna height and calculates the antenna height at the other site to meet the clearance criteria. This report is useful in those cases where the final antenna heights may be changed during construction and the antenna heights can be adjusted accordingly.

Enter the start and end antenna heights.

Select either the main or diversity clearance criteria.

Click the OK button to generate the report.

VHF-UHF ANTENNA HEIGHTS

The Antenna Heights module in VHF-UHF applications is implemented as a subset of the microwave antenna heights. In most cases, VHF-UHF antenna heights are not set using clearance criteria. Instead the heights are chosen to meet an area coverage objective or to achieve an acceptable receive signal on diffracted paths. The following features are not available:

- Switching between main and diversity clearance criteria is not applicable.

- A single clearance criteria is used.

- The calculate clearance criteria feature is not implemented.

- Reports are not implemented.

Otherwise, the operation is identical with the microwave antenna height implementation.

Set Clearance Criteria	
OK Cancel Help	
Earth Radius Factor K	1.333
% First Fresnel Zone Radius	0.00
Fixed Height (m)	
Frequency (MHz)	450.00
Earth Radius Factor K :	

If the antenna configuration is TR-TXRX as shown in the display on the right or TXRX-TR, the behavior of antenna heights display is different than the microwave antenna heights display. In the auto mode, both lines from the TR antenna will be changed. Only the active antenna height at the TXRX site will change. The active antenna height line is colored red, the inactive is blue. To switch between the two double click the left mouse button on the blue line.

To complete the antenna height settings, it is more expedient to switch to the manual mode. Click the left mouse on the status bar mode box or press the F4 key.
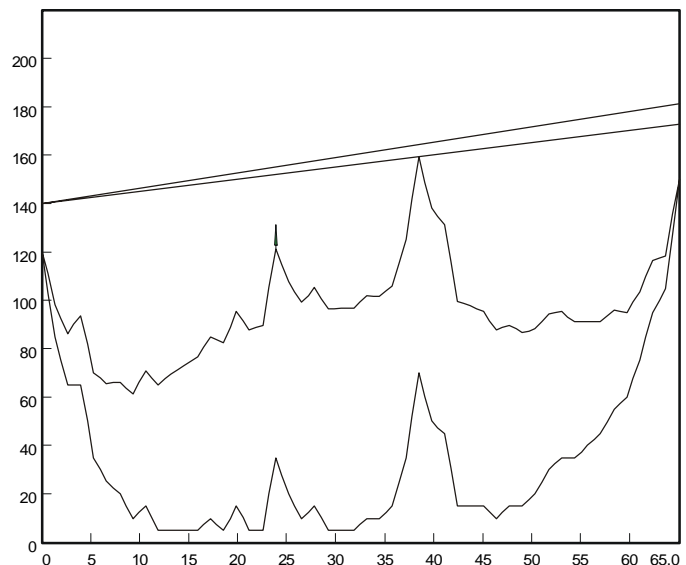
CLEARANCE CRITERIA

Antenna heights are calculated to meet specified clearance criteria. A clearance criteria is defined as the sum of the following three components:

- the earth bulge for a specified value of the earth radius factor, K

- a percentage of the first Fresnel Zone radius

- an arbitrary fixed height

The three clearance criteria components are shown in Figure (1) for a flat terrain profile. The profile is represented by the shaded area. The curve labelled "Clearance Criteria" is the sum of the three components. This is the graphical format used to calculate antenna centerline heights in the Antenna Heights module.
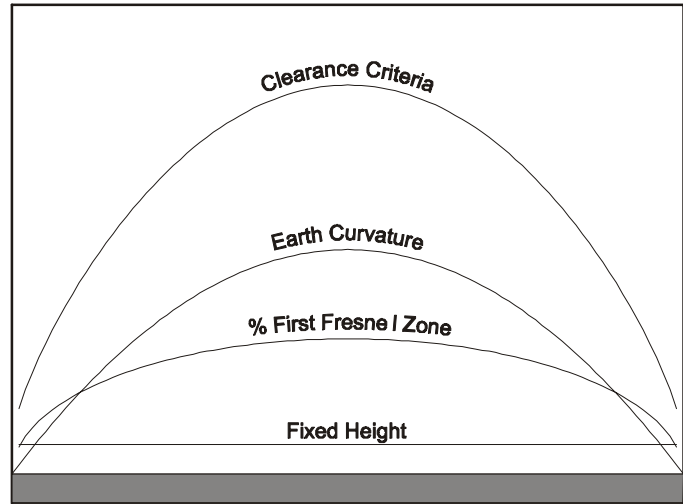

Figure 1: Clearance Criteria

In order to correctly display the clearance criteria, additional terrain points are inserted into the input data so that the minimum spacing between points is one percent of the path length. Linear interpolation is used to add these points. At each point, the clearance criteria, L, is calculated as shown in Equation (1) and added to the profile elevation.

$$L = L_K + L_F + L_{FH}$$

$$L_K = \frac{d_1 \cdot (d - d_1)}{12.75 \cdot K}$$ (1)

$$L_{Fz} = 17.3 \cdot Fz \sqrt{\frac{d_1 \cdot (d - d_1)}{f_{GHz} \cdot d}}$$

d	path length in kilometers
d_1	distance to the point from Site 1 in kilometers
K	earth radius factor
Fz	fraction of the first Fresnel zone radius
L_{FH}	fixed height component in meters

Therefore, any line between the antennas which is above or at the clearance criteria curve, represents a combination of antenna heights which satisfy the clearance criteria.

Traditionally, the overall clearance criteria is specified in terms of two independent sets of parameters. At each point on the profile, the clearance criteria is calculated for each set of parameters as in Equation (1). The greater of two values is added to the terrain elevation to construct the clearance criteria curve.

Figure (2) illustrates the use of a clearance criteria derived from the following two sets of parameters:

#1   100% F1 @ K = 4/3

#2   30% F1 @ K = 2/3

In this case, the 100% F1 @ K = 4/3 criteria controls the clearance at the ends of the path. The 30% F1 @ K = 2/3 criteria controls the clearance in the central region of the path. A fixed height component has not been included in the criteria for clarity. Note that when using two sets of parameters, only the maximum of the two criteria is graphically displayed.
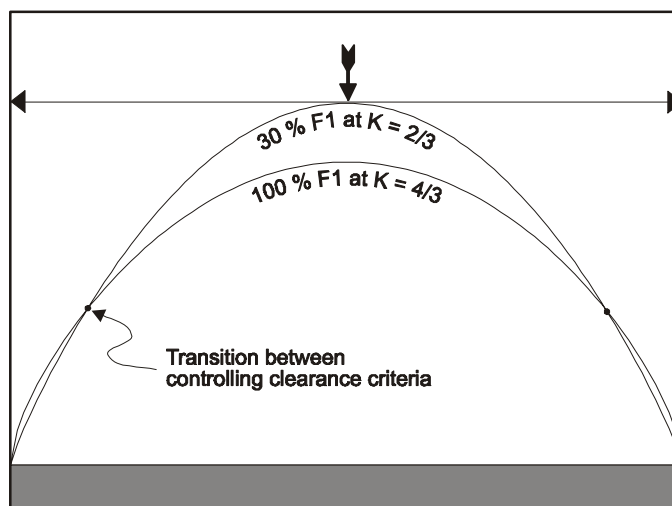

Figure 2: Dual Clearance Criteria

ANTENNA HEIGHT CONSIDERATIONS

In general, clearance criteria are chosen to meet the following performance objectives:

- To achieve free space propagation conditions at the median value of K.

- To control the additional loss which can occur at the lowest expected value of K.

The first objective is relatively straightforward. The minimum clearance for free space loss conditions is 60% of the first Fresnel zone radius. The second objective, unfortunately, is more complex and can lead to excessive tower heights, severe multipath fading and fading due to specular reflections.

Consider the following example of a 37.5 mile (60.3 kilometer) path designed with the following common clearance criteria, usually referred to as the heavy route:

         100% F1 @ K = 4/3 and   30% F1 @ K = 2/3

The frequency is 1925 MHz. The terrain profile used in this example is included in the Examples section. The antenna centerline calculation is shown in Figure (3).

With the specified clearance criteria, the path will certainly not suffer from serious diffraction fading; however, consider the operation at the median value of K.

Figure (4) shows the second Fresnel zone reference on the path using an earth radius factor of K = 4/3. This display is available in the Diffraction Analysis module. The path has second Fresnel zone clearance in the central region. If the path is actually reflective in this area, then the reflected signal will cancel the direct path signal. This will result in significant fading during average propagation conditions.

It is not possible to specify a rigid set of clearance criteria which will work under all conditions on all paths. The clearance criteria might be better stated as "the minimum antenna heights which achieve the required propagation reliability". This is certainly true from a tower cost viewpoint.

To achieve minimum antenna heights, the following additional considerations are taken into account:

- Multipath fading is most severe at very high or negative values of K and is negligible at low values of K.

- In general, multipath fading tends to increase with increasing tower heights and path clearance. Therefore, paths with a minimum clearance would be less subject to multipath fading.

- The probability that the earth radius factor, K, will be less than a specified value is a function of the path length. A typical relationship between K and the path length is shown in Figure (5) for continental temperate climate regions and has been taken from Reference 1.
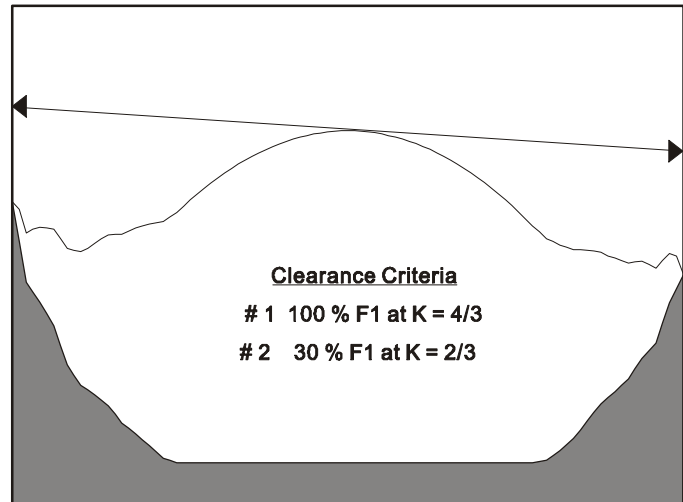

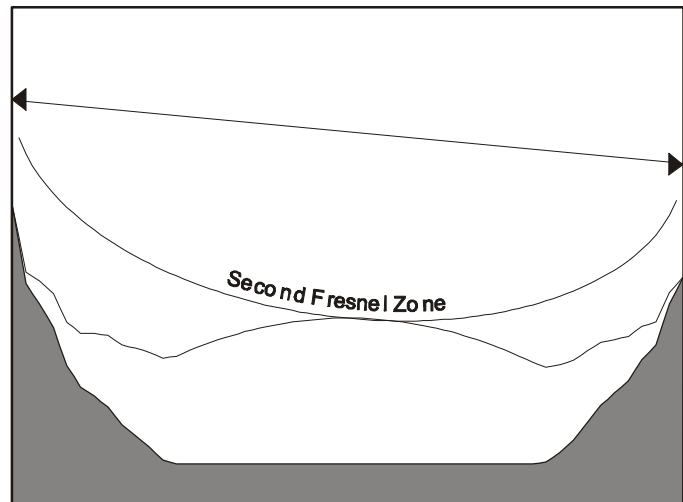Figure 3: Antenna Centerline Calculation

Figure 4: Second Fresnel Zone Clearances

The minimum antenna centerline heights now become a matter of determining the diffraction loss at the lowest expected value of K and relating this to the thermal fade margin of the path. The basic procedure is outlined in the following steps:

1   Calculate the antenna heights using a minimum clearance criteria of 60% F1 @ K = 4/3.

2   Calculate the thermal fade margin of the path in the Worksheet module.

3   Determine the value of K which will be exceeded for 99.9% of the time from Figure (5).

4   Using the value of K from step 3, determine the antenna heights that produce the following values of diffraction loss:

50% of the thermal fade margin if the path is characterized by a single isolated obstacle.

25% of the thermal fade margin if the path is characterized by irregular terrain or multiple obstacles.

5   Use the Variable Parameter selection in the Diffraction module to determine the antenna heights.

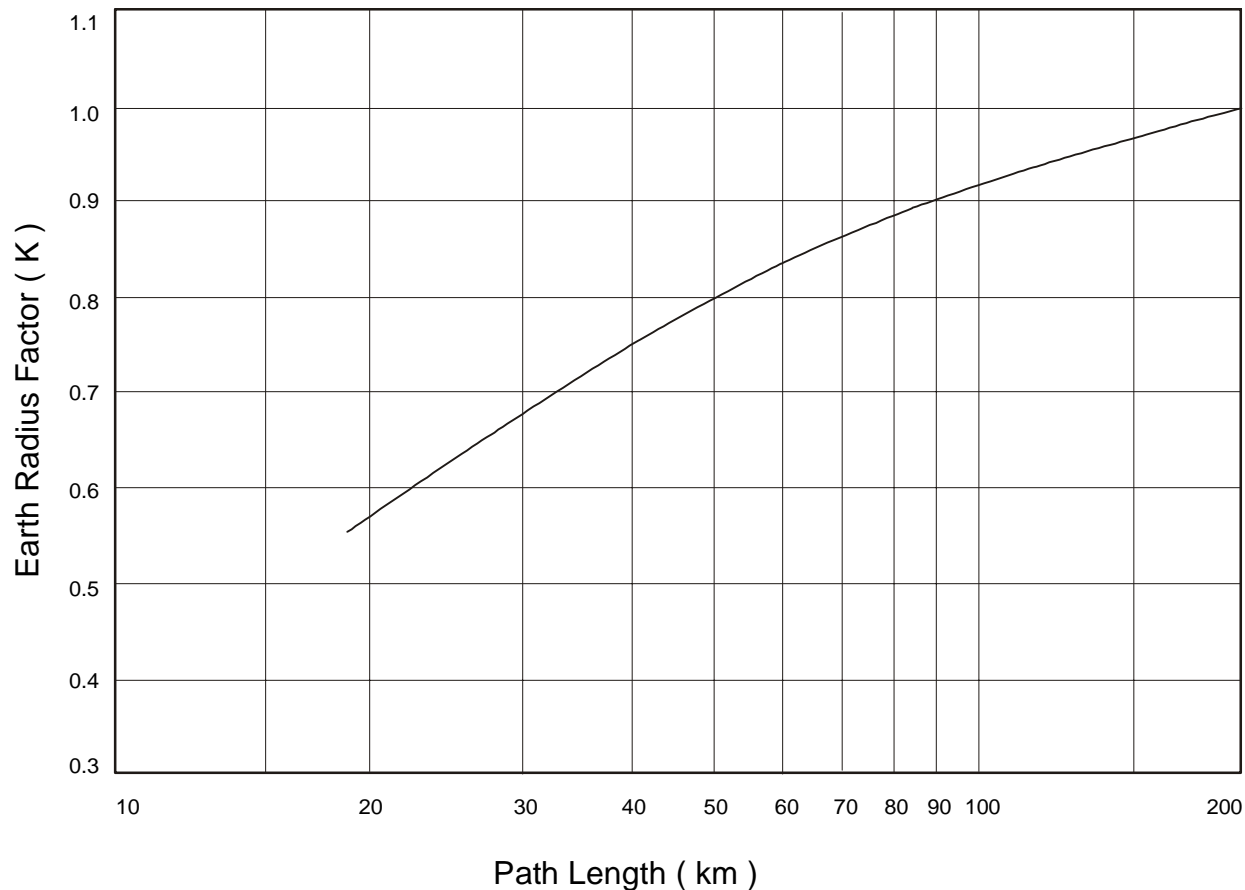6   Use the maximum values of the antenna heights determined in step 1 and step 4.

Figure 5: Value of K exceeded 99.9% of the worst month

REFERENCES

1. ITU Recommendation P.530-7Propagation Data and Prediction Methods for Terrestrial Line of Sight Systems

MICROWAVE WORKSHEET

OVERVIEW

Fading on a microwave path can occur from any of the following propagation mechanisms:

- multipath fading which follows a Raleigh probability distribution

- fades produced by rain attenuation at high frequencies

- diffraction fading at low values of the earth radius factor K

- fading due to a specular reflection where the main and reflected signal add vectorially to produce signal nulls

- fading due to anomalous propagation conditions including ducting and space wave fadeouts

With the exception of a specular reflection, these fade mechanisms are mutually exclusive events i.e. they do not occur at the same time. A microwave path design considers the outage probability of each of these mechanisms and the effect on the overall performance objective. The microwave worksheet deals with the outage probability due to multipath fading and rain attenuation. Rain attenuation is covered separately under the Rain section of this manual.

The microwave worksheet is used to create passive repeater links. This feature is described in the Passive Repeater section.

The display shows a microwave block diagram for the selected antenna configuration. All calculations are based on this antenna configuration. Each icon in the block diagram represents a data entry form. Click on the icon to bring up its data entry form. Alternately use the tab key to shift the focus to the next icon and then press Enter.

The worksheet uses standard data entry forms and grid data entry displays. Refer to the General Program Operation section for a description of these forms.

Data can be imported into the worksheet from lookup tables, radio and antenna data files (codes) or from another Pathloss data file using the Template selection.

The lower part of the display shows all of the calculations. The worksheet is automatically recalculated as data is entered. The calculation starts by erasing the calculation display and the status is shown on the status bar as ✖ or ✓. If the ✖ is displayed, click the left mouse button on the ✖ to display the error which caused the calculation to terminate.

Not all data entries will be applicable to your application. If a data entry is not applicable, leave it blank. Do not enter a zero, as this is considered as an entry and will be printed up in the worksheet reports. To erase an entry, place the cursor on the entry and press the F3 key.

Status Bar

The status bar at the bottom of the display shows the site names, measurement system, reliability method, antenna configuration and the calculation status as an ✖ or ✓.

Click on the measurement system box to change between miles-feet and kilometers-meters.

Click on the antenna configuration box to select a new antenna configuration.

Click on the reliability method box to select a new reliability method.

Calculation Status

The calculation is complete if a green ✓ is displayed on the status bar. If a red ✖ is displayed, click the left mouse button on the ✖ to display the error which terminated the calculation. A list of all error messages is given below:

Path length missing   Frequency missing

Incomplete passive data   No receive signal

No diversity receive signal   No thermal fade margin

Negative fade margin   Reliability data missing

Average temperature missing TX channels required for FD

FD improvement < 1   Zero antenna separation

SD improvement < 1   Hybrid & angle diversity not allowed

Rain error - outage probability < 1E-8 - Crane

Rain error - outage probability > 0.50 - Crane

Rain error - frequency out of range 1 to 100 GHz

Rain error - negative rain rate

Rain error - lower limit exceeded - ITU530

The "No receive signal" error means that the data entry is incomplete. An antenna gain, transmit power or path length is missing.

The "No thermal fade margin" usually means that the receive threshold level has not been specified.

MICROWAVE NET PATH LOSS COMPONENTS

Figure (1) shows the block diagram of the net path loss components used in the microwave worksheet. This is a general diagram and not all of these components may apply to your configuration. Enter values for the applicable components and the basic path parameters to produce a value net path loss in the worksheet. As a minimum the path length, frequency and the antenna gains are required.

If a space diversity antenna configuration is specified, then the data for these antennas and transmission lines must be entered.

Other components are optional and will depend on the specific equipment configuration.

Terminology

The main net path loss at Site 1 is the total loss from the transmitter output at Site 2 to the receiver input at Site 1.

Diversity net path loss at Site 1 is defined as the total loss from the transmitter output at Site 2 to the diversity receiver input at Site 1.

The main net path loss at Site 2 is the total loss from the transmitter output at Site 1 to the receiver input at Site 2.

Diversity net path loss at Site 2 is defined as the total loss from the transmitter output at Site 1 to the diversity receiver input at Site 2.

Field margin is a maintenance margin to account for such long term effects as antenna orientation accuracy. Typical values are from 1 to 2 dB.
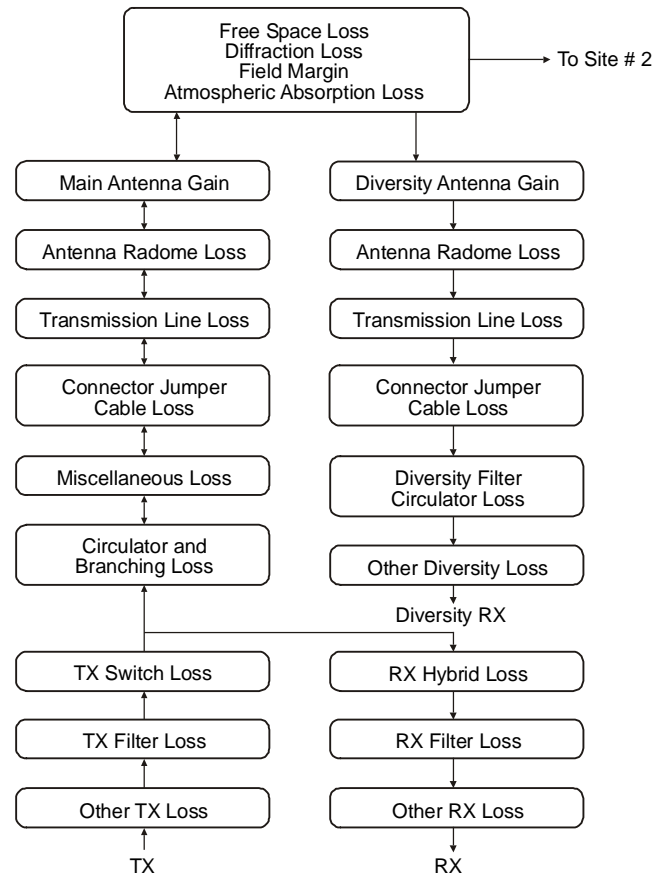
Figure 1:Microwave Net Path Loss Components

RELIABILITY OPTIONS

Select Operations - Reliability Method from the worksheet menu bar to access the Reliability Options dialog box. Alternately, click on the reliability method box on the status bar. Six methods are provided for propagation reliability calculations. The specific data entries are made in the Path Data entry form which will be formatted for the selected reliability method.

The following reliability methods are available:

Method	Required Parameters
Vigants - Barnett	C factor or Climatic factor and terrain roughness
Recommendation ITU-R P.530-6	path inclination grazing angle geoclimatic factor
Recommendation ITU-R P.530-7/8	path inclination geoclimatic factor
K Q Factor	K Q factor distance exponent frequency exponent
K Q Factor $* S^{-1.3}$	KQ factor distance exponent frequency exponent terrain roughness
Recommendation ITU-R P.530-9	path inclination geoclimatic factor

Note that the value of the geoclimatic factors used in P.530-6, P.530-7/8 and P530-9 are not the same numerically.

Complete details of these reliability methods are given in the technical part of this section.

Calculation Method
Each of the above reliability methods calculates the probability of the receive signal fading below its threshold level in the worst month due to multipath fading only. The duration of the fade below the threshold level is not considered and the resultant outage time is the total time below level.

ITU provides the following additional breakdown of the total time below level:

- Fades below threshold which last 10 consecutive seconds or longer are defined as unavailable time.

- Fades below threshold which last less than 10 consecutive seconds (all other fades) are defined as severely errored seconds.

Total Annual Time Below Level
Outage times are reported for the worst month and annually without considering the fade duration. The relation between the worst month and annual depends on the average annual temperature for the area. If a rain calculation is active, the annual rain outage is simply added to the annual multipath outage for the total annual outage. This assumes that the conditions for high intensity rain and severe multipath fading are different and the two fading mechanisms do not occur at the same time.

Outage probabilities can be expressed as availability (99.9999%) or unavailability (0.0001%). This selection is made in Time percentages and is only applicable to the total time below level calculation method.

ITU T G.821 Severely Errored Seconds Ratio (SESR) - Unavailability (PDH radios)

SESR is reported for the worst month in seconds and as a ratio. Unavailability is reported in minutes per year. If a rain calculation is active, it is assumed that a rain fade will always last longer than 10 consecutive seconds; and therefore, the rain outage is always classed as unavailability.

Multipath fades can contribute to both the SESR and unavailability and a separate option is provided for this calculation.

The receive threshold level must correspond to a bit error rate of 10^{-3}.

ITU T G.826 SESR, BBER, ESR, Unavailability (SDH radios)

SESR is reported for the worst month in seconds and as a ratio. BBER and ESR are reported for the worst month as a ratio. Unavailability is reported in minutes per year. If a rain calculation is active, it is assumed that a rain fade will always last longer than 10 consecutive seconds; and therefore, the rain outage is always classed as unavailability.

Multipath fades can contribute to both the SESR and unavailability and a separate option is provided for this calculation.

The receive threshold level must correspond to the special SDH bit error rate referred to as the SES BER. Numerically this is between 10^{-3} and 10^{-6}. In addition, the calculation of BBER and ESR require several additional radio parameters defined in G.826. These include bits per block, blocks per second, $\alpha1$, $\alpha2$ and $\alpha3$.

REGIONAL STANDARDS

These options determine the methods to be used to calculate selective outages and diversity improvement factors.

North America - dispersive fade margin

Selective outage is calculated using the dispersive fade margin as modified by the dispersive fade occurrence factor. The dispersive fade margin is an equipment parameter in the radio data entry form. The dispersive fade occurrence factor is accessed in the path parameters data entry form. The diversity options dialog box contain operations for space diversity and quad diversity improvement factors. These options are only available with the North American - dispersive fade margin option.

ITU P-530 strict - equipment signature

Selective outage is calculated using the equipment signature. This is an equipment parameter in the radio data entry form and consists of the following terms: signature width, signature delay, signature depth for minimum and non minimum phase.

In this option all diversity improvements are calculated strictly in accordance with ITU-530-9. The settings in the diversity options dialog are not available when this option is selected.

MULTIPATH OUTAGE TREATMENT

Multipath outages are initially calculated as the total time below level in the worst month considering all fades. The duration of these fades will depend on the link fade margin. At high fade margins, most of the fades will last less than 10 consecutive seconds. As the fade margin decreases, the probability of a fade lasting longer than 10 consecutive seconds increases.

The technical reference in this section provides additional information. An option is available to treat multipath as SES only (consider all fade durations to be less than 10 consecutive seconds) or as a combination of SES and unavailability.

COCHANNEL OPERATION

The capacity of a link can be effectively doubled by simultaneously transmitting a channel on both horizontal and vertical polarization. This mode is referred to as cochannel operation. The viability of the link will be determined by the increased outage time resulting from the mutual interfering effect of this operation when the cross polarized discrimination degrades during multipath and high intensity rain conditions. Cochannel operation is invoked by checking this option in the Reliability Options dialog. Select Operations - Cochannel XPD Interference to access the data entry form for this option.

Details of the calculation are provided in the technical reference in this section.

Data entry consists of the following:

Antenna XPD - This will be automatically entered if the antenna data entry form contains an antenna code.

TX antenna spacing - If separate antennas are used for vertical and horizontal enter the vertical separation between antennas. Otherwise, this entry must be blank (F3 key).

Cochannel XPD Interference

OK Cancel Help

	Site 1	Site 2
Antenna XPD (dB)	40.00	40.00
TX antenna spacing (m)		
XPIF (dB)	17.00	17.00
XPIC device XPD (dB)	42.00	42.00
XPD fade margin - multipath (dB)	45.76	44.27
XPD threshold degradation - multipath (dB)	1.32	1.76
XPD fade margin - rain (dB)	54.10	54.26
XPD threshold degradation - rain (dB)	0.22	0.21

Site 1 Antenna XPD (dB) :

XPIF - If a antenna system is equipped with a cross polarized improvement device (XPIC device), enter the XPD improvement produced by the device. Otherwise, this entry must be blank (F3 key).

XPIC device XPD - If an XPIC device is equipped then enter the cross polarized discrimination of the XPIC device itself. Otherwise, this entry must be blank (F3 key).

The interference fade margin and threshold degradation are calculated for both rain and multipath activity on the path.

DIVERSITY OPTIONS

Select Operations - Diversity Calculation to access the Diversity Options dialog box. Settings for space, frequency, angle, quad and hybrid diversity are made in this dialog box.

Diversity Radio Type

Space diversity configurations which employ IF combining can improve the thermal fade margin up to 3 dB. The actual improvement depends on the level difference between the main and diversity receive signals and the combiner efficiency. A practical upper limit is 2.6 dB. It can be argued that this improvement is artificial and is not realized in practice. During deep fades, there will be significant difference between the main and diversity signals; and therefore, the performance will be identical to a baseband switching system.

This option effectively increases the space diversity improvement factor up to 2.6 dB.

Space Diversity Method

Options for calculating the space diversity improvement factor are available as currently employed by several microwave radio manufacturers. Refer to the technical portion of this section. This option is not available when the ITU strict option has been selected in the reliability options dialog box.

Angle Diversity

Angle diversity can be specified at either or both sites. A space diversity antenna configuration must be selected. Angle diversity cannot be used with a hybrid diversity antenna configuration. At the angle diversity site set both antenna heights to the same value. The display will show a 30 foot (9.1 meter) angle diversity separation between the antennas. The overall improvement for angle diversity is calculated using a 30 foot separation. The improvement will be the same for the dispersive component as in conventional space diversity; however, the improvement to the flat component will be one tenth of conventional space diversity.

Frequency Diversity

Frequency diversity is assumed if the transmit channel table contains more than one frequency entry. The effective frequency spacing is automatically calculated based on the number of channels. If the "Use TX channel assignments is not checked", frequency diversity will not be calculated unless values for the frequency spacing at both sites are entered.

Quad / Hybrid Diversity Method

On systems using space and frequency diversity, the overall improvement can be calculated by one of the following methods:

- the product of the frequency and space diversity improvement factors. This is generally considered to be overly optimistic.

- the square root of the sum of the squares of the two improvement factors.

- the maximum of the two improvement factors. Use this method on hybrid diversity systems.

- the sum of the two diversity improvement factors.

This option is not available when the ITU P.530 Strict option has been selected under regional standards in the reliability options dialog.

Maximum Diversity Improvement Factor
This sets the upper limit for all types of diversity improvement. If this field is blank, the calculated diversity improvement factor will be used.

MICROWAVE WORKSHEET OPTIONS

Select Operations - Options from the Worksheet menu bar to set the options listed below:

Water Vapour Density
Atmospheric absorption loss is calculated using the specified value of water vapour density. The default value is 7.5 gm /m2.

FCC EIRP Warning
When this option is checked, the EIRP is shown in red letters if the value exceeds the FCC limits. No other action is taken.

ITU Rain Warning
ITU-530-7 states that the valid range of the annual rain outage probability is 0.001 - 1%. The algorithm used in the Pathloss program allows a much wider range. The rain outage is printed in red letters in the microwave worksheet screen display when this range is exceeded. No other action is taken.

Report Header
The worksheet report header uses the site name. This can be expanded to include the call sign, station code and state by checking these options.

LOOKUP TABLES

Lookup tables are provided for microwave antennas, transmission lines and radios. These use the standard grid data entry display. Refer to the General Program Operation section for details of this display.

Lookup tables are saved in a binary format and cannot be edited externally. The column header buttons sort the table in an ascending order.

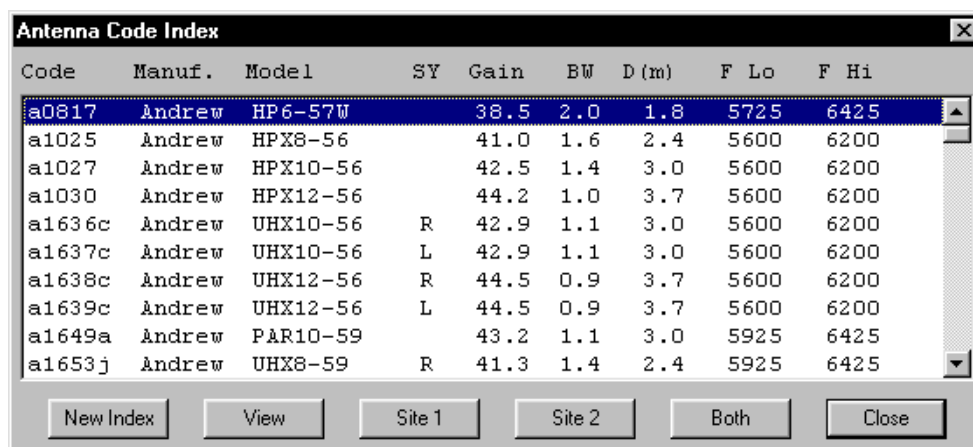Microwave antenna and radio lookup tables are used in conjunction with microwave antenna and radio data (*.mas and *.mrs) files. Information on these files is given in the Data Files section of the manual. You can import data from these files directly into the microwave worksheet or you can import the data files into a lookup table and then into the worksheet. Most projects use a small number of antenna and radio models.

Rather than search through thousands of antenna data files in multiple directories, it makes sense to create a project lookup table. Radio data files only contain a default transmit power level. You can import the file into a lookup table and then copy the entries for the other power options. Note that there is no equivalent data file for transmission lines. Data must be imported from a lookup table.

Lookup tables are accessed from the antenna, transmission line and radio data entry forms in the microwave worksheet. The antenna and radio data files are also accessed from their data entry forms.

Importing a Data File into the Worksheet

The procedure is illustrated using antenna data files (*.mas). Click the left mouse button on any of the antenna icons in the microwave worksheet display to bring up an Antenna data entry form. Alternately, use the tab key to set the focus on an antenna icon and press Enter.

Select Code Index from the data entry form menu bar. The Antenna Pattern Index dialog shows the antennas in a single directory. If there is no data available, click the New Index button to display the Select Antenna Pattern Subdirectory. Select a directory containing antenna data files (*.mas). Click OK to select the directory displayed. The program will read all mas files in the directory and create an index. The width of the Antenna Pattern Index dialog is determined from the initial data on entry. If the width is too narrow to display all of the fields, just close the dialog and reopen it.

Hilite the desired antenna. Click the Site 1, Site 2, or Both button to enter the data into the antenna data entry form. Click the View button to display the antenna specifications and radiation pattern envelope.
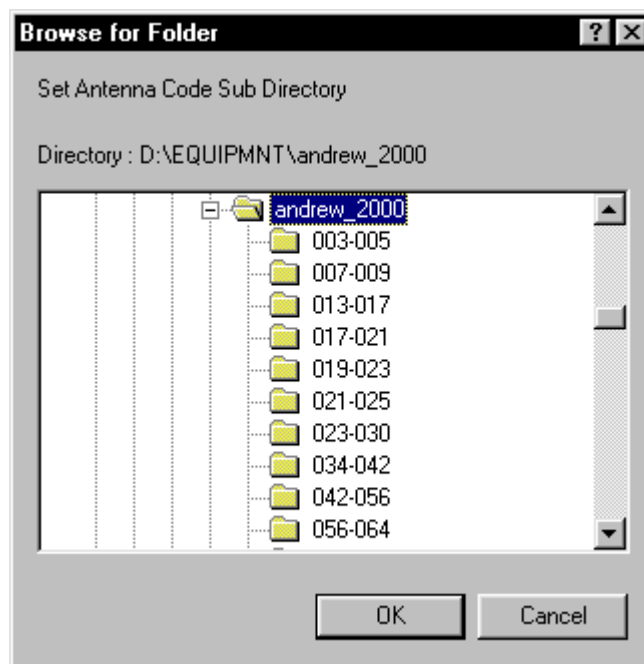
Creating a Lookup Table from Data Files

The procedure is illustrated using a radio lookup table. Click the left mouse button on any of the radio icons in the microwave worksheet display. Alternately, use the tab key to set the focus on a radio icon and press Enter.

Select Lookup from the radio data entry form menu bar. The last lookup tables used is automatically loaded. If there is an existing lookup table, Select Files - New from the lookup table menu bar to clear the table.

Select Code Index from the lookup table menu bar to display the Radio Specifications Index dialog. Note that this is a multiselect list box. Hold down the Shift or Ctrl key while selecting the radios.

Add Item	
OK Cancel	
Description	Acme SDH-11
Radio model	SDH-11
TX power (dBm)	25.00
RX Criteria	4.60E-04 BERses
RX Thresh (dBm)	-73.10
Disp FM (dB)	
Max RX Level (dBm)	
Code	SDHRADIO
Emission designator	
Traffic code	STM1-64TCM
RX Threshold 10-6 (dbm)	-70.00
T to I Cochannel (dB)	26.80
Spectrum BW (MHz)	18.00
Signature delay (ns)	6.30
Signature width (MHz)	28.00
Signature depth min phase (dB)	23.40
Signature depth nonmin phase (dB)	23.40
Freq Lo (MHz)	10700.00
Freq Hi (MHz)	11700.00

Radio data files include specifications for both 10-3 and 10-6 BER parameters. Check the required option to be imported. Click the add button to import the selected radios into the lookup table.

A radio data file contains a default transmit power option. You can create additional entries in the lookup table for other power options by doing the following:

- Click the row number cell for the radio entry to be modified. The row number color changes to red.

- Select Edit - Add from the lookup menu bar or press "Ctrl A" to bring up the add item entry form.

- Change the transmit power to the new value and Click OK on the menu bar.

MICROWAVE WORKSHEET DATA ENTRY FORMS

The data entries in each data entry form in the worksheet are summarized in this paragraph. If a specific entry is not required for your application, leave it blank. A line with blank entries will not be printed on the worksheet reports. Use the F3 key to erase an entry. The F4 key copies the value of the opposite site.

As each entry is made, the worksheet is recalculated. On completion of the entries in a form, click the OK menu item. If you click the Cancel item, all data entries in the form will be reset to their original values.

Antenna Data Entry Form

	Grande Prairie	Beaverlodge
Antenna model	UHX10-58W (R)	HPX8-58W
Antenna diameter (m)	3.05	2.44
Antenna height (m)	82.50	50.00
Antenna gain (dBi)	42.10	40.80
Radome loss (dB)		
Code	A2008	A1992
Antenna 3 dB beamwidth (°)	1.10	1.40
True azimuth (°)	271.71	91.27
Vertical angle (°)	0.25	-0.48
Antenna Azimuth (°)		
Antenna Downtilt (±°)		
Orientation Loss (dB)		

Grande Prairie Antenna model :

Antenna model	Information only.
Antenna Diameter	Information only but required for rectangular passive repeater applications.
Antenna height	Antenna heights are normally calculated in the Antenna Heights module. If you change the value here, be sure to reassess the clearance.
Antenna gain (dBi)	Antenna gains are a required entry.
Radome loss	Optional entry. On high frequency systems, where rain attenuation is a factor, the value should reflect the wet radome loss.
Code	The antenna code is required for interference calculations. Note that the code cannot be directly entered and must be loaded from a lookup table or antenna data file. A code can be directly entered or erased in the Summary module.
Antenna 3 dB beamwidth	Information only. This will become the default value for antenna discrimination calculations in the Reflection and Multipath modules.
True azimuth	This value is calculated from the geographic coordinates and cannot be edited.
Vertical angle	The calculated vertical angle for an earth radius factor of $K = 4/3$. A path profile must be available. For antenna configurations with more than one antenna, the vertical angle is calculated for the first antenna only and is assumed to be the same for the others.
Antenna Azimuth	This will be primarily used for the hub site on point to multi point applications where a fixed antenna azimuth interconnects with remote antennas. The antenna discrimination is determined from the difference of the true azimuth

and the antenna azimuth. If this entry is blank (F3 key), the horizontal antenna orientation is assumed to correspond to the true azimuth.

Antenna Downtilt
This is the corresponding fixed vertical angle at a hub site in a point to multipoint application. Downtilt is positive below the horizontal. The antenna discrimination is determined from the difference of the actual vertical angle and the antenna downtilt. In a microwave application, the vertical angle is calculated at K = 4/3 and line of sight is assumed. In a VHF-UHF application, the vertical angle will be the horizon angle on an obstructed path. If this entry is blank (F3 key), the vertical antenna orientation is assumed to correspond to the vertical angle. Note that in a VHF-UHF application the antenna boresight is always horizontal.

Orientation Loss
This the antenna response to the off azimuth and off elevation and off vertical angles above. Refer to the technical reference at the end of this section for details. An antenna code must be available for this calculation.

Transmission Lines Data Entry Form

The caption on the data entry form shows the current antenna configuration and the antenna heights. The TX line loss is automatically calculated from the TX line length and the TX line

Transmission Lines TR - TR (82.5 - 50.0)		
OK Cancel Lookup Help		
	Grande Prairie	Beaverlodge
TX line type	EWP63-59W	EWP63-59W
TX line length (m)	93.00	60.00
TX line unit loss (dB/100 m)	4.89	4.89
TX line loss (dB)	4.55	2.93
Connector loss (dB)	0.50	0.50
Grande Prairie TX line type :		

unit loss entries. The entries are unaffected by any subsequent changes made to the antenna heights. Be sure to check the values in this form when finalizing a design.

Branching Network Data Entry Form

The entries in the Branching Network data entry form depend on the antenna configuration. In the case of a TXRXDR_TXRXDR antenna configuration, there will be three different levels to enter branching network data for. Refer to the overall block diagram in Figure (1).

Branching Network TR - TR		
OK Cancel Help		
	Grande Prairie	Beaverlodge
Miscellaneous loss (dB)		
Circ. branching loss (dB)		
TX switch loss (dB)		
TX filter loss (dB)		
Other TX loss (dB)		
RX hybrid loss (dB)	1.00	1.00
RX filter loss (dB)		
Other RX loss (dB)		
Grande Prairie Miscellaneous loss (dB) :		

Radio Equipment Data Entry Form

This specific entries and formatting of this form depends on the radio type (PDH or SDH) and the selection of the regional standard in the reliability options dialog box

Radio Equipment		
	Grande Prairie	Beaverlodge
Radio model	MDR-6706-8	MDR-6706-8
Traffic code	8DS1-128TCM	8DS1-128TCM
Emission designator	2M50D7W	2M50D7W
Code	6706-8	6706-8
TX power (watts)	0.79	0.79
TX power (dBm)	29.00	29.00
RX threshold criteria	BER 10-3	BER 10-3
RX threshold level (dBm)	-81.00	-81.00
Maximum receive signal (dBm)	-8.00	-8.00
RX Threshold BER 10-6 (dBm)	-79.00	-79.00
T to I Cochannel (dB)	34.00	34.00
Dispersive fade margin (dB)	70.00	70.00

Grande Prairie Radio model :

Menu: OK Cancel Lookup Code Index View BER Help

Radio model	Information only.
Traffic code	This term consists of the digital capacity and the modulation and is automatically generated when the data is imported from a radio data file. It is used in interference calculations to identify receivers with the same characteristics.
Emission designator	Information only.
Code	The radio code is used in interference calculations. Note that the code cannot be entered directly and must be loaded from a lookup table or radio data file. A code can be directly entered or erased in the Summary module.
TX power	A required entry. The value may be entered in watts or dBm. The opposite entry is automatically calculated.
RX Threshold criteria	Information only.
RX threshold level	Required entry. The thermal fade margin is based on this entry.
Maximum receive signal	Information only at present.
RX Threshold BER 10-6	Required for interference calculations even if you have specified this threshold in the RX threshold level above. Duplication is necessary in this case.
T to I Cochannel	Required for interference calculations.
Dispersive fade margin	Optional entry. If the dispersive fade margin entry is blank or the dispersive fade factor in the Path data entry form is blank, the calculation will not consider dispersive (digital) fading. Both must be entered; otherwise, the system is considered to be narrow band or analog.

Path Data Entry Form
The path data entry form will be formatted for the specific entries required for the selected reliability method. The common entries are listed first, followed by the required entries for the five reliability methods.

Path Profile Data	
OK Cancel Rough Help	
Frequency (MHz)	5882.50
Path length (km)	33.63
Field margin (dB)	
Diffraction loss (dB)	
Climatic factor	1.00
Terrain roughness (m)	42.67
C factor	0.26
Fade occurrence factor (Po)	3.49E-02
Average annual temperature (°C)	-5.00
Dispersive fade occurrence factor	1.00
Frequency (MHz) :	

Frequency   Required entry. This is the design frequency used throughout the program. The program does not check the validity of antenna and radio models. This is the users responsibility.

Path Length   If a path profile exists, the path length is taken as the last point in the profile; otherwise, the path length is calculated from the coordinates. In either of these cases, the path length cannot be edited; otherwise, any value for the path length can be entered. If you are using the worksheet to determine performance as a function of distance, create a new file. Select Files - New on the Microwave Worksheet menu bar.

Field Margin   This is a safety factor which represents the long term degradation of connectors and antenna orientation in a practical installation. A typical value would be in the order of 1 dB.

Diffraction Loss   Diffraction loss calculations are carried out the Diffraction module are not automatically transferred to the Microwave Worksheet. If a diffraction calculation exists and the value is different from the worksheet entry, you will be prompted to update the worksheet with the new calculated value. The Diffraction module is used for a variety of different analysis and there is no way of determining whether a diffraction loss calculation should be included in the worksheet. The question "When should diffraction loss be entered into the Microwave worksheet?" arises here. Suppose a link design had 6 dB of diffraction loss at K = 4/3 and free space loss only at K = 5. The purpose of the microwave worksheet is to calculate the propagation reliability due to multipath fading. This typically occurs at high values of K. Therefore, in this example, free space loss conditions exist during the fading and the diffraction loss should not be considered for the reliability calculation.

Average annual temperature   This entry is not used in the unavailability - severely errored seconds reliability calculation. In the total annual time below level calculation, the average annual temperature is used to determine the length of the fading season.

Fade occurrence factor   This is a calculated value of the fade probability P_O and is provided for information purposes only.

Dispersive fade occurrence factor   This factor derates the dispersive fade margin. The dispersive fade margin must be specified in the radio data entry form and the fade occurrence factor must be specified here in order to calculate dispersive outage. Otherwise, performance will be calculated as an analog system.

Vigants Barnett Reliability Method

This method uses a C factor to calculate propagation reliability. The value can be obtained from the maps in the technical portion of this section. The following guidelines are given for direct entry of the C factor:

C = 0.25   good propagation conditions in mountainous and dry climates
C = 1   average propagation conditions for average terrain and climatic conditions
C = 4 to 6   difficult propagation conditions over water and in gulf coastal areas

Alternately, the C factor can be derived from the terrain roughness and a climatic factor. Refer to the maps in the technical portion for climatic factors or use the typical values given below.

cf = 0.5   good propagation conditions in mountainous and dry climates
cf = 1   average propagation conditions for average terrain and climatic conditions
cf = 2   difficult propagation conditions over water paths and in gulf coastal areas

The preferred method is to calculate the C factor from a Climatic factor and the terrain roughness. This may be entered directly into the Path Profile data entry form or calculated if a terrain profile is available. Select Rough on the Path data entry form menu bar to bring up the Terrain Roughness display. Details of the terrain roughness calculation are given later in this section.

Recommendation ITU-R P.530-6

This method requires three parameters to calculate propagation reliability.

Path Inclination

The path inclination is calculated from the site elevations, the antenna heights and the path length. The path inclination can be entered directly in milliradians; however, the value will be overwritten if the antenna heights, site elevation or path length are changed.

Grazing Angle

The grazing angle is the angle of incidence or reflection at the reflection point. The value can be entered directly into the Path Profile data entry form in milliradians or calculated if a terrain profile is available. Select Graze on the Path Profile data entry form menu bar to bring up the Grazing Angle display. Details of the grazing angle calculation are given later in this section.

Geoclimatic Factor

The geoclimatic factor can be entered directly into the Path Profile data entry form in scientific notation "e.g. 1.45E-5" or calculated by selecting Geoclimatic Factor on the Path Profile data menu bar.

Method 1

The geoclimatic factor is calculated from the probability (Pl) that the refractivity gradient is less than -100 N units /kilometer. Refer to the refractivity gradient atlases in the reference section for the months of February, May, August and November. The month with the highest value of Pl (worst month) should be used. An exception to this is the map for February which should <u>not</u> be used in the Arctic. Enter this value in the field "Probability dN/dh <= 100 N units/ km".

The geographic coordinates of the general area of the path are required in this method. If site coordinates are available, these will be used to determine the coordinates at mid path; otherwise, enter the approximate coordinates of the path. This is not critical.

Select the type of terrain which best approximates the path profile.

Click the OK button to calculate the geoclimatic factor and enter this into the Path Profile data entry form.

Method 2 (Canada Only)

Check the "Logarithmic Geoclimatic Factor - Canada" box. Refer to the logarithmic geoclimatic factor atlas for Canada in the reference section. Determine the logarithmic geoclimatic factor for the area of the path. Click the OK button to calculate the geoclimatic factor and enter this into the Path Profile data entry form.

The following refinements are recommended for the Canadian logarithmic geoclimatic factor:

- At latitudes above 60 degrees, add 5 dB to the value in the atlas.

- For paths over medium sized bodies of water (Bay of Fundy, Strait of Georgia, Frobisher Bay, Lake Ontario, Lake Erie), add 6 dB to the values in the atlas. Add 11 dB if the path is above 60 degrees latitude.

- For paths over large bodies of water (Hudson Strait, Viscount Melville Sound, Hecate Strait, Cabot Strait, Lake Superior, Lake Huron, Lake Michigan), add 14 dB to the value in the atlas. Add 19 dB if the path is above 60 degrees latitude.

Recommendation ITU-R P.530-7 / 8
Two parameters are required in this method:

Path Inclination

The path inclination is calculated from the site elevations, the antenna heights and the path length. The path inclination can be entered directly in milliradians; however, the value will be overwritten if the antenna heights, site elevation or path length are changed.

Geoclimatic Factor

The geoclimatic factor can be entered directly into the Path Profile data entry form in scientific notation "e.g. 1.45E-5" or calculated by selecting Geoclimatic Factor on the Path Profile data menu bar.

The geoclimatic factor is calculated from the probability (Pl) that the refractivity gradient is less than -100 N units /kilometer. Refer to the refractivity gradient atlases in the reference section for the months of February, May, August and November. The month with the highest value of Pl (worst month) should be used. An exception to this is the map for February which should <u>not</u> be used in the Arctic. Enter this value in the field "Probability dN/dh <= 100 N units/ km".

The geographic coordinates of the general area of the path are required in this method. If site coordinates are available, these will be used to determine the coordinates at mid path; otherwise, enter the approximate coordinates of the path. This is not critical.

Select the type of terrain which best approximates the path profile. If this is an over water path or in a coastal area, check the "Use over water modifications" box and select the water classification. There are some ambiguities in the selections. Refer to the reference section for the exact wording used in P.530-7. The term "rc (0 to 1)" is the fraction of the profile actually over water and within a certain elevation range. Refer to the reference section for details on determining this parameter.

Click the OK button to calculate the geoclimatic factor and enter this into the Path Profile data entry form.

K Q Factor
A single parameter, K Q is required in this method. The value must be entered in scientific notation e.g. 1.2E-9. Note that the values used must correspond to the worst month and be expressed as a decimal and not as a percent. Typical values for the K Q factor are given in the reference section

The propagation reliability is calculated using the frequency and distance exponents defined in the Reliability Options dialog box.

K Q Factor and Terrain Roughness

This method requires both the K Q factor and the terrain roughness. The terrain roughness may be entered directly or calculated using the Rough menu selection. The K Q factor must be entered in scientific notation "e.g. 2.1E-5" and must correspond to the worst month and be expressed as a decimal and <u>not</u> as a percent.

The propagation reliability is calculated using the frequency and distance exponents defined in the Reliability dialog box.

Recommendation ITU-R P.530-9

Two parameters are required in this method:
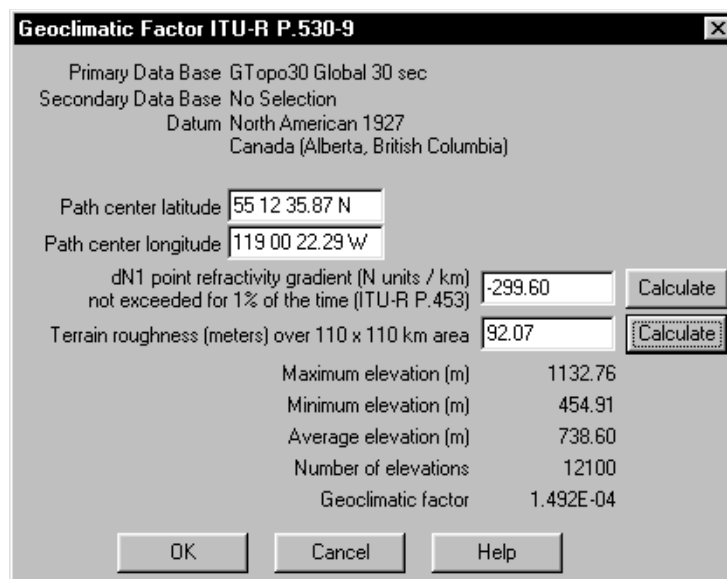
Path Inclination

The path inclination is calculated from the site elevations, the antenna heights and the path length. The path inclination can be entered directly in milliradians; however, the value will be overwritten if the antenna heights, site elevation or path length are changed.

Geoclimatic Factor

The geoclimatic factor can be entered directly into the Path Profile data entry form in scientific notation "e.g. 1.45E-5" or calculated by selecting Geoclimatic Factor on the Path Profile data menu bar.

The geoclimatic factor is calculated from the following two factors. You must click the calculate button for each each of these.

The point refractivity gradient that is not exceeded for 1% of the time is determined from tables in ITU-R P.543. The calculation is based on the center of the path and uses bilinear interpolation methods based on the nearest four points in the data file.

The area terrain roughness is calculated using the currently configured terrain database.

Interference

The results of an interference calculation are entered into the worksheet in the Interference data entry form. Select Operations - Interference from the Worksheet menu bar. The data is usually entered in as a threshold degradation. In most cases, the data will be automatically imported into the work-

	Grande Prairie	Beaverlodge
Number of exposures	2	3
Interference fade margin - multipath (dB)	38.45	38.29
Threshold degradation - multipath (dB)	7.21	7.34
Interference fade margin - rain (dB)	55.00	55.00
Threshold degradation - rain (dB)	0.39	0.39

Beaverlodge Interference fade margin - rain (dB) :

sheet from an interference calculation. Fade correlation has been implemented by providing separate components for multipath and rain.

The interference fade margin will be automatically calculated. The number of exposures is for information only and is not used in any calculations. If a rain calculation exists, the rain outage will change if you have selected the flat fade margin for rain calculations.

TX Channel Assignments

Select Equipment - TX Channels to bring up the transmit channels data entry form. Transmit channel assignments must be specified to run an interference analysis. The channel assignments are also used to calculate the effective frequency spacing in frequency diversity applications.

		Hedley TX					Anarchist Mountain TX			
	Ch ID	TX (MHz)	ATPC	Pwr.rd.	Pol	Ch ID	TX (MHz)	ATPC	Pwr.rd.	Pol
1		3540.0000			H		3580.0000			H
2		3620.0000			V		3660.0000			V
3		3700.0000			H		3740.0000			H
4		3780.0000			V		3820.0000			V
5		4565.0000			H		4755.0000			H
6		4605.0000			V		4795.0000			V
7		4645.0000			H		4835.0000			H
8		4685.0000			V		4875.0000			V
9					H					H
10					H					H
11					H					H
12					H					H

Hedley Channel ID 1 :

The data entry form contains the following fields for each site:

Channel ID	The channel identifier is used to determine if a high - low violation exists at a site. To accomplish this, the last letter of the channel identifier must be an H (high) or L (low). The test for a high low violation is carried out in the Network module under the Interference menu item.
TX Frequency	The transmit center frequency expressed in MHz.
ATPC Range	The automatic transmit power control range in dB. This is only used in an interference calculation as described below.
Power Reduction	The transmit power used in an interference calculation can be reduced from the design power on an individual channel.
Polarization	Press Enter or double click on the polarization cell to change between horizontal polarization. If the site 1 polarization is changed, the site 2 polarization and the design polarization are both automatically changed to the site 1 polarization. Changing the site 2 polarization does not have the equivalent effect. In most cases the site 1 and site 2 polarization will be the same; however, in some frequency plans and links using back to back antennas as a passive repeater, opposite polarizations will be used at each site.

The ATPC range and power reduction fields determine the transmit power to be used in an interference calculation. The transmit power used to calculate the interfering signal level is given by:

design power - ATPC range - power reduction

Transmit Channel Lookup Table

Lookup tables are available for the transmit channel assignments. These use a standard grid data entry form. Refer to the General Program Operation section in this manual for details on the use of this form. The last used TX Channel lookup file is automatically loaded when the lookup table is accessed.

	ID Hi	TX Hi (MHz)	ID Lo	TX Lo (MHz)
1	1h	10518.0000	1l	10168.0000
2	2h	10546.0000	2l	10196.0000
3	3h	10574.0000	3l	10224.0000
4	4h	10602.0000	4l	10252.0000
5	5h	10630.0000	5l	10280.0000

The menu items Site <u>1</u> Hi and Site <u>2</u> Hi load the channel assignment of the selected item into the TX Channel data entry form. The <u>U</u>p and <u>D</u>own menu items move the hilite bar in the TX Channel data entry form to facilitate multiple channel entries.

The Hi-Lo menu item sets the difference between the high and low frequencies. This is used when a lookup table is created. When the TX Hi frequency is entered, the TX Lo frequency is automatically assigned a value given by TX Hi - spacing. Entering a value for the TX Lo frequency does <u>not</u> have an equivalent effect. To disable this feature, erase the frequency spacing.

TEMPLATES

The fastest way to enter data into the microwave worksheet is to import the data from another Pathloss data file. Select Template on the Worksheet menu bar and open the Pathloss data file which will be used as a template. Only the equipment specific data will be imported. The antenna configuration will be set to that used in the template file.

TERRAIN ROUGHNESS CALCULATION

The terrain roughness calculation is accessed from the Path data entry form. Select Rough on Path data menu bar. This terrain roughness uses a standard profile display screen. Refer to the General Program Operation section for details of this display.

This display uses the flat earth profile. To calculate terrain roughness, you must define the end points of a reflective plane for the path. The roughness limits are 6 meters (20 feet) minimum and 42 meters (140 feet) maximum for the Vigants - Barnett reliability method. These limits are imposed when the roughness is transferred to the Path data entry form. Note that a terrain roughness calculation is also made in the Reflection module. The limits of the Vigants - Barnett method do not apply to the Reflection module.

The reflective plane definition is saved in the Pathloss data file.
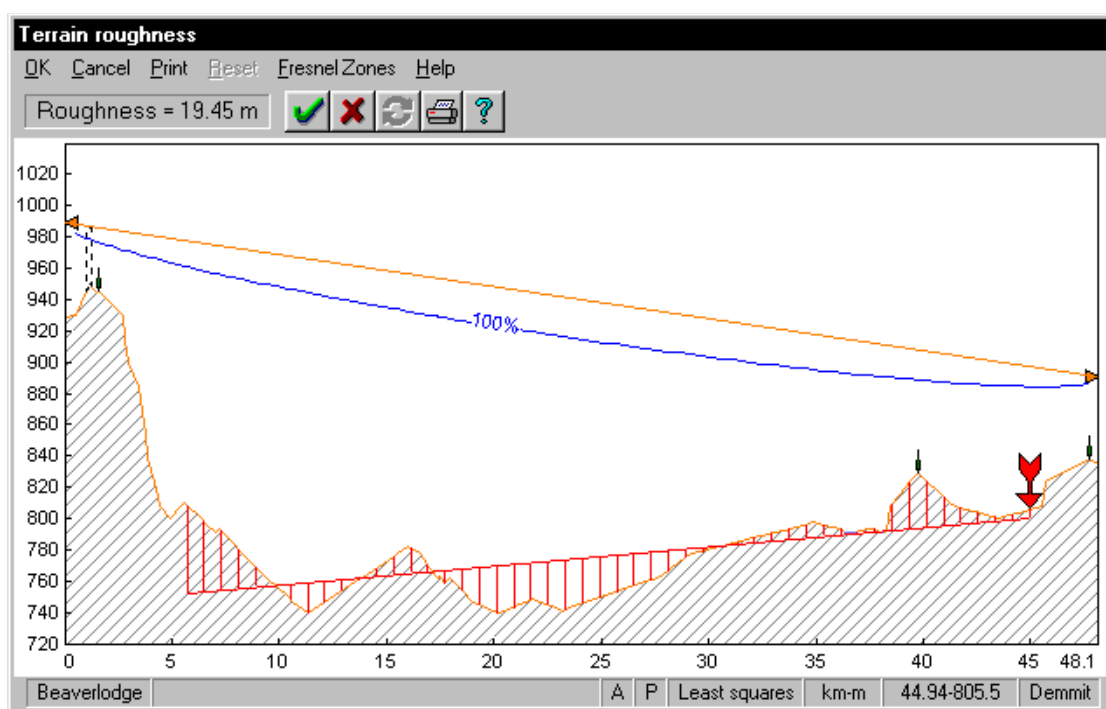
The roughness calculation interpolates 50 uniformly spaced points between the end points of the reflective plane. Terrain roughness is defined as the standard deviation of the terrain elevations (square root of the average square of the deviation from the mean). Two calculation methods are available. In the first method, the elevations are referenced to sea level. In the second method, the elevations are referenced to a least squares fit (y = ax + b) of the terrain over the profile segment defined by the end points of the reflective plane.

The calculation method is shown on the status bar. To change methods, click the left mouse button on the calculation method box.

Significant differences will occur on paths with a uniform slope and an elevation difference between the end points greater than 40 meters. If the least squares method is used, the terrain roughness will be the minimum value. If the sea level reference is used, the terrain roughness will be the maximum value. In strict accordance with the original reference, "Space Diversity Engineering by A. Vigants", the elevations should be relative to sea level.

The Vigants-Barnett method does not take into account the path inclination. In practice, a high to low path, with an elevation difference of several hundred meters performs better than a flat path with the same terrain characteristics. If terrain roughness is calculated using a sea level reference, the higher terrain roughness is more applicable. However, if the elevation difference of the path is in the order of 50 meters and relatively flat, the least squares method should be used. Refer to the Reflection Analysis section of the manual for further information on the definition of a reflective plane.

Status Bar

The status bar shows the site names, cursor style and movement state, the calculation method, measurement system, the antenna combination and the cursor location.

To display the current terrain point data, click the left mouse button on the cursor location box or press the Ins key.

If the antenna configuration supports more than one antenna combination, you can change antenna combination by clicking the left mouse button on the antenna combination box.

To change the calculation method from least squares to sea level, click the left mouse button in the calculation method box.

Procedure
- Place the arrow at one end of the section over which terrain roughness is to be calculated and press the F1 key or click the right mouse button.
- Move the arrow to the opposite end and press the F1 key or click the right mouse button again.

The Reset button is active when the first point has been selected. This will only cancel the first point selection.

To repeat a terrain roughness calculation, just reselect the end points of the new reflective plane. This is carried out over the existing calculation.

Click the OK button to accept the calculated value of terrain roughness. The Cancel button discards the calculation.

GRAZING ANGLE CALCULATION
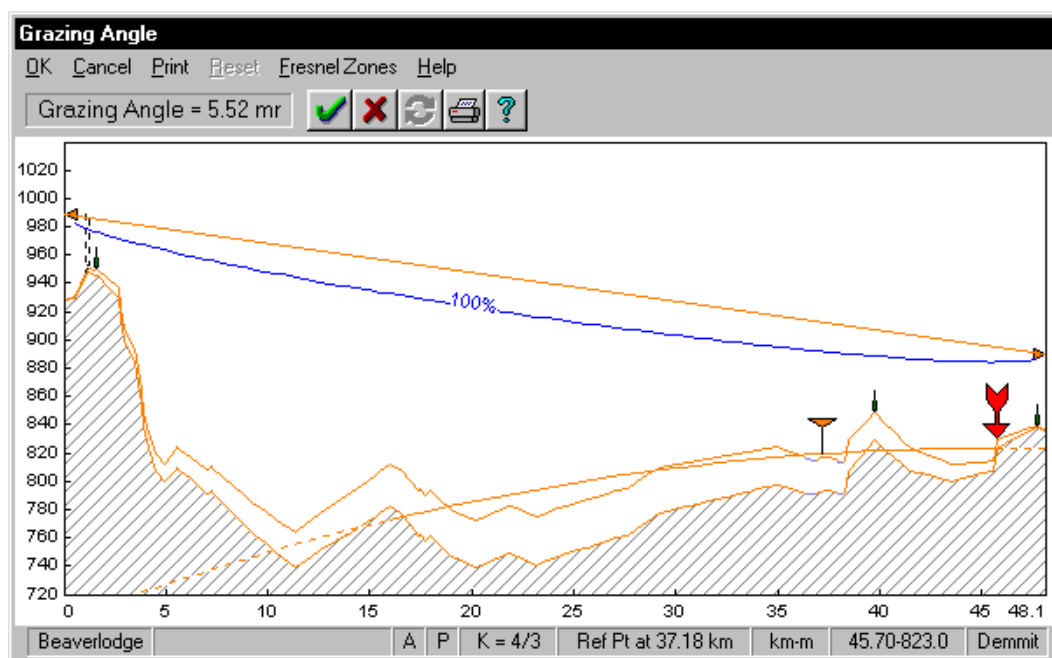
The terrain grazing angle calculation is accessed from the Path Profile data entry form when the ITU-530-6 reliability method has been selected. Select Graze on Path Profile data entry form menu bar. This grazing angle calculation uses a standard profile display screen. Refer to the General Program Operation section for details of this display.

The profile is displayed with an earth radius factor of K = 4/3 using the antenna combination shown on the status bar. The lower filled profile represents the flat earth profile. A reflective plane must be defined to calculate the grazing angle. The location of the geometric reflection point is calculated and displayed on the reflective plane. The reflective plane is determined by a least squares fit of the form y = ax + b over the defined range using the flat earth profile and displayed at K = 4/3. Effective antenna heights are determined by extending the reflective plane to the end points of the profile. The effective antenna heights are the heights of the antenna above the reflective plane end points.

The reflective plane definition is saved in the Pathloss data file.

Refer to the Reflection Analysis section of the manual for further information on the definition of a reflective plane.

Status Bar

The status bar shows the site names, cursor style and movement states, K, reflection point location, measurement system, the antenna combination and the cursor location.

To display information at the terrain point under the arrow, click the left mouse button on the cursor location box or press the Ins key.

If the antenna configuration supports more than one antenna combination, you can change the antenna combination by clicking the left mouse button on the antenna combination box.

Procedure

- Place the arrow at one end of the reflective plane and press the F1 key or click the right mouse button.

- Move the arrow to the opposite end and press the F1 key or click the right mouse button again.

The following error messages may appear:

Plane is not Valid   The reflective plane elevation at one end of the profile is greater than the antenna height. Redefine the reflective plane.

Reflection Point not Found   The algorithm failed to locate the reflection point. This can occur if the reflection point is very close to one of the sites. Increase the antenna heights or change the reflective plane definition.

Reflection Point outside Plane Limits   The location of the reflection point is outside of the defined range. Either the reflective plane definition is questionable or the path does not have a reflection point in this area.

- The Reset button is active when the first point has been selected. This will only cancel the first point selection.

- To repeat a grazing angle calculation, just reselect the end points of the new reflective plane. This is carried out over the existing calculation.

- Click the OK button to accept the calculated value of the grazing angle. The Cancel button discards the calculation.

On over water paths or paths which are predominately flat, the choice of end points is obvious. On other paths, some judgment is required to define the reflective plane. The following guidelines can be used.

- Draw a 100% first Fresnel zone reference and note the extent of the terrain closest to this Fresnel zone reference.

- Place the arrow at the center of this extent and press the Ins key to display the terrain point data. Note the clearance to the first Fresnel zone ratio (C/F1).

- Using this value as a guide, draw additional Fresnel zone references until approximately 50% of the Fresnel zone reference is below the terrain.

- Define the end points of the reflective plane at the first and last intersections of the Fresnel zone reference with the terrain.

VHF-UHF WORKSHEET

OVERVIEW

The VHF-UHF worksheet is intended for point to point analysis at frequencies below 1000 MHz. At these frequencies, antenna gains are usually expressed in dBd (dB with respect to a half wave dipole). The antenna can be set to a fixed azimuth and mechanical downtilt to handle broadcast and point to multipoint application. The antenna response to both horizontal and vertical angles is automatically calculated using antenna data files.

Antenna beam widths are relatively wide with the result that propagation due to ground scatter is a significant component. Additionally, diffracted paths are common at these frequencies. Under these circumstances, the traditional path reliability calculations as used in the microwave worksheet are not considered valid; particularly, at the lower fade margins found in VHF-UHF applications. The reliability is expressed using two methods: a Raleigh fade probability which accounts for multipath fading and a log normal fade probability which accounts for the specific location of the receiver.

The display shows the VHF-UHF system block diagram for the selected antenna configuration. All calculations are based on this antenna configuration. Each icon in the block diagram represents a data entry form. Click on the icon to bring up its data entry form. Alternately, use the tab key to shift the focus to the next icon and then press Enter. The data entry forms will be formatted for the VHF-UHF antenna configuration which allows tower mounted preamplifiers to be included with receive only antennas.

The worksheet uses standard data entry forms and grid data entry displays. Refer to the General Program Operation section for a description of these forms.

Data can be imported into the worksheet from lookup tables, VHF-UHF antenna data files or from another Pathloss data file using the Template selection.

The lower part of the display shows all of the calculations. The worksheet is automatically recalculated as data is entered. The calculation starts by erasing the calculation display and the status is shown on the status bar as a ✖ or ✓. If the ✖ is displayed, click the left mouse button on the ✖ to display the error which caused the calculation to terminate.

Not all data entries will be applicable to your application. If a data entry is not applicable, leave it blank. Do not enter a zero as this is considered to be a valid entry and will be printed up in the worksheet reports. To erase an entry, place the cursor on the entry and press the F3 key. The F4 key copies the entry in the adjacent cell to the current cell.

Status Bar

The status bar in the VHF-UHF worksheet shows the site names, the antenna configuration and the measurement system. To change either the antenna configuration or the measurement system, click the left mouse button on the corresponding box on the status bar.

The status bar also shows the current state of the calculation as a green ✓ or a red ✖. If the ✖ is displayed, click on this to show the reason that the calculation is incomplete.

VHF-UHF NET PATH LOSS COMPO-NENTS

Figure (2) shows the net path loss components used in the VHF-UHF worksheet. As in the case of the microwave worksheet, this is a general diagram and not all of these components may apply to your configuration. Enter values for the applicable components and the basic path parameters to produce a value net path loss in the worksheet. As a minimum the following parameters are required:

Path length   Frequency

Site 1 antenna gain   Site 2 antenna gain

Other components are optional and will depend on the specific equipment configuration.

Terminology

The net path loss at Site 1 is the total loss from the transmitter output at Site 2 to the receiver input at Site 1.

The net path loss at Site 2 is the total loss from the transmitter output at Site 1 to the receiver input at Site 2.
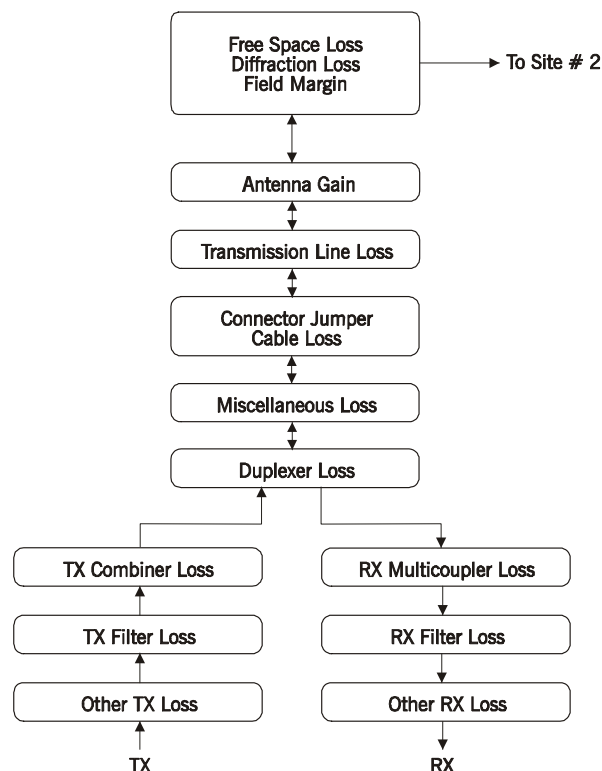
Figure 2: VHF-UHF net path loss components

Receiver multicouplers are usually active devices and have a gain. Positive values are interpreted as a loss. To enter a gain, you must enter a negative sign in front of the value (a negative loss).

VHF-UHF WORKSHEET DATA ENTRY FORMS

First determine the parameters of your application. The worksheet data entry forms include a generalized set of data entries, not all of which may apply to your equipment and antenna configuration. For example, if the transmitter power and receiver sensitivity are defined at the antenna port, then it will not be necessary to enter any data for the duplexers. Refer to the basic block diagram of the VHF-UHF loss gain components in Figure (2). Calculated parameters are shown in the table at the bottom of the display. The calculations are automatically updated as data entry proceeds. On completion of the entries in a form, click the OK menu item. If you click the Cancel menu, all data entries will be reset to their original values.

If a parameter has not been calculated, then one or more data items required for the calculation are missing. If a green ✓ is displayed on the status bar, the calculation is complete; otherwise a red ✘ will be displayed. Click on this ✘ to show the reason the calculation has not been completed.

You can erase a data entry with the F3 key. The F4 key copies the data from the opposite cell into the current cell.

Antenna Data Entry Form

Antennas TR - TR		
OK Cancel Lookup Code Index View Help		
	Site #1	Site #2
Antenna model	SRL310-C4 L/2	SRL 307-2
Antenna height (m)	36.58	7.62
Antenna gain (dBi)	10.15	14.65
Antenna Gain (dBd)	8.00	12.50
Code	310C401L	307-201M
True azimuth (°)	33.00	213.34
Vertical angle (°)	-0.06	-0.03
Antenna Azimuth (°)	45.00	
Mechanical Downtilt (°)		
Electrical Downtilt (°)	0.00	0.00
Orientation Loss (dB)	3.30	0.00
Site #2 Antenna model :		

Antenna model	Information only.
Antenna height	If a significant change is made to an antenna height, check the clearance or recalculate the diffraction loss.
Antenna gain	The antenna gains can be entered in either dBi (isotropic radiator) or dBd (dipole). The other gain format is automatically calculated. Most antenna specifications below 900 MHz assume dBd.
Preamplifier gain	This entry appears only on receive antennas and represents either a tower mounted or "in building" receive preamplifier. This is a positive number.
Code	The antenna code index cannot be entered directly. Use the antenna code index or lookup table to enter a code. An antenna code is required to calculate the orientation loss due a fixed antenna azimuth or mechanical down tilt.
True azimuth	This is the value calculated from the geographic coordinates of the two sites and cannot be edited.
Vertical angle	On line of sight paths, this is the vertical angle between sites. On an obstructed path, this is the horizon angle. The vertical angle is calculated from the path geometry and cannot be edited. A path profile is required.
Antenna azimuth	This is the actual antenna boresight azimuthal angle. This is specified on a point to multipoint or base station application. On a point to point link, leave this entry blank. It will be assumed that the antenna is oriented at the true azimuth. An antenna code is required for the orientation loss.
Mechanical downtilt	If this entry is blank, a horizontal antenna boresight is assumed and the orientation loss will be calculated using the vertical angle. Downtilt is entered

as a positive number. A negative number means that the antenna is tilted up-
wards.

Electrical downtilt   This value is read from the antenna data file corresponding to is the antenna
code and cannot be edited.

Orientation loss   This is the calculated antenna response at the azimuthal and vertical angles.
An antenna code is required.

Transmission Lines Data Entry Form

	Site #1	Site #2
TX line type	LDF5-50A	LDF4-50A
TX line length (m)	40.00	8.00
TX line unit loss (dB/100 m)	2.56	4.66
TX line loss (dB)	1.02	0.37
Connector loss (dB)	0.50	0.50

Transmission Lines TR - TR (36.6 - 7.6)
OK Cancel Lookup Help
Site #1 TX line type :

The caption on the data entry form, shows the current antenna configuration and the antenna heights. The
entries are unaffected by any subsequent changes made to the antenna heights. Be sure to check the values
in this form when finalizing a design.

The transmission line type is a descriptive term and is an optional entry.

The transmission line loss can be entered directly or will be automatically calculated if the line length and
unit loss have been entered. Connector loss is an optional entry.

Branching Network Data Entry Form

The specific format of the branching network
data form will depend on the antenna configu-
ration. In the case of a TR-TXRX antenna con-
figuration, there will be three data entry forms
to complete.

Refer to the overall block diagram in Figure
(2). If the transmit power and receiver sensitiv-
ity are defined at the antenna port, then this
form is not required.

Duplexer and miscellaneous loss entries are
common losses.

The TX combiner, TX filter and other TX loss
are in the transmit line.

Branching Network TR - TR
OK Cancel Help

	Site #1	Site #2
Miscellaneous loss (dB)		
Duplexer loss (dB)	1.20	
TX Combiner loss (dB)	4.60	
TX filter loss (dB)		
Other TX loss (dB)		
RX Multicoupler loss (dB)	-6.00	
RX filter loss (dB)		
Other RX loss (dB)		

Site #1 RX Multicoupler loss (dB) :

The RX multicoupler, RX filter and other RX loss are located in the receive line.

Note that all entries default to a loss. The RX multicoupler may have a gain. This must be entered as a negative number.

Radio Equipment Data Entry Form

Radio Equipment		
OK Cancel Lookup Help		
	Site #1	Site #2
Radio model	Base	Mobile
TX power (watts)	35.00	5.00
TX power (dBm)	45.44	36.99
RX Sensitivity Criteria	12 dB SINAD	12 dB SINAD
RX Sensitivity (dBm)	-113.01	-106.99
RX Sensitivity (µv)	0.50	1.00
Site #2 Radio model :		

Radio Model	Information only.
TX Power	The transmit power can be entered in either watts or dBm. The other value is automatically calculated.
RX Sensitivity Criteria	This describes the receive sensitivity criteria e.g 20 dB Quieting.
RX Sensitivity	The receive sensitivity can be entered in either micro volts or dBm. The other value is automatically calculated.

Both the transmit power and the receive sensitivity level must be entered in order to calculate the fade margin.

Path Data Entry Form

|	
Frequency	This is the design frequency used throughout the program. The user is responsible to check that the frequency is within the operating range of the antennas, transmission lines and radios.

Path Profile Data	
OK Cancel Help	
Frequency (MHz)	450.00
Path length (km)	48.28
Field margin (dB)	
Diffraction loss (dB)	32.44
Frequency (MHz) :		

Path length	If a path profile exists, the path length is taken as distance of the last point in the profile; otherwise, the path length will be calculated from the geographic coordinates. In both of these cases, the path length cannot be edited; otherwise any path length can be entered. If you are using the worksheet to determine performance as a function of distance, create a new data file. Select Files - New on VHF-UHF Worksheet menu bar.
Field Margin	This is an optional safety factor to account for the degradation of antennas and connectors. A typical value for the field margin is 1 to 3 dB.

Diffraction Loss   Diffraction loss calculations are carried out in the diffraction module. These are not automatically transferred to the VHF-UHF worksheet. If a diffraction calculation exists and the value is different from the worksheet entry, you will be prompted to update the worksheet with the new calculated value.
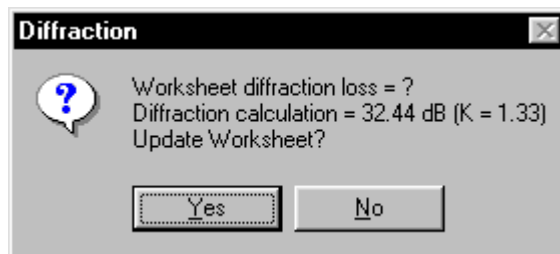
VHF-UHF WORKSHEET OPTIONS

The worksheet report header uses the site names. This can be expanded to include the call sign, station code and state.

The log normal fade probability calculation uses the standard deviation specified in the location drop down list.

WORKSHEET REFERENCE

MULTIPATH PROPAGATION RELIABILITY

Fading on a microwave link can result from any of the following mechanisms:

- atmospheric multipath fading

- rain attenuation

- diffraction fading at low values of K

- fades produced by a specular reflection

- propagation anomalies produced by atmospheric ducts or layers

Each of these mechanisms can contribute to the overall propagation reliability and must be separately analysed. The parameter of particular interest is the total time that the receive signal is below its threshold level.

It is generally assumed that these fading mechanisms are mutually exclusive events and the total time below the threshold level is the sum of the outage times for each mechanism. For example, multipath fading does not occur during periods of heavy rainfall; and therefore, the multipath and rain outage times can be added together.

Atmospheric multipath fading is the result of a number of rays with varying length paths arriving at the receive antenna. The different ray paths can result from both changes in the refractivity gradient and diffuse ground reflections. The rays add vectorially in the receive antenna to produce both signal enhancement and fades.

Multipath fading follows a Raleigh probability distribution. The fade probability represents the fraction of time (in the worst month), that the depth of multipath fades will exceed the fade margin. Note that this fade probability does <u>not</u> include any of the other fade mechanisms mentioned above and does not include the additional time required to reframe the digital signal following a fade which results in loss of framing.

The fade probability, *P*, is a function of the frequency, path length and the fade margin of the radio link and takes the following general form:

$$P \propto f^b \cdot d^c \cdot 10^{-\frac{A}{10}} \tag{1}$$

where:

d	path length
f	frequency
A	fade margin in dB

Note that *P* is expressed as a fraction of time and <u>not</u> as a percentage. Equation (1) is valid for fade margins greater than 15 dB and applies to unprotected (non diversity) radio systems in one direction of transmission. The exponents *b* and *c* and the constant of proportionality in Equation (1) are based on empirical data.

Five methods of calculating the fade probability are available in the Pathloss program.

- Vigants - Barnett
- Recommendation ITU-R P.530-6
- Recommendation ITU-R P.530-7/8
- Recommendation ITU-R P.530-9/10
-
- K·Q Factor
- K·Q Factor including terrain roughness

Additional performance parameters can be calculated from the fade probability P, as follows:

- Worst month unavailability (%) $100 \cdot P$
- Worst month availability (%) $100 \cdot (1 - P)$
- Worst month outage time (sec) $P \cdot \text{seconds\_month}$

Assuming 3 heavy fading months per year (0.25 of a year), the annual performance can be expressed as:

- Annual unavailability (%) $100 \cdot P \; 0.25$
- Annual availability (%) $100 \cdot (1 - 0.25 \cdot P)$
- Annual outage time (sec) $0.25 \cdot P \cdot \text{seconds\_year}$

Multipath fading is a warm weather phenomenon. The length of the fading season is proportional to the average annual temperature and is given in Reference (4). The fade duration, T_o, expressed as a fraction of a year, is given by:

$$T_0 \;=\; 0.25 \cdot \left(\frac{t}{50} \right) \tag{2}$$

t is the average annual temperature in $^\text{o}\text{F}$

$35 < t < 75 \; ^\text{o}\text{F}$
$2 < t < 24 \; ^\text{o}\text{C}$
$0.175 < T_0 < 0.375$

The annual one way performance is expressed in terms of T_o as follows:

Annual unavailability (%) $100 \cdot T_o \cdot P$
Annual availability (%) $100 \cdot (1 - T_o \cdot P)$
Annual outage time (sec) $T_o \cdot P \cdot \text{sec\_year}$

Figure (7), Figure (8) and Figure (9) provide geographic maps showing the average annual temperature for the United States, Canada and the world respectively.

Fade Margins

The fade probability of a microwave radio link is a function of its fade margin. The fade margin consists of a flat component and a dispersive component. The flat fade margin considers the total power in the passband, whereas the dispersive fade margin deals with the amplitude - frequency response in the passband. The dispersive component is applicable to digital radios only. Analog radios (FM-FDM) are not sensitive to the passband frequency response. The flat fade margin is made up of the thermal fade margin and an interference fade margin.

Thermal Fade Margin

The thermal fade margin is the difference between the free space receive signal and the receiver threshold level. This represents the additional attenuation to the free space received signal required to produce an outage due to thermal noise alone, independent of any interference.

Interference Fade Margins

Interference effectively degrades the receiver threshold. The interference fade margin is defined as the additional attenuation to the free space received signal required to produce an outage due to the interference, independent of thermal noise.

Flat Fade Margin

The flat fade margin A_F, consists of the thermal and interference fade margins combined as follows:

$$A_F \quad = \quad -10 \cdot \log \left(10^{-\frac{A_t}{10}} + 10^{-\frac{A_i}{10}} \right) \tag{3}$$

A_t thermal fade margin in dB

A_i channel interference fade margin in dB

Dispersive Fade Margin

The North American selective outage calculation is based on the dispersive fade margin. This is defined as the average depth of multipath fade which causes an outage, independent of thermal noise and interference. This is a measured equipment parameter in accordance with Reference (1). The dispersive fade margin depends on the equipment design and the specific type of equalizer provided. The basic measurement procedure for a 45 Mbs 64QAM radio is described below:

A 6.3 nanosecond frequency response notch is introduced into the RF /IF passband. The center of the notch is moved across the passband. At each frequency, the depth of the notch is adjusted to produce a 10^{-3} BER. The results are shown in Figure (3) and are referred to as an equipment signature, M or W curves.
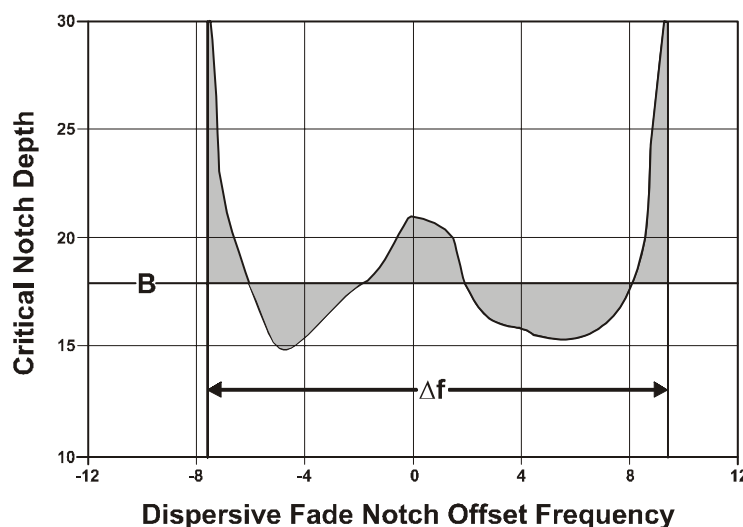
Figure 3: Dispersive fade margin measurement

The average depth of multipath fade, B, is determined by integrating the curve. The dispersive fade margin, A_d, is given by:

$$
\begin{aligned}
S &= 2 \cdot \Delta f \cdot e^{-\frac{B}{3.8}} \\
A_d &= 17.6 - 10 \cdot \log\left(\frac{S}{158.4}\right)
\end{aligned}
\tag{4}
$$

Typical values of the dispersive fade margin for 64 QAM modulation are 50 dB for a radio equipped with an adaptive transversal equalizer, and as low as 35 dB for the same radio without equalization.

Dispersive Fade Factor

The dispersive fade margin measurement procedure is based on the fade statistics of a 26 mile path from Palmetto to Atlanta, Georgia. In general, dispersive multipath fading depends on the following:

- terrain roughness and ground type
- climatic conditions
- path length
- path clearance

To account for these factors, it is necessary to adjust the value of the dispersive fade margin. This is accomplished with the term, "fade occurrence factor" in the Pathloss program. By definition, the fade occurrence factor is equal to 1 for the Palmetto - Atlanta path. At present, there are no published guidelines for this factor. Experience on extremely difficult paths in eastern Ontario and Florida indicate that factor may be as high as 9. The following values are suggested:

good propagation conditions	0.5 to 1
average propagation conditions	3
difficult propagation conditions	5 to 7
extremely difficult propagation conditions	9

Effective Fade Margin

The effective fade margin, *A*, combines the flat and dispersive fade margin components as follows:

$$
A = -10 \cdot \log\left(10^{-\frac{A_f}{10}} + R_d \cdot 10^{-\frac{A_d}{10}}\right)
\tag{5}
$$

A_f	flat fade margin in dB
Rd	fade occurrence factor
A_d	dispersive fade margin in dB

ITU 530 Selective Outage Fade Probability

ITU standards use the equipment signature to calculate the fade probability of a selective outage. This is a measured equipment parameter consisting of the following components: signature delay, signature width

and the signature depth for minimum and non minimum phase. The outage probability is defined as the probability that the BER exceeds a given threshold as defined by the BER of the signature data.

Step 1: Calculate the mean path delay τ_m from Equation (6):

$$\tau_m \quad = \quad 0.7 \cdot \left(\frac{d}{50}\right)^{1.3} \text{nanoseconds} \tag{6}$$

where

d is the path length in kilometers

Step 2: Calculate the multipath activity factor η from Equation (7)

$$\eta \quad = \quad 1 - e^{-\left(0.2 \cdot P_0^{0.75}\right)} \tag{7}$$

where

P_0 fade occurrence factor

Step 3: Calculate the selective outage probability Ps from Equation (8)

$$P_s \quad = \quad 2.15 \cdot \eta \cdot W \cdot \frac{\tau_m^2}{\tau_r}\left(10^{\frac{-B_m}{20}} + 10^{\frac{-B_{nm}}{20}}\right) \tag{8}$$

where

W signature width in GHz
B_m minimum phase signature depth in dB
B_{nm} non minimum phase signature depth in dB
τ_r reference delay in nanoseconds used to obtain the signature

ITU Unavailability - Severely Errored Seconds Definitions
The above paragraphs show the basic relation between the fade margin and the probability of a fade below threshold level P. The formulation of dispersive fade margin allows the dispersive fade margin to be logarithmically added to the flat fade margin (effective fade margin). This allows *P* to be calculated from Equation () for both flat and dispersive fades. In the ITU method, the selective fade probability is separately calculated.

All multipath propagation models (e.g ITU-530) calculate the fade probability for the worst month in one direction of transmission. The fade probability is defined as the probability that the receive signal is below the specified receiver threshold. The fade probability considers the sum of all fades and does not take into account the duration of the individual fades.

G.821 and G.826 take this analysis one step further and classify fades lasting longer than 10 consecutive seconds as unavailability and all other fades as severely errored seconds (SES). The SES term is often referred to as performance. The duration of a multipath fade depends on the fade margin. The probability of a multipath fade lasting longer than 10 consecutive seconds increases with decreasing fade margin.The relationship is shown in Figure (4).
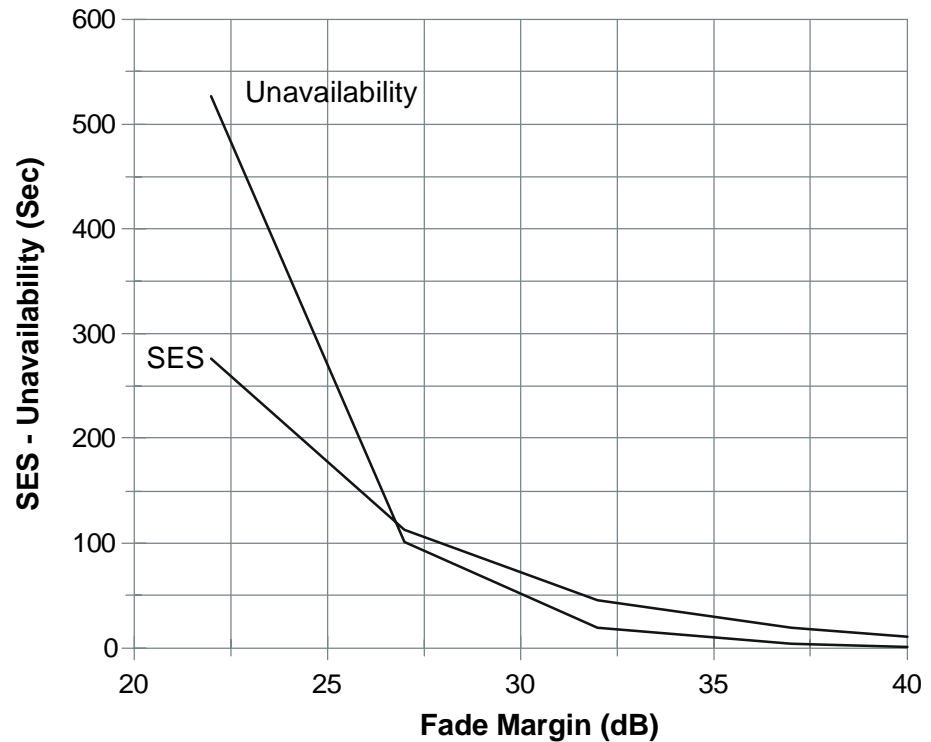
In the case of rain fades, it is universally agreed that a rain fade will always last longer than 10 consecutive seconds and is classified as unavailability only.

G.821 and G.826 provide performance objectives in terms of SES and unavailability without stating the relationship between the two parameters

Figure 4: Relationship between SES - Unavailability and Fade Margin

$$\text{worst month time below level} \;=\; \text{unavailability} + SES \tag{9}$$

At very high frequencies, multipath fading becomes negligible compared to the rain fades.

At lower frequencies where rain is insignificant, two different approaches have been taken:

- Multipath is considered to affect the performance only and in this scenario the severely errored seconds ratio (SESR) is equal to multipath fade probability. Objectives are more difficult to achieve as the allowance for unavailability cannot be used. The real reason for this approach is the lack of any published procedures to breakdown the total time below level into SES and unavailability.

- Other companies have developed their own fade duration statistics to carry this out however, the formulas have not been published.

The Pathloss program has used these equations for G.821 performance calculations since version 3.0. The specific equations are shown below.

Using the dispersive fade margin, the total fade probability P is separated into the flat and dispersive components P_f and P_d as shown below

$$P_f \propto f^b \cdot d^c \cdot 10^{-\frac{A_f}{10}}$$

$$P_d \propto f^b \cdot d^c \cdot 10^{-\frac{A_d}{10}}$$

(10)

where:

A_f flat fade margin (dB)

A_d dispersive fade margin (dB)

As described above P_d is calculated from the equipment signature under ITU standards.

The probability of a non selective (flat) fade lasting longer than t consecutive seconds is given by:

$$\rho_f = 0.5 \cdot \text{erfc}\left(\frac{\ln\left(\frac{t}{T_d}\right) + 0.673}{1.27 \cdot \sqrt{2}} \right)$$

$$T_d = 163 \cdot k \cdot \sqrt{\frac{d}{f}} \cdot 10^{-\frac{A_f}{20}}$$

(11)

where:

erfc()   complementary error function

T_d average fade duration

k 0.5 for space diversity

                0.5 for 1: 1 frequency diversity

                0.75 for 1: N frequency diversity (N > 1)

                1.0 for non diversity

d path length in kilometers

f frequency in GHz

The probability of a selective (dispersive) fade lasting longer than t consecutive seconds is given by:

$$\rho_d(t) = \left(1 + 0.85 \cdot \sqrt{t} + 0.36 \cdot t\right) \cdot e^{-0.85\sqrt{t}}$$

(12)

The ITU definition of multipath unavailability is the probability of fades below threshold lasting 10 consecutive seconds or longer. Severely errored seconds represents the probability of all other fades below threshold. i.e fades which last less than 10 consecutive seconds. The unavailability and severely errored seconds probability are given by:

$$U_{ITU} = \rho_f \cdot P_f + \rho_d \cdot P_d$$
$$SES_{ITU} = (1 - \rho_f) \cdot P_f + (1 - \rho_d) \cdot P_d$$

(13)

VIGANTS - BARNETT

The Vigants - Barnett fade probability (Reference (4) and Reference (5)) is given by:

$$P = 2.5 \cdot 10^{-6} \cdot C \cdot f \cdot d^3 \cdot 10^{-\frac{A}{10}}$$
$$d \quad \text{in} \quad \text{miles}$$

(14)

$$P = 6.0 \cdot 10^{-7} \cdot C \cdot f \cdot d^3 \cdot 10^{-\frac{A}{10}}$$
$$d \quad \text{in} \quad \text{kilometers}$$

(15)

where

d	path length
f	frequency in GHz
C	C Factor
A	effective fade margin in dB

The following guidelines are given for values of the C factor.

$C = 0.25$ good propagation conditions - mountainous and dry climates
$C = 1$ average propagation conditions - average terrain and climatic conditions
$C = 4$ difficult propagation conditions - over water paths and gulf coastal areas

In areas with very difficult propagation, a value of C as high as 6 may be applicable. Figure (10), Figure (11) and Figure (12) provide geographic maps showing typical ranges of the C Factor for the United States, Canada and the world respectively. Alternately, the C Factor can be calculated from the terrain roughness and a climatic factor, c_f, in accordance with the following formula:

$$C = c_f \cdot \left(\frac{S}{50}\right)^{-1.3}$$
$$S \quad \text{in} \quad \text{feet} \quad (20 \leq S \leq 140)$$

(16)

$$C = c_f \cdot \left(\frac{S}{15.2}\right)^{-1.3}$$
$$S \quad \text{in} \quad \text{meters} \quad (6 \leq S \leq 42)$$

Typical values for the climatic factor are:

$c_f = 0.5$ good propagation conditions - mountainous and dry climates

$c_f = 1$ average propagation conditions - average terrain and climatic conditions

$c_f = 2$ difficult propagation conditions - over water paths and gulf coastal areas

Terrain Roughness

Terrain roughness is defined as the standard deviation of the terrain profile (square root of the average square of the deviation from the mean). In Reference (4), terrain elevations are referenced to sea level and are taken at one mile increments excluding the end points of the profile. Other references use a one kilometer increment. In the Pathloss program, terrain roughness is calculated using 50 uniformly spaced points over a user defined range on the profile. The value of terrain roughness is limited to a range between 20 to 140 feet (6 to 42 meters).
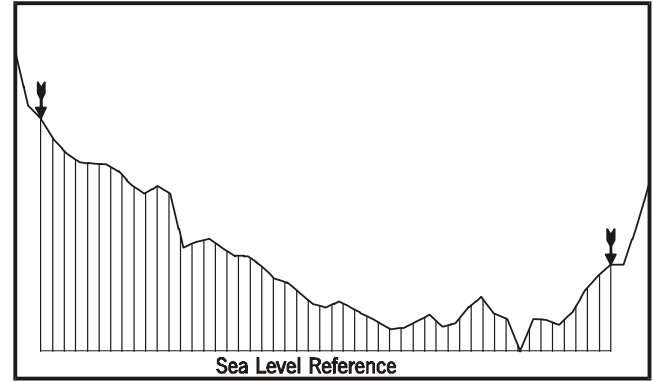
Figure 5: Terrain roughness - sea level reference

Terrain roughness can be calculated with respect to sea level as shown in Figure (5) or with respect to a least squares fit as shown in Figure (6). In both cases, the user must define the end points of the range over which terrain roughness will be calculated. This is similar to the definition of a reflective plane described in the Reflections section of this manual.

Significant differences will occur on paths with a uniform slope and an elevation difference between the end points greater than 140 feet. If the least squares method is used, the terrain roughness will be the minimum value. If the sea level reference is used, the terrain roughness will be the maximum value. In strict accordance with Reference (4), the elevations should be relative to sea level. This will provide some correlation between the terrain roughness and path inclination. The propagation reliability on a high - low path is better than a flat path. If the elevation difference is in the order of one hundred feet, the least squares reference should be used. The equations used to calculate terrain roughness are given below:
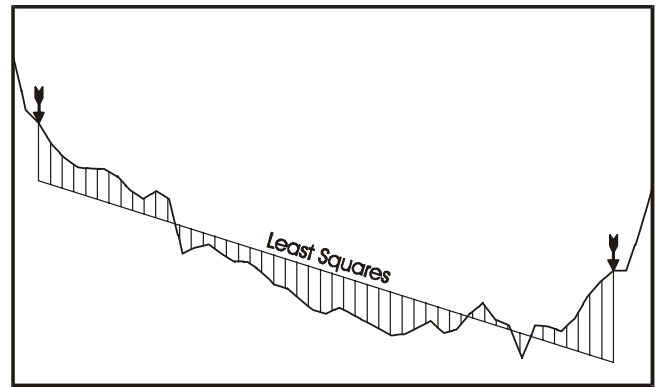

Figure 6: Terrain roughness - least squares refer-

$$S \quad = \quad \sqrt{\frac{1}{50}\sum_{i=1}^{50}(x_i - M)^2}$$

(17)

$$M \quad = \quad \frac{1}{50}\sum_{i=1}^{50}X_i$$

RECOMMENDATION ITU-R P.530-6

The following description is essentially taken from paragraph 2.3.2 "Method for detailed link design at small percentages of time (Method 2)" of this report. The fade probability P that fade depth A (dB) is exceeded in the worst month from is given by:

$$P \ = \ K \cdot d^{3.3} \cdot f^{0.93} \cdot \left(1 + \varepsilon_p\right)^{-1.1} \cdot \theta^{-1.2} \cdot 10^{-\frac{A}{10}} \tag{18}$$

K	geoclimatic factor for the worst fading month
d	path length in kilometers
f	frequency in GHz
ε_p	path inclination in milliradians
θ	average grazing angle in milliradians corresponding to a 4/3 earth radius factor.
A	effective fade margin in dB

Geoclimatic Factor

For the path location in question, estimate the geoclimatic factor K for the average worst month from fading data for the area. If such data are not available, K can be estimated from the percentage of time P_L that the average refractivity gradient in the lowest 100 m of the atmosphere is less than –100 N units/km. Refer to the contour maps shown in Figure (13), Figure (14), Figure (15) and Figure (16) in this section for values of P_L. The value for the worst month should be used, The geoclimatic factor is then given by:

- overland links for which the lower of the transmitting and receiving antennas is less than 700 m above mean sea level (see Note 2)

$$K \ = \ 10^{-(5.4 - C_{lat} - C_{lon})} P_L^{1.5} \tag{19}$$

- overland links for which the lower of the transmitting and receiving antennas is higher than 700 m above mean sea level (see Notes 1 and 2 for links crossing small lakes and rivers)

$$K \ = \ 10^{-(6.0 - C_{lat} - C_{lon})} P_L^{1.5} \tag{20}$$

- links over medium-sized bodies of water (see Note 3), coastal areas beside such bodies of water (see Note 4), or regions of many lakes (see Note 5)

$$K \ = \ 10^{-(4.8 - C_{lat} - C_{lon})} P_L^{1.5} \tag{21}$$

- links over large bodies of water (see Note 3), or coastal areas beside such bodies of water (see Note 4)

$$K \ = \ 10^{-(4.4 - C_{lat} - C_{lon})} P_L^{1.5} \tag{22}$$

where the coefficient C_{Lat} of latitude ξ is given by:

$C_{Lat} = 0$ for 53° S $\geq \xi \leq 53^{\circ}$ N

$C_{Lat} = -5.3 + \xi/10$ for 53° N or S $< \xi < 60^o$ N or S
$C_{Lat} = 0.7$ for $\xi \geq 60^o$ N or S

and the longitude coefficient C_{Lon}, by:

$C_{Lon} = 0.3$ for longitudes of Europe and Africa
$C_{Lon} = -0.3$ for longitudes of North and South America
$C_{Lon} = 0$ for all other longitudes

The month that has the highest value of P_L should be chosen for the months of February, May, August and November. An exception to this is that only the maps for May and August should be used for latitudes greater than 60° N or 60° S.

NOTE 1 – In mountainous areas for which the data used to prepare the maps in Figure (13), Figure (14), Figure (15) and Figure (16) (Recommendation ITU-R P.453) were non-existent or very sparse, these maps have insufficient detail and the value of K estimated from Equation (19) tends to be an upper bound. Such areas include the mountainous regions of Western Canada, the European Alps and Japan. The adjustment contained in Equation (20) can be used until a more detailed correction is available.

NOTE 2 – Links passing over a small lake or river should normally be classed as overland links. In cases of uncertainty, replace exponent coefficient 5.4 by 5.1 in Equation (19). (see also Note 4)

NOTE 3 – Medium-sized bodies of water include the Bay of Fundy (east coast of Canada) and the Strait of Georgia (west coast of Canada), the Gulf of Finland, and other bodies of water of similar size. Large bodies of water include the English Channel, the North Sea, the larger reaches of the Baltic and Mediterranean Seas, Hudson Strait, and other bodies of water of similar size or larger. In cases of uncertainty as to whether the size of the body of water in question should be classed as medium or large, the first coefficient in the exponent of Equation (21) or Equation (22) should be replaced by 4.6.

NOTE 4 – The link may be considered to be crossing a coastal area if a section of the path profile is less than 100 m above mean sea level and within 50 km of the coastline of a medium or large body of water, and if there is no height of land above 100 m altitude between the link and the coast. If the entire path profile is less than 100 m above mean sea level, then K should be obtained from Equation (21) or Equation (22) as appropriate. If only a fraction, r_c, of the path profile is below 100 m altitude and within 50 km of the coastline, then the coefficient 4.8 in the exponent of Equation (21) can be replaced by $4.8 - 0.6\,r_c$ and the exponent 4.4 in Equation (22) by $5.4 - r_c$

NOTE 5 – Regions (not otherwise in coastal areas) in which there are many lakes over a fairly large area are known to behave like coastal areas. The region of lakes in southern Finland provides the best known example. Until such regions can be better defined, K can be obtained from Equation (21). In cases of uncertainty, the coefficient 4.8 in the exponent of Equation (21) can be replaced by 5.1.

Geoclimatic Factor - Canada
A logarithmic geoclimatic factor, G, is used in Canada and is defined by:

$$G = 10 \cdot \log(K) + 46$$
$$K = 10^{\frac{G}{10} - 4.6} \tag{23}$$

Figure (17) provides a map of G for Canada. The following refinements are recommended:

- At latitudes above 60 degrees, add 5 dB to the value in Figure (17).

- For paths over medium sized bodies of water (Bay of Fundy, Strait of Georgia, Frobisher Bay, Lake Ontario, Lake Erie), add 6 dB to the values in Figure (17). Add 11 dB if the path is above 60 degrees latitude.

- For paths over large bodies of water (Hudson Strait, Viscount Melville Sound, Hecate Strait, Cabot Strait, Lake Superior, Lake Huron, Lake Michigan), add 14 dB to the value in Figure (17). Add 19 dB if the path is above 60 degrees latitude.

Path Inclination

The path inclination, ϵ_p, is given by:

$$1000 \cdot \text{atan}\left(\frac{|h_t - h_r|}{1000 \cdot d}\right) \text{milliradians} \tag{24}$$

h_t transmitter antenna height in meters above sea level
h_r receiver antenna height in meters above sea level
d path length in kilometers

The valid range of the path inclinations is from 0 to 24 milliradians. The program does not impose any restrictions on this value.

Grazing Angle

The grazing angle is the angle of incidence or reflection at the reflection point of a reflective plane using an earth radius factor of 4/3. The average grazing angle θ, is determined by first defining the dominant reflective plane for the terrain profile. This plane is represented by a least squares fit, $(y = a \cdot x + b)$ over a user defined range of the terrain profile. Effective antenna heights h_1 and h_2, are then calculated from this plane by the equations:

$$h_1 = h_t - b$$
$$h_2 = h_r - a \cdot d - b \tag{25}$$

where h_t and h_r are the transmit and receive antenna heights above ground level and d is the path length.

The average grazing angle θ, is given by:

$$\theta = \frac{h_1 + h_2}{d} \cdot \left(1 - m \cdot \left(1 + b^2\right)\right) \text{milliradians}$$

$$m = \frac{d^2}{4 \cdot a_e \cdot \left(h_1 + h_2\right)}$$

(26)

$$c = \frac{\left|h_1 - h_2\right|}{h_1 + h_2}$$

$$b = 2\sqrt{\frac{m+1}{3 \cdot m}} \cdot \cos\left[\frac{\pi}{3} + \frac{1}{3} \cdot \arccos\left(\frac{3 \cdot c}{2} \sqrt{\frac{3 \cdot m}{\left(m+1\right)^3}}\right)\right]$$

where

h_1 effective transmitter antenna height
h_2 effective receiver antenna height
a_e effective earth radius (8500 km for K = 4/3)

The coefficients m and c must be calculated with a_e, d, h_1 and h_2 expressed in the same units.

In the calculation of θ, h_1 and h_2 are expressed in meters and d in kilometers to obtain the required value in milliradians. The valid range of average grazing angles is from 1 to 12 milliradians. The program does not impose any limits on this value.

Equation (18) applies only to narrow-band systems. It is considered valid for fade depths greater than about 15 dB or the value exceeded for 0.1% of the worst month, whichever is greater. Equation (18) was derived from fading data paths with lengths in the range 7-95 km, frequencies in the range 2-37 GHz, path inclinations for the range 0-24 mrad, and grazing angles in the range 1-12 mrad. Checks using several other sets of data for paths up to 189 km in length and frequencies as low as 500 MHz suggest, however, that they are valid for larger ranges of path length and frequency. The results of a semi-empirical analysis indicate that the lower frequency limit of validity is inversely proportional to path length. A rough estimate of this lower frequency limit f_{min} can be obtained from:

$$f_{\text{min}} = \frac{15}{d} \text{ GHz}$$

(27)

RECOMMENDATION ITU-R P.530-7/8

The following description is essentially taken from paragraph 2.3.1 "Method for small percentages of time" of the subject report. The fade probability P that fade depth A (dB) is exceeded in the average worst month from is given by:

$$P = K \cdot d^{3.6} \cdot f^{0.89} \cdot \left(1 + \varepsilon_p\right)^{-1.4} \cdot 10^{-\frac{A}{10}}$$

(28)

K	geoclimatic factor for the worst fading month
d	path length in kilometers
f	frequency in GHz
ε_p	path inclination in milliradians
A	effective fade margin in dB

Geoclimatic Factor

For the path location in question, estimate the geoclimatic factor K for the average worst month from fading data for the geographic area of interest if these are available.

Inland Links

If measured data for K are not available, K can be estimated for links in inland areas (see Note 1 for definition of inland links) from the following empirical relation in the climatic variable P_L (i.e., the percentage of time that the refractivity gradient in the lowest 100 m of the atmosphere is more negative than –100 N units/km in the estimated average worst month; see below):

$$K = 5.0 \cdot 10^{-7} \cdot 10^{-0.1(C_0 - C_{lat} - C_{lon})} P_L^{1.5} \tag{29}$$

Table 1: Values of C_o for Antenna Altitudes and Terrain Types

Terrain Characteristics	C_0(dB)
Low altitude antenna (0 - 400 m) - Plains Overland or partially overland links, with lower antenna altitude less than 400 m above mean sea level, located in largely plains areas	0.0
Low altitude antenna (0 - 400 m) - Hills Overland or partially overland links, with lower antenna altitude less than 400 m above mean sea level, located in largely hilly areas	3.5
Medium altitude antenna (400 - 700 m) - Plains Overland or partially overland links, with lower antenna altitude in the range 400 - 700 m above mean sea level, located in largely plains areas	2.5
Medium altitude antenna (400 - 700 m) - Hills Overland or partially overland links, with lower antenna altitude in the range 400 - 700 m above mean sea level, located in largely hilly areas	6.0
High altitude antenna (> 700 m) - Plains Overland or partially overland links, with lower antenna altitude more than 700 m above mean sea level, located in largely plains areas	5.5
High altitude antenna (> 700 m) - Hills Overland or partially overland links, with lower antenna altitude more than 700 m above mean sea level, located in largely hilly areas	8.0

Table 1: Values of C_o for Antenna Altitudes and Terrain Types

Terrain Characteristics	C_0(dB)
High altitude antenna (> 700 m) - Mountains Overland or partially overland links, with lower antenna altitude more than 700 m above mean sea level, located in largely mountainous areas	10.5

The value of the coefficient C_0 in Equation (29) is given in Table (1) for three ranges of altitude of the lower of the transmitting and receiving antennas and three types of terrain (plains, hills, or mountains). In cases of uncertainty as to whether a link should be classified as being in a plains or hilly area, the mean value of the coefficients C_0 for these two types of area should be employed. Similarly, in cases of uncertainty as to whether a link should be classified as being in a hilly or mountainous area, the mean value of the coefficients C_0 for these two types of area should be employed. Links traversing plains at one end and mountains at the other should be classified as being in hilly areas. For the purposes of deciding whether a partially over water path is in a largely plains, hilly, or mountainous area, the water surface should be considered as a plain.

For planning purposes where the type of terrain is not known, the following values of the coefficient C_0 in Equation (29) should be employed:

C_0 = 1.7   for lower-altitude antenna in the range 0-400 m above mean sea level
C_0 = 4.2   for lower-altitude antenna in the range 400-700 m above mean sea level
C_0 = 8   for lower-altitude antenna more than 700 m above mean sea level

The coefficient C_{Lat} in Equation (29) of latitude ξ is given by:

C_{Lat} = 0   for 53° S $\geq \xi \leq$ 53° N
C_{Lat} = $-53 + \xi$ for 53° N or S $< \xi <$ 60° N or S
C_{Lat} = 7   for $\xi \geq$ 60° N or S

and the longitude coefficient C_{Lon}, by:

C_{Lon} = 3   for longitudes of Europe and Africa
C_{Lon} = -3 for longitudes of North and South America
C_{Lon} = 0   for all other longitudes

The value of the climatic variable P_L in Equation (29) is estimated by taking the highest value of the –100 N units/km gradient exceedance from the maps for the four seasonally representative months of February, May, August and November shown in Figure (13), Figure (14), Figure (15) and Figure (16). These correspond to Figures 7-10 of Recommendation ITU-R P.453. An exception to this is that only the maps for May and August should be used for latitudes greater than 60° N or 60° S.

Coastal Links Over /Near Large Bodies of Water
If measured data for *K* are not available for coastal links (see Note 2 for definition) over/near large bodies of water (see Note 3 for definition of large bodies of water), *K* can be estimated from:

$$K_{cl} = 2.3 \cdot 10^{-4} \cdot 10^{-0.1 \cdot C_0 - 0.011 \|\varepsilon\|}$$

$$if \quad K_{cl} \geq K_i$$

$$K = 10^{(l - r_c) \cdot \log_{10}(K_i) + r_c \cdot \log_{10}(K_{cl})} \tag{30}$$

$$if \quad K_{cl} < K_i$$

$$K = K_i$$

where r_c is the fraction of the path profile below 100 m altitude above the mean level of the body of water in question and within 50 km of the coastline, but without an intervening height of land above 100 m altitude, K_i is given by the expression for *K* in Equation (29) with C_0 given in Table (1). Note that the condition $K_{cl} < K_i$ in Equation (30) occurs in a few regions at low and mid latitudes.

Coastal Links Over /Near Medium Sized Bodies of Water
If measured data for *K* are not available for coastal links (see Note 2 for definition) over/near medium-sized bodies of water (see Note 3 for definition of medium-sized bodies of water), *K* can be estimated from:

$$K_{cm} = 10^{0.5 \cdot (\log_{10}(K_i) + \log_{10}(K_{cl}))}$$

$$if \quad K_{cm} \geq K_i$$

$$K = 10^{(l - r_c) \cdot \log_{10}(K_i) + r_c \cdot \log_{10}(K_{cm})} \tag{31}$$

$$if \quad K_{cl} < K_i$$

$$K = K_i$$

with K_{cl} given by Equation (30). Note that the condition $K_{cm} < K_i$ in Equation (31) occurs in a few regions at low and mid latitudes.

NOTE 1 – Inland links are those in which either the entire path profile is above 100 m altitude (with respect to mean sea level) or beyond 50 km from the nearest coastline, or in which part or all of the path profile is below 100 m altitude for a link entirely within 50 km of the coastline, but there is an intervening height of land higher than 100 m between this part of the link and the coastline. Links passing over a river or a small lake should normally be classed as passing over land. For links in a region of many lakes, see Note 4.

NOTE 2 – The link may be considered to be crossing a coastal area if a fraction rc of the path profile is less than 100 m above the mean level of a medium-sized or large body of water and within 50 km of its coastline, and if there is no height of land above the 100 m altitude (relative to the mean altitude of the body of water in question) between this fraction of the path profile and the coastline.

NOTE 3 – The size of a body of water can be chosen on the basis of several known examples: Medium-sized bodies of water include the Bay of Fundy (east coast of Canada) and the Strait of Georgia (west coast of Canada), the Gulf of Finland, and other bodies of water of similar size. Large bodies of water include the English Channel, the North Sea, the larger reaches of the Baltic and Mediterranean Seas, Hudson Strait, and other bodies of water of similar size or larger. In cases of uncertainty as to whether the size of body of water in question should be classed as medium or large, K should be calculated from:

$$K = 10^{(l-r_c)\cdot\log_{10}(K_i)+0.5\cdot r_c\cdot(\log_{10}(K_{cm})+\log_{10}(K_{cl}))} \tag{32}$$

Note 4 – Regions (not otherwise in coastal areas) in which there are many lakes over a fairly large area are believed to behave somewhat like coastal areas. The region of lakes in southern Finland provides the best known example. Until such regions can be better defined, K should be calculated from:

$$K = 10^{0.5\left[(2-r_c)\log K_i+r_c\log K_{cm}\right]} \tag{33}$$

Path Inclination

From the antenna heights h_t and h_r (m above sea level or some other reference height), calculate the magnitude of the path inclination $|\epsilon_p|$ (mrad) from:

$$\varepsilon = 1000\cdot\mathrm{atan}\left(\frac{|h_t - h_r|}{1000\cdot d}\right)\mathrm{milliradians} \tag{34}$$

where d, is the path length (km).

Equation (28) was derived from fading data on paths with lengths in the range 7-95 km, frequencies in the range 2-37 GHz, path inclinations for the range 0-24 mrad, and grazing angles in the range 1-12 mrad. Checks using several other sets of data for paths up to 237 km in length and frequencies as low as 500 MHz suggest, however, that it is valid for larger ranges of path length and frequency. The results of a semi-empirical analysis indicate that the lower frequency limit of validity is inversely proportional to path length. A rough estimate of this lower frequency limit, f_{min}, can be obtained from:

$$f_{min} = \frac{15}{d} \ \mathrm{GHz} \tag{35}$$

KQ FACTOR

The fade probability (Reference (2)) is given by:

$$P = K\cdot Q\cdot f^b\cdot d^c\cdot 10^{-\frac{A}{10}} \tag{36}$$

d path length in kilometers
f frequency in GHz

| *b, c* | factors to account for regional effects |
| *A* | effective fade margin in dB |

Typical values of $K \cdot Q$ and the frequency - distance exponents b and c are given in Table (2).

Table 2: KQ Factors

		Japan	N.W. Europe	USSR
$b(f^b)$		1.2	1.0	1.5
$c(d^c)$		3.5	3.5	2.0
K-Q	maritime temperature, Mediterranean, coastal or high humidity and temperature climatic regions			$2 \cdot 10^{-5}$
	continental temperature climates or mid latitude inland climatic regions with average rolling terrain	10^{-9}	$1.4 \cdot 10^{-8}$	$4.1 \cdot 10^{-6}$
	temperature climates, coastal regions with fairly flat terrain	$9.9 \; 10^{-8} / H$		$2.3 \cdot 10^{-5}$ to $4.9 \cdot 10^{-5}$

$$H \quad = \quad \sqrt{h_1 + h_2} \tag{37}$$

h_1 and h_2 are the antenna heights in meters above ground level

K-Q FACTOR INCLUDING TERRAIN ROUGHNESS

The fade probability (Reference (2)) is given by:

$$P \quad = \quad \frac{K \cdot Q}{S^{1.3}} \cdot f^b \cdot d^c \cdot 10^{-\frac{A}{10}} \tag{38}$$

d	path length in kilometers
f	frequency in GHz
S	terrain roughness in meters
A	effective fade margin in dB

Table (3) shows typical values of the K-Q factors using frequency and distance exponents of 1 and 3 respectively. This is equivalent to the Vigants Barnett method described above.

Table 3: K-Q Factors Including Terrain Roughness

$b(f^b)$		1.0
$c(d^c)$		3.0
K·Q	maritime temperate, Mediterranean, coastal or high humidity and temperature climatic regions	$4.1 \cdot 10^{-5} \cdot S^{-1.3}$
	maritime subtropical climate regions	$3.1 \cdot 10^{-5} \cdot S^{-1.3}$
	continental temperate climates or mid latitude inland climatic regions with average rolling terrain	$2.1 \cdot 10^{-5} \cdot S^{-1.3}$
	high dry mountainous climatic regions	$10^{-5} \cdot S^{-1.3}$

S is the terrain roughness in meters (6<S<42)

RECOMMENDATION ITU-R P.530-9

The ITU-R P.530-9 prediction for single frequency or narrow band fading distribution at large fade depths in the average worst month in any part of the world is defined in the following steps. Note that only the detailed link design method has been implemented in the Pathloss program

Step 1

Calculate the geoclimatic factor *K* for the average worst month from Equation (39) below

$$K \quad = \quad 10^{-3.9-0.003dN_1} \cdot s_a^{-0.42} \tag{39}$$

where

dN_1 is the point refractivity gradient in the lowest 65 m of the atmosphere not exceeded for 1% of an average year. Data for dN_1 is provided on a 1.5 grid in latitude and longitude in Recommendation ITU-R P.453. This data has been incorporated into the Pathloss program. The value at the latitude and longitude of the centre of the path is determined by bilinear interpolation of the four closest grid points.

s_a is the area terrain roughness. This is defined as the standard deviation of terrain heights (m) within a 110 km by 110 km area with a 1 kilometer resolution. The area is aligned about the center of the path.

Step 2

Calculate the path inclination ε_p using equation Equation (40) below

$$\varepsilon_p \quad = \quad \left|\text{atan}\frac{h_r - h_e}{d \cdot 1000}\right| \tag{40}$$

where

h_r and h_e are the antenna heights in meters above sea level
d is the path length in kilometers

Step 3

For detailed link design applications, calculate the percentage of time p_w that fade depth A (dB) is exceeded in the average worst month from Equation (41)

$$p_w \quad = \quad K \cdot d^{3.2} \cdot \left(1 + |\varepsilon_p|\right)^{-0.97} \cdot 10^{0.032 f - 0.00085 h_L - \frac{A}{10}} \tag{41}$$

where

f frequency in GHz
h_L altitude of the lower antenna (i.e. the smaller of h_r and h_e)
K geoclimatic factor from Equation (39)

FREQUENCY DIVERSITY SYSTEMS

North American Standards
The frequency diversity improvement factor, I_{fd}, is based on Reference (4) and given by:

$$
\begin{aligned}
I_{fd} \quad &= \quad 50 \cdot \frac{\Delta f}{f^2 \cdot d} \cdot 10^{\frac{A}{10}} \\
&\quad\quad\quad d \quad \text{in} \quad \text{miles} \\
I_{fd} \quad &= \quad 80.5 \cdot \frac{\Delta f}{f^2 \cdot d} \cdot 10^{\frac{A}{10}} \\
&\quad\quad\quad d \quad \text{in} \quad \text{kilometers}
\end{aligned}
\tag{42}
$$

Δf effective frequency spacing in GHz
f frequency in GHz
d path length
A effective fade margin in dB

Equation (42) is applicable to analogue, narrow band digital and wideband digital radio systems. The fade probability for a frequency diversity system, P_{fd}, is given by:

$$P_{fd} = \frac{P}{I_{fd}} \tag{43}$$

The above applies to a one for one frequency diversity system. In the case of a one for N switching system, the equivalent channel spacing as defined in Reference (6) must be used as follows:

$$\Delta f = \frac{N}{\sum_k \left(\frac{1}{\Delta f_k}\right)} \tag{44}$$

Note that the above factors are the same for selective and non selective fades.

ITU 530 Frequency Diversity

The non selective frequency diversity improvement is essentially the same as the North American formula:

$$I_{fdns} = \frac{80}{f \cdot d} \cdot \frac{df}{f} \cdot 10^{\frac{A}{10}} \tag{45}$$

The ITU method calculates the selective outage exactly as in the case of space diversity described in the following paragraphs using $I_{comb} = 0$ and $L_{comb} = 1$.

SPACE DIVERSITY BASEBAND SWITCHING SYSTEMS

The space diversity improvement factor, I_{sd}, is based on Reference (4) and given by:

$$I_{sd} = 7 \cdot 10^{-5} \cdot \frac{f}{d} \cdot s^2 \cdot v^2 \cdot 10^{\frac{A}{10}}$$

$$\begin{array}{lll} s & \text{in} & \text{feet} \\ d & \text{in} & \text{miles} \end{array}$$

$$I_{sd} = 1.2 \cdot 10^{-3} \cdot \frac{f}{d} \cdot s^2 \cdot v^2 \cdot 10^{\frac{A}{10}}$$

$$\begin{array}{lll} s & \text{in} & \text{meters} \\ d & \text{in} & \text{kilometers} \end{array}$$

(46)

$$v_{dB} = 20 \cdot \log(v)$$

s	vertical spacing of the receiving antennas
f	frequency in GHz
d	path length
v_{dB}	difference between the main and diversity received signals in dB

The fade probability P_{sd}, for space diversity systems is given by: $P_{sd} = \dfrac{P}{I_{sd}}$

Experience with space diversity on wide band digital radio systems has led to the following observations:

- The space diversity improvement factor, for the dispersive component of the fade margin, is independent of the vertical antenna separation for spacings greater than 10 feet. As the antenna separation is reduced below 10 feet, the improvement factor increases rapidly.

- The space diversity improvement factor for the dispersive component of the fade margin can be equated to a fixed value of vertical antenna spacing.

- The space diversity improvement factor for the flat component of the fade margin is proportional to the square of the antenna separation.

To account for these observations, two methods are used to calculate the space diversity improvement factor as currently used by two major microwave radio manufacturers.

Method 1 (Nortel)

The fade probability is expressed in general terms as follows:

$$P \quad \propto \quad 10^{-\frac{A}{10}}$$

$$I_{sd} \quad \propto \quad s^2 \cdot 10^{\frac{A}{10}}$$

$$P_{sd} \quad \propto \quad \left(\frac{10^{-\frac{A}{10}}}{s} \right)^2 \tag{47}$$

$$_{sd} \quad \propto \quad \left(\frac{10^{-\frac{A_f}{10}}}{s} + \frac{R_d \cdot 10^{-\frac{A_d}{10}}}{s} \right)^2$$

The vertical antenna spacing, *s*, is replaced with a fixed value s_d for the dispersive component. The default value of s_d is 8.5 meters based on Reference (7). The result is given below:

$$P_{sd} \quad \propto \quad \left(\frac{10^{-\frac{A_f}{10}}}{s} + \frac{R_d \cdot 10^{-\frac{A_d}{10}}}{s_d} \right)^2 \tag{48}$$

Method 2 Alcatel (Richardson)

This method treats the flat and dispersive components separately as shown below:

$$P_{sd} \quad = \quad \frac{P_f}{I_{sd\_flat}} + \frac{P_d}{I_{sd\_disp}} \tag{49}$$

$$I_{sd\_disp} \quad = \quad 0.09 \cdot \frac{f}{d} \cdot 10^{\frac{A_d}{10}}$$

where:

I_{sd_flat}	is given by Equation (46)
f	frequency in GHZ
d	path length in miles

SPACE DIVERSITY - IF COMBINING

In an IF combining system, the main and diversity received signals are combined in an intermediate frequency combiner. In this configuration, the combined thermal fade margin, A_c, is given by:

$$A_c \quad = \quad A_t + 2.6 + 20 \cdot \log\left(\frac{l+v}{2} \right)$$

$$v_{dB} \quad = \quad 20 \cdot \log(v) \tag{50}$$

where:

A_t greater of the main and diversity thermal fade margins

v_{dB} difference between the main and diversity received signals in dB

In this case, the flat fade margin, A, becomes:

$$A = -10 \cdot \log \left(10^{-\frac{A_c}{10}} + 10^{-\frac{A_{ac}}{10}} + 10^{-\frac{A_{ex}}{10}} \right) \tag{51}$$

To account for the effects of IF combining, the space diversity improvement factor given in Equation (46) is modified as follows:

$$I_{sd} = 7 \cdot 10^{-5} \cdot \frac{f}{d} \cdot s^2 \cdot \frac{16 \cdot v^2}{(1+v)^4} \cdot 10^{\frac{A}{10}}$$

s   in   feet
d   in   miles

$$\tag{52}$$

$$I_{sd} = 1.2 \cdot 10^{-3} \cdot \frac{f}{d} \cdot s^2 \cdot \frac{16 \cdot v^2}{(1+v)^4} \cdot 10^{\frac{A}{10}}$$

s   in   meters
d   in   kilometers

$$v_{dB} = 20 \cdot \log(v)$$

s vertical antenna spacing
f frequency in GHz
d path length
v_{db} difference between the main and diversity received signals in dB

As in the case of space diversity on baseband switching systems, the independence of the dispersive component of the fade margin to the vertical antenna spacing is accounted for by the methods given above.

ITU SPACE DIVERSITY SYSTEMS

The non selective space diversity improvement factor is given by:

$$I_{sdns} = \left[1 - \exp\left(-3.34 \cdot 10^{-4} \cdot S^{0.87} \cdot f^{-0.12} \cdot d^{0.48} \cdot P_o^{-1.04} \right) \right] \cdot 10^{\frac{A - dG + I_{comb}}{10}} \tag{53}$$

where

P_0 fade occurrence factor
dG absolute value of the difference of the main and diversity antenna gains
A flat fade margin
S vertical separation between main and diversity antennas (m center to center)
d path length (km)
I_{comb} IF combiner gain dB (0 for baseband switching applications)

The selective outage probability is calculated as follows:

Calculate the square of the non selective correlation coefficient, k_{ns}

$$K_{ns}^2 \ = \ 1 - \frac{I_{ns} \cdot P_{ns}}{n} \tag{54}$$

where

I_{ns} non selective space diversity improvement factor
P_{ns} probability of a non selective outage
n multipath activity factor

Calculate the square of the selective correlation coefficient, k_s

$$k_s^2 \ = \ 0.8238 \quad \text{for} \quad r_w \le 0.5$$

$$k_s^2 \ = \ 1 - 0.195 \cdot (1 - r_w)^{0.109 - 0.13 \cdot \log_{10}(1 - r_w)} \text{for} \quad 0.5 < r_w \le 0.9628$$

$$k_s^2 \ = \ 1 - 0.3957 \cdot (1 - r_w)^{0.5136} \text{for} \quad r_w > 0.9628 \tag{55}$$

$$r_w \ = \ 1 - 0.9746 \cdot (1 - k_{ns}^2)^{2.170} \text{for} \quad k_{ns}^2 \le 0.26$$

$$r_w \ = \ 1 - 0.6921 \cdot (1 - k_{ns}^2)^{1.034} \text{for} \quad k_{ns}^2 \le 0.26$$

The non selective outage probability is given by:

$$p_{sdns} \ = \ \frac{P_{ns}}{I_{sdns}} \tag{56}$$

The selective outage probability is given by:

$$P_{sds} \;\; = \;\; \left(\frac{\dfrac{P_s}{L_{comb}}}{n \cdot \left(1 - k_s^2\right)} \right)^2 \tag{57}$$

where L_{comb} is the selective improvement factor due to the combiner.

The total outage probability is then given by:

$$P_{sd} \;\; = \;\; \left(P_{sdns}^{0.75} + P_{sds}^{0.75} \right)^{1.33} \tag{58}$$

ITU QUAD DIVERSITY IMPROVEMENT

The non selective quad diversity improvement factor is the sum of the space and frequency diversity factors:

$$I_{qdns} \;\; = \;\; I_{sdns} + I_{fdns} \tag{59}$$

The square of the non selective correlation coefficient is given by:

$$K_{ns} \;\; = \;\; K_{nssd} \cdot k_{nsfd} \tag{60}$$

The selective outage is calculated exactly as in the case of space diversity using

$$I_{comb} \;\; = \;\; 0 \; and \; L_{comb} = 1 \tag{61}$$

for baseband switching applications.

ANGLE DIVERSITY

Angle diversity can be specified at either or both sites using a space diversity antenna configuration. Angle diversity cannot be combined with hybrid diversity. The implementation of angle diversity is based on the following observations:

- For antenna separations greater than 10 feet, the dispersive fading improvement factor is independent of the spacing. As the spacing is reduced below 10 feet, the improvement factor increases rapidly.

- Large improvement factors to dispersive fading occur when the main and diversity antennas are mounted next to each other, with the antennas slightly offset from each other horizontally.

- Angle diversity antennas approximate the above arrangement and achieve large dispersive improvement factors.

- The improvement to the flat component of the fade margin with angle diversity is not clear at present.

Angle diversity improvement is calculated by assigning a fixed vertical antenna spacing of 9.1 meters (30 feet). The angle diversity improvement for the flat fade margin is ten percent of the value calculated for

conventional space diversity up to a maximum of 20. The angle diversity improvement for the dispersive fade margin is the same as that for conventional space diversity.

FREE SPACE PATH LOSS

The free space path loss between two isotropic radiators is given by the equation:

$$A \; = \; 92.4 + 20 \cdot \log(f) + 20 \cdot \log(d) \; dB \qquad \text{(62)}$$

f frequency in GHz
d path length in kilometers

$$A \; = \; 96.6 + 20 \cdot \log(f) + 20 \cdot \log(d) \; dB \qquad \text{(63)}$$

f frequency in GHz
d path length in miles

ATMOSPHERIC ABSORPTION

Atmospheric Absorption is the sum of the specific absorption of oxygen and water vapour and is based on Reference (9).

Oxygen Absorption

The specific attenuation of oxygen, γ_o, is given by the equation:

$$\gamma_0 \; = \; \left[7.19 \cdot 10^{-3} + \frac{6.09}{f^2 + 0.227} + \frac{4.81}{(f-57)^2 + 1.50} \right] \cdot f^2 \cdot 10^{-3} \; dB/km$$

for $f < 57 GHz$

(64)

$$\gamma_0 \; = \; \left[3.79 \cdot 10^{-7} + \frac{0.265}{(f-63)^2 + 1.59} + \frac{0.028}{(f-118)^2 + 1.47} \right] \cdot (f+198)^2 \cdot 10^{-3} \; dB/km$$

for $f > 63 GHz$

where:

f frequency in GHz

Note that in the frequency range 57 to 63 GHz, Equation (64) is not defined due to the complicated spectrum structure which is height dependant. The program coding provides a uniform transition in this range with an attenuation of 15 dB /km at 60 GHz.

Water Vapour

The specific attenuation of water vapour, γ_w, is given by the equation:

$$\gamma_w = \left[0.067 + \frac{3}{(f-22.3)^2 + 7.3} + \frac{9}{(f-183.3)^2 + 6} + \frac{4.3}{(f-323.8)^2 + 10}\right] \cdot f^2 \cdot \rho \cdot 10^{-4} \, dB/km$$

(65)

for $f < 350 GHz$ and $\rho < 12\frac{g}{m^3}$

f frequency in GHz

ρ water vapour density in gm / m^3 at ground level and at a temperature of 15°C.

COCHANNEL OPERATION

This paragraph describes the procedure to calculate the threshold degradation due to the cross polarized discrimination on radio links operating in a cochannel mode. The XPD will degrade under multipath fading and high intensity rain conditions.

XPD Degradation due to Multipath

1. Calculate

$$XPD_0 = XPD_g + 5 \; for \; XPD_g \le 35$$
$$XPD_0 = 40 \; for \; XPD_g > 35$$

(66)

where *XPDg* is the minimum value of the transmit and receive antenna *XPD* is measured on the boresight.

2. Calculate the multipath activity parameter

$$\eta = 1 - e^{-0.2 \cdot P_0^{0.75}}$$

(67)

where P_0 is the multipath occurrence factor corresponding to the percentage of time that a fade greater than *0 dB* occurs in the average worst month.

3. Calculate

$$Q = 10 \cdot \log_{10}\left(\frac{K_{XP} \cdot \eta}{P_0}\right)$$

(68)

where

$$K_{XP} = 0.7 \text{ for one transmit antenna}$$

(69)

$$K_{XP} = 1 - 0.3 \cdot \exp\left[-4 \cdot 10^{-6} \cdot \left(\frac{s_t}{\eta}\right)^2\right] \text{ for two transmit antennas}$$

(70)

4. Calculate

$$C = XPD_0 + Q \tag{71}$$

The carrier to cochannel interference ratio is then given by:

$$\frac{C_0}{I_{cock\ mpth}} = -10 \cdot \log_{10}\left(10^{-\frac{XPD_{GTS}}{10}} + 10^{-\frac{XPD_{GRX}}{10}} + 10^{-\frac{(C-A)}{10}} \right) + 2 \tag{72}$$

for radios not equipped with an XPIC device and by the following equation for XPIC equipped radios.

$$\frac{C_0}{I_{cock\ mpth}} = -10 \cdot \log_{10}\left(10^{-\frac{XPD_{xpic}}{10}} + 10^{-\frac{XPD_{GTX}+XPIF}{10}} + 10^{-\frac{XPD_{GRX}+XPIF}{10}} + 10^{-\frac{(C+XPIF-A)}{10}} \right) \tag{73}$$

where

XPIF	is the improvement due to the XPIC device
XPD_G	is the cross polarized discrimination of the antennas
XPD_{xpic}	is the XPD of the XPIC device
A	is the fade margin including the effects of interference due to other transmitters

The 2 dB improvement in the non XPIC case is due to the Gaussian properties of the interfering crosspolar signal. This figure is included in the XPIF for XPIC equipped radios.

XPD Degradation due to Rain

The XPD reduction factor due to high intensity rain is given by the equation:

$$
\begin{aligned}
XPD_{RAIN} &= 15 + 30 \cdot \log_{10}(f_{GHz}) - 12.8 \cdot f_{GHz}^{0.19} \cdot \log_{10}(A) \text{ for } f_{GHz} \le 20GHz \\
XPD_{RAIN} &= 15 + 30 \cdot \log_{10}(f_{GHz}) - 22.6 \cdot \log_{10}(A) \text{ for } f_{GHz} \le 20GHz
\end{aligned}
\tag{74}
$$

The corresponding carrier to cochannel interference ratio is then given by:

$$\frac{C_0}{I_{coch\ rain}} = -10 \cdot \log_{10}\left(10^{-\frac{XPD_{GTX}}{10}} + 10^{-\frac{XPD_{GRX}}{10}} + 10^{-\frac{XPD_{RAIN}}{10}} \right) + 2$$

$$\tag{75)}$$

$$\frac{C_0}{I_{coch\ rain}} = -10 \cdot \log_{10}\left(10^{-\frac{XP_{xpic}}{10}} + 10^{-\frac{XP_{GTX}+XPIF}{10}} + 10^{-\frac{XPD_{GRX}+XPIF}{10}} + 10^{-\frac{XPD_{RAIN}+XPIF}{10}} \right) + 2$$

where the parameters are the same as defined above.

ITU-T G.826 ERROR PERFORMANCE OBJECTIVES

ITU-T G.826 defines performance of SDH radio systems in terms of the following parameters.

Severely Errored Seconds Radio (*SESR*)
Background Block Error Rate (*BBER*)
Errored Seconds Ratio (*ESR*)

This section describes the Pathloss implementation of this recommendation.

SESR Bit Error Rate

A modified bit error rate is first determined as follows:

$$BER_{SES} \quad = \quad \frac{0.458 \cdot a_1}{\text{bits per block}} \tag{76}$$

Table 4: BERses for various SDH paths and MS sections

Path type	Bit rate	BER_{ses} (Notes 1 and 2)	Block per second (Note 2)	Bits per Block (Note 2)
VC-11	1.5	$5.4 \times 10^{-4} \, \alpha$	2000	832
VC-12	2	$4.0 \times 10^{-4} \, \alpha$	2000	1120
VC-2	6	$1.3 \times 10^{-4} \, \alpha$	2000	3424
VC-3	34	$6.5 \times 10^{-5} \, \alpha$	8000	6120
VC-4	140	$2.1 \times 10^{-5} \, \alpha$	8000	18792
STM-1	155	$2.3 \times 10^{-5} \, \alpha$ $1.3 \times 10^{-5} \, \alpha + 2.2$	8000 192000	19940 801

NOTE 1 $\alpha = 1$ indicates a Poisson distribution of errors.

NOTE 2   The block/s are defined in ITU-T G.826 for SDH path, in ITU-T G.829 for SDH sections. Some STM-1 equipment might be designed with 8000 blocks/s (19940 bits/block), but ITU-T G.829 defines the block rate and size to be 192000 blocks/s and 801 bits/block, respectively.

The value of the BER_{SES} will lie between the 10^{-3} and 10^{-6} *BER*. Determine the RX threshold level at the BER_{SES} as follows:

$$m = \frac{RXthreshold_{BER10^{-3}} - RXthreshold_{BER10^{-6}}}{3}$$

$$RXthreshold_{BER_{SES}} = RXthreshold_{BER10^{-6}} + m \cdot \left(\log_{10}\left(BER_{SES}\right) + 6\right)$$

$$(77)$$

Multipath

The severely errored seconds ratio is the worst month multipath fade probability at the BER_{SES} receiver threshold.

$$SESR = P_{tSES} = P_t(BER_{SES})$$

Determine the fade probability in the worst month at the residual bit error rate receive threshold level. The residual BER (*RBER*) is in the range from 1×10^{-10} to 1×10^{-13}.

$$P_{tR} = P_t(RBER)$$

Calculate the slope of the BER distribution curve on a log - log scale for BER in the range BER_{SES} to *RBER*

$$m = \left| \frac{\log_{10}\left(RBER\right) - \log_{10}\left(BER_{SES}\right)}{\log_{10}\left(P_{tR}\right) - \log_{10}\left(P_{tSES}\right)} \right| \tag{78}$$

The background block error rate (*BBER*) is then given by:

$$BBER = SESR \cdot \frac{\alpha_1}{2.8 \cdot \alpha_2 \cdot (m-1)} + \frac{N_B \cdot RBER}{\alpha_3} \tag{79}$$

where

α_1 10 to 30, number of errors per burst for the BER in the range from 1_10^{-3} to BER_{SES}
α_2 1 to 10, number of errors per burst for the BER in the range from BER_{SES} to *RBER*
α_3 1, number of errors per burst for the BER lower than *RBER*
N_B number of bits per block from the above table

The errored second ratio (*ESR*) is given by:

$$ESR = SESR + \sqrt[m]{n} + \frac{n \cdot N_B \cdot RBER}{\alpha_3} \tag{80}$$

where

n number of blocks per second from the above table.

RAIN

Calculate the unavailability due to rain, P_{aR} in the worst month at the BER_{SES} receiver threshold level. The BBER and ESR values for rain are obtained by substituting P_{aR} for SESR in the multipath calculation.

WORKSHEET FORMATS

The following format conventions have been adopted:

- Rain calculations are carried carried out in both directions.

- An annual unavailability in minutes is shown in both directions. If the multipath is treated as SES and unavailability, then the conversion from worst month to annual is given in ITU-R P.530-9 paragraph 2.3.4 - "Conversion from average worst month to average annual distributions" as described below.

the logarithmic geoclimatic conversion factor ΔG is given by:

$$\Delta G = 10.5 - 5.6 \cdot \log_{10}\left(1.1 \pm \left|\cos\left(2 \cdot \xi\right)\right|^{0.7}\right) - 2.7 \cdot \log_{10}\left(d\right) + 1.7 \cdot \log_{10}\left(\left|\varepsilon_p\right| + 1\right) \tag{81}$$

$$\Delta G \leq 10.8$$

where

ξ	latitude (°N or °S)
d	path length (km)
ε_p	magnitude of path inclination (milliradians)

The positive sign in equation Equation (81) is employed for $\xi \leq 45°$ and the negative sign for $\xi > 45°$

The annual fade probability ρ is related to the worst month ρ_w by the equation:

$$\rho = \rho_w \cdot 10^{\frac{-\Delta G}{10}} \% \tag{82}$$

The following worksheet terminology is used:

SESR expressed as a worst month ratio	G.821 and G.826
SES expressed in seconds /month	G.821 and G.826
BER - multipath expressed as a worst month ratio	G.826
ESR - multipath expressed as a worst month ratio	G.826
multipath unavailability expressed as a worst month ratio	G.821 and G.826 (optional)
multipath unavailability in seconds /month	G.821 and G.826 (optional)
annual rain outage expressed in minutes	G.821 and G.826
BBER - rain expressed as a worst month ratio	G.826
ESR - rain expressed as a worst month ratio	G.826
BBER - multipath + rain expressed as a worst month ratio	G.826

ESR - multipath + rain expressed as a worst month ratio   G.826

Annual unavailability expressed as a ratio   G.821 and G.826

Annual unavailability expressed in minutes /year   G.821 and G.826
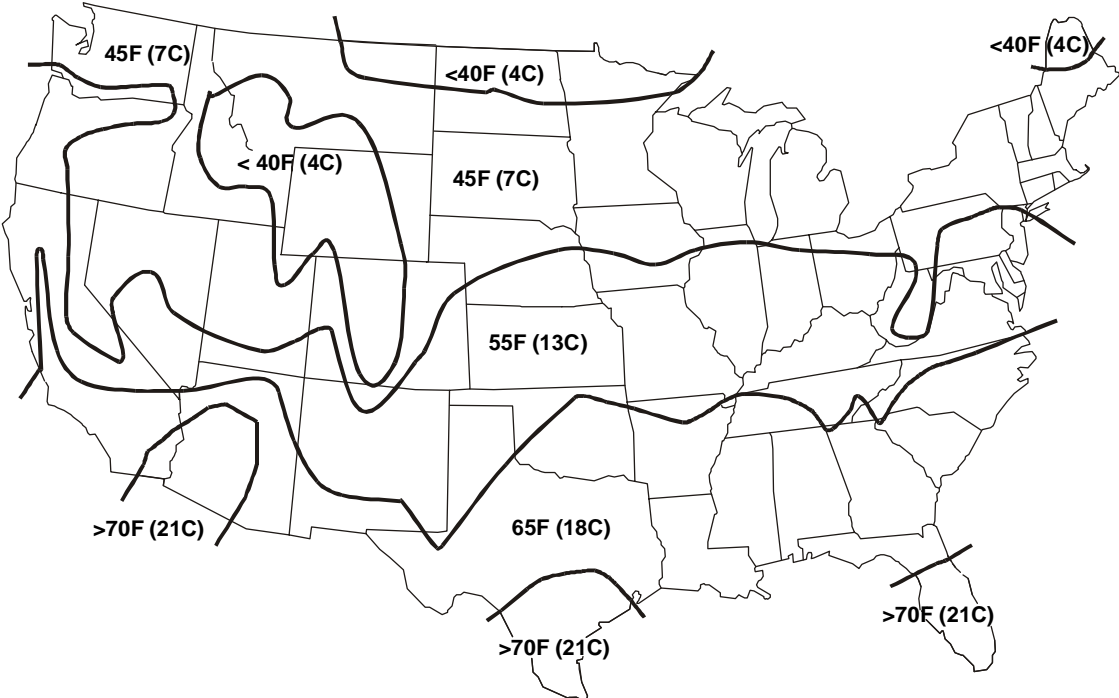
Figure 7: Average Annual Temperature - United States
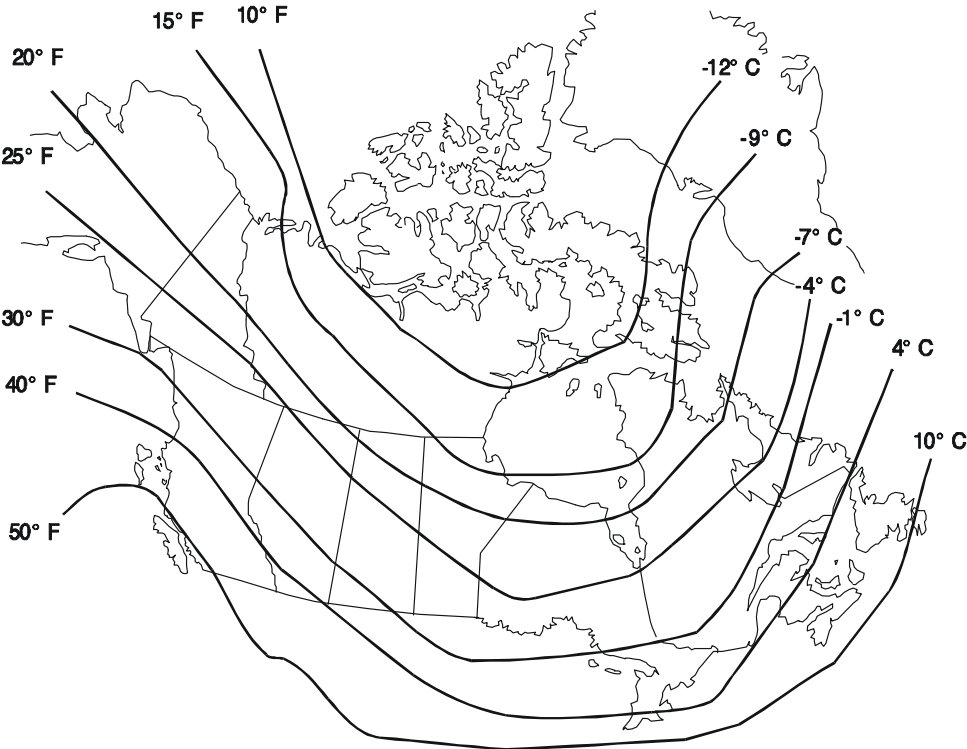
Figure 8: Average Annual Temperature - Canada
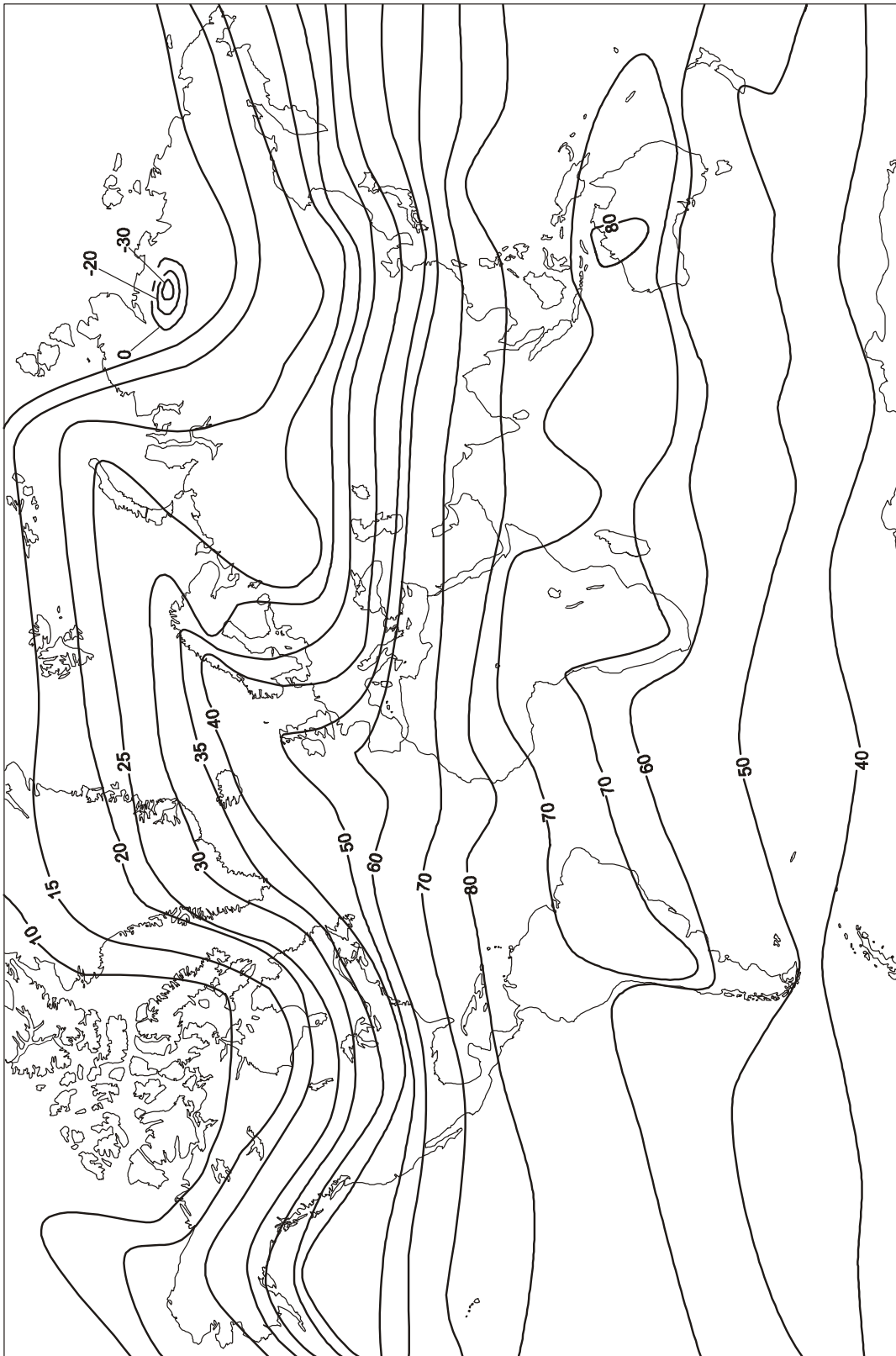
Figure 9: Average Annual Temperature - World
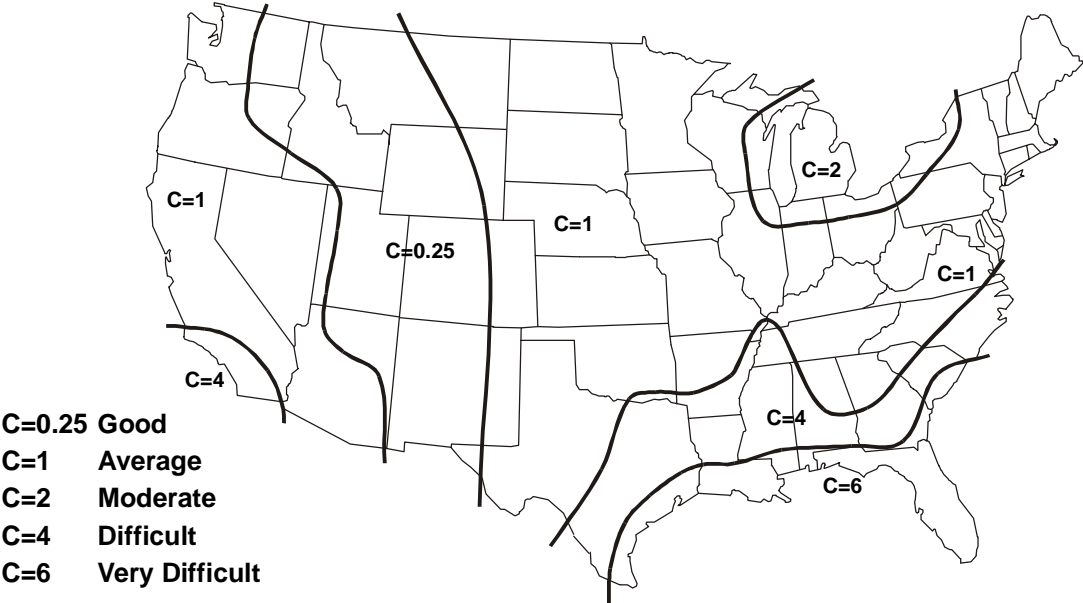
Figure 10: C Factors - United States

C=0.25 **Good**
C=1   **Average**
C=2   **Moderate**
C=4   **Difficult**
C=6   **Very Difficult**
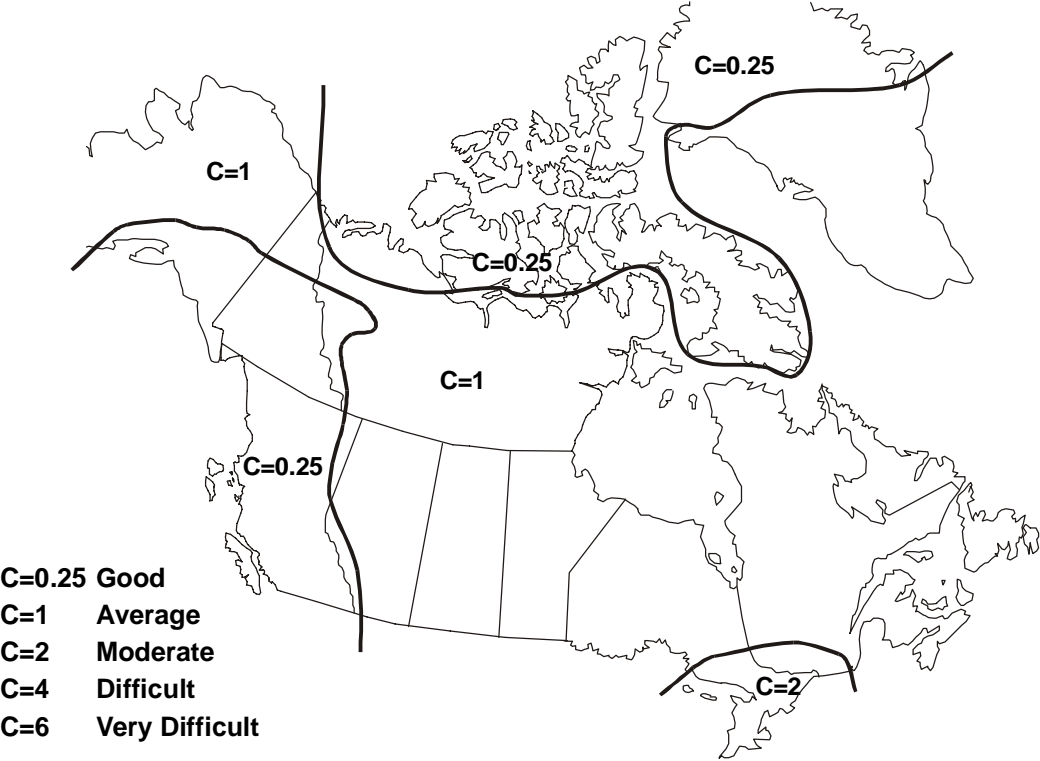
Figure 11: C Factors - Canada

C=0.25 **Good**
C=1   **Average**
C=2   **Moderate**
C=4   **Difficult**
C=6   **Very Difficult**
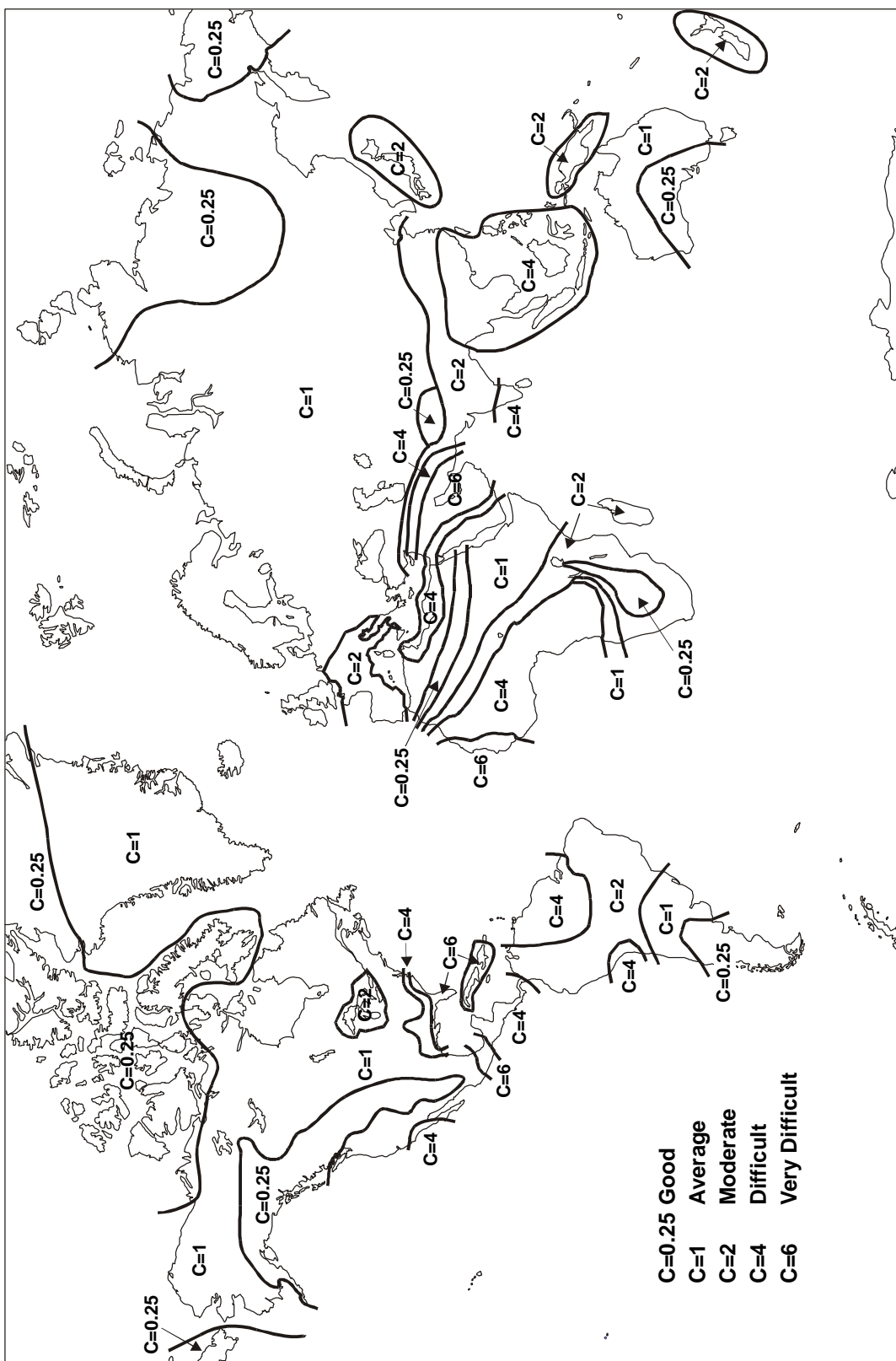
Figure 12: C Factors - World
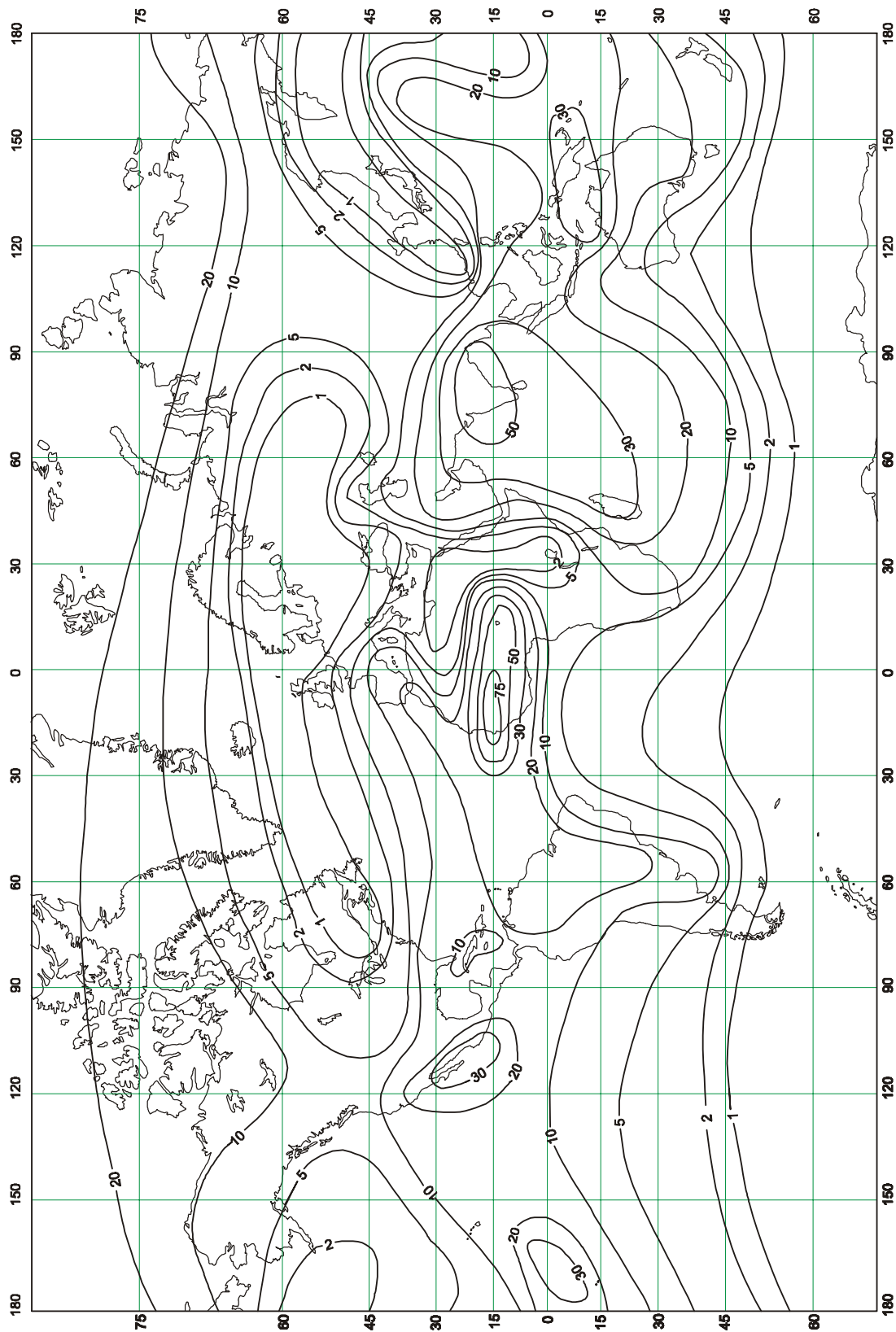
Figure 13: Percent of Time Gradient ≤ −100 N units / km - February
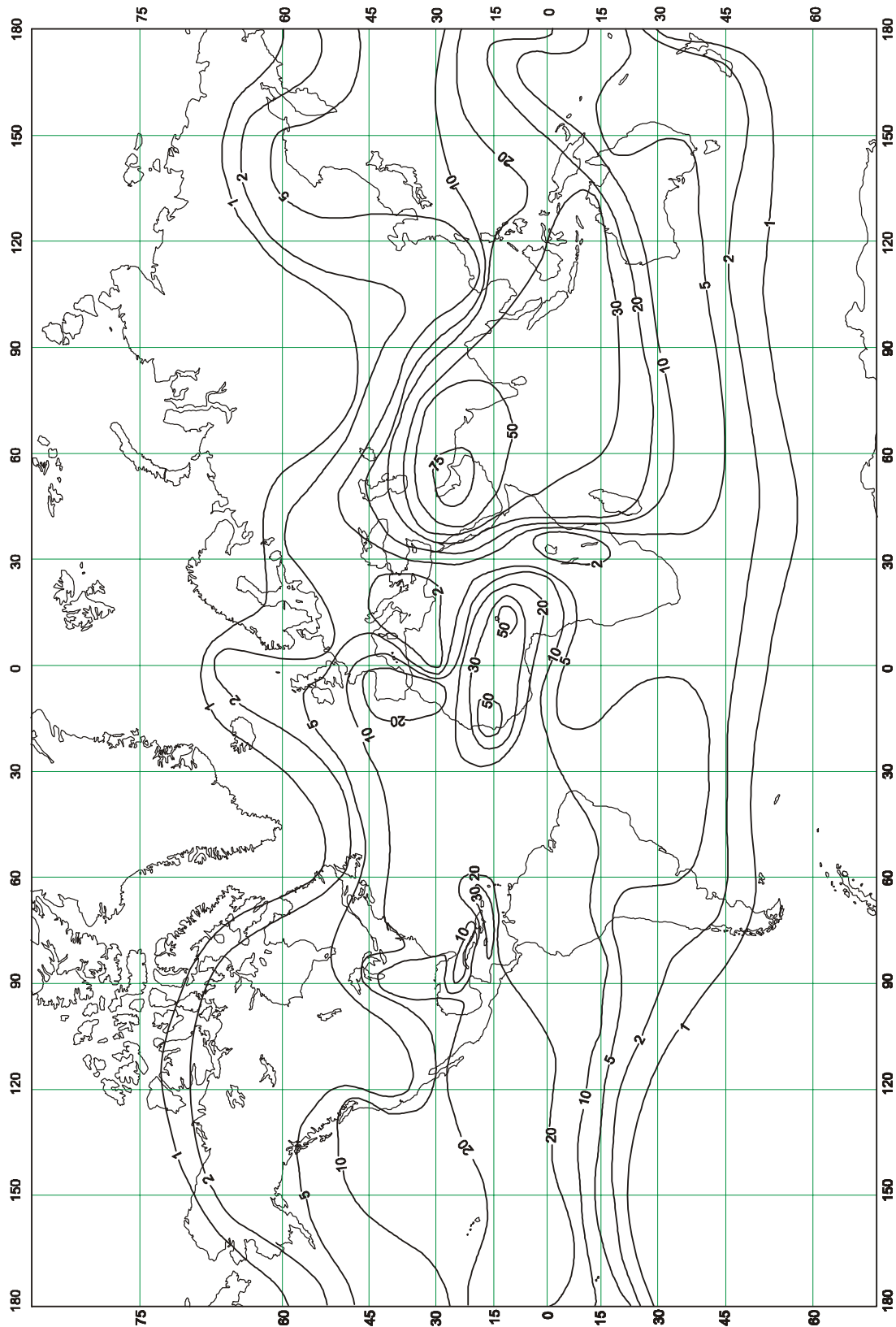
Figure 14: Percent of Time Gradient ≤ −100 N units / km - May
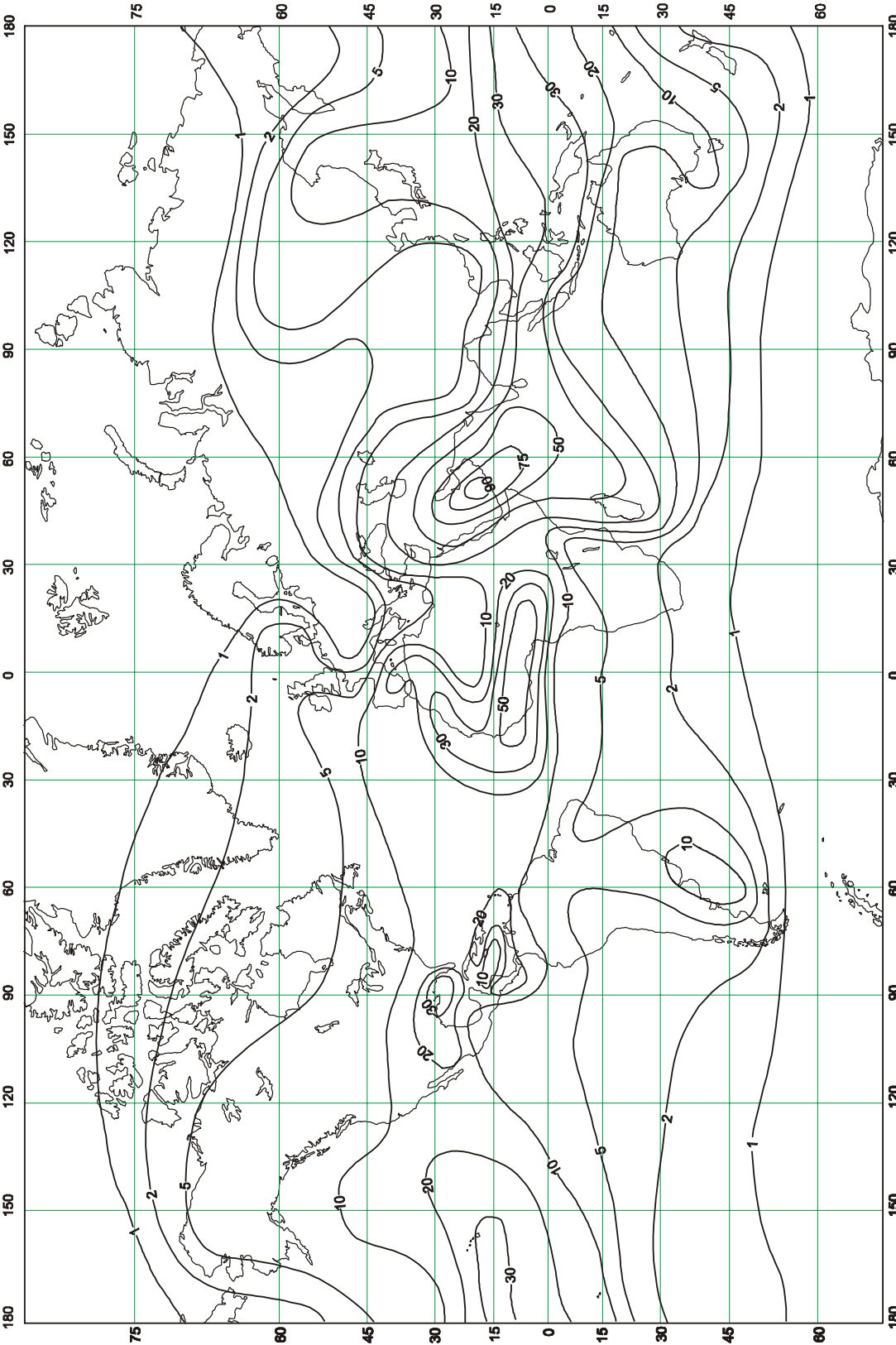
Figure 15: Percent of Time Gradient ≤ −100 N units / km - August
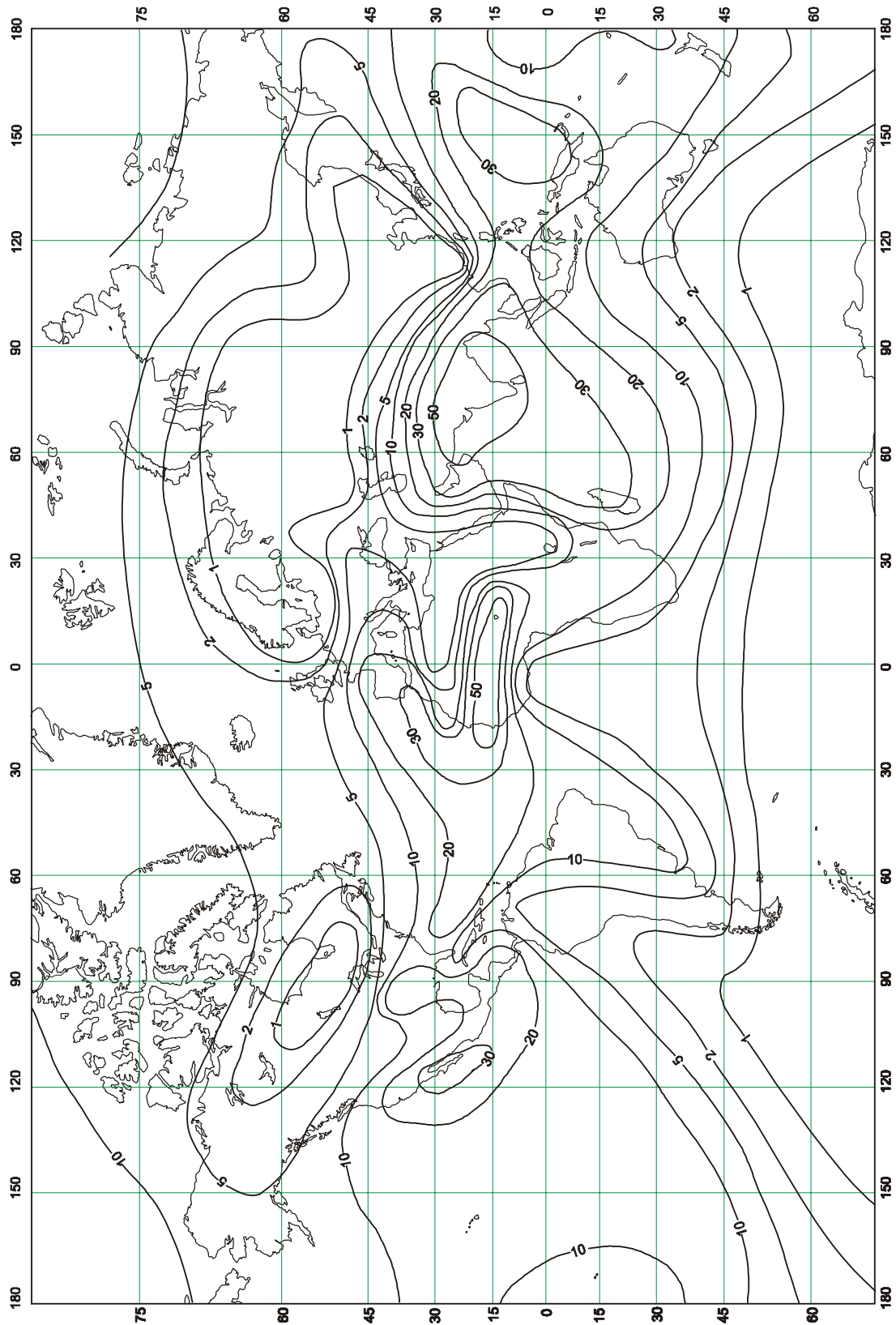
Figure 16: Percent of Time Gradient ≤ −100 N units / km - November
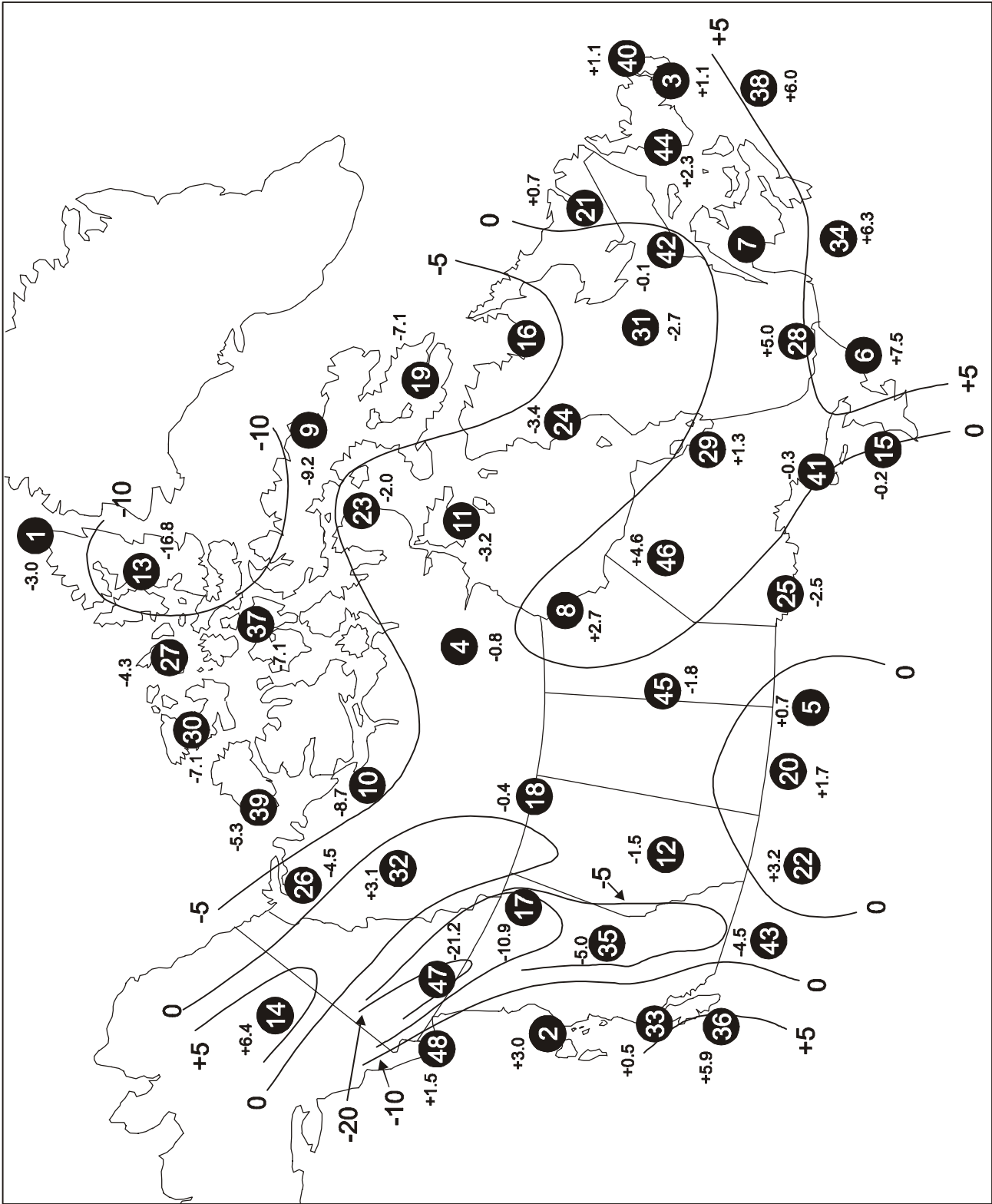
Figure 17: Geoclimatic Factors - Canada

EFFECTIVE RADIATED POWER

In microwave applications, the effective radiated power expressed in dBm is the power at the antenna terminals expressed in dBm plus the antenna gain expressed in dBi.

In VHF-UHF applications, the effective radiated power expressed in dBm is the power at the antenna terminals expressed in dBm plus the antenna gain expressed in dBd.

The notation EIRP and ERP is used to distinguish between the two formats.

LOG NORMAL FADE PROBABILITY

The log normal fade probability accounts for the location variability of the mobile. In a point to point link with well sited antenna, this term does not have any real significance. The fade probability is given by:

$$P = 100 - 50 \cdot erfc\left(\frac{A}{\sqrt{2} \cdot \sigma}\right)\% \tag{83}$$

A fade margin in dB
σ is the log normal standard deviation
$erfc$ is the complimentary error function

The log normal standard deviation is set in the Options dialog box by selecting a location. The following values are used:

Metropolitan   12 dB
Urban   10 dB
Suburban   8 dB
Woodland   6 dB
Open Terrain   4 dB

RALEIGH FADE PROBABILITY

The Raleigh fade probability represents the probability that the received signal will be less than the specified threshold level in a multipath fading environment. This probability is given by:

$$\Pr = 100 \cdot \left(1 - e^{\left(-10^{-\frac{A}{10}}\right)}\right) \tag{84}$$

FIELD STRENGTH AND POWER DENSITY

The average power density, S, of a wave with E volts (RMS) per meter field strength is given by:

$$S = \frac{E^2}{Z_0} \tag{85}$$

where Z_o is the intrinsic impedance of free space (377 Ω)

The maximum effective aperture of a linear half wave dipole with sinusoidal current distribution is 0.13 square wavelengths. Therefore, the power can be expressed as:

$$
\begin{aligned}
P_{watts} &= 0.13 \cdot \frac{E^2}{Z_0} \cdot \lambda^2 \\
P_{watts} &= 0.13 \cdot \frac{E^2}{377} \cdot \left(\frac{300}{F_{MHz}}\right)^2 \\
P_{dBm} &= 10 \cdot \log(P) + 30 \\
P_{dBm} &= 10 \cdot \log\left(\frac{E_{\frac{\mu V}{m}}}{377 \cdot 10^{12}} \cdot 0.13 \cdot \left(\frac{300}{F_{MHz}}\right)^2\right) + 30 \\
P_{dBm} &= 20 \cdot \log\left(E_{\frac{\mu V}{m}}\right) - 20\log(F_{MHz}) - 75 \\
E_{\frac{\mu V}{m}} &= 10
\end{aligned}
\tag{86}
$$

Equation (86) has been taken from Reference (12). The actual equation used in the program is taken from Recommendation ITU-R PN.525-2 as shown in the equation below:

$$e = \sqrt{\frac{377 \cdot p}{4\pi d^2}} = \frac{\sqrt{30 \cdot p}}{d} \tag{87}$$

e   rms field strength in volts per meter
p   equivalent isotropically radiated power in the direction of the receive location
d   distance from the transmitter to the receive location in meters

ANTENNA RESPONSE

Antenna data files (MAS - VAS) are used to determine the response to an incoming signal with horizontal and vertical angles, θ_H and θ_V relative to the mechanical boresight of the antenna.

In VHF-UHF applications, it is assumed that the antenna is always physically mounted vertically (i.e. the mechanical boresight is horizontal). Therefore, a non zero vertical angle will produce an orientation loss. In the absence of electrical downtilt, the electrical and mechanical boresight are the same.

In microwave applications, it is assumed that the antenna is always vertically orientated.

In the following descriptions, the horizontal and vertical patterns are denoted by $G_H(\theta)$ and $G_V(\theta)$ respectively.

Mechanical Downtilt

In the pathloss program, the sign convention for vertical angles is positive for angles above the horizon and negative for angles below the horizon. A positive downtilt, however, means that the antenna boresight is pointing down to the ground.

The effects of mechanical downtilt are accounted for by modifying the vertical angle θ_V. The effect is to increase the vertical angle at the front of the antenna and decrease the vertical angle at the rear. At 90º off of boresight, (V = 90º) mechanical down tilt has no effect. The modification is given by the following equation.

$$
\begin{aligned}
\Delta\theta &= \frac{\theta_{MD}}{90} \cdot (90 - \theta_H) \ \ for \ 0_H \le \theta \le 180 \\
\Delta\theta &= \frac{\theta_{MD}}{90} \cdot (-270 + \theta_H) \ \ for \ 180 \le \theta_H \le 360 \\
\theta_{V\,mod} &= \theta_V + \Delta\theta
\end{aligned}
$$

(88)

where:

θ_{Vmod}	is the modified vertical angle
$\Delta\theta$	is the correction to the vertical angle
θ_{MD}	is the mechanical downtilt angle (positive down)
θ_H	is the azimuth angle relative to the antenna boresight

Note that on directional / sectorized antennas, mechanical downtilt may degrade the horizon pattern of the antenna due to the sidelobe structure in the E plane.

Omnidirectional Antennas

It is assumed that the vertical pattern of an omnidirectional is rotationally symmetric. The response, R_{dB} is given by:

$$
\begin{aligned}
R_{dB} &= G_h(\theta_h) + G_v(\theta_v) \\
G_h(\theta_h) &= 0 \ \ for \ an \ omnidirectional \ antenna
\end{aligned}
$$

(89)

Directional Antennas

The situation in a directional antenna is more complex and assumes that the field distributions are separable into two orthogonal components. The response, R_{dB} is given by Equation (90) below:

$$
\begin{aligned}
\Omega &= \sin^{-1}\left(\cos\left(\theta_h\right)\cdot\sin\left(\theta_v\right)\right) \\
R_{dB} &= G_H\left(\theta_h\right)+G_v\left(\Omega\right)
\end{aligned}
\tag{90}
$$

In Equation (90), an effective vertical angle, Ω is first determined. The vertical response is read from the antenna data file E plane data at the angle Ω.

REFERENCES

1. Bell Communications Research Advisory - TA-TSY-000236
    Issue 1 December 1984
    Preliminary Addendum to 4, 6, and 11 GHz Digital Radio Systems Requirements and Objectives

2. Recommendation ITU-R P.530-6

3. Recommendation ITU-R P.530-5

4. Space Diversity Engineering - A. Vigants
    Bell System Technical Journal - January 1975

5. Multipath Propagation at 4, 6, and 11 GHz - W.T. Barnett
    Bell System Technical Journal - February 1972

6. Transmission Unavailability of Frequency Diversity Protected Microwave FM Radio Systems
    Caused by Multipath Fading - A. Vigants and M.V. Pursley
    Bell System Technical Journal - October 1979

7. Northern Telecom - Practice 415-3041-150 Issued 87 12 22

8. Kazuo Morita - Review of the Electrical Communication Laboratory
    Volume 18, Numbers 11-12, November, December 1970

9. Propagation in Non Ionized Media - Report 719-2
    Recommendations and Reports of the CIR - Volume V

10. Engineering Considerations for Microwave Communication Systems
    GTE Lenkurt Incorporated

11. Digital Line of Sight Radio Links - A. A. R. Townsend
    Prentice Hall

12. Handbook of Land-Mobile Radio System Coverage
    Garry C. Hess
    Artech House Publishers

RAIN ATTENUATION

OVERVIEW

A rain calculation answers the following questions:

- What rain rate produces an attenuation equal to the path fade margin?

- How often is this rain rate exceeded?

Rain attenuation affects both directions of transmission simultaneously. In the case of unequal fade margins, the lowest fade margin is used. Rain attenuation is a function of frequency, path length and polarization.

The calculations use rain statistics files. These are simple ASCII test files which list the rain rate and the probability that this rain rate will be exceeded. Files are provided for the Crane, modified Crane (1996), ITU rain regions and the 47 radiosonde locations in Canada. The rain statistics file format is provided at the end of this section. This will allow users to create new files when the data is available. The rain files are installed in the subdirectory RAIN in the Pathloss program directory under four subdirectories:

CRANE, CRANE_96, ITU-530 and CANADA. The default file extension for rain statistics is "rai".

Both the Crane and the ITU Recommendation 530 calculation methods are provided. A rain statistics file is required to use the Crane method. The ITU530 method calculation is based entirely on the rain rate which is exceeded for 0.01% of the time (R0.01). This value can be read from a rain statistics file or entered directly. Any of the rain statistics files can be used with either the Crane or ITU-530 methods.

Rain calculations are made in the worksheet module and reported as an extension of the worksheet.

OPERATION

Click on the cloud icon above the path profile drawing in the worksheet module to bring up the Rain dialog box. The cloud icon (sunny or rain) indicates whether a rain calculation is active or inactive.

Method

Select either the Crane or one of the ITU 530 methods.Both ITU 530-7 and 530-8 are included for backward compatibility. If the Crane method is selected, you must load a rain file. Refer to the maps at the end of this section to determine which rain statistics file is applicable to your area.

The ITU methods only requires the 0.01% rain rate. This value can be determined by loading a rain file or entering the value directly. The latitude must be specified for the ITU 530-8 method. The worksheet report format is shown below for total annual performance:

1. Rain region   Edmonton Alberta

2. 0.01% Rain rate (mm.hr)   115.00 (ITU-530 only)

3. Rain rate (mm/hr)   180.59

4. Rain attenuation (dB)   29.92

5. Annual rain outage (%-sec)   0.00016 - 48.91

6. Annual multipath + rain (%-sec)   0.00016 - 51.39

Line 3 is the rain rate which produces an outage i.e. the rain attenuation is equal to the fade margin. This is determined by interpolating the rain statistics file with the rain outage probability on line 5. This will not be calculated using the ITU-530 methods under the following conditions:

- A rain statistics file has not been loaded.

- The 0.01% rain rate is not the same as the value in the rain statistics file. i.e. the user has changed the value.

Polarization
Rain attenuation is significantly higher for horizontal polarization. The polarization shown in the Rain dialog box is the design polarization for the path. If this is changed, remember to check the polarizations of the specific radio channel frequencies.

Reset
The reset button unloads a rain file and effectively removes the rain calculation from the worksheet.

Rain Error Messages
The rain calculation is made when the Rain dialog box is closed. If the rain portion of the calculation display is blank, click the X button on the status bar to display the error message.

outage probability < 1E-8 - Crane	Rain is insignificant on this path. The annual outage time is less than 10^{-8}.
outage probability > 0.50 - Crane	The outage probability has exceeded 50%.
frequency out of range (1 to 100 GHz)	The frequency must be between 1 and 100 GHz. Check that the frequency has been correctly entered in MHz.
negative rain rate	The interpolation algorithm has failed due to a negative 0.01% rain rate in the ITU method or other invalid entry in the worksheet.
lower limit exceeded - ITU530	The interpolation algorithm has failed. Refer to the technical description of the ITU-530 rain calculation.

REGRESSION COEFFICIENTS

The regression coefficients (α and β) are given in Table (1) below for horizontal and vertical polarizations as a function of frequency.

Table 1: Regression Coefficients

Frequency (GHz)	α_h	α_v	β_h	β_v
1.0	3.870e-05	3.520e-05	0.912	0.880
2.0	1.540e-04	1.380e-04	0.963	0.923
4.0	6.500e-04	5.910e-04	1.121	1.075
6.0	1.750e-03	1.550e-03	1.308	1.265
7.0	3.010e-03	2.650e-03	1.332	1.312
8.0	4.540e-03	3.950e-03	1.327	1.310
10.0	1.010e-02	8.870e-03	1.276	1.264
12.0	1.880e-02	1.680e-02	1.217	1.200
15.0	3.670e-02	3.350e-02	1.154	1.128
20.0	7.510e-02	6.910e-02	1.099	1.065
25.0	0.124	0.113	1.061	1.030
30.0	0.187	0.167	1.021	1.000
35.0	0.263	0.233	0.979	0.963
40.0	0.350	0.310	0.939	0.929
45.0	0.442	0.393	0.903	0.897
50.0	0.536	0.479	0.873	0.868
60.0	0.707	0.642	0.826	0.824
70.0	0.851	0.784	0.793	0.793
80.0	0.975	0.906	0.769	0.769
90.0	1.060	0.999	0.753	0.754
100.0	1.120	1.060	0.743	0.744

The following equations are used to interpolate values of the regression coefficients, α_x and βx, for a specific frequency, f_x.

$$\alpha_x = log^{-1}[log\,\alpha_1 - M \cdot (log\,\alpha_1 - log\,\alpha_2)]$$

$$\beta_x = b_1 - M \cdot (\beta_1 - \beta_2)$$

$$M = \left(\frac{logf_1 - logf_x}{logf_1 - logf_2}\right)$$

$$f_1 < f_x < f_2$$

$$\alpha_1 < \alpha_x < \alpha_2$$

$$\beta_1 < \beta_x < \beta_2$$

(1)

RAIN ATTENUATION - CRANE

The attenuation due to rain, A, is based on Reference (1) and is given by the equation:

$$A = \alpha R_p^{\beta}\left(\frac{e^{\mu\beta D} - 1}{\mu \cdot \beta} - \frac{b^{\beta}e^{c\beta d}}{c \cdot \beta} + \frac{b^{\beta}e^{c\beta D}}{c \cdot \beta}\right)dB$$

$$for\ d \leq D \leq 22.5km$$

$$A = \alpha R_p^{\beta}\left(\frac{e^{\mu\beta D} - 1}{\mu \cdot \beta}\right)dB$$

$$for\ D < d$$

(2)

$$\mu = \frac{1n(be^{cd})}{c}$$

$$b = 2.3R_p^{-0.17}$$

$$c = 0.026 - 0.031n(R_p)$$

$$d = 3.8 - 0.61n(R_p)$$

where:

R_p	rain rate in millimeters per hour
D	path length in kilometers
α,β	regression coefficients

Rain performance in the Crane method is estimated as follows:

- Determine the rainfall rate required to produce an attenuation equal to the fade margin. This depends only on the frequency and path length.

- Determine the percent of the year that this rain rate is exceeded. This represents the annual two way rain outage time for the path and is calculated using high intensity rainfall statistics for the specific geographic region.

- In accordance with Reference (1), if the path length is greater than 22.5, rain attenuation is calculated using a value of 22.5 kilometers. The effect of the increased path length is taken into account by using a modified value for the "Percent of Year Exceeded" defined as follows:

$$P_1 = P\left(\frac{22.5}{d}\right) \tag{3}$$

where:

P_1 is the modified value for "Percent of Year Exceeded".

P is the value of "Percent of Year Exceeded" shown in the worksheet.

d is the path length in kilometers.

RAIN ATTENUATION - ITU RECOMMENDATION 530

The rain calculation in ITU-R P.530-8 uses a modified algorithm for latitudes between 30° north and south. This has been implemented as a separate option by adding a latitude edit control to the rain dialog box. If geographic coordinates are available, the latitude of the center or the path will be used. If the latitude field is blank, then the rain calculation will be made assuming that the latitude is greater than 30 degrees and the results will correspond to ITU-R P.530-7.

Rain outage times are calculated using the following steps as described in Reference (5).

Determine the rain rate, $R_{0.01}$, exceeded for 0.01% of the time. This value will be interpolated from the rain statistics file or the user can manually enter this value.

- Calculate the specific attenuation, γ, as shown below:

$$\gamma = \alpha \cdot R_{0.01}^{\beta} \tag{4}$$

  where α and β are the regression coefficients given in Table (1).

- Calculate the effective path length, d_e, is calculated as:

$$d_e = \frac{d}{1 + \dfrac{d}{d_0}}$$

$$d_0 = 34 \cdot e^{-(0.015 \cdot R_{0.01})} \tag{5}$$

  where d is the path length in kilometers. An upper limit of 100 mm/hr is set for $R_{0.01}$ in the above equation.

- The path attenuation, $A_{0.01}$, exceeded for 0.01% of the time is given by:

$$A_{0.01} = \gamma \cdot d_e \tag{6}$$

- Attenuations, A, exceeded for other percentages of time, P, are derived from the equations:

  for latitudes equal to or greater than 30° north or south

$$\frac{A}{A_{0.01}} = 0.12 \cdot P^{-(0.546 + 0.043 \cdot \log_{10}P)} \tag{7}$$

  for latitudes less than 30° north or south

$$\frac{A}{A_{0.01}} = 0.07 \cdot P^{-(0.855 + 0.139 \cdot \log_{10}P)} \tag{8}$$

- The attenuation A in the above equations, is set to the fade margin and the equation is solved for P using the following equations:

  for latitudes equal to or greater than 30° north or south

$$log_{10}(P) = 11.628 \cdot \left(-0.546 + \sqrt{0.29812 + 0.172 \cdot log_{10}\left(\frac{0.12 \cdot A_{0.01}}{A}\right)}\right) \tag{9}$$

  for latitudes less than 30° north or south

$$log_{10}(P) = 3.59712 \cdot \left(-0.855 + \sqrt{0.731025 + 0.556 \cdot log_{10}\left(\frac{0.07 \cdot A_{0.01}}{A}\right)}\right) \tag{10}$$

ITU-530 clearly states that the equations are valid only in the range from 1% to 0.001%. On many practical links, this range will be exceeded especially on short links with high fade margins.

If the argument of the square root is negative, the results will be extrapolated from the valid part of the curve. If the "ITU rain warning" option has been set has been set under the menu selection Operations - Options, the results will be shown in red in the worksheet calculation summary if they are outside the range 1% to 0.001%.

WORST MONTH RAIN OUTAGE PROBABILITY

Both the Crane and ITU-530 methods calculate the annual probability of a rain outage. The worst month rain outage probability is given by:

$$T_{wm} = 1.22 \cdot T_{an}^{0.87}$$

$$P_{wm} = \left(\frac{P_{an}}{0.3}\right)^{0.87} \tag{11}$$

where:

T_{wm}	worst month outage time in seconds
T_{an}	annual outage time in seconds

P_{wm} worst month rain outage probability

P_{an} annual rain outage probability

HIGH INTENSITY RAIN STATISTICS

High intensity rainfall statistics are contained in external, user definable ASCII text files. These consist of a table of rainfall rates and the corresponding annual percentage of time that the rain rate is exceeded. The following rain statistics files are provided:

Crane Rain Regions

The rain statistics for the Crane and modified Crane (1996) rain regions are taken from references 1 and 4. The Crane regions are shown geographically for the United States and the world in Figure (1) and Figure (3). The corresponding file names and descriptions are as follows:

Region	File Name	Description
A	CRANE_A.RAI	Polar Tundra (Dry)
B	CRANE_B.RAI	Polar Taiga (Moderate)
C	CRANE_C.RAI	Temperate Maritime
D	CRANE_D.RAI	Temperate Continental
E	CRANE_E.RAI	Sub Tropical Wet
F	CRANE_F.RAI	Sub Tropical Arid
G	CRANE_G.RAI	Tropical Moderate
H	CRANE_H.RAI	Tropical

The temperate continental region D, for the United States has been subdivided into three sub regions: D1, D2 and D3 as shown in Figure (1). The corresponding file names are crane_d1.rai, crane_d2.rai and crane_d3.rai respectively. The modified Crane (1996) rain statistics are shown in Table (3) and the original Crane rain statistics are given in Table (2).

Figure (4) shows a world map for the modified Crane (1996) rain regions.

ITU Rain Regions

The ITU rain regions A to Q are base on Reference (2) and shown in Table (4). A world map showing the ITU rain regions is given in Figure (2). The file naming convention simply uses the rain region to identify the file e.g. ccir_b.rai is the rain file for CCIR rain region B.

Canadian Radiosonde Locations

Rainfall rate statistics for 47 Canadian radiosonde locations are given in Reference (3). The file naming convention is based on the geographic location.

RAIN FILE FORMAT

The format of the rain files is shown below using the file CRANE_D2.RAI as an example. Rain files can be created with any text editor.

Line 1	File identifier	PL-2.0	
Line 2	Number of points	11	
Line 3	Rain region (24 ch)	D2 Temp. Continental	
Line 4	Data points	0.001	102.0
Line 5		0.002	86.0
Line 6	first term is the percent	0.005	64.0
Line 7	of time that the rain rate	0.010	49.0
Line 8	is exceeded.	0.020	35.0
Line 9	second term is the rain	0.050	22.0
Line 10	rate in mm /hr	0.100	15.0
Line 11		0.200	9.5
Line 12		0.500	5.2
Line 13		1.000	3.0
Line 14		2.000	1.8

Table 2: Crane Rain Statistics

% of Year Exceeded	Crane Rain Climate Region Point Rainfall Rate R_p (mm/hour)									
	A	B	C	D1	D2	D3	E	F	G	H
0.001	28.0	54.0	80.0	90.0	102.0	127.0	164.0	66.0	129.0	251.0
0.002	24.0	40.0	62.0	72.0	86.0	107.0	144.0	51.0	109.0	220.0
0.005	19.0	26.0	41.0	50.0	64.0	81.0	117.0	34.0	85.0	178.0
0.010	15.0	19.0	28.0	37.0	49.0	63.0	98.0	23.0	67.0	147.0
0.020	12.0	14.0	18.0	27.0	35.0	48.0	77.0	14.0	51.0	115.0
0.050	8.0	9.5	11.0	16.0	22.0	31.0	52.0	8.0	33.0	77.0
0.100	6.5	6.8	7.2	11.0	15.0	22.0	35.0	5.5	22.0	51.0
0.200	4.0	4.8	4.8	7.5	9.5	14.0	21.0	3.2	14.0	31.0
0.500	2.5	2.7	2.8	4.0	5.2	7.0	8.5	1.2	7.0	13.0
1.000	1.7	1.8	1.9	2.2	3.0	4.0	4.0	0.8	3.7	6.4
2.000	1.1	1.2	1.2	1.3	1.8	2.5	2.0	0.4	1.6	2.8
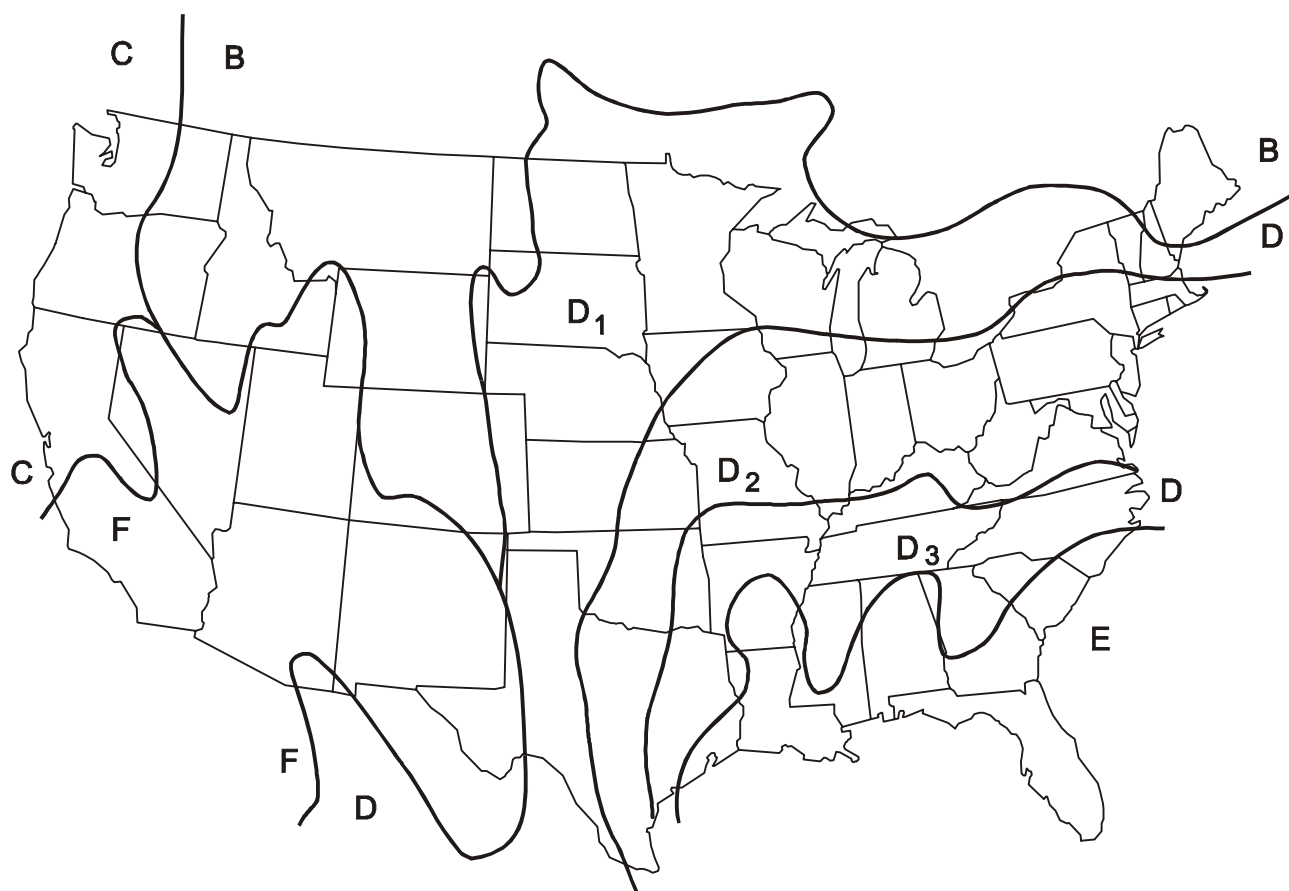
Figure 1: Crane US Rain Regions

Table 3: Modified Crane (1996) Rain Statistics

% of Year Exceeded	Crane 1996 Rain Climate Regions								Point Rainfall Rate Rp (mm/hour)			
	A	B	B1	B2	C	D1	D2	D3	E	F	G	H
0.001	28.1	52.1	42.6	63.8	71.6	86.6	114.1	133.2	176.0	70.7	197.0	542.6
0.002	20.9	41.7	32.7	50.9	58.9	69.0	88.3	106.6	145.4	50.4	159.6	413.9
0.003	17.5	36.1	27.8	43.8	50.6	60.4	75.6	93.5	130.0	41.4	140.8	350.3
0.005	13.8	29.2	22.3	35.7	41.4	49.2	62.1	78.7	112.0	31.9	118.0	283.4
0.01	9.9	21.1	16.1	25.8	29.5	36.2	46.8	61.6	91.5	22.2	90.2	209.3
0.02	6.9	14.6	11.3	17.6	19.9	25.4	34.7	47.0	72.2	15.0	66.8	152.4
0.03	5.5	11.6	9.0	13.9	15.6	20.3	28.6	39.9	62.4	11.8	55.8	125.9
0.05	4.0	8.6	6.8	10.3	11.5	15.3	22.2	31.6	50.4	8.5	43.8	97.2

Table 3: Modified Crane (1996) Rain Statistics

% of Year Exceeded	Crane 1996 Rain Climate Regions						Point Rainfall Rate Rp (mm/hour)					
	A	B	B1	B2	C	D1	D2	D3	E	F	G	H
0.1	2.5	5.7	4.5	6.8	7.7	10.3	15.1	22.4	36.2	5.3	31.3	66.5
0.2	1.5	3.8	2.9	4.4	5.2	6.8	9.9	15.2	24.1	3.1	22.0	43.5
0.3	1.1	2.9	2.2	3.4	4.1	5.3	7.6	11.8	18.4	2.2	17.7	33.1
0.5	0.5	2.0	1.5	2.4	2.9	3.8	5.3	8.2	12.6	1.4	13.2	22.6
1.0	0.2	1.2	0.8	1.4	1.8	2.2	3.0	4.6	7.0	0.6	8.4	12.4
2.0	0.1	0.5	0.4	0.7	1.1	1.2	1.5	2.0	3.3	0.2	5.0	5.8
3.0	0.02	0.3	0.2	0.4	0.6	0.6	0.9	0.8	1.8	0.1	3.4	3.3
5.0	0.01	0.2	0.1	0.2	0.3	0.2	0.3	0.01	0.2	0.1	1.8	1.1

Table 4: ITU Rain Climate Zones - Percent of Time Rainfall Intensity Exceeded (mm/hour)

%	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
1.0	0.1	0.5	0.7	2.1	0.6	1.7	3	2	8	1.5	2	4	5	12	24
0.3	0.8	2	2.8	4.5	2.4	4.5	7	4	13	4.2	7	11	15	34	49
0.1	2.0	3	5	8	6	8	12	10	20	12	15	22	35	65	72
0.03	50	6	9	13	12	15	20	18	28	23	33	40	65	105	96
0.01	8	12	15	19	22	28	30	32	35	42	60	63	95	145	115
0.003	14	21	26	29	41	54	45	55	45	70	105	95	140	200	142
0.001	22	32	42	42	70	78	65	83	55	100	150	120	180	240	170

Figure 2: ITU World Rain Regions
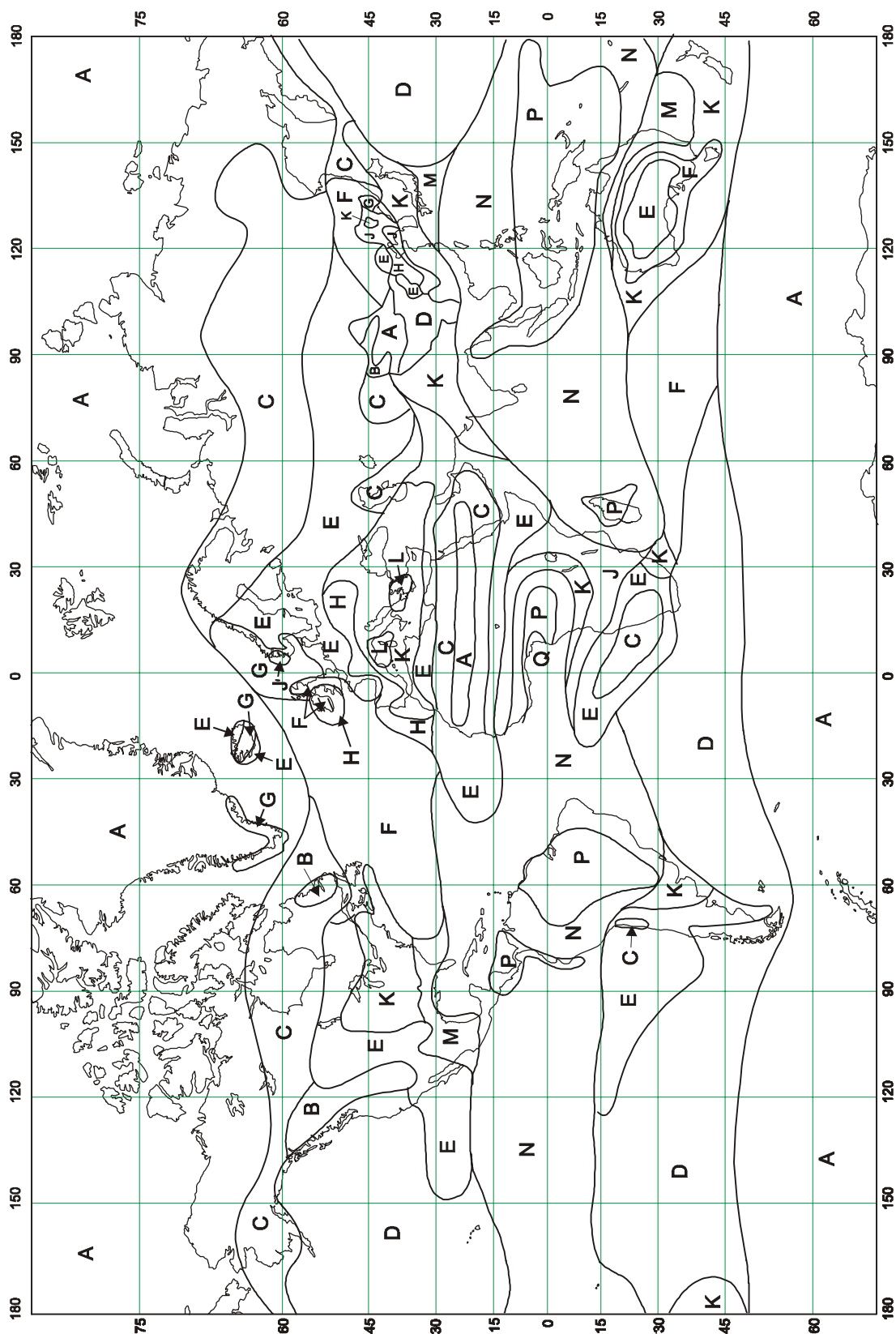
Figure 3: Crane World Rain Regions
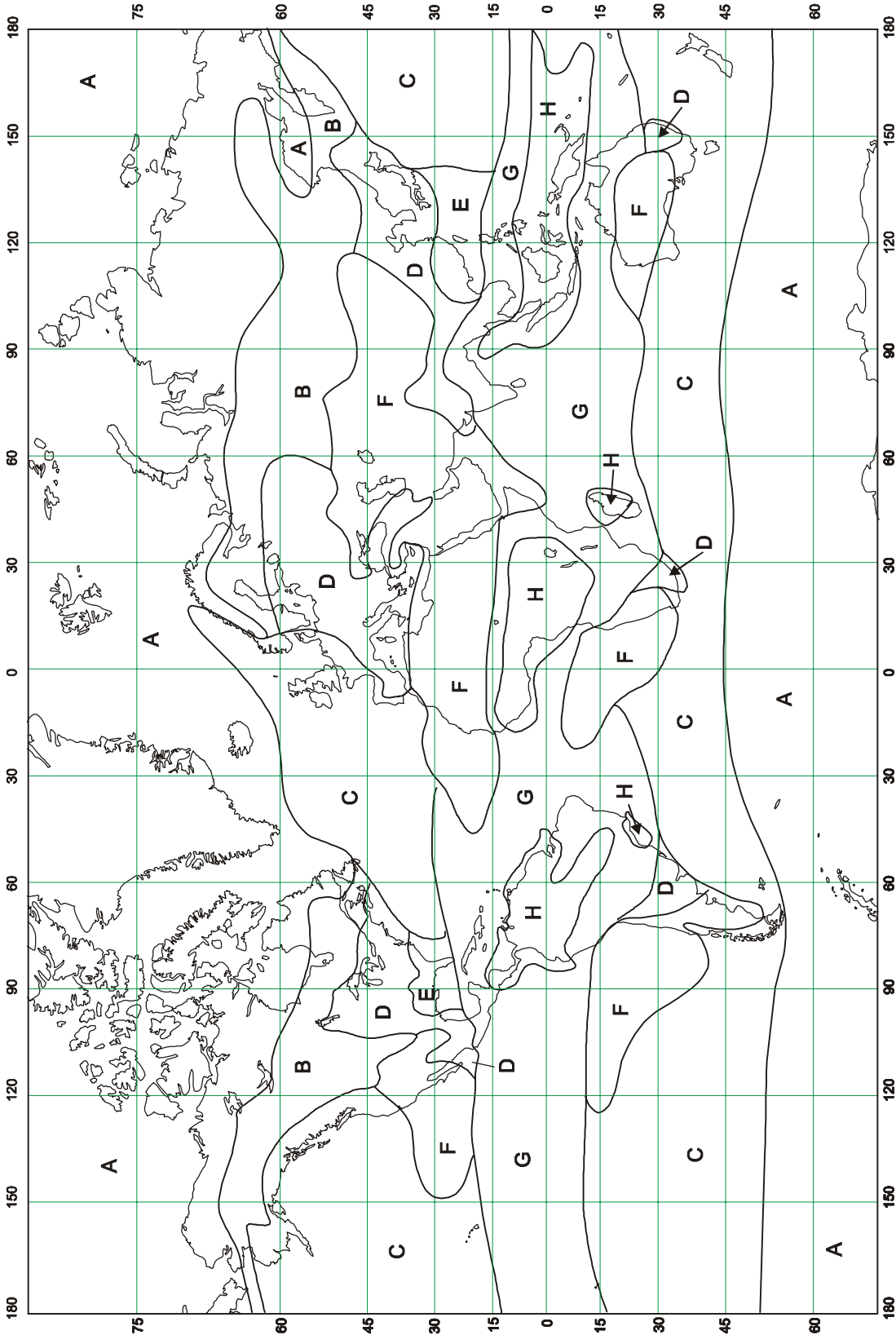
Figure 4: Modified Crane (1996) World Rain Regions
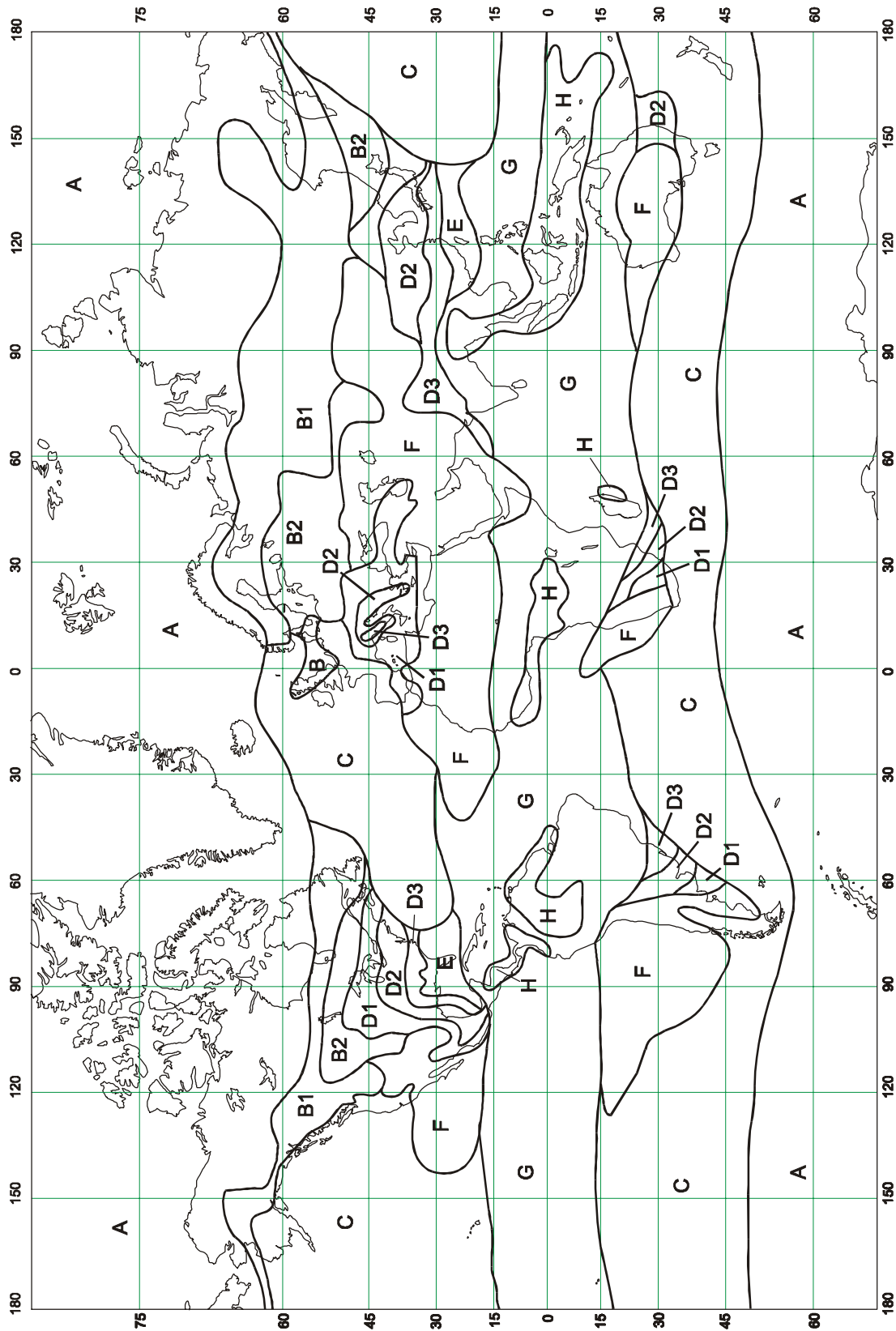
REFERENCES

1.   Prediction of Attenuation by Rain - Robert K. Crane
           IEEE Transactions on Communications
           VOL. COM-28 NO 9, September 1980

2.   Characteristics of Precipitation for Propagation Modeling
           Recommendation ITU-R Pn.837-1

3.   High Intensity Rainfall Statistics for Canada - B. Segal
           Communications Research Centre, Department of Communications
           Ottawa Canada CRC Report Number 1329-E

4.4   Electromagnetic Wave Propagation through Rain - Robert K. Crane
           A Wiley Interscience Publication
           John Wiley & Sons Inc. (1996)

5.   Propagation Data and Prediction Methods Required for the Design of Terrestrial Line of Sight
           Systems - ITU Recommendation P.530-7

PASSIVE REPEATERS

OVERVIEW

A complete transmission path design can be carried out using the following types of passive repeaters:

- single rectangular passive

- close coupled double rectangular passive

- back to back antennas

A path can include up to three passive repeaters using any combination of the above types.

Separate path profiles are required for each passive link. For example, if the design will use two single passive repeaters, then three path profiles will be required. These individual profiles are joined together in the Microwave Worksheet module to form the composite path. The geometry for each passive is determined from the site coordinates and elevations.

Passives must be implemented as a microwave application.

The calculations for single and close coupled double rectangular passive repeaters are based on the Microflect Passive Repeater Engineering manual (Reference 1).

PROCEDURE

Path Profiles

The first step in the design of a passive link is to create a path profile for each link of the overall path. Using the diagram on the left as an example of a single rectangular passive, two path profiles would be required. The profile must include coordinates and the coordinates and elevations at the passive site must be exactly the same in both path profiles. In a preliminary feasibility study, each profile can consist of only the two end points. The site elevations will be used to establish the vertical angles and the coordinates will determine the included angle.

Site 1
55 00 36.43 N
118 00 00.00 W

Passive
55 00 00.00 N
118 00 00.00 W

Site 2
54 59 46.29 N
117 58 56.00 W
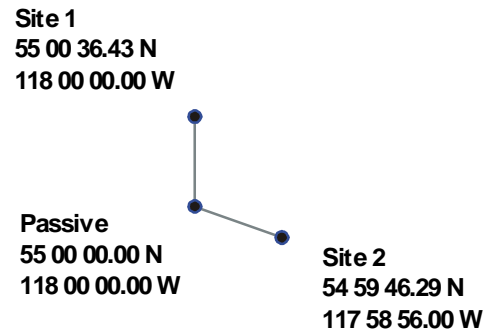
In a detailed design, each path is treated as a separate design. In particular, the antenna heights must be established. For rectangular passives, the antenna height should be the center of the passive above ground level. The path should be analyzed for both reflections and operation at the lowest expected value of K. This analysis must be carried out at this point in the design. Once the individual link profiles have been added together, it will not be possible to access any of the following design modules:

        antenna heights   multipath

        diffraction   reflection

Equipment parameters can be entered during this stage for the end sites; however, this is optional. If back to back antennas are employed, these may be entered for the passive site. Save the Pathloss data files as the link designs are completed.

Creating a Passive Repeater

Load one of the passive link data files and select the Microwave Worksheet module. The remaining passive links will now be added on to the first link. Select Operations - Create Passive Repeater from the Microwave Worksheet menu bar. Identify the type of passive and click the OK button to load the second passive link. If the design includes multiple passive repeaters, repeat this step for all passive link files. The order that the files are loaded is unimportant. The program will determine which ends match using the coordinates and elevations and if necessary will reverse one of the profiles to correctly join the two together. A passive icon is inserted at each passive location.
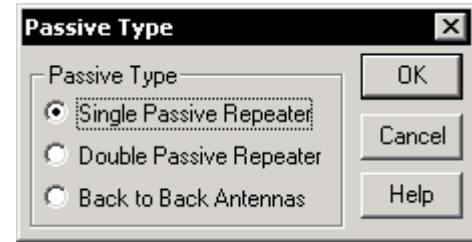
The passive type selection cannot be reversed. If the wrong type of passive was selected, load the first file again and repeat the process. On a complicated design consisting of two single rectangular passives and a close coupled double rectangular passive, make a note of the passive types associated with each file.

The completed passive path should be saved as a separate data file. Do not overwrite any of the passive link files as these may be required for further analysis.

The next step will be to enter the data for each passive. Click on the passive icon to bring up its data entry form. The data entry form will be formatted for the particular type of passive.

Single Rectangular Passive

The initial data entry display shows the included angle, the passive face angle and the vertical angles to the co-ordinating sites. These have been calculated from the coordinates and site elevations. The azimuths to the coordinating sites are used as the titles.

The passive width and height must be entered.

The loss factor represents the effect of the passive surface imperfections. Refer to the manufacturer's specifications for the loss factor at the design frequency.

Single Passive Repeater	Azimuth 244.93°	Azimuth 244.93°
Passive height (m)	24.00	
Passive width (m)	30.00	
Passive center height (m)	54.00	
Loss Factor (dB)		
Vertical angle (°)	0.009	0.009
Included Angle (°)	0.000	
Face angle (°)	0.009	
Effective area (m²)	720.00	
Far field gain (dB)	130.84	
Inverse K	2.35	2.35
L value	0.08	
Alpha (dB)	-9.88	
Near field effect (dB)	-0.33	
Passive Gain (dB)	130.51	
Loss Factor (dB) :		

The passive center height is the distance from ground level to the center of the passive. The calculation details are given at the end of this section. If the final passive gain is not calculated, check that the antenna diameters have been specified at the end sites. These are required to determine if the passive is in the near field of an antenna.

Close Coupled Double Rectangular Passive Repeater

The included angle is automatically calculated for single rectangular passive repeaters based on the coordinates. In the case of double passives, there is not enough information available to calculate these angles and the user must determine the required geometry and included angles. Only the vertical angles are calculated. The required entries are: passive widths and heights, included angles and the distance between the passives.

The passive center height is the distance from ground level to the center of the passive.

Double Passive Repeater
OK Cancel Help

	Azimuth 64.41°	Azimuth 64.41°
Passive height (m)	24.00	24.00
Passive width (m)	30.00	30.00
Passive center height (m)	25.00	25.00
Included Angle (°)	40.000	60.000
Distance between passives (m)	50.00	
Loss Factor (dB)		
Vertical angle (°)	-0.222	-0.222
Face angle (°)	-0.118	-0.128
Effective area (m²)	676.58	623.54
Close coupling loss (dB)	-1.00	
Far field gain (dB)	129.59	
Inverse K	2.72	2.72
L value	0.08	0.08
Alpha (dB)	-11.19	-11.19
Near field effect (dB)	-0.39	-0.39
Passive Gain (dB)	127.81	

Azimuth 64.41° Passive height (m) :

The loss factor represents the effect of the passive surface imperfections. Refer to the manufacturer's specifications for the loss factor at the design frequency.

The calculation details are given at the end of this section. If the final passive gain is not calculated, check that the antenna diameters have been specified at the end sites. These are required to determine if the passive is in the near field of an antenna.

Back to Back Antennas

The passive gain of back to back antennas is calculated as the sum of the antenna gains minus the transmission line and connector loss. The vertical angle is shown for reference only. If the antenna data is added when the individual link profiles are created, the data will be transferred to this data entry form.

Back to Back Antennas
OK Cancel Help

	Azimuth 64.41°	Azimuth 64.41°
Antenna model	HPX8-58W	HPX8-58W
Antenna height (ft)	259.84	259.84
Antenna gain (dBi)	40.80	40.80
Radome loss (dB)		
Vertical angle (°)	-0.29	-0.29
TX line type	EWP63-59W	
TX line length (ft)		
TX line unit loss (dB/100 ft)	1.49	
TX line loss (dB)	3.12	
Connector loss (dB)	0.50	
Passive Gain (dB)	77.98	

Azimuth 64.41° Radome loss (dB) :

Editing Passive Data

Once the passive has been created, only the Terrain Data, Print Profile and Worksheet design modules can be accessed. The passive coordinates and site name can be edited in the Terrain Data module:

Place the cursor on the structure field containing the passive and press the Enter key. Alternately, double click on this field. The entries shown in the data entry form on the left can be edited. Note that any significant changes to the coordinates will invalidate the terrain profile.

Single Passive Repeater - 78.93 mi	
OK Cancel Help	
Site Name	Brownvale
Latitude	56 04 24.00 N
Longitude	117 52 47.00 W
Call Sign	CHW615
Station Code	W599
State	
Owner Code	
State : |	

The passive elevation can be changed directly in the terrain data entry form.

The height of the passive above ground and the antenna heights of back to back antennas can be changed in the passive data entry forms in the Worksheet module.

Propagation Reliability Calculations on Passive Repeaters

The fade probability P is a function of frequency (f), path length (d) and the fade margin (A) and is given by the general equation:

$$P = C \cdot f^a \cdot d^b \cdot 10^{\frac{-A}{10}} \tag{1}$$

Where a and b are constants for the specific method used.

The passive repeater effectively divides the path up into segments and the overall fade probability is the sum of the fade probabilities for each segment. For a single passive with link path lengths d_1 and d_2, the fade probability is given by:

$$P = (C_1 \cdot f^a \cdot d_1^b + C_2 \cdot f^a \cdot d_2^b) \cdot 10^{\frac{-A}{10}} \tag{2}$$

Equation (2) can be extended for any number of passives. If the Vigants-Barnett or ITU-530-6 methods are used to calculate propagation reliability, the factors $C1 .. Cn$ are different for each segment and it is necessary to calculate the terrain roughness or grazing angle for each passive link on the profile. When a passive is created in the Microwave Worksheet, the path icon is divided into segments at the passive location(s). The terrain roughness / grazing calculation is applicable to the selected segment.

Passive Reports

The report format for a single rectangular passive repeater is given below:

```
                    Passive Name
          Latitude    55 00 00.00 N
         Longitude    18 00 00.00 W
   Elevation (ft)     1000.00
   Frequency (MHZ)         11200.00
Coordinating Station    Site 2             Site 1
```

```
              Latitude        55 00 26.36 N      55 00 36.43 N
             Longitude        117 36 10.26 W     118 00 00.00 W
       Elevation (ft)         1000.00            1000.00
Antenna diameter (ft)         10.00              6.00
Passive azimuth (°)           88.00              .000
 Vertical Angle (°)           -0.09              0.00
        Distance (mi)         15.80              0.70
 Included Angle (°)           88.00
      Face angle (°)          -0.06
Passive height (ft)                   24.00
 Passive width (ft)                   30.00
 Passive center height (ft)   25.00
Effective area (ft²)                  517.92
Far field gain (dB)                   118.53
             Inverse K    11.11              0.49
                L value                       0.23
                  Alpha                       2.82
Near field effect (dB)                        -1.22
  Passive Gain (dB)        117.30
```

Comparison of Results

The following points should be noted when comparing the results of the passive repeater calculations with the Microflect examples:

- A direct comparison with the Microflect results cannot be made on near field paths due to differences in the format. The receive signals must be compared in these cases.

- Atmospheric absorption loss is always included in the Pathloss calculation.

- Vertical angles in the Pathloss program are calculated using an effective earth radius of K=4/3.

RECTANGULAR PASSIVE GAIN

Figure 1: Passive Repeater Geometry

The theoretical gain of a rectangular passive repeater is given by:

$$G \ = \ 20 \cdot log_{10} \left(\frac{4 \cdot II \cdot a \cdot cos\left(\frac{C}{2}\right)}{\lambda^2} \right)$$

(3)

$$cos\left(\frac{C}{2}\right) \ = \ \frac{sin(\theta_1) + sin(\theta_2)}{2 \cdot sin(\theta_3)}$$

θ_1 is the least vertical angle from the passive center to Site1 / Site 2

θ_2 is the greatest vertical angle from the passive center to Site1 / Site 2

θ_3 is the passive vertical face angle and is calculated by Equation (4)

$$tan(\Delta a) = \frac{tan(\alpha) \cdot (cos(\theta_1) - cos(\theta_2))}{cos(\theta_1) + cos\,\theta_2}$$

(4)

$$tan\,\theta_3 = \frac{cos(\Delta\alpha) \cdot (sin(\theta_1) + sin(\theta_2))}{cos(\alpha) \cdot (cos(\theta_1) + cos(\theta_2))}$$

α is the horizontal included angle.

NEAR FIELD LOSS - GAIN

The near field loss-gain (αn) is determined from Figure (2) using the parameters $\frac{1}{K}$ and L given by the equations below:

$$\frac{1}{K} = \frac{II \cdot \lambda \cdot d}{4 \cdot a^2}$$

(5)

where

d distance between the antenna and the passive
λ wavelength
a^2 effective area of the passive

All of the above parameters must be in the same units.

$$L = D\sqrt{\frac{II}{4 \cdot a^2}}$$

(6)

where

D antenna diameter
a^2 effective area of the passive

All of the above parameters must be in the same units.

If $\frac{1}{K} > 3$, then the passive is in the far field and L and αn are not calculated.

Note that in the Microflect format, αn effectively replaces the passive gain and the free space loss between the antenna and the near field passive. In the Pathloss program the passive gain is modified by the term "near field effect" defined as follows:

near field effect $=$ free space loss $+$ αn - G

The passive gain including the near field effect is equal to the far field gain (G) + near field effect.
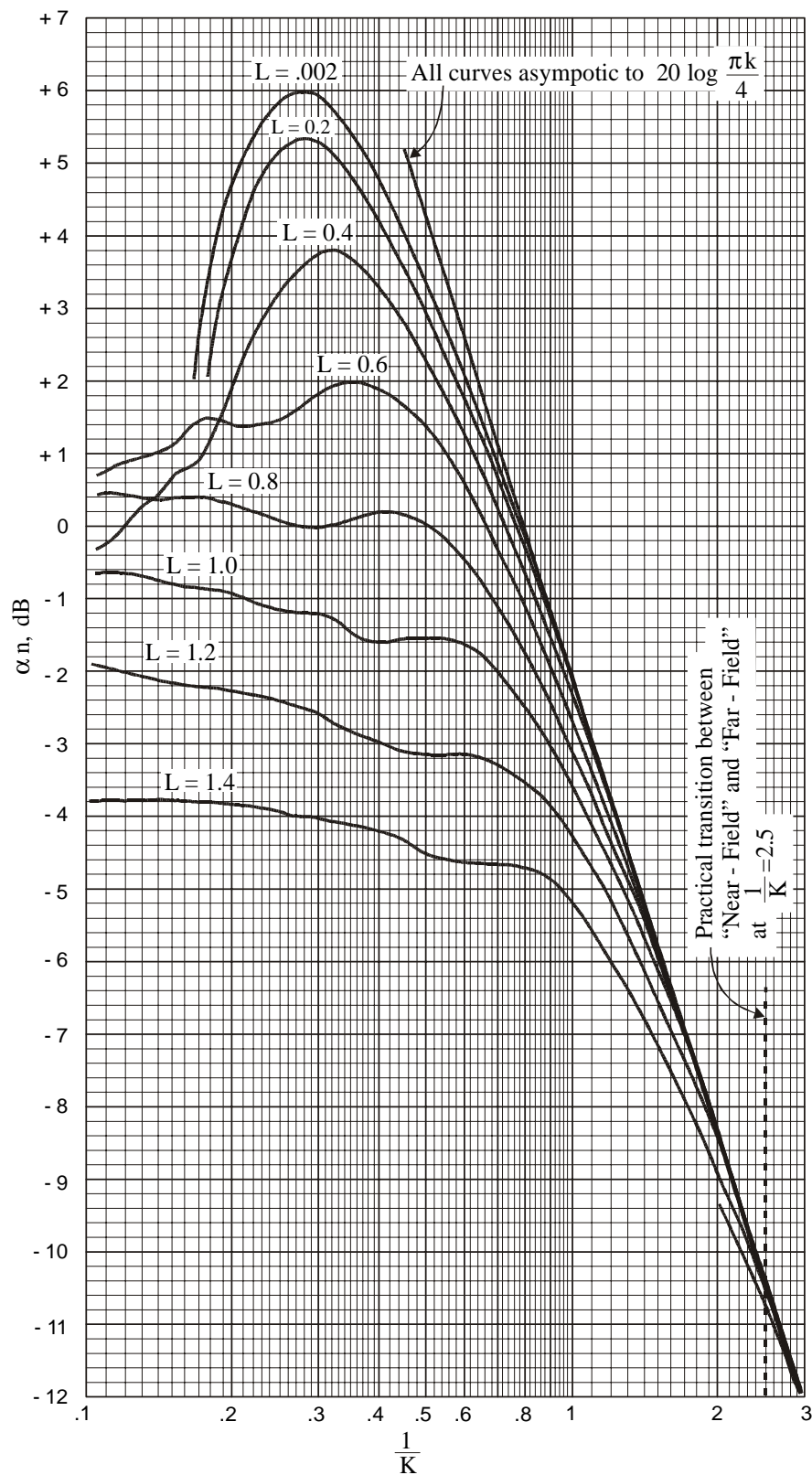
Figure 2: Near Field Loss - Gain

CLOSE COUPLING LOSS - DOUBLE PASSIVES

The close coupling loss αp on double passive repeaters is determined from Figure (3) with the parameters:

$\dfrac{1}{K^2}$ *and* $\dfrac{b}{a}$ defined as follows:

$$\frac{1}{K^2} = \frac{2 \cdot \lambda \cdot d}{a^2}$$

$$\frac{b}{a} = \sqrt{\frac{b^2}{a^2}}$$

(7)

where

d	distance between passives
a^2	smaller effective area of the two passives
b^2	larger effective area of the two passives
λ	wavelength

The same units must be used for all parameters.
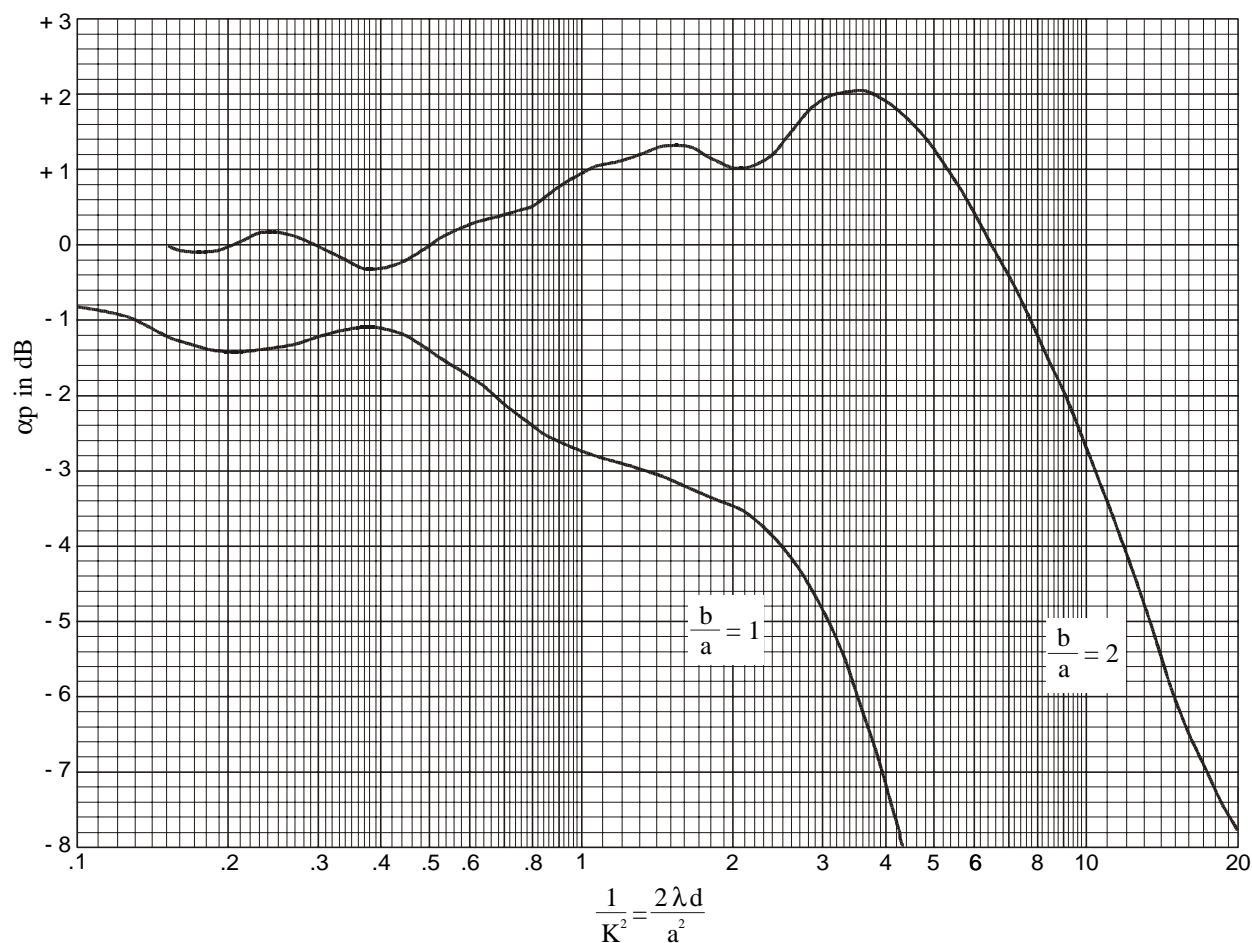
Figure 3: Double Passive Repeater Close Coupling Loss

REFERENCES

1.   Passive Repeater Engineering
          Microflect Manual No. 161

DIFFRACTION - OPERATION

HISTORICAL PERSPECTIVE

Calculating the diffraction loss of a radio wave propagating over irregular terrain is not an exact science. The uncertainty becomes more serious when one attempts to account for the surface cover of the terrain. The effects of trees, buildings and street alignment in an urban environment can lead to large discrepancies between measured and predicted results. It is worthwhile to review diffraction loss calculations from a historical perspective to understand the present day state of the art.

The term diffraction, was first coined by Grimaldi in the year 1665 to describe the complex transition pattern between the illuminated and shadow regions, formed when light strikes an opaque object.

In the year 1818, Fresnel developed the mathematical theory of diffraction. Fresnel's model incorporated most of the physical principles in modern diffraction theory including Fresnel zones and Fresnel integrals. A subsequent refinement, known as the Fresnel-Kirchhoff theory forms the basis of modern day diffraction theory.

An exact calculation of diffraction loss for simple obstacle geometries was now possible; the most notable of these being a simple knife edge.

The first successful application of knife edge diffraction theory at radio frequencies was carried out in 1933, over a mountain range by ATT (Schelling et. al) in the VHF frequency band.

When the Fresnel - Kirchhoff theory was first applied to radio propagation, it became apparent that a closed form solution to irregular terrain was not possible. The problem was described as one of the most difficult facing the mathematical physical sciences. This was attributed to the extremely small wavelengths in comparison to the radius of the earth.

The case of propagation over a smooth spherical earth became the major objective as the range of radio transmission increased. The special case of propagation over flat earth had been previously solved by Sommerfeld.

One of the first solutions to the smooth spherical earth is credited to Bremmer for work carried out during the years 1944-45 at the Philips Research Laboratory in Holland. The solution is in the form of an infinite series known as the residue series. The series converged rapidly for paths well beyond the horizon, but very slowly for path lengths near the horizon distance.

At this point, solutions were available for the two limiting cases: knife edge and smooth earth diffraction. Unfortunately , the majority of practical terrain profiles fall in between these two extremes. Two approaches have been taken to handle the intermediate cases.

The first was the use of numerical methods to solve the Fresnel-Kirchoff equations over irregular terrain using high speed computers. Numerous papers were published describing the methods and the results; however, it is generally accepted that this approach is not practical for general design purposes.

In the second approach, hybrid propagation models were developed which characterize the earth as a series of knife edge obstacles and combinations of smooth earth and knife edge diffraction. The major work in

this area was carried out in the years 1950 to 1970 under the auspices of the US National of Bureau of Standards. The results are embodied in the publication:

Transmission Loss Predictions for Tropospheric Communication Circuits

Technical Note 101

Longley, Rice, Norton and Baris

The diffraction algorithms used in the Pathloss program are based on this document. Significant errors can occur when the terrain does not fit the diffraction model for which it was developed. Diffraction loss calculations consider a terrain profile as a slice through a section of the earth. The terrain across or perpendicular to the path is assumed to be constant. The effects of reflections and scatter from terrain and structures which are not on the direct path are ignored.

In recent years, ray tracing and rendering techniques have been applied to propagation over three dimensional surfaces; and in particular, digital models of cities. This approach is expected to become more commonplace as computer speeds increase and the cost of digital models of cities become more affordable.

DIFFRACTION MODULE OVERVIEW

A terrain profile is required for a diffraction loss calculation. An accurate representation of the effective earth radius is achieved by adding temporary points to the profile using linear interpolation so that the minimum spacing between points is one percent of the profile length.

All calculations are inhibited if either antenna height is zero.

Diffraction loss calculation is saved in the Pathloss data file; however, the results are automatically erased whenever a parameter is changed, which would invalidate these results. These parameters include:

terrain profile elevations	path length
structures (locations and heights)	frequency
polarization	antenna heights
earth radius factor K	the diffraction algorithm

The diffraction loss is <u>not</u> automatically transferred to the worksheet. Many operations are carried out in the diffraction module which are not applicable to the transmission path. These include the calculation of diffraction loss as a function of the earth radius factor (K) and analyzing the loss from a reflection point to an antenna. If the worksheet diffraction loss entry is different than the current diffraction loss calculation, you will be prompted to use the calculated value.
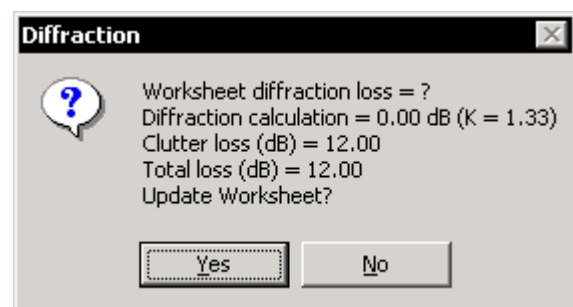
Diffraction Algorithms
The following diffraction algorithm selections are available on the control bar.
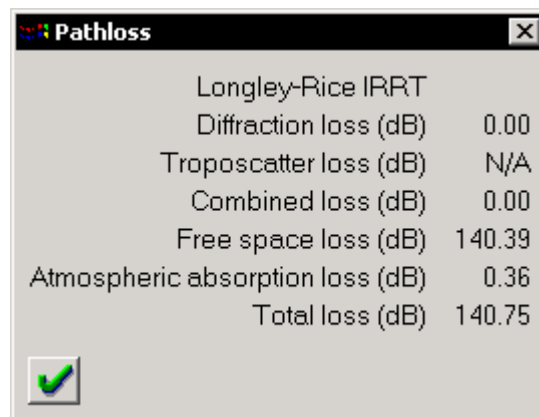
Knife Edge   Average

Isolated Obstacle   Height Gain

Longley & Rice Irregular Terrain   Two Ray Optics

Pathloss   TIREM (terrain integrated rough earth model)

NSMA (National Spectrum Managers Association)

Automatic Diffraction Algorithms

The algorithms Pathloss, TIREM and NSMA are referred to as the automatic algorithms. When one of these have been selected, just click the Calculate button or press F9 to carry out the calculation. These algorithms analyze the terrain profile in accordance with a set of rules, and determine which algorithm, or combination of algorithms to use. Note that the pathloss algorithm can be configured for special cases. The choice of diffraction algorithm depends on your application. The following are some general guide lines:

- The NSMA algorithm is intended for interference calculations. This is the current standard of the North American frequency coordination industry.

- The TIREM algorithm has been used as the base algorithm for the design of most cellular radio networks.

- The Pathloss algorithm (using the default configuration) is recommended for transmission applications.

Manual Diffraction Algorithms

The remaining algorithms are referred to as manual calculations. The user analyzes the profile and decides which algorithm(s) to use on which segment of the profile. Manual calculations are used to validate the automatic algorithms in critical applications.

Knife Edge - Isolated Obstacle - Average

These algorithms all depend on the clearance to first Fresnel zone ratio (C/F1) at the selected point on the profile. The results are cumulative. This allows a path to be analyzed as a succession of discreet calculations, by selecting different profile segments and calculating the loss of each segment.

Height Gain

This is only used with the above C/F1 type algorithms and represents the additional loss which occurs when there is less than 60% first Fresnel zone clearance between an antenna and its horizon. The calculation is made for both ends of the path and is automatic in the sense that it is not necessary to select a profile segment. The Height Gain is valid only on obstructed paths. The height - gain algorithm is used in all three automatic algorithms.

Longley & Rice Irregular Terrain

This algorithm is applicable to both line of sight and obstructed paths and can only be used over the complete profile. Previous versions of the Pathloss program used the Longley & Rice algorithm as an alterna-

tive to the height gain calculation, using the profile segment between an antenna and its horizon. This approach really over extends the use of the Longley & Rice algorithm and has been discontinued.

On obstructed paths the Longley & Rice algorithm will automatically calculate the diffraction loss. On line of sight paths, a reflective plane definition is required.

Two Ray Optics

Two ray optics is valid on line of sight paths over the complete profile. This has been included primarily to assess the effects of a specular reflection and is not intended as a diffraction loss algorithm. This algorithm requires a reflective plane to be defined.

Tree - Building Loss

The additional loss of trees and buildings on the profile or ranges of trees and buildings is calculated with any of the automatic diffraction algorithms

Clutter Loss

Clutter represents the additional loss produced by trees and buildings in the immediate foreground of a site. The clutter loss calculation is used when it is not practical to enter these structures on the path profile. Instead, a clutter loss calculation is made in a worksheet and is shown as a separate term in a total loss display.

Variable Parameters

Diffraction loss can be calculated as a function of antenna heights, earth radius factor, frequency or distance along the path. The selected automatic diffraction algorithm will be used for the calculations. If any of the manual diffraction algorithms have been selected, then the Pathloss automatic diffraction algorithm will be used.

Tropospheric Scatter Loss

Scatter loss is automatically calculated on obstructed paths and displayed on the status bar. The calculation is valid for an earth radius factor (K) in the range 1.2 to 1.5. Scatter loss is not calculated for paths close to grazing. Two methods of calculating scatter loss are available. The selection is made in the Diffraction Options dialog box.

TOTAL LOSS CONCEPT

All losses are relative to free space loss. The concept of total loss is described below for line of sight paths and obstructed paths.

Line of Sight Paths

The total loss on a line of sight path consists of the components shown on the right. Note that diffraction loss will occur on a line of sight path if there is less than 60% first Fresnel zone clearance on the path.

Diffraction Loss
↓
Atmospheric Absorption Loss
↓
Free Space Loss
↓
Clutter Loss
↓
Total Loss

Obstructed Paths

On an obstructed path, the total loss concept is somewhat more complicated in that the loss is time variant. When a diffraction loss calculation is carried out, the results are displayed as the total loss as shown below.

Diffraction Loss   Tropospheric Scatter Loss
↓   │
Combined Loss ←─────────────────────┘
↓
Atmospheric Adsorption Loss
↓
Free Space Loss
↓
Clutter Loss
↓
Total Loss
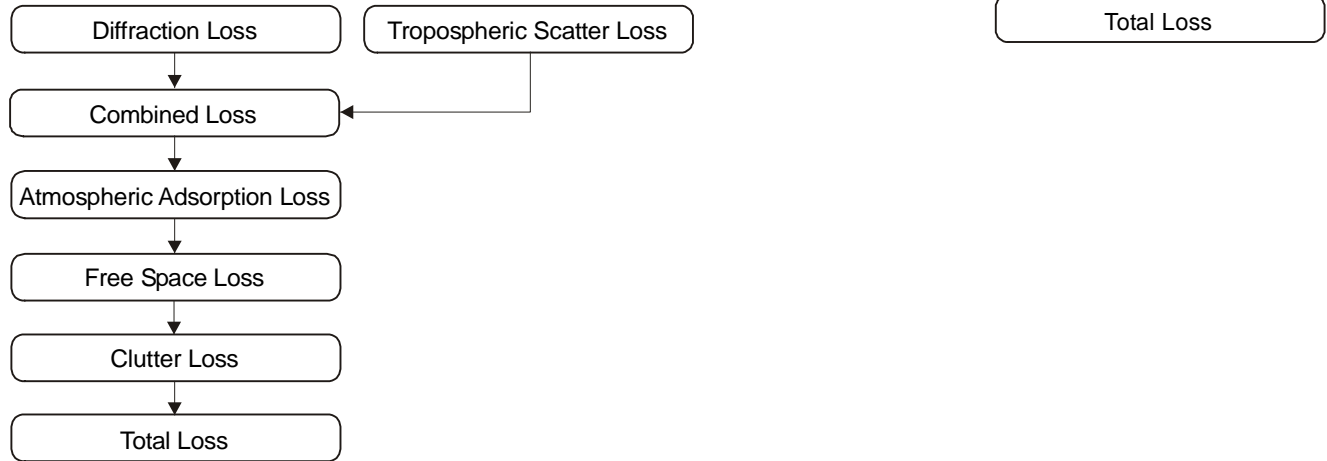
Tropospheric scatter loss is combined with the diffraction loss using the formula below:

$$L_c = 10 \cdot \log_{10}\left[10^{-\frac{L_d}{10}} + 10^{-\frac{L_s}{10}} \right]$$

where:

L_c	is the combined loss
L_d	is the diffraction loss
L_s	is the tropospheric scatter loss

Diffraction and scatter loss are two independent propagation mechanisms and can be considered as two resistors in parallel. If the diffraction loss is much greater than the scatter loss, the combined result is effectively equal to the scatter loss. Conversely, if the scatter loss is much greater than the diffraction loss, the result is equal to the diffraction loss. If the results are equal, then the combined loss will be 3 dB less than either value. The combined loss is always less than either the diffraction or scatter loss.

OHLOSS Format

The OHLOSS (Over the Horizon Loss) format considers the time variability of the loss due to changes in the atmospheric conditions. The combined loss is subjected to a empirical analysis using data for a specific climatic region to determine the time variability.

The median loss is first calculated by adding a correction factor to the combined loss. This accounts for differences between the long term measured and calculated values.

The median loss is then subjected to a time variability analysis for a range of time percentages. These are divided into 50% and 95% confidence factors. A 95% confidence factor means that if 100 measurements were taken over a long time period, then 95% of the measurements would be within the specified ranges.

GENERAL OPERATION OF THE DIFFRACTION MODULE

Fresnel Zone Reference

Fresnel zone references are used to analyze the clearance on a profile. Select Operations - Fresnel Zones or press the F2 key to bring up the Fresnel Zone Reference dialog box. The Fresnel zone can be expressed as either a percentage of the first Fresnel zone or a Fresnel number. The drop down lists contain commonly used values. New values can be added to the lists.

Three types of Fresnel zone formats are available. The selection will be limited by the path geometry and the calculation state.

End to End	A single Fresnel zone reference is drawn between the end points of the display. This format always available and is only meaningful on line of sight paths.
Between Horizons	A series of Fresnel zones are drawn between the horizons on the profile. This format is limited to obstructed paths.
To Reflection Point	The Fresnel zone is drawn from the antennas to the reflection point. Both the upper and lower Fresnel zones are drawn. This format is only available if a reflective plane exists.

The Fresnel zone can be labeled. The label is drawn in the center of the display.

Diffraction Display Status Bar

| Site #1 | 450.00 MHz | D - 33.00 dB | S - 41.65 dB | A | P | TR - TR | km-m | 32.84-29.4 | Site #2 |

The status bar provides general information on the status and parameters of the calculation and also provides access to certain options in the program. The site names are always at the end of the status bar. A description of the remaining items follows:
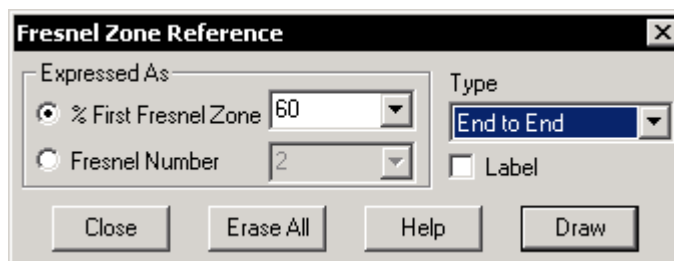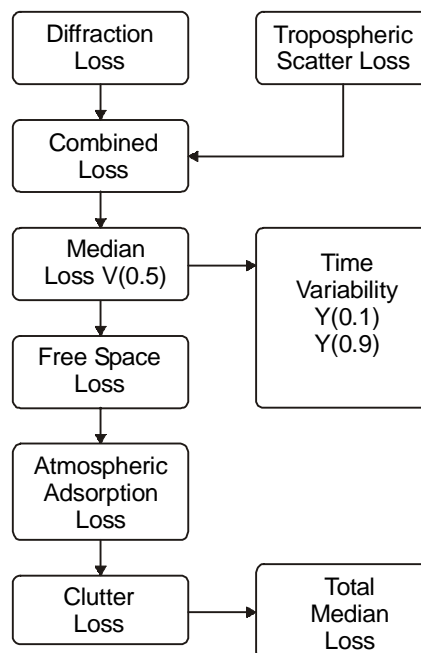
Frequency

This is the global design frequency. Click on this box to access the Diffraction Parameters dialog box in which the frequency can be changed

Diffraction Loss

This box (D) shows the calculated diffraction loss. If a question mark is displayed, then no calculation has been made. Click on this box to display the total loss summary.

Scatter Loss

This box (S) shows the scatter loss. If "N/A" is displayed, then the scatter loss is not applicable for any of the following reasons:

- the path is line of sight

- the earth radius factor (K) is outside the range 1.2 to 1.5

- the path is close to grazing and the scatter loss calculation is not valid

Click on this box to access the Diffraction Parameters dialog box in which the method of calculating scatter loss can be changed.

Cursor Style and Movement

The letters A and P in the above status bar display represent the cursor style (arrow or lines) and the movement (on profile, peaks or continuous). These can be changed by clicking the left mouse button on the associated box. Cursor control is described in detail in a following paragraph.

Antenna Combination

The current antenna combination is displayed. If the antenna configuration supports more than a single combination, click on this box to change the antenna combination.

Measurement System

The measurement system status box displays the current units of measurement. This is an information only status box.

Cursor Location Status Box

This box shows the current location of the cursor. Click on this box or press the Ins key for an information display on the selected point.

Cursor Control

A cursor is used for the following operations:

- to select a segment of the profile

- to identify the peak of an obstacle using the knife edge, average and isolated obstacle algorithms

- to define a reflective plane

- to obtain additional information on a profile point

Cursor Style

The default cursor is a vertical arrow. This can be changed to lines from the antennas. Press the letter 'A' to toggle between the two formats. Alternately, click on the Cursor Style box on the status bar.

Cursor Movement

There are three cursor movement modes:

> P   the cursor can be located on all profile points
>
> S   the cursor can be located on profile peaks only
>
> C   the cursor movement is continuous and is not constrained to the profile

These modes are set with the letters P, S or C as indicated above. Alternately, you can click on the cursor movement box on the status bar. The cursor is moved with either the keyboard cursor keys or with the mouse. The movement depends on which cursor movement mode has been selected as described below:

Cursor on All Profile Points

The left and right cursor keys move the cursor to the next profile point in that direction. The left mouse button moves the cursor to the first profile point past the mouse cursor location. The home and end keys move the cursor to the left and right ends of the display.

Cursor on Profile Peaks Only

The left and right cursor keys move the cursor to the next profile peak, or to the end of the display if no peaks are found. The left mouse button moves the cursor to the first peak past the mouse cursor location, or to the end of the display, if a peak is not found in this direction.

Continuous Cursor

The cursor can be positioned anywhere on the display. The left, right, up and down cursor keys move the cursor one increment. The increment is an arbitrary number of pixels established by the screen resolution at start up. The + and - keys increase and decrease this increment. There is no visible indication of the magnitude of the increment.

If the cursor is moved above the top of the display, the display will be rescaled by 80%. This may be required to calculate effective knife edge diffraction.

If the cursor is moved below the display and the display has been rescaled, it will be reset to the initial state.

Clicking the left mouse button moves the cursor to the mouse cursor location. The cursor can be moved by holding down the left mouse button and dragging the cursor to its new location.

Keyboard Control

The following list summarizes all keyboard commands used in the Diffraction module.

> P   set cursor movement to all profile points
>
> S   limit the cursor movement to peaks of the profile

C	allow continuous cursor movement
A	change between an arrow cursor and lines to the antennas
Home	moves the cursor to the left side display limit
End	moves the cursor to the right side display limit
+	increases the cursor movement increment in the continuous cursor mode and increases the radius increment in the isolated obstacle diffraction option
-	decreases the cursor movement increment in the continuous cursor mode and decreases the radius increment in the isolated obstacle diffraction option
F1	select the point at the cursor location in a select profile segment or define reflective plane operation
F2	display the Fresnel zone reference dialog box
F3	erase all diffraction loss calculations
F4	select a diffraction algorithm
F5	reformat the profile so that the end points have equal elevations
F6	define a reflective plane
Ctrl F6	erase a reflective plane
F7	switch the radius calculation on or off in the isolated obstacle diffraction algorithm
F8	reset a profile segment to the complete profile, or cancel a select segment operation.
F9	calculate the diffraction loss
Ctrl F9	calculate the loss of a single tree or building on the profile
Tab	move the cursor from the top of a tree or building to ground level
D	display a summary of the diffraction loss calculations
Ins	display the data of the profile point at the cursor location

Display Zoom Feature

Any portion of the diffraction display can be selected and displayed as a full screen. This zoom feature is only implemented in the Antenna Heights and Diffraction modules. This is particularly useful on profiles with near in obstructions or buildings.

Position the mouse cursor at one corner of the area to be selected. Hold down the Ctrl key and then hold down the left mouse button and drag the cursor to the opposite corner. Release the mouse button and the selected area will be scaled to fill the window.

To reset the display, hold down the Ctrl key and click the right mouse button.

PATHLOSS ALGORITHM

The default settings are recommended for transmission applications. The algorithm can be configured for special applications or to compare the results with those of other programs.

Radius Method

This setting refers to the radius calculation used by the isolated obstacle algorithm when the terrain is characterized as a single or multiple knife edge. The isolated obstacle algorithm is equivalent to a knife edge if the radius is not used.

No radius
The loss is always calculated as a single knife edge for single or multiple knife edge paths. The results are usually lower than the measured value.

All obstacles
A radius will be used for all obstacles. On multiple knife edge paths, this setting usually results in higher than measured value.

Major obstacle only
If the path contains a single obstacle, the radius will be used. In the case of multiple obstacles, the radius will only be applied to the major obstacle. The major obstacle is the one with the minimum clearance to first Fresnel zone ratio (C /F1). Note that the reference end points are different in the Deygout and Epstein & Peterson multiple knife edge models. In the Deygout model, the C /F1 is referenced to the end points of the profile. In the Epstein & Peterson model, the C/F1 is referenced to the horizons of the obstacle under test.

Multiple Knife Edge Method

Deygout (default)
This model is limited to a double knife edge path. The clearance to first Fresnel zone ratio is calculated for each obstacle, with respect to the end points of the profile, to determine the major obstacle.

The loss of the major obstacle is calculated as a knife edge or isolated obstacle referenced to the end points of the profile, as if the second obstacle did not exist. The loss of the minor obstacle is then calculated with respect to its horizons. The resultant loss is the total of the two calculations.

Epstein & Peterson
In this model, there is no theoretical limit to the number of knife edges; however, the program has an internal limit of 10. The user can set an upper limit in the range 2 to 10. If this limit is exceeded, the Longley & Rice irregular terrain algorithm will be used.
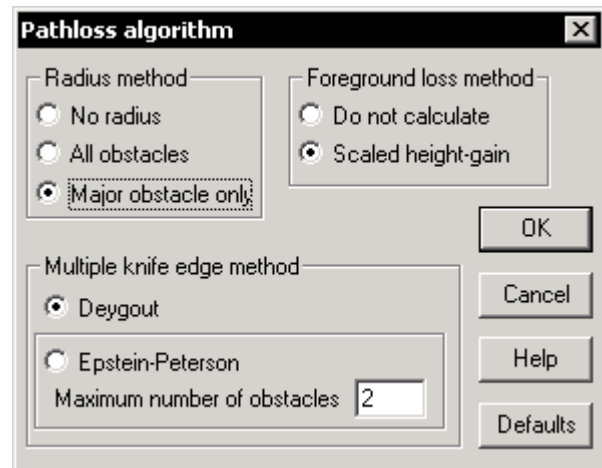
The Epstein & Peterson model treats the terrain as a succession of knife edges. The loss of each knife edge is calculated using the horizons of the knife edge as the end points. The resultant loss is the sum of the individual knife edge calculations.

The results of the Deygout model will always be higher than the Epstein & Peterson model, and therefore, provides a conservative design approach. When the obstacles are widely separated, the Epstein & Peterson model is more accurate. When the obstacles are close together, the Epstein & Peterson model will seriously under-predict the loss.

Foreground Loss Method

When the terrain is characterized as a single or multiple knife edge, it is necessary to examine the terrain between an antenna and its horizon. If the clearance to first Fresnel zone ratio in this region is less than 60%, additional loss will occur and must be taken into account. This is referred to as the foreground loss.

This calculation is carried out using the height - gain algorithm and should always be used. An option to not calculate this loss is provided primarily as a means to compare the results with other programs.

DIFFRACTION PARAMETERS

Scatter Method

Tropospheric scatter loss can be calculated using either of the following relationships:

30 C log(Frequency)

36 + 20 C log(Frequency)

The latter relationship effectively removes the frequency dependence in tropospheric scatter loss. The cross over frequencies of these two definitions is 3981 MHz. If the scatter loss method is set to Auto, then the program will use the correct method, based on the specified frequency.

If the NSMA automatic diffraction algorithm is selected, then the 36 + 20•log(f) relationship will always be used.

Tree Type

If trees have been entered in the terrain profile, then the tree loss will be calculated using the parameters of the specified tree type.

Frequency

This is the design frequency and is global to all modules in the program.

Polarization

This is the design polarization and is global to all modules in the program. With the exception of the two ray optics algorithm, polarization does not significantly affect the diffraction loss calculations.
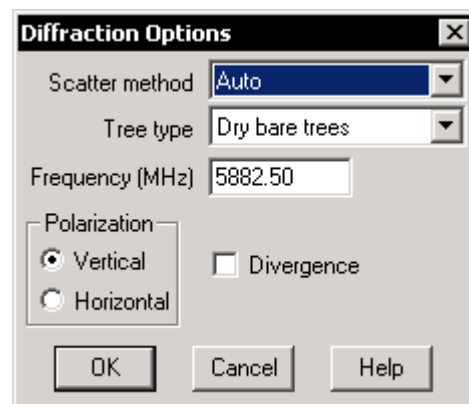
Divergence

Divergence is the scattering of a reflected wave due to the curvature of the earth. This applies to the two ray optics algorithm only. The option is global and its primary use is in the Reflection module.

MANUAL DIFFRACTION LOSS ALGORITHMS

Selecting a Profile Segment

Any section of the profile can be selected when using the knife edge, average or isolated obstacle manual diffraction algorithms. The clearance and C /F1 ratio are referenced to the end points of the selected segment. This feature is required to calculate multiple knife edge diffraction. The following steps describe how to select a profile segment:

- Move the cursor to one end of the segment and press the F1 key or click the right mouse button to select the first end point. Note that the arrow will be above the antenna if it is positioned on one of the sites. The reset button is now enabled and the point selection can be canceled by clicking this button or pressing the F8 key.

- Move the cursor to the other end of the segment and press the F1 key again or click the right mouse button.

The display is reformatted for the selected segment. All diffraction loss calculations are referenced to the end points of this segment.

To reset the display back to the complete profile, click the reset button or press the F8 key.

Knife Edge Diffraction

The knife edge diffraction algorithm is used for single, multiple and effective knife edge diffraction loss calculations. A knife edge produces the lowest loss of any algorithm and can be considered as a lower limit.

The clearance and diffraction loss are calculated at the cursor location, with respect to the end points of the display. If the complete profile is displayed, the clearance and loss are referenced to the profile end points. If a segment of the profile has been selected, the clearance and loss are referenced to the end points of this segment. The basic procedure for knife edge calculations is described below:

- Select the knife edge diffraction algorithm from the drop down list box on the control bar.

- Place the arrow on the peak of the obstruction.

- Click the calculate button or press the F9 key.

- Click the OK button on the diffraction loss display to accept the calculation or the Cancel button to discard the calculation.

This procedure can be extended to multiple knife edges by selecting the appropriate segments of the profile.

Average Diffraction

Recognizing that an ideal knife edge rarely occurs in practice, the average diffraction algorithm was formulated by AT&T. This is the same algorithm used in ITU - 530. The algorithm is a linear relationship between loss and the clearance to the first Fresnel zone ratio and is based on empirical data. The primary application was to estimate the fading produced by low values of K on microwave radio paths.

The clearance and the average diffraction loss is calculated at the cursor location, with respect to the end points of the display. If the complete profile is displayed, the clearance and loss are referenced to the end points of the profile. If a segment of the profile has been selected, the clearance and loss are referenced to the end points of this segment. The basic procedure is described below:

- Select the average diffraction algorithm from the drop down list box on the control bar.

- Place the arrow on the peak of the obstruction.

- Click the calculate button or press the F9 key.

- Click the OK button on the diffraction loss display to accept the calculation or the Cancel button to discard the calculation.

Isolated Obstacle Diffraction

The isolated obstacle algorithm extends the ideal knife edge algorithm to include the effects of the breadth of obstacle along the path. This is accounted for by the radius of the obstacle; and therefore, an estimate of the radius of the obstacle must be made. This algorithm produces the most realistic prediction of diffraction loss on a path with a single obstruction. The algorithm is valid when the obstacle is isolated from both sites.

The clearance and diffraction loss are calculated at the cursor location, with respect to the end points of the display. If the complete profile is displayed, the clearance and loss are referenced to the end points of the profile. If a segment of the profile has been selected, the clearance and loss are referenced to the end points of this segment. The procedure for the isolated obstacle calculation is described below:

- Select the isolated obstacle diffraction algorithm from the drop down list box on the control bar.

- Place the arrow at the peak of the obstruction and press the F7 key to initiate the radius calculation. The screen display shows an arc of a circle below the arrow. The radius is shown on the control bar prompt box. Note that the circular arc appears parabolic due to the differences in the horizontal and vertical scales. If the arrow was located on a peak when the F7 key was pressed, the program will calculate the radius based on the slope of the terrain on either side of the peak; otherwise, a default radius of 250 km will be displayed.

- To change the radius, move the mouse cursor to one of the grip boxes at the ends of the arc. Hold down the left button and drag the mouse to change the radius. Alternately, hold down the Ctrl key and use the left, right, up or down cursor keys to change the radius. The radius is changed in increments. The size of the increment is changed with the + and -keys. There is no visible display of the increment.

- Change the radius to match the shape of the obstacle. This is best accomplished by selecting a continuous cursor movement. In this mode, the radius can be dragged by holding down the right mouse button or with any of the cursor keys.

- Note that the radius may be greater than the path length. An extreme example of a radius calculation is a smooth earth profile where the obstruction is formed by the bulge of the earth. The radius of the obstruction, in this case, is the earth radius factor, (K) times the earth radius. For the median value of K, the radius of the obstruction is 1.33 x 6375 = 8478 km.

- When the radius of the obstacle has been determined, click the calculate button or press the F9 key to calculate the diffraction loss.

- Click the OK button on the diffraction loss display to accept the calculation or the Cancel button to discard the calculation.

This procedure can be extended to multiple obstacle paths by selecting the appropriate segments of the profile and repeating the calculation for each segment. If the radius is calculated for all of the obstacles, the results tend to produce a somewhat high loss.

If there is a significant elevation difference between the ends of the path, if may be difficult to define the obstacle radius. In these cases, the profile can be reformatted so that the end points are at the same elevation. Press F5 to equalize the profile. This feature is only enabled when the knife edge, average or isolated obstacle algorithm has been selected.

Height - Gain Algorithm

If the path is being analyzed as a single or multiple knife edge, then it is necessary to examine the terrain between each site and its horizon. If there is less than 60% first Fresnel zone clearance in this region, then additional loss will occur and must be taken into account. This can be calculated with the height - gain algorithm.

Select the height - gain algorithm on the control bar and click the Calculate button of press F9. Click OK to accept the result or Cancel to discard the calculation.

Longley & Rice Irregular Terrain - Obstructed Paths

On obstructed paths, the Longley-Rice irregular terrain algorithm estimates the loss using the weighted average of the smooth earth loss and the loss of a double knife edge. The weighting factor is based on empirical data and considers the following parameters:

terrain roughness	effective antenna heights
frequency	horizon angles

For smooth paths, the loss approaches the smooth earth value. For very rough paths the loss approaches the double knife edge value. The Pathloss automatic diffraction algorithm defaults to irregular terrain when the path cannot be characterized as a single or multiple isolated obstacle(s).

- Select the irregular terrain algorithm from the drop down list box on the control bar.

- Click the calculate button or press the F9 key to calculate the diffraction loss.

- Click the OK button on the diffraction loss display to accept the calculation or the Cancel button to discard the calculation.

Longley & Rice Irregular Terrain - Line of Sight Paths

On line of sight paths, the Longley - Rice irregular terrain algorithm interpolates the diffraction loss from three separate calculations at distances d_0, d_1 and d_2. The distances d_0 and d_1 are chosen within the horizon and the loss at these distances is calculated using two ray optics. The distance, d_2 is beyond the horizon and the loss is calculated using the irregular terrain algorithm for obstructed paths. A smooth curve is fitted to the three points and the loss at the path length is interpolated.

This algorithm requires a reflective plane to be defined. The plane can be predefined before the calculation; otherwise, you will be prompted to define the plane when the calculation starts. Refer to the Reflective

Plane Definition later in this section for additional details. The following steps predefine the reflective plane before calculating the diffraction loss:

- Press F6 to begin the reflective plane definition.

- Move the cursor to one end of the plane and press the F1 key or click the right mouse button.

- Move the cursor to the opposite end of the plane and press the F1 key again or click the right mouse button.

- If the plane definition is not satisfactory, repeat the above steps. The new reflective plane will replace the existing one.

- Select the irregular terrain algorithm from the drop down list box on the status bar.

- Click the calculate button or press the F9 key.

- Click the OK button on the diffraction loss display to accept the calculation or the Cancel button to discard the calculation.

Two Ray Optics

The two ray optics algorithm calculates the vector sum of a direct and a reflected signal. This algorithm can only be used on a line of sight path. If the clearance at the reflection point is less than 0.57 first Fresnel zone radius, the result is always a loss and is referred to as plane earth loss. For a clearance above this value, the result can be a loss or a signal enhancement (gain). At clearances close to grazing, the algorithm produces an unrealistically high loss.

The two ray optics algorithm requires a reflective plane to be defined. The plane establishes location of the reflection point and the grazing angles. Terrain roughness is automatically calculated over the defined end points of the plane.

The plane can be predefined before the calculation; otherwise, you will be prompted to define the plane when the calculation starts. Refer to the Reflective Plane Definition later in this section for additional details. The following steps predefine the reflective plane before using two ray optics:

- Press the F6 key to begin the reflective plane definition.

- Move the cursor to one end of the plane and press the F1 key or click the right mouse button.

- Move the cursor to the opposite end of the plane and press the F1 key again or click the right mouse button.

- If the plane definition is not satisfactory, repeat the above steps. The new reflective plane will replace the existing one.

- Select the two ray optics algorithm from the drop down list box on the status bar.

- Click the calculate button or press the F9 key.

- Click the OK button on the diffraction loss display to accept the calculation or the Cancel button to discard the calculation.

Reflective Plane Definition

A reflective plane is required with the irregular terrain - line of sight and two ray optics algorithms. In addition, a reflective plane can be defined for the purpose of evaluating the clearance and loss from a reflection point to either site. This loss can be used in the Reflections module to modify the amplitude of the reflected signal.

The selected segment must be line of sight path to define a reflective plane. The steps below describe the definition of a reflective plane:

- Place the arrow at one end of the reflective plane and click the right mouse button or press the F1 key.

- Place the arrow at the opposite end of the reflective plane and click the right mouse button or press the F1 key again.

The reflective plane is determined from a least squares fit of the form $y = aC\,x + b$ over the defined range using the flat earth profile. The reflective plane is displayed for the current value of K and the location of the reflection point is marked. Effective antenna heights are determined by extending the reflective plane to the end points of the profile. The effective antenna heights are the heights of the antenna above the reflective plane end points. The following error messages may appear:

- The plane is non line of sight at the specified values of K and antenna heights. Select another value of K on the control bar.

- The plane elevation at Site 1 is higher than the antenna height.

- The plane elevation at Site 2 is higher than the antenna heigh.t

- The reflection point is outside the defined limits of the plane.

- The reflection point could not be located. The algorithm failed to locate the reflection point. This can occur if the reflection point is very close to one of the sites. Increase the antenna heights or change the reflective plane.

If the plane definition is not satisfactory, repeat the above steps. The new reflective plane will replace the existing one.

On over water paths or paths which are predominately flat, the selection of the end points of the reflective plane is obvious. On other paths, some judgement is required to define the reflective plane. The following guidelines can be used:

- Draw a 100% first Fresnel zone reference and note the extent of the terrain closest to this Fresnel zone reference.

- Place the arrow at the center of this extent and press the Ins key to display the terrain point data. Note the clearance to the first Fresnel zone ratio (C/F1).

- Using this value as a guide, draw additional Fresnel zone references until approximately 50% of the Fresnel zone reference is below the terrain.

- Define the end points of the reflective plane at the first and last intersections of the Fresnel zone reference with the terrain.

- Draw 100% first Fresnel zone references to the reflection point. Select To Ref Pt. from the Fresnel menu or press the CTRL F6 keys. The intersections of the Fresnel zone with the terrain represent the

area along the profile required to support a specular reflection. The end points of the reflective plane should encompass this area.

The Examples section of this manual includes an example of manual diffraction loss calculations and a comparison of the results of the various methods used to analyze the terrain profile.

CLUTTER

Select Operations - Clutter from the Diffraction menu to access the clutter data entry form. Clutter accounts for trees and buildings in the immediate vicinity of the site where it is impractical to enter these on the path profile. The analysis considers the depth of the trees / buildings along the path and the width across the path. All measurements are in feet or meters as determined by the program setting. Enter the values in accordance with the prompts. Note that the clutter loss can

Clutter type	Wet evergreen trees
Distance to clutter (ft)	50.00
Height above antenna (ft)	3.00
Depth on path (ft)	50.00
Width across path (ft)	100.00
Clutter loss (dB)	12.00
Height above antenna (ft) :	

be directly entered. Click OK to accept the clutter loss. This will be included as an additional loss in all diffraction loss reports.

To erase or remove a clutter calculation, select Operations - Erase Clutter from the Diffraction menu bar or hold down the Ctrl key and press F3.

VARIABLE PARAMETERS

Diffraction loss can be calculated as a function of antenna heights, earth radius factor and frequency. In microwave applications, this feature is used to determine the additional loss that will occur at the lowest value of the earth radius factor (K).

Select Variable from the Diffraction menu bar and then select the specific variable parameter.

Complete the required entries for the start and end values and the constant values. If the antenna configuration supports multiple antenna combinations, click the Antenna Combination button to select a specific combination.

All parameters used in variable calculations except polarization are local variables and do not change the corresponding values outside of this calculation.

Click the OK button to calculate and display the results.

Vary Earth Radius Factor (K)

Start Earth Radius Factor (K)	0.50
End Earth Radius Factor (K)	2.00
Site 1 Antenna Height (ft)	79.20
Site 2 Antenna Height (ft)	85.20
Frequency (MHz)	58882.50
Number of Points	50

Polarization
○ Vertical
○ Horizontal

TR - TR

Microwave Antenna Combination

OK   Cancel   Help

When the earth radius factor (K) is the variable parameter, the horizontal scale is formatted as arctangent(K). Several common K values are also displayed on the graph. The following examples illustrate the format:

K = 1   arctangent(K) = 45°

K = 4   arctangent(K) = 90°

K = 4/3   arctangent(K) = 53.1°
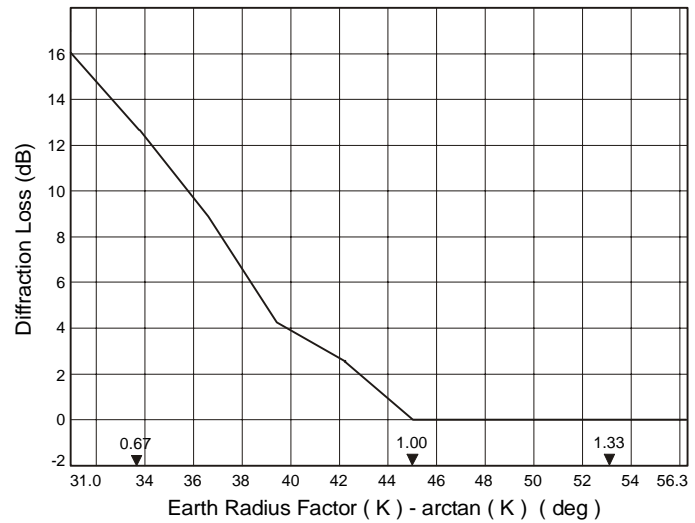
DIFFRACTION - TECHNICAL REFERENCE

TRANSHORIZON PATH GEOMETRY

Figure (1) shows the basic geometry of a transhorizon path. By convention, the transmit site is on the left and the receive site is on the right side of the display. The terminology is defined below and is used throughout this section.

h_{ts}	transmit antenna height above sea level
h_{rs}	receive antenna height above sea level
d_{lt}	distance from the transmit site to its horizon
h_{lt}	transmit horizon elevation above sea level
θ_{et}	transmit horizon elevation angle
d_{lr}	distance from the receive site to its horizon
h_{lr}	receive horizon elevation above sea level
θ_{er}	receive horizon elevation angle
d	great circle arc path length
θ	cross over angle of the horizon rays
d_1	distance from the transmit site to the cross over point of the horizon rays
d_2	distance from the receiver site to the cross over point of the horizon rays
ds	distance between the transmit and receive horizons
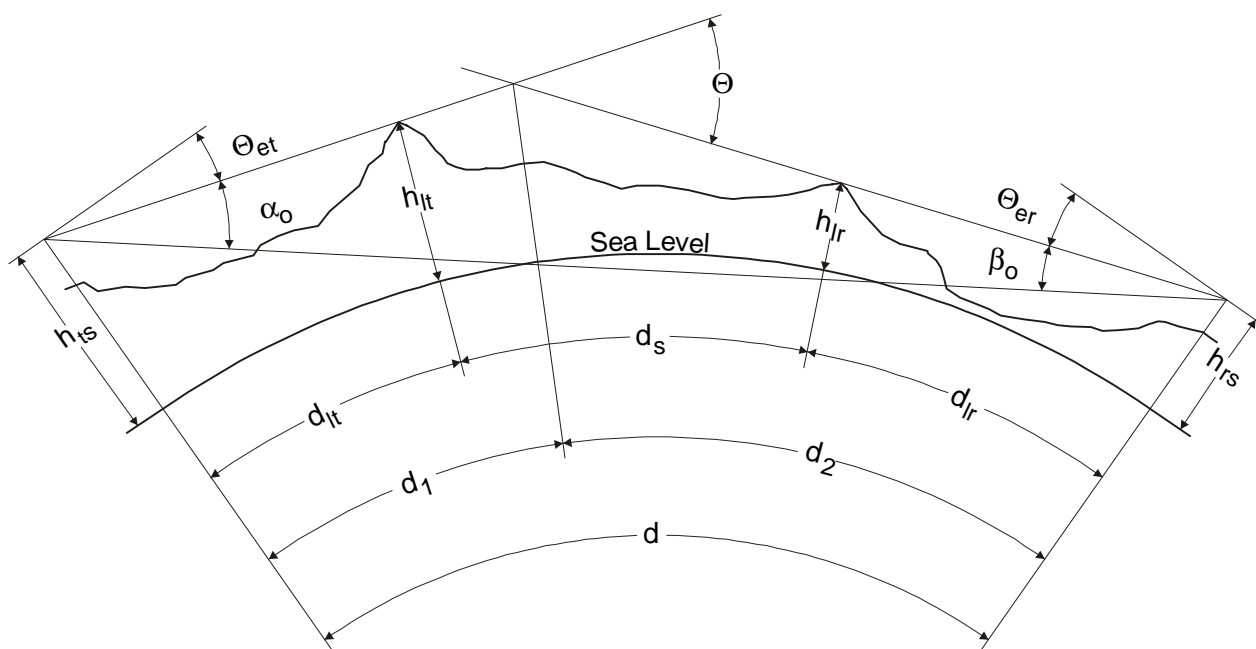
Figure 1: Transhorizon Path Geometry

The following formulas are taken from Reference (1). All distances and elevations are expressed in the same units. It is assumed that all angles are small and that $\tan(\Theta) \approx \Theta$. In the Pathloss program, all angles are calculated using the arctangent of the specific expressions.

Horizon Elevation Angles

The transmit and receive elevation angles, Θ_{et} and Θ_{er}, are calculated by:

$$\Theta_{et} = \frac{h_{lt} - h_{ts}}{d_{lt}} - \frac{d_{lt}}{2 \cdot a} radians \tag{1}$$

$$\Theta_{er} = \frac{h_{lr} - h_{rs}}{d_{lr}} - \frac{d_{lr}}{2 \cdot a} radians$$

In Equation (1), the effective earth radius a, is calculated as the actual earth radius (a_o = 6370 km) times the earth radius factor K ($a = KCa_o$). Alternately, a, can be expressed in terms of the surface refractivity, N_s, as:

$$a = \frac{a_o}{1 - 0.04665 \cdot e^{0.005577 \cdot N_s}} \tag{2}$$

The angles, α and β, are calculated as:

$$\alpha_o = \Theta_{et} + \frac{d}{2 \cdot a} + \frac{h_{ts} - h_{rs}}{d} \tag{3}$$

$$\beta_o = \Theta_{er} + \frac{d}{2 \cdot a} + \frac{h_{rs} - h_{ts}}{d}$$

Angular Distance

The angular distance, Θ, is the cross over angle of the horizon rays. This is sometimes referred to as the scatter angle and is always positive for a transhorizon path.

$$\Theta = \Theta_{et} + \Theta_{er} + \frac{d}{a} \tag{4}$$

Or

$$\Theta = \alpha_o + \beta_o$$

The distances, d_1 and d_2, from the cross over point of the horizon rays to the transmit and receive sites are given by:

$$d_1 = \frac{d \cdot \beta}{\Theta} \quad d_2 = \frac{d \cdot a}{\Theta} \tag{5}$$

Path Clearance

Path clearance, *C*, is defined in Figure (2). *C* is positive for line of sight paths and negative for an obstructed path. The normalized path clearance is expressed as the ratio of the clearance to the first Fresnel zone radius and is defined by:

$$\frac{C}{F1} = \frac{C}{17.3}\sqrt{\frac{f_{GHz} \cdot d}{d_1 \cdot d_2}} \qquad (6)$$

where *d*, d_1, and d_2 are defined in Figure (2) and are expressed in kilometers. The clearance *C*, is expressed in meters.

The parameter, *V*, is used as an alternate definition of path clearance and is defined by Equation (7) using the terminology in Figure (2).

Figure 2: Path Clearance

$$V = \sqrt{\frac{2 \cdot d \cdot tan(a_o) \cdot tan(\beta_o)}{\lambda}} \qquad (7)$$

λ	wavelength
d	path length
λ and *d*	are expressed in the same units

V is positive for obstructed paths and negative for line of sight paths. The two normalized clearance parameters are related by:

$$V = -\frac{C}{F1} \cdot \sqrt{2} \qquad (8)$$

Note that *V* is defined at the intersection of the horizon rays; and therefore, Equation (8) is true only if the transmit and receive horizons are located at the same point.

EFFECTIVE ANTENNA HEIGHTS

Two methods of calculating effective antenna heights on obstructed paths are used in the program. The Tirem and NSMA algorithms use the height above average terrain. The Pathloss algorithm uses a least squares fit.
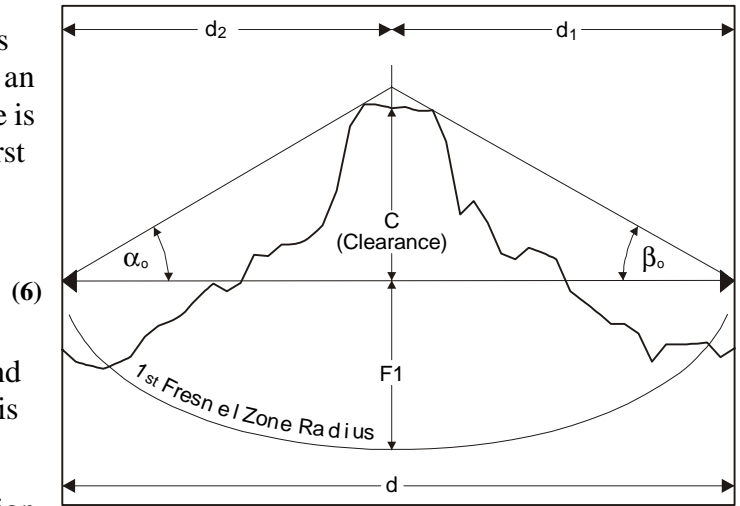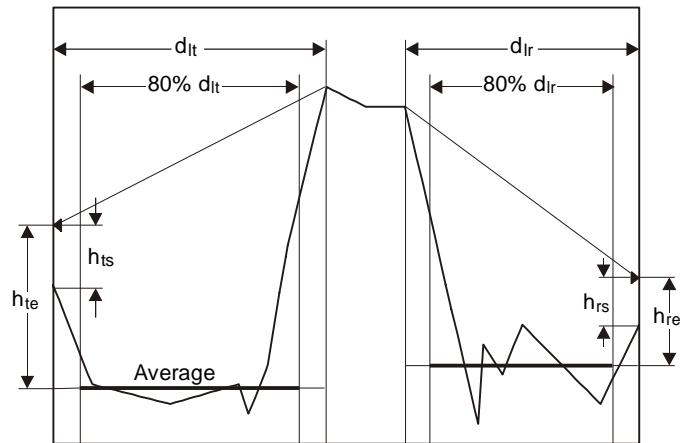
Figure 3: Effective Antenna Heights - Average

Height Above Average Terrain

The effective antenna heights, h_{te} and h_{re}, at the transmit and receive site are calculated as shown in Figure (3). The average elevation in the central 80% of the terrain between an antenna and its horizon is calculated.

The effective antenna height is defined as the height of the antenna above this average elevation.

Height Above Least Squares Fit

Construct a two term least squares fit to the central 80% portion of the terrain between an antenna and its horizon. Extend this least squares fit line to the sites. The effective antenna heights are defined in Figure (4). The terminology used in Figure (3) and Figure (4) is given below:
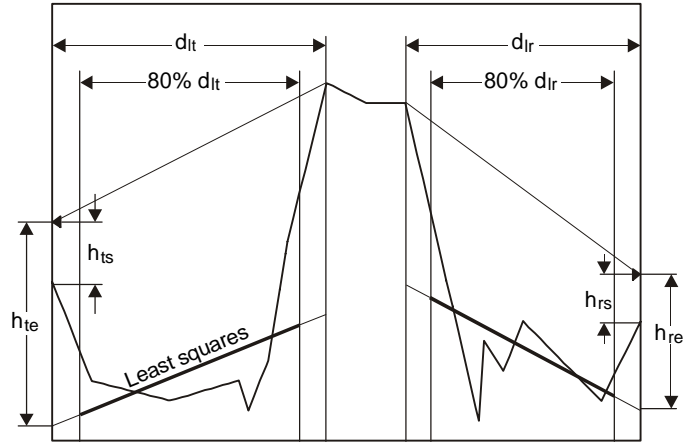
Figure 4: Effective Antenna Heights - LSQ

d_{lt}	distance to the transmitter horizon
d_{lr}	distance to the receiver horizon
h_{ts}	structural transmitter antenna height
h_{rs}	structural receiver antenna height
h_{te}	transmitter effective antenna height
h_{re}	receiver effective antenna height

The effective antenna heights cannot be less than the structural antenna heights.

SINGLE KNIFE EDGE DIFFRACTION LOSS (SKE)

The Fresnel-Kirchhoff knife edge diffraction loss, $A(v,\theta)$, is defined in Reference (1), and is given by:

$$
\begin{aligned}
A(v, \theta) &= 6.02 + 9.0v + 1.65 \cdot v^2 \\
&\quad for - 0.8 \leq v \leq \theta \\
A(v, \theta) &= 6.02 + 9.11 \cdot v - 1.27 \cdot v^2 \\
&\quad for\ \theta < v \leq 2.4 \\
A(v, \theta) &= 12.953 + 20 \cdot \log(v) \\
&\quad for\ v > 2.4
\end{aligned}
$$

(9)

Note that for values of v, less than -0.8, the knife edge diffraction loss is zero. The corresponding value of *C/F1* from Equation (8), is 56.57% of the first Fresnel zone radius. In practice, the value has been rounded to 60% and represents the minimum clearance criteria for free space loss conditions.

ISOLATED OBSTACLE DIFFRACTION LOSS (ISOL)

An ideal knife edge rarely occurs in practice. The isolated obstacle algorithm adds additional terms to the basic knife edge diffraction formula in Equation (9) to account for the finite radius of the obstruction. From Reference (1), the isolated obstacle diffraction loss is given by:

$$A(v, \rho) = A(v, \theta) + A(\theta, \rho) + U(v \cdot \rho)$$

$$A(\theta, \rho) = 6.02 + 5.556 \cdot \rho + 3.148 \cdot \rho^2 + 0.256 \cdot \rho^3$$

$$U(v \cdot \rho) = 11.45 \cdot v \cdot \rho + 2.19 \cdot (v \cdot \rho)^2 - 0.206 \cdot (v \cdot \rho)^3 - 6.02$$

for $v \cdot \rho \leq 3$

$$U(v \cdot \rho) = 13.47 \cdot v \cdot \rho + 1.058 \cdot (v \cdot \rho)^2 - 0.048 \cdot (v \cdot \rho)^3 - 6.02 \qquad \textbf{(10)}$$

for $3 < v \cdot \rho \leq 5$

$$U(v \cdot \rho) = 20 \cdot v \cdot \rho - 18.2$$

for $v \cdot \rho > 5$

$$\rho = 0.676 \cdot R^{\frac{1}{3}} \cdot f_{MHz}^{-\frac{1}{6}} \cdot \sqrt{\frac{d}{d_1 \cdot d_2}}$$

R radius of the obstacle in kilometers

Obstacle Radius

The radius of the obstacle is calculated by locating three points on the obstruction as shown in Figure (5). The central point is taken at the crossover of the horizon rays. The two adjacent points are determined by the slope of the terrain from the horizon points.

Far Field

The following condition is used to determine if an isolated obstacle is in the far field of the transmit and receive sites.
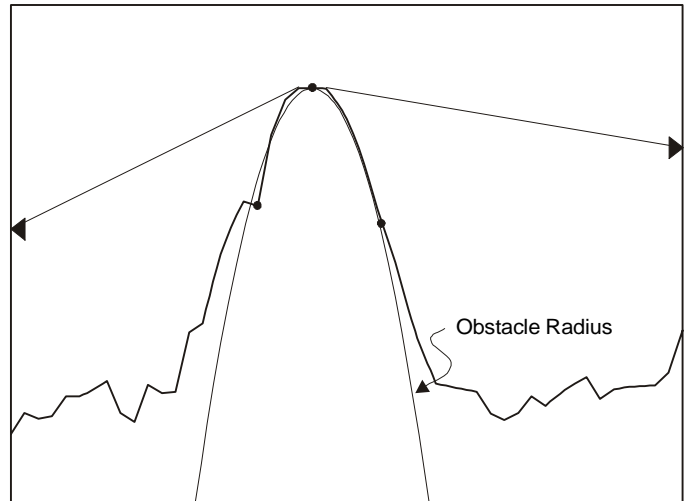
Obstacle Radius

Figure 5: Isolated Obstacle Radius

$$h \cdot \frac{2 \cdot \pi}{\lambda} \cdot \left(\frac{\lambda}{\pi \cdot R} \right)^{\frac{1}{3}} \ll 1 \qquad \text{(11)}$$

$$h = \sqrt{d_1^2 + R^2} - R$$

d_l is the transmitter or receiver horizon distance (d_{lt} or d_{lr})

MULTIPLE KNIFE EDGE DIFFRACTION LOSS (MKE, DKE)

An irregular terrain path can be analyzed as a series of knife edges. The total diffraction loss is taken as the sum of the individual knife edges. There are two methods of calculating multiple knife edge diffraction loss (MKE).

Epstein-Peterson

The Epstein-Peterson method is described in Reference (9). A double knife edge (DKE) example of this method is shown in Figure (6). The diffraction loss of each knife edge is calculated over the profile segment formed by the horizons of the knife edge. In Figure (6), the knife edge located at B, is calculated over the profile segment from A to C. The knife edge located at C, is calculated over the segment from B to D. There is no limit to the number of knife edges on the path

Figure 6: Double Knife Edge - Epstein-Peterson

using this method. Best results are obtained when the individual knife edges are widely separated.

Deygout

The Deygout method is described in Reference (8) and Reference (10) and is limited to a double knife path. An example of the Deygout method is shown in Figure (7). The parameter V, is first calculated for both of the knife edges located at B and C over the entire profile from A to D. The major obstacle is defined as the knife edge with the maximum value of V.

In Figure (7), the major knife edge located at C, is calculated over the complete profile from A to D. The second knife edge, located at B, is calculated over the profile segment A to C. Best accuracy is obtained when the knife edges are relatively close together.
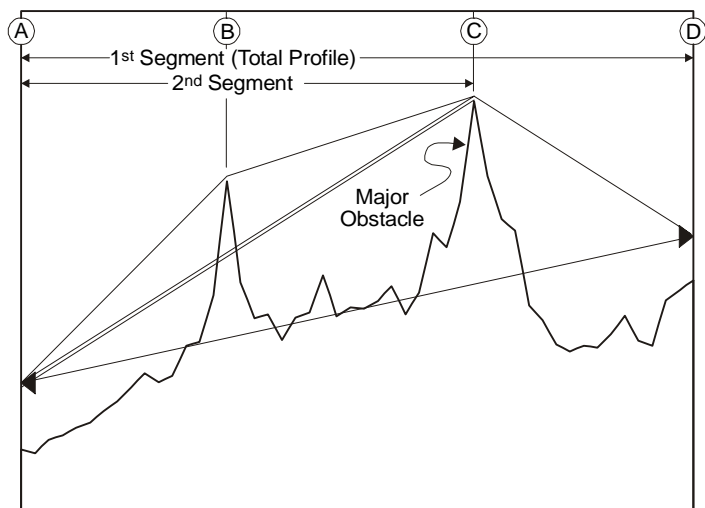
Figure 7: Double Knife Edge - Deygout

A discussion and comparison of the two methods is given in Reference (12).

EFFECTIVE KNIFE EDGE (EFFKE)

In the effective knife edge method, the diffraction loss of irregular terrain is calculated as a single knife edge located at the intersection of the horizon rays. The method is described in Reference (11) and shown in Figure (8).

Note that the definition of the parameter V, in Equation (7) and Figure (2), will inherently calculate the effective knife edge diffraction. Effective knife edge and single knife edge diffraction are equal if the transmit and receive horizons are located at the same point.
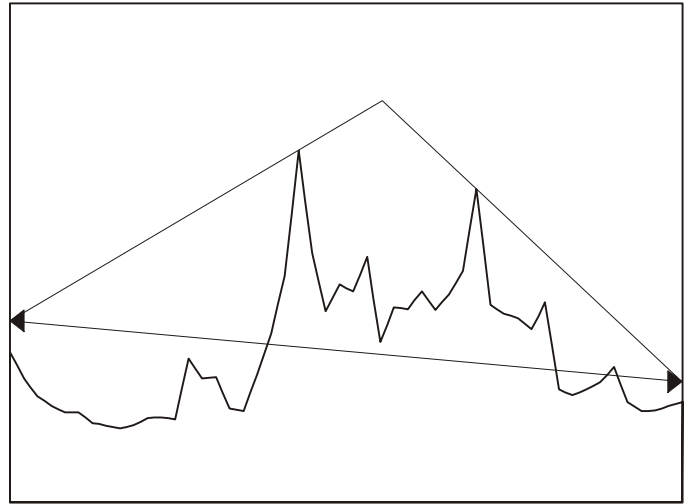
Figure 8: Effective Knife Edge

AVERAGE DIFFRACTION

The average diffraction algorithm represents the diffraction loss of a typical wooded hill and is based on Reference (7). Figure (9) shows the characteristics of the average diffraction curve in comparison to the limiting cases of knife edge and smooth earth diffraction. Average diffraction is dependant only on the ratio of clearance to the first Fresnel zone radius and uses a linear relationship between *C/F1* and diffraction loss defined by the following equation

$$A = 90 - 19.7 \cdot \left(\frac{C}{F1} + 4 \right) \qquad (12)$$

IRREGULAR TERRAIN (IRRT)

Reference (3) describes the irregular terrain prediction algorithm. It is outside the scope of this manual to provide a complete listing of all equations used in the algorithm. A basic description of the methodology is presented here.

Figure 9: Average Diffraction

Interdecile Terrain Elevation Range

This term is used to characterize the terrain roughness and is calculated as follows:

- create an array of the elevations at 60 uniformly spaced points along the terrain profile.

- sort the array in terms of increasing elevation.

- the interdecile terrain elevation range is then given by array[54] - array[6].

On line of sight paths, the interdecile terrain elevation range is calculated over the defined end points of the dominant reflective plane and all elevations are referenced to the reflective plane.

On non line of sight paths, the interdecile terrain elevation range is calculated over the entire profile.

Obstructed Paths

Diffraction loss for non line of sight paths is calculated by combining estimates of knife edge diffraction, A_k and diffraction over smooth terrain A_r.

The knife edge diffraction, A_k, is calculated considering the path to be a double knife edge using the Epstein - Peterson method.

The diffraction loss, A_d, is calculated as a weighted average of the two estimates A_k and A_r:

$$A_d = (1 - w) \cdot A_k + w \cdot A_r \tag{13}$$

where the weighting factor, w, is determined empirically as a function of frequency, path geometry and the interdecile terrain elevation range. For very rough terrain, A_d approaches the knife edge value, A_k. For smooth terrain, A_d approaches the smooth earth value, A_r.

Two values of diffraction loss, A_3 and A_4, are calculated at distances d_3 and d_4 in the far diffraction region. A straight line through these points, (A_3, d_3) and (A_4, d_4) is then defined by the intercept (A_{ed}) and slope (m) as follows :

$$m = \left(\frac{A_4 - A_3}{d_4 - d_3} \right) \frac{dB}{km} \tag{14}$$

$$A_{ed} = A_4 - m \cdot d_4$$

The diffraction loss, A_{cr}, at any distance d, which is greater than the smooth earth horizon distance, is given by:

$$A_{cr} = A_{ed} + m \cdot d \tag{15}$$

Line of Sight Paths

Distances d_0 and d_1 are chosen well within the horizon. Distance d_0 represents the greatest distance at which free space conditions apply. The distance d_1 is greater than d_0, but well within the range for which two ray optics formulas are valid. The diffraction loss, A_0 and A_1, at distances d_0 and d_1 is calculated using two ray optics.

The diffraction loss, A_{ls}, is calculated at the smooth earth horizon distance d_{ls} using the obstructed path method described above.

The three values of diffraction loss A_0, A_1 and A_{ls}, calculated at distances d_0, d_1 and d_{ls} respectively, are used to determine the slopes, k_1 and k_2, of a smooth curve of loss versus distance.

The attenuation A_{cr}, at any distance d less than d_{ls}, is then given by:

$$A_{cr} = A_o + k_1 \cdot (d - d_o) + k_2 \cdot log\left(\frac{d}{d_o}\right) \tag{16}$$

ROUGH EARTH DIFFRACTION (RED)

Rough earth diffraction is based on Reference (1) and Reference (4). The single effective earth radius is replaced with four different radii for the following regions of the path:

- transmit site to the transmit horizon
- transmit horizon to the cross over point of the horizon rays
- receive site to the receive horizon
- receive horizon to the cross over point of the horizon rays

The diffraction loss is calculated using smooth earth diffraction theory modified to accommodate the four different effective earth radii. A complete discussion of the algorithm is outside the scope of this manual.

HEIGHT GAIN TERMS

In the region between an antenna and its horizon, additional diffraction loss may occur due to lack of clearance. A clearance test must be made at the transmit and receive sites when using any of the knife edge diffraction algorithms. This includes single knife edge, multiple knife edge and effective knife edge diffraction models. One method of calculating this additional loss, is a sub set of the rough earth diffraction model described above. In this case, a smooth curve is fitted to the terrain between an antenna and its horizon and smooth earth diffraction is applied to this section of the profile. The term, height gain, is used to denote the resulting loss. The term is a misnomer as the result is always a loss.

TIREM ALGORITHM

Background

The TIREM (Terrain Integrated Rough Earth Model) algorithm was originally developed as part of the Master Propagation System by the Institute for Telecommunication Sciences (ITS), a Department of Commerce agency in Boulder, Colorado. The original version ran on a UNISYS 1100 and 2200 series main frame computer in batch mode. A second version, MPSII, was implemented on the PDP-11 series of minicomputers in an interactive mode. The Pathloss implementation of the TIREM algorithm is based on the MPSII version. The TIREM program is currently maintained by the Electromagnetic Compatibility Analysis Center (ECAC), a department of Defense Agency in Annapolis, Maryland. Certain revisions to the program have been made which are presented later in this section.

$$\theta_{min} = \frac{0.03}{(0.75 \cdot K \cdot f_{MHz})^{\frac{1}{3}}}$$

SKE	Single Knife Edge
MKE	Multiple Knife Edge
EFFKE	Effective Knife Edge
RED	Rough Earth Diffraction

HG 1/2	Height Gain Terms
A	Diffraction Loss
W	Weighting Function

Figure 10: TIREM Obstructed Path Model Selection

Obstructed Model

The path profile is analyzed as shown in Figure (10) to determine the appropriate propagation model.

The criteria for each model selection is given below:

- Single knife edge diffraction loss is calculated if the transmit and receive horizons are at the same point on the profile.

- Multiple knife edge diffraction loss using the Epstein-Peterson method is calculated if the conditions listed below are satisfied. There is no limit to the allowable number of knife edges

  - all of the horizon points correspond to the peaks of the knife edges

  - the clearance between knife edges must be at least 50% of the first Fresnel zone radius

- If the path is close to line of sight, as determined by Equation (17), then the path is calculated as an effective knife edge.

$$\theta < \frac{0.03}{(0.75 \cdot K \cdot f_{MHz})^{\frac{1}{3}}} \tag{17}$$

Θ cross over angle of the horizon rays

K earth radious factor

- If the distance between the transmit and receive horizons is greater than 2 miles, the rough earth diffraction loss algorithm is used.

- In all other cases, a weighted average of the effective knife edge diffraction and rough earth diffraction is calculated as shown below:

$$A_{dl = EFFKE + HG1/2}$$

$$A_{d2 = RED} \tag{18}$$

$$A = \left(1 - \frac{d_s}{2}\right) \cdot A_{dl} + \left(\frac{d_s}{2}\right) \cdot A_{d2}$$

The requirement for the height gain terms are determined by the minimum value of the clearance, C_{min}, between an antenna and its horizon as follows:

- If C_{min} is greater than 150% of the first Fresnel zone radius, the height gain term is not calculated.

- If the clearance is less than 50% of the first Fresnel zone radius, the height gain term is calculated.

- For clearances between 50% and 150% of the first Fresnel zone radius, the height gain term is calculated and weighted in accordance with the following equation:

$$HG_C = HG \cdot (1.5 - C_{min}) \tag{19}$$

Line of Sight Model

The path is first tested for clearance. If the clearance at each point on the profile is greater than 150% of the first Fresnel zone radius, then free space conditions apply and diffraction loss is not calculated.

At frequencies greater than 200 MHz, the empirical Longley - Reasoner formula of Reference (2) is used to calculate the diffraction loss as shown in Equation (20) below:

$$\Delta h = \frac{I_e}{1 - 0.8 \cdot e^{-0.03 \cdot d}}$$

$$A = 9 \cdot (1 + e^{-0.01 \cdot \Delta h}) - 3.5 log\left(\frac{h_{min}}{\lambda}\right) + 0.113 \cdot d \tag{20}$$

I_e	interdecile terrain elevation range
Δh	terrain roughness
h_{min}	is the smaller value of the transmit and receive effective antenna heights
d	path length

At frequencies less than 150 MHz, the line of sight irregular terrain model of Reference (3) is used to calculate the diffraction loss.

At frequencies between 150 and 200 MHz, a weighted average of the Longley-Reasoner and irregular terrain is used according to the following equation:

$$A = \frac{A_{d1} \cdot (200 - f_{MHz}) + A_{d2} \cdot (f_{MHz} - 150)}{50} \tag{21}$$

A_{d1}	Longley Reasoner diffraction loss
A_{d2}	irregular terrain diffraction loss

If the minimum path clearance, C/F1 is greater than 0.5, the diffraction loss value is weighted as follows:

$$A = A \cdot \left(1.5 - \frac{C}{F1}\right) \tag{22}$$

Note that the TIREM algorithm employs an extremely conservative clearance criteria on line of sight paths. The clearance to first Fresnel zone ratio must be greater than 1.5 to achieve free space loss conditions. Due to the empirical nature of the diffraction loss calculations, a path with a *C /F1* ratio of 0.6 will produce a diffraction loss.

ECAC Changes

The TIREM algorithm, as currently implemented by the Electromagnetic Compatibility Analysis Center is significantly different than the above description for obstructed paths. Diffraction loss is always calculated as a multiple knife edge using the Epstein Peterson method. If the obstructed portion of the path is over water, the loss is calculated as smooth earth diffraction.

This ECAC version is not specifically implemented in the Pathloss program; however, it can be simulated by the following switch settings in the Pathloss diffraction algorithm.

Multiple Knife Edge Method	Epstein-Peterson
Maximum Number of Obstacles	10
Include Obstacle Radius	No
Foreground Loss	Scaled Height Gain

NSMA ALGORITHM

The NSMA algorithm has been proposed by the US National Spectrum Managers Association as a reference diffraction loss calculation for interference analysis. The results provide conservative estimates of the diffraction loss. The algorithm is shown in Figure (11).
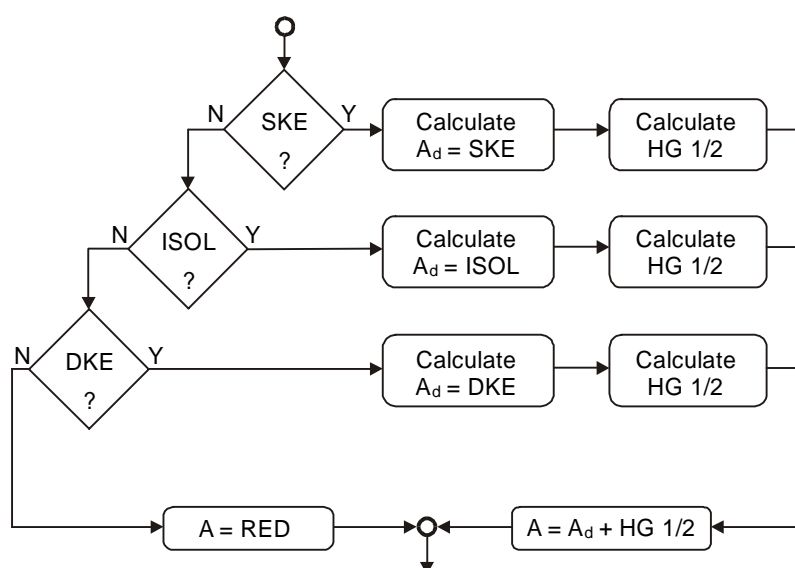
Figure 11: NSMA Diffraction Algorithm

The following criteria are used to select the diffraction loss method:

- The height gain term is calculated if more than 50% of the terrain between an antenna and its horizon has less than 100% first Fresnel zone clearance.

- Single knife edge diffraction is calculated if the transmit and receive horizons are located at the same point.

- Isolated obstacle diffraction loss is calculated if the distance between the transmit and receive horizons is less than 0.3 miles.

- Double knife edge diffraction loss is calculated, according to Epstein-Peterson, if a line of sight condition exists between the transmit and receive horizon points.

Line of Sight

The NSMA algorithm is intended for obstructed paths and does not contain recommendations for line of sight paths. In this implementation, the TIREM line of sight algorithm is used.

PATHLOSS ALGORITHM

The Pathloss algorithm is based on the premise that an ideal knife edge rarely occurs in practice. An obstacle always has a finite radius. A knife edge is simply the limiting case of an obstacle with zero radius. The TIREM and NSMA algorithms treat a path as an ideal knife edge whenever the transmit and receive horizons correspond to the same point on the profile. This criteria is very dependant on the specific points in the terrain profile.

Obstructed Path Algorithm

The basic algorithm is shown in Figure (12).

The following criteria are used for obstructed paths:

- If the path geometry consists of two horizon rays, single isolated obstacle diffraction loss is calculated provided that obstacle radius is less than 80% of the effective earth radius.

- If path geometry consists of three horizon rays, double isolated obstacle diffraction loss using the Deygout method is calculated, provided that each obstacle radius is less than 80% of the effective earth radius.

Figure 12: Pathloss Diffraction Algorithm

- If a radius calculation point is located at either the transmit or receive sites, foreground loss is not calculated. In this case, the obstacle of the radius is assumed to allow for the additional loss. Similarly, if the obstacle is in the near field of the transmitter or receiver site, as determined by Equation (11), the foreground loss is not calculated.

- In all other cases, the height gain algorithm is used to calculate the foreground loss.

Line of Sight Algorithm

If the clearance at each point is greater than 56.57% of the first Fresnel zone radius, the path is considered to be free space.

The intersections of the 56.57% first Fresnel zone reference and the terrain are first calculated. The path is analyzed as a series of isolated obstacles providing the following criteria are met:

- less than 60% of the path exceeds the Fresnel zone reference

- the number of obstacles does not exceed three

- the radius of any obstacle does not exceed 80% of the effective radius
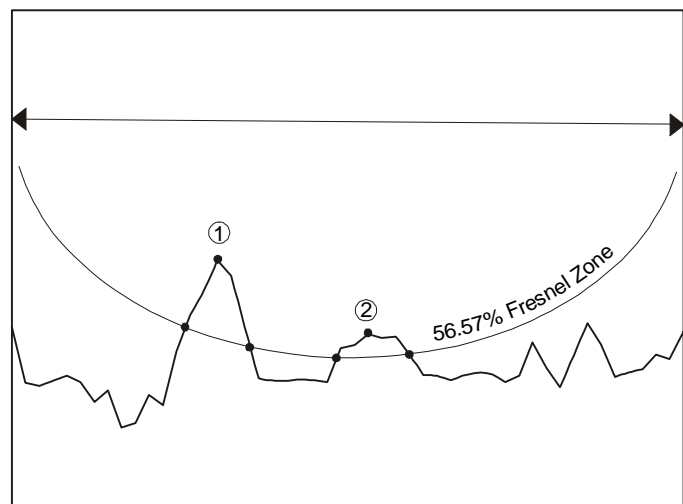
Figure 13: Isolated Obstacles - LOS

- Fresnel zone reference clearance exists at each site

The radius of each obstacle is calculated using the peak and the intersection with the Fresnel zone reference, as shown in Figure (13).

If the above criteria are not met the path is analyzed using the irregular terrain algorithm. A reflective plane is defined between the first and last intersections of the terrain with the Fresnel zone reference, as shown in Figure (14). A two term least squares fit is use to generate the plane. The transmit and receive effective antenna heights, h_{te} and h_{re}, are determined from this reflective plane.
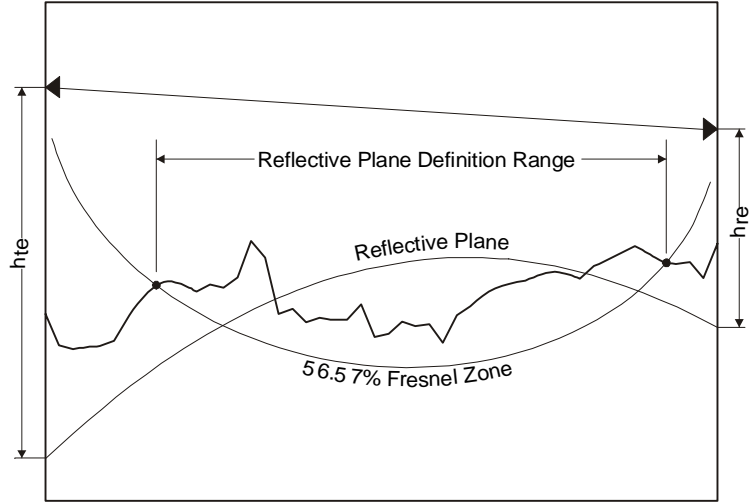
Figure 14: Irregular Terrain - LOS

TROPOSPHERIC SCATTER LOSS

Tropospheric scatter loss, L_{sr}, is based on Reference (5) and is given by:

$$L_{sr} = 30 \cdot log(f_{MHz}) - 20 \cdot log(d) + F(\theta \cdot d)$$
$$for\, N_S = 301$$
$$where$$
$$F(\theta \cdot d) = 135.82 + 0.33\,\theta d + 30 log(\theta d)$$
$$for\ 0.01 < \theta d < 10$$
$$F(\theta \cdot d) = 129.5 + 0.212 \cdot \theta D + 37.5 \cdot log(\theta \cdot d)$$
$$for\ 10 < \theta \cdot d < 70$$
$$F(\theta \cdot d) = 119.2 + 0.157 \cdot \theta \cdot D + 45 \cdot log(\theta \cdot d)$$
$$for\ \theta \cdot d > 70$$

$$F(\theta \cdot d, N_s) = F(\theta \cdot D) - \left[0.1 \cdot (N_s - 301)e^{\frac{-\theta \cdot d}{40}} \right]$$

(23)

N_s	surface refractivity
d	path length in kilometers
G_t	transmit antenna gain (dB)
G_r	receiver antenna gain (dB)

Note that Equation (23) represents the total transmission loss between the transmit and receive sites due to tropospheric scatter. In the Pathloss program, tropospheric scatter loss is expressed relative to the free space loss. As stated in Reference (6), Equation (23) has not been validated for frequencies above 4 GHz. Theoretical calculations suggest that at frequencies between 2000 and 6000 MHz, the frequency dependence of

tropospheric scatter loss will change from *30 log(f)* to *20 log(f)*. Accordingly, Equation (23) is modified as shown below.

$$L_s = 36 + 20 \cdot log(f_{MHz}) - 20 \cdot log(d) + F(\theta \cdot d) \qquad \text{(24)}$$

The transition frequency between Equation (23) and Equation (24) is 3981 MHz. The Pathloss program provides the following three options to calculate scatter loss:

> *30 log(f)*
>
> *36 + 20 log(f)*
>
> *30 log(f)*   for $f \leq 3981$ MHz
>
> or
>
> *36 + 20 log(f)*   for $f > 3981$ MHz.

CLUTTER

Clutter loss is defined as the loss produced by trees or buildings in the immediate foreground of an antenna and is calculated in accordance with Reference (13). Due to the proximity of these local obstructions to the antenna, it is not practical to enter these in the terrain profile. Instead, the clutter loss is calculated separately in the clutter module and added to the combined diffraction and tropospheric scatter loss.

Clutter loss is a function of the type of clutter and the following parameters:

d_c distance from the antenna to the clutter
hc height of the clutter above the antenna
d_p depth of the clutter along the path
w_c width of the clutter across the path

The clutter parameters are specified in feet or meters, depending on the measurement system selected. <u>Do not use miles or kilometers</u>.

Tree Clutter

Tree clutter is calculated as the minimum value of the following three propagation mechanisms:

- Attenuation through the trees

- Lateral wave propagation along the tree tops

- Knife edge diffraction over the tree tops

Each propagation mechanism is discussed in the following paragraphs using the metric system of measurements.

Attenuation Through Trees

The conductivity, σ, for various types of trees is given in Table 1

The attenuation through the trees, L_a, is given by:

$$\gamma = 1637 \cdot \sigma + 0.334 \cdot exp\left(-\frac{90}{f_{MHz}}\right) \cdot log \qquad (25)$$

for vertical polarization

$$\gamma = 1637 \cdot \sigma + 0.427 \cdot exp\left(-\frac{210}{f_{MHz}}\right) \cdot log \qquad (26)$$

for horizontal polarization

$$L_a = \gamma \cdot d_p \qquad (27)$$

For thin screens of trees, the depth of the trees along the path, d_p, is increased by the following factor:

$$EffectiveDepth = \sqrt{d_p^2 + (7 \cdot log(f_{MHz}))^2} \qquad (28)$$

Table 1: Constants

Tree Type	σ
Dry Bare Trees	7.0e-6
Dry Full Leaf Trees	1.0e-5
Dry Evergreen Trees	3.0e-5
Dry Rain Forest	2.0e-4
Wet Bare Trees	1.4e-6
Wet Full Leaf Trees	2.0e-5
Wet Evergreen Trees	6.0e-5
Wet Rain Forest	4.0e-4

Lateral Wave Along Tree Tops

The attenuation of a lateral wave travelling across the tree tops is given by:

$$if \; \sigma < 0.0002 \, dB_{lat} = 30$$

$$if \; \sigma < 0.00001 \, dB_{lat} = 12 \qquad (29)$$

$$otherwise \; dB_{lat} = 40$$

$$L_1 = 6 + (dB_{lat} - 6) \cdot \left(1 - e^{-\frac{h_c}{10}}\right)$$

Diffraction Over Tree Tops

The knife edge diffraction algorithm, described in the Diffraction Algorithms section of the manual, is used to calculate the diffraction over tree tops. The parameter *V*, is calculated as follows:

$$V = 0.082 \sqrt{\frac{h_c^2 \cdot f_{MHz}}{d_c}} \qquad (30)$$

Building Clutter

Building clutter is calculated as the minimum value of the following three propagation mechanisms:

- Attenuation through the building

- Building multipath propagation loss

- Knife edge diffraction over the top of the building

Attenuation Through Buildings

The attenuation through a 15 meter thick building for various types of construction is given in the following table.

Building attenuation, L_a, as a function of the depth of buildings along the path, d_p, is given by:

$$L_a = \frac{d_p \cdot E_m}{15} \qquad (31)$$

Table 2: Building Attenuation

Building Type	Attenuation E_m
Wood Buildings	15 dB
Brick Buildings	30 dB
Concrete Buildings	30 dB
Metal Buildings	45 dB

Building Multipath Propagation Loss

The multipath transmission loss due to buildings, L_m, is given by

$$L_m = 20 \cdot log(f_{MHz}) \qquad (32)$$

Diffraction Over the Top of Buildings

Diffraction over the top of buildings is calculated in the same manner as trees.

Diffraction Around Buildings and Trees

Due to the finite width of the clutter across the path, energy will be transmitted around the trees and buildings. The reduction in loss due to this propagation mechanism is given by:

$$L_1 = L \cdot \left(1 - e^{-\frac{2 \cdot w_c}{d_c}} \right) \qquad (33)$$

TREE - BUILDING LOSS ON TERRAIN PROFILES

This section describes the methods used to calculate the additional loss due to trees or buildings when these structures have been entered into the path profile. An automatic structure loss calculation is carried out if the Pathloss, TIREM or NSMA diffraction algorithm has been selected. Additionally, it is possible to calculate the loss of an individual tree or building.

Tree Loss

Tree loss is calculated as the minimum of the following components:

- Knife edge diffraction loss measured at the top of the tree minus the knife edge diffraction loss measured at the base of the tree. In other words, only the contribution of the tree is considered.

- The loss of a lateral wave traveling along the tree tops.

Building Loss

Building loss is calculated as the minimum of the following components:

- Knife edge diffraction calculated in the same manner as tree loss.

- Building multipath propagation loss.

The reduction in loss due to the transmission of energy around the trees or buildings is not included. There is no provision to specify the width of the structure across the path.

The transmission loss through the structure is not considered. There is no provision to specify the depth of the trees or buildings along the path.

Line of Sight Paths

On line of sight paths, the loss of each structure is separately calculated as described above. The tree /building loss is taken to be the maximum value of the individual calculations.

In Figure (15), five trees have been entered into the path profile. All of the trees extend into the 56.57 first Fresnel zone reference. The loss of each tree is calculated. The path tree loss will be assigned the maximum of the five individual losses.
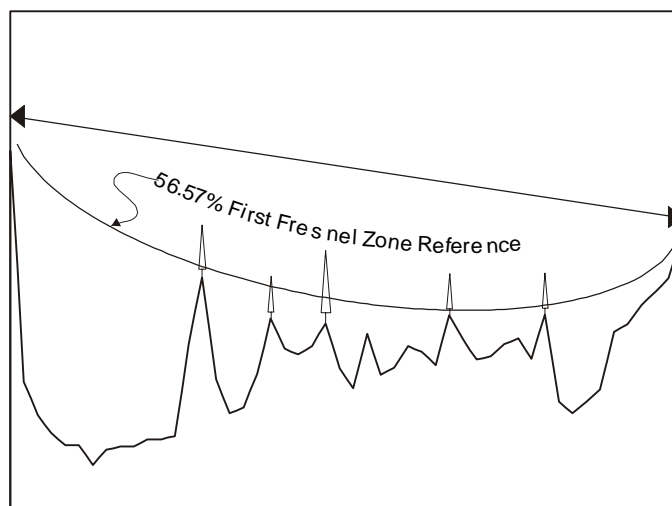
Figure 15: Tree Loss - Line of Sight Paths

Obstructed Paths

The structure loss calculation on obstructed paths treats the path as a multiple knife edge path using the Epstein-Peterson convention. On each segment of the profile, the knife edge loss is calculated at the top of the structure and the bottom. The structure loss is the difference of the two values. The structure loss is summed over the profile in this manner.

In the region of an antenna to its horizon, the structure loss is calculated using the line of sight method described above and added to the obstructed values.

A double knife edge path with trees on the major peaks is shown in Figure (16). The tree loss at B is calculated over the first segment of the profile from A to C. The tree loss at C is calculated over the second segment from B to D. The tree loss between C and D is calculated over the line of sight segment from C to D. The total loss is the sum of the individual tree loss calculations.
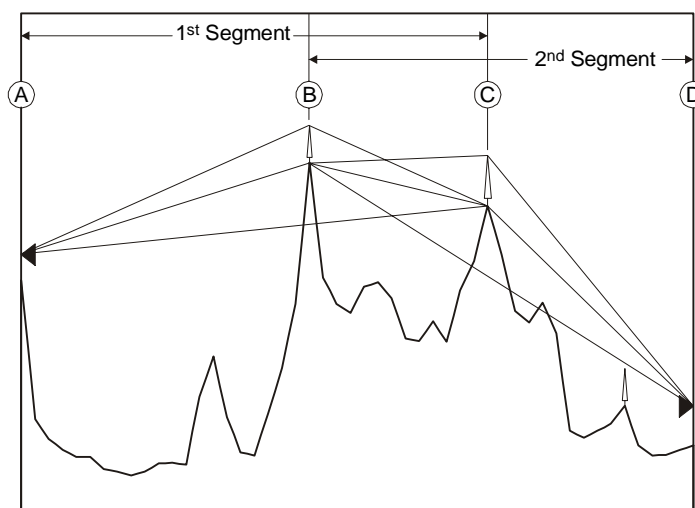
Figure 16: Tree Loss - Obstructed Paths

Entering Structures on the Terrain Profile

The structure loss algorithm will prevent excessive losses due to the indiscriminate entry of trees, in most cases. Several points to consider for tree /building entry are given below:

- Enter a single structure on the major peaks of the path profile. Entering more than one serves no purpose.

- On line of sight paths, several trees or buildings may be entered. The loss is always calculated as the maximum loss of all of the individual structure losses.

Manual Structure Loss Calculation

Provision is made to calculate the loss of individual structures in the Diffraction module. This feature is only enabled for the manual diffraction algorithms.
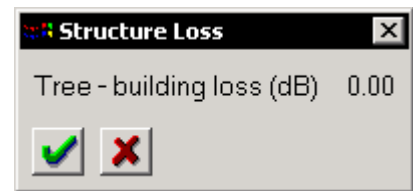
Position the arrow on the tree or building. Hold down the Ctrl key and press the F9 key (^F9). Click OK to incorporate the calculated loss into the overall diffraction loss. Note that the structure loss will be calculated using the clearance to first Fresnel zone ratio established by the currently selected profile segment i.e the ends of the display.

OHLOSS (OVER THE HORIZON LOSS)

Transhorizon Path Loss Components

Figure (17) shows the components of a transhorizon path loss calculation. The diffraction and tropospheric scatter loss are combined and adjusted for regional geographic effects to produce a median value of the transhorizon path loss.

The time variability is calculated as the cumulative probability distribution of loss as a function of time, using 50% and 95% confidence factors.

Options are provided for both interference and transmission applications. The probability distributions are not the same for the two cases. In the interference case, the minimum value of the path loss is given as a function of time. In the transmission case, the maximum value is calculated.

The total loss is calculated as the sum of the median loss, free space loss, atmospheric absorption loss and clutter loss, (if separately calculated).
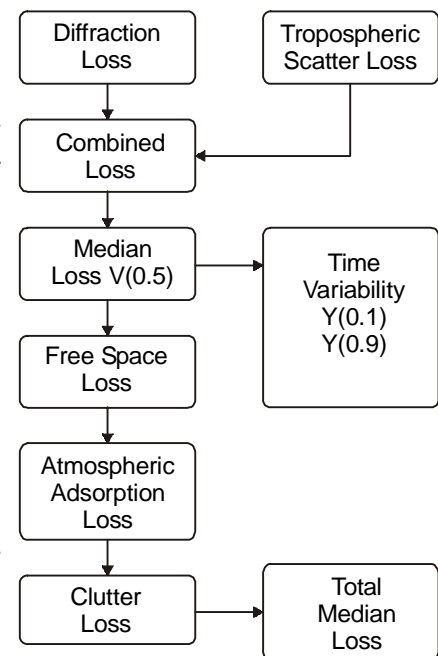
Figure 17: Transhorizon Path Loss

OHLOSS Report Terminology

Loss Summary
The OHLOSS report loss summary below represents the components shown in Figure (17).

Diffraction loss (dB)	34.75
Tree - building loss (dB)	0.00
Troposcatter loss (dB)	41.65
Combined loss (dB)	33.94
Median loss (dB)	33.51
Free Space loss (dB)	119.21
Atmospheric Absorption loss (dB)	0.14
Clutter Loss (dB)	Note (1)
Total loss (dB)	152.85

Note (1) Clutter loss must be separately calculated to be included in the OHLOSS report.

Cumulative Loss Distribution

This section of the OHLOSS report presents a cumulative probability distribution of the combined median loss for both interference and transmission applications as shown below. The values of loss in the column P=0.5, represents the median or average value of the expected loss as a function of time. The values in the column (P=0.95) are adjusted for a 95% confidence level. The 50% values for P=0.5 are the same for both interference and transmission applications.

Median Loss Time Variability

Time (%)	Minimum Loss		Maximum Loss	
	(P=50%)	(P=95%)	(P=50%)	(P=95%)
50.0000	33.51	27.66	33.51	39.36
80.0000	30.45	24.34	36.14	42.18
90.0000	28.85	22.42	37.26	43.49
99.0000	24.19	16.29	40.34	47.37
99.9000	20.78	11.48	42.56	50.35
99.9900	17.99	7.40	44.40	52.92
99.9950	17.43	6.58		
99.9975	16.68	5.47		

All loss values are artificially limited to -6.0 dB in interference applications. No limits are imposed on the values of loss in the transmission option.

Terrain Profile Listing

The OHLOSS report includes an optional listing of the terrain profile. The following terminology is used:

DIST   The cumulative path distance measured from Site 1.

GND   The ground elevation corresponding to DIST measured above mean sea level.

OBST   The height of any obstruction (tree or building) measured above ground level.

CLR   The absolute clearance measured from the top of an obstruction to the line between anten-
            nas. The effects of the earth radius factor (K) are included in the clearance.

Path Characteristics

The following conditions are tested and printed if true:

- Path is line of sight (LOS) for flat earth.

- Path has a common horizon.

- Path has separate horizons.

- Path is blocked between horizons.

- Path is blocked by ___ obstacle(s).

Combined Loss

Diffraction and tropospheric scatter are treated as two independent transmission mechanisms. Tropospheric scatter loss represents the limiting value of the transmission loss. The combined loss, L_c, is calculated as:

$$L_c = 10 \cdot log \left[10^{\left(-\frac{L_d}{10}\right)} + 10^{-\frac{L_s}{10}} \right] \tag{34}$$

L_d calculated diffraction loss
L_s calculated tropospheric scatter loss

Median Transmission Loss

The median transmission loss, $L_n(0.5)$, is obtained by applying a climatic adjustment factor to the basic combined loss. The climatic adjustment factor is defined as:

$$L_n(0.5) = L_c - V_n(0.5, d_e) \tag{35}$$

n denotes a particular climatic region.
d_e effective distance

The effective distance is given by:

$$d_{sl} = 65 \cdot \left(\frac{100}{f_{MHz}}\right)^{\frac{1}{3}}$$

$$d_L = 3\sqrt{2 \cdot h_{te}} + 3\sqrt{2 \cdot h_{re}}$$

$$for\ d \le d_L + d_{sl} \tag{36}$$

$$d_e = 130 \cdot \frac{d}{d_L + d_{sl}}$$

$$for\ d > d_L + d_{sl}$$

$$d_e = 130 + d - (d_L + d_{sl})$$

h_{te} transmit effective antenna height in meters
h_{re} receive effective antenna height in meters
d path length in kilometers

$V_n(0.5)$ is given by the following general analytic expression. The constants to evaluate V_n are given in
Table 3.

$$\begin{pmatrix} V(0.5) \\ Y(0.1) \\ Y(0.9) \end{pmatrix} = [c_1 \cdot d_e^{n_1} - f_2(d_e)] e^{-(c_3 \cdot d_e^{n_3})} + f_2(d_e) \tag{37}$$

$$f_2(d_e) = f_\infty + (f_m - f_\infty) \cdot e^{-(c_2 \cdot d_e^{n_2})}$$

Time Variability Factors
The time variability factor is defined as:

$$L_n(q) = L_n(0.5) - Y_n(q, d_e) \tag{38}$$

n denotes a particular climatic region
q percent of time that the predicted loss will be different than the median transmission loss

The procedure used in Pathloss Version 3.0, calculated the time variability factor using the general analytic
expression given in Equation (37). In interference calculations, *Y(0.1)* was calculated using the constants

in Table 4. This results in the value of transmission loss which will be exceeded for 90% of the time. Values for other time percentages were determined by the following multipliers:

50.0000 $L_n(0.5)$

80.0000 $L_n(0.5) - 0.6567 \cdot Y(0.1)$

90.0000 $L_n(0.5) - Y(0.1)$

99.0000 $L_n(0.5) - 2.0 \cdot Y(0.1)$

90.9000 $L_n(0.5) - 2.73 \cdot Y(0.1)$

99.9900 $L_n(0.5) - 3.33 \cdot Y(0.1)$

99.9950 $L_n(0.5) - 3.45 \cdot Y(0.1)$

99.9975 $L_n(0.5) - 3.61 \cdot Y(0.1)$

In transmission applications, the parameters in Table 5 were used to calculate $Y(0.9)$. This represents the value of transmission loss that will be exceeded for 10% of the time. Values for other time percentages were determined by the following multipliers:

50.0000 $L_n(0.5)$

20.0000 $L_n(0.5) + 0.7 \cdot Y(0.9)$

10.0000 $L_n(0.5) + Y(0.9)$

01.0000 $L_n(0.5) + 1.82 \cdot Y(0.9)$

00.1000 $L_n(0.5) + 2.41 \cdot Y(0.9)$

00.0100 $L_n(0.5) + 2.9 \cdot Y(0.9)$

This approach produced a reasonable approximation of the curves in Technical Note 101 for the 0.1 and 0.9 time percentages. For other time percentages, the above scaling factors only produced good agreement with the Continental Temperate climatic region. In Version 4.0, all of the time variability curves in Technical Note 101 have been digitized. The value at any time percentage is determined by interpolating the specific curves.

95 Percent Confidence Factor Adjustment

The adjustment for a 95 percent confidence level is given by:

$$L_n(q) \pm 1.64\sqrt{12.73 + 0.12Y^2(q)} \tag{39}$$

The adjustment is negative for the interference elimination option and positive for the transmission option.

Table 3: $V_n(0.5)$ Evaluation Constants

Region	C_1	C_2	C_3	n_1	n_2	n_3	f_m	f_∞
Continental Temperate	1.59e-05	1.56e-11	2.77e-08	2.32	4.08	3.25	3.90	0.00
Maritime Temperate Overland	1.12e-04	1.26e-20	1.17e-11	1.68	7.30	4.41	1.70	0.00
Maritime Temperate Overseas	1.18e-04	3.33e-13	3.82e-09	2.06	4.60	3.75	7.00	3.20
Maritime Subtropical Overland	1.09e-04	5.89e-18	2.21e-07	2.06	6.81	2.97	5.80	2.20
Desert (Sarhara)**	8.85e-07	2.76e-14	2.25e-12	2.80	4.82	4.78	8.40	8.20
Equatorial	3.45e-07	3.74e-12	6.97e-08	2.97	4.43	3.14	1.20	-8.40

** The constants shown for the Desert (Sahara) climatic region calculate the value for $-V_n(0.5)$

Table 4: $Y(0.1)$ Evaluation Constants

Region	C_1	C_2	C_3	n_1	n_2	n_3	f_m	f_∞
Continental Temperate	3.56e-02	9.85e-08	1.50e-11	1.13	2.80	4.85	10.50	5.40
Maritime Temperate Overland	6-28e-04	3.19e-08	6.06e-12	1.92	2.96	5.05	13.00	12.50
Maritime Temperate Overseas	182e-02	2.40e+00	6.92e-15	1.29	0.00	5.78	19.00	14.00
Maritime Subtropical Overland	4.33e-02	7.13e-11	1.19e-12	1.09	3.89	4.93	17.50	13.60
Desert (Sahara)	6.09e-02	1.36e-05	3.18e-11	1.08	1.84	4.60	15.10	6.00
Equatorial	5.22e-03	1.57e-04	5.22e-17	1.39	1.46	6.78	8.50	3.20
Continental Subtropical	1.01e-02	2.26e-07	3.90e-09	1.46	2.67	3.78	16.00	9.10

Table 5: Y(0.9) Evaluation Constants

Region	C_1	C_2	C_3	n_1	n_2	n_3	f_m	f_∞
Continental Temperate	9.48e-03	5.70e-11	5.56e-06	1.33	3.96	2.44	8.20	3.00
Maritime Temperate Overland	1.29e-04	1.93e-15	2.81e-04	2.14	5.80	1.65	10.00	4.50
Maritime Temperate Overseas	1.25e-03	6.57e-16	1.49e-09	1.72	5.96	3.84	12.00	4.00
Maritime Sub-tropical Overland	7.24e-03	4.26e-15	1.12e-06	1.35	5.41	2.56	12.70	8.40
Desert (Sahara)	3.19e-02	5.66e-08	7.39e-11	1.14	2.76	4.40	11.40	3.30
Equatorial	6.51e-03	2.53e-04	2.61e-16	1.36	1.36	6.55	8.40	2.70
Continental Subtropical	3.49e-03	1.08e-09	9.15e-11	1.55	3.49	4.48	10.10	3.50

Time Variability Curves

The remainder of this section contains the time variability curves actually used in the program. These have been digitized from Technical Note 101 and form the basis of all time variability calculations.

The upper set of curves (0.1 to 0.0001) represents the up fade probability and are used in the interference calculations.

The lower set of curves (0.9 to 0.9999) represents the down fade probability and are used in transmission applications.
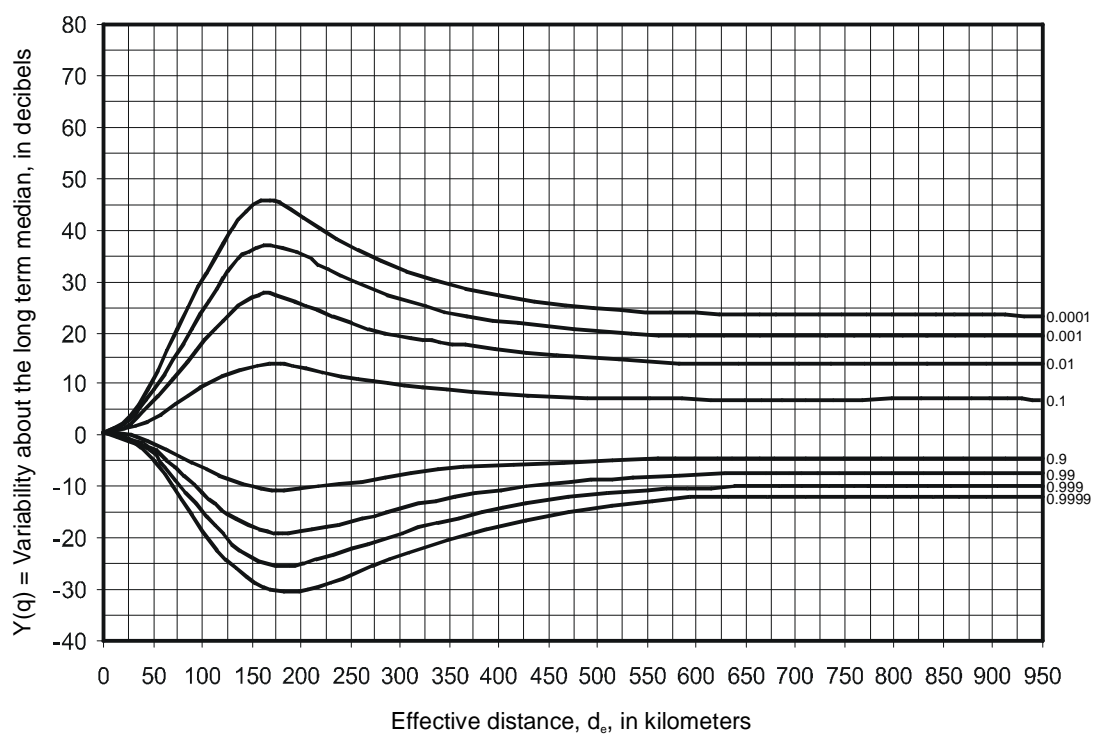
Figure 18: Continental Temperate Climate 88 - 108 MHz
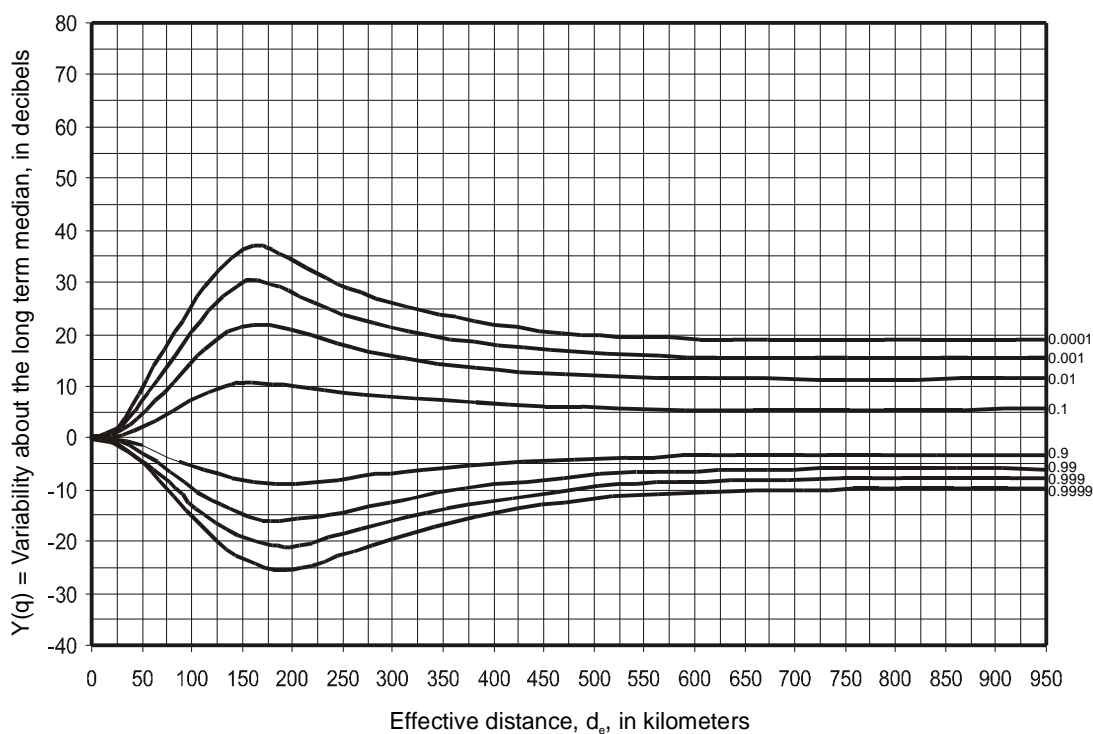
Figure 19: Continental Temperate Climate 40 - 88 MHz
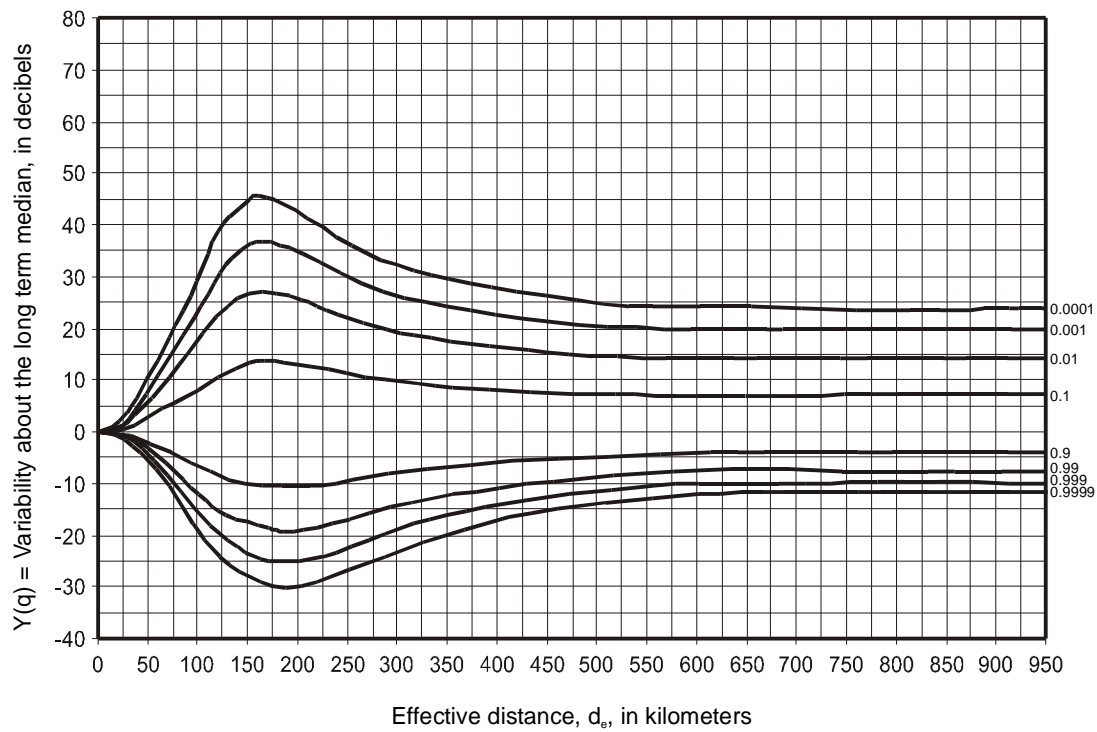
Figure 20: Continental Temperate Climate 108 - 250 MHz
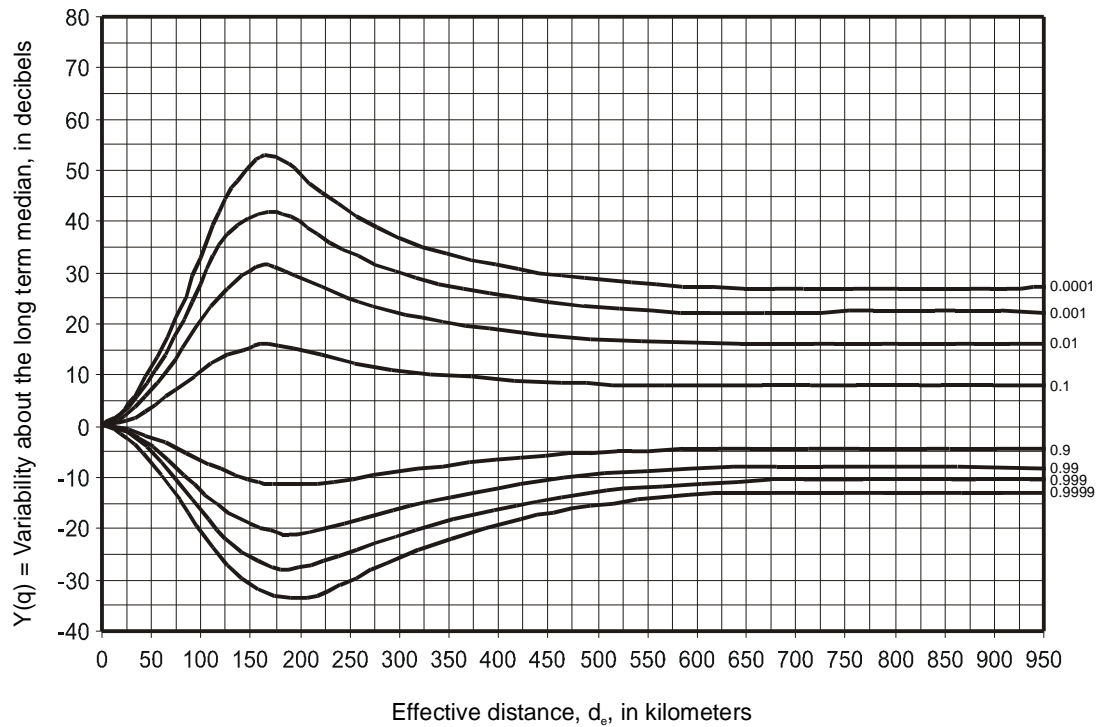
Figure 21: Continental Temperate Climate 250 - 450 MHz
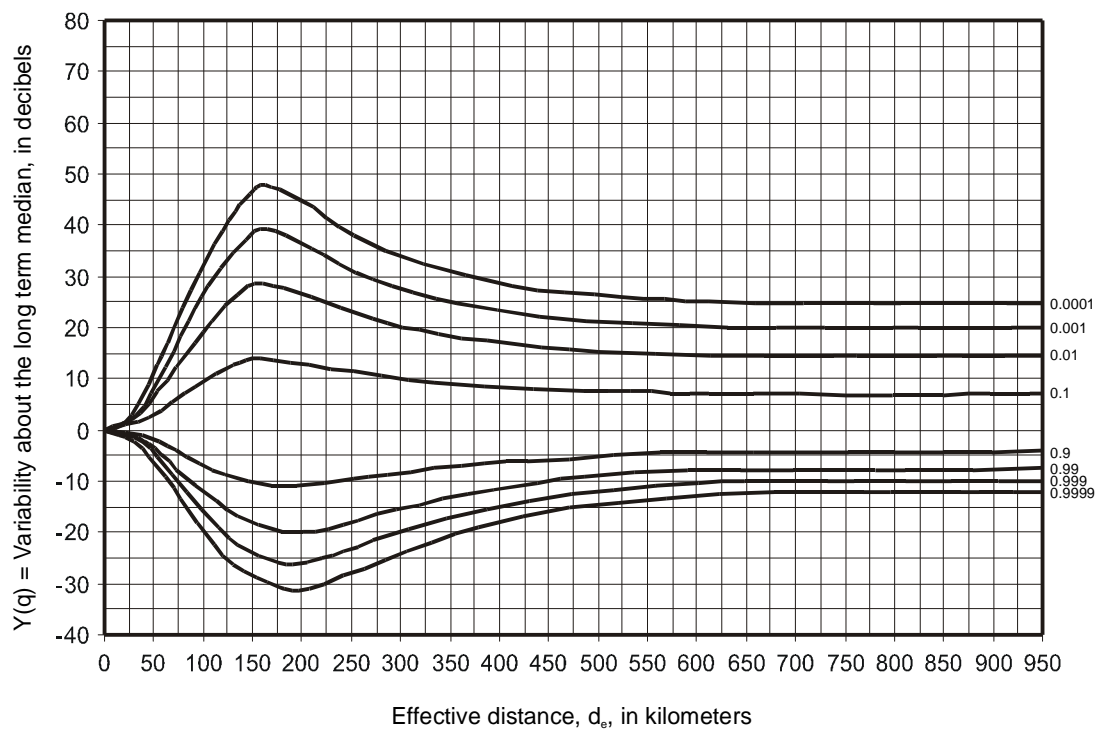
Figure 22: Continental Temperate Climate 450 - 1000 MHz
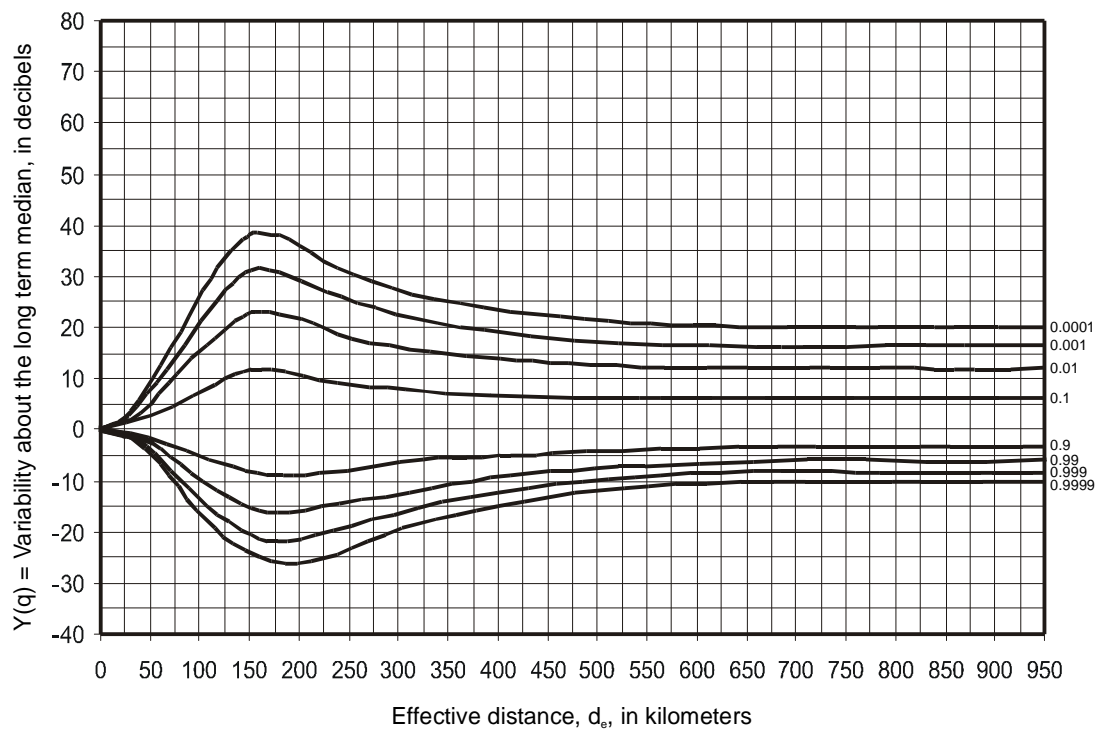
Figure 23: Continental Temperate Climate > 1000 MHz
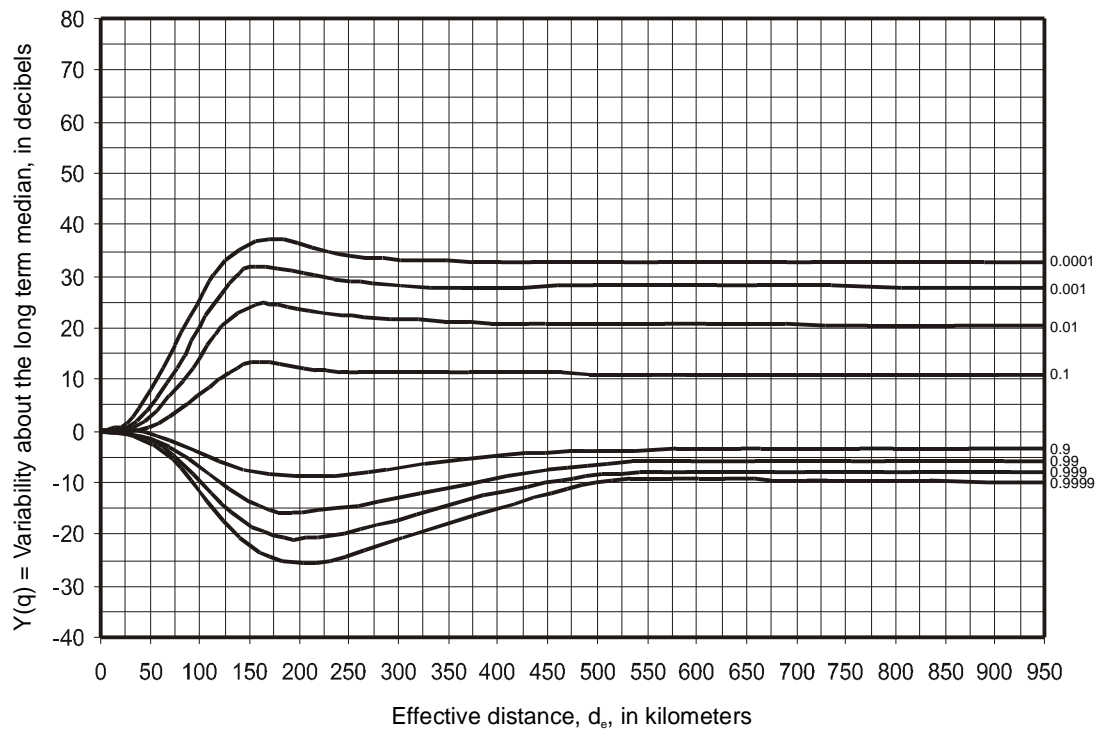
Figure 24: Maritime Temperate Climate Overland 40 - 100 MHz
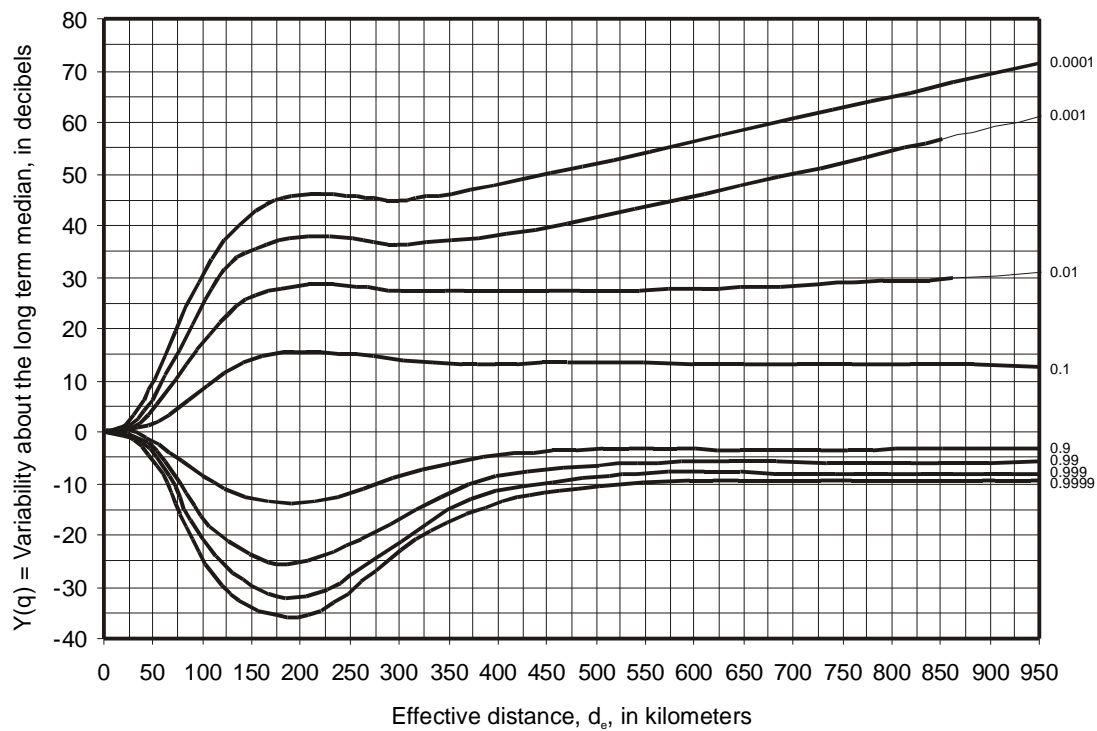
Figure 25: Maritime Temperate Climate Oversea 40 - 100 MHz
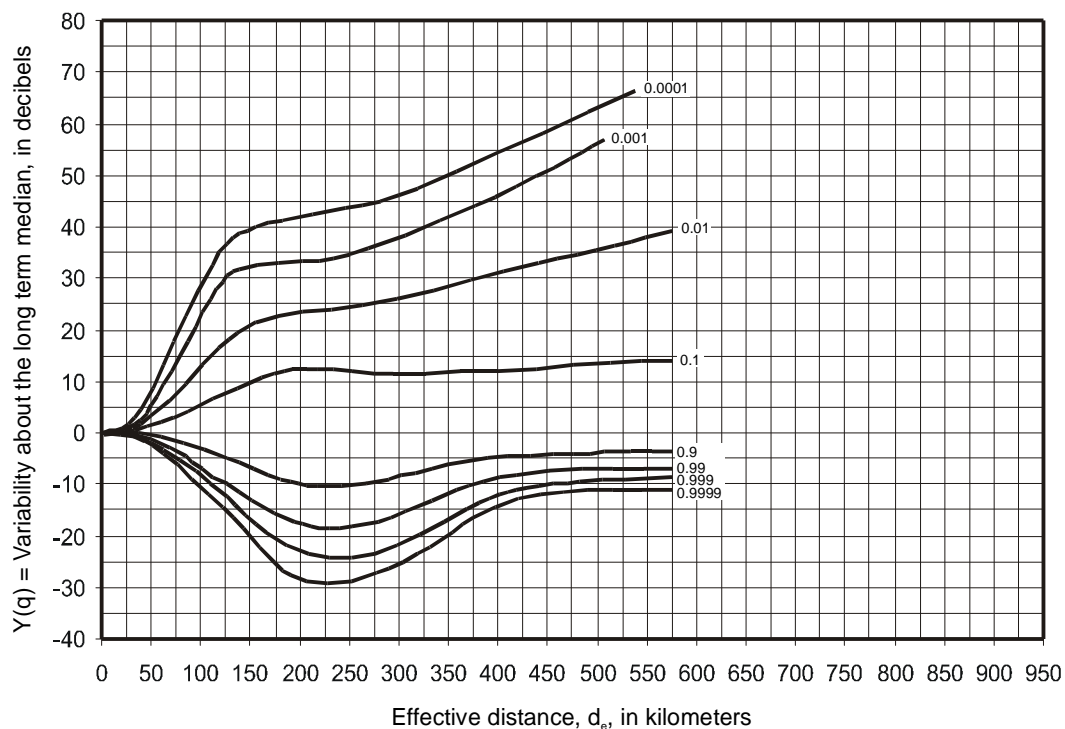
Figure 26: Maritime Temperate Climate Overland 150 - 250 MHz
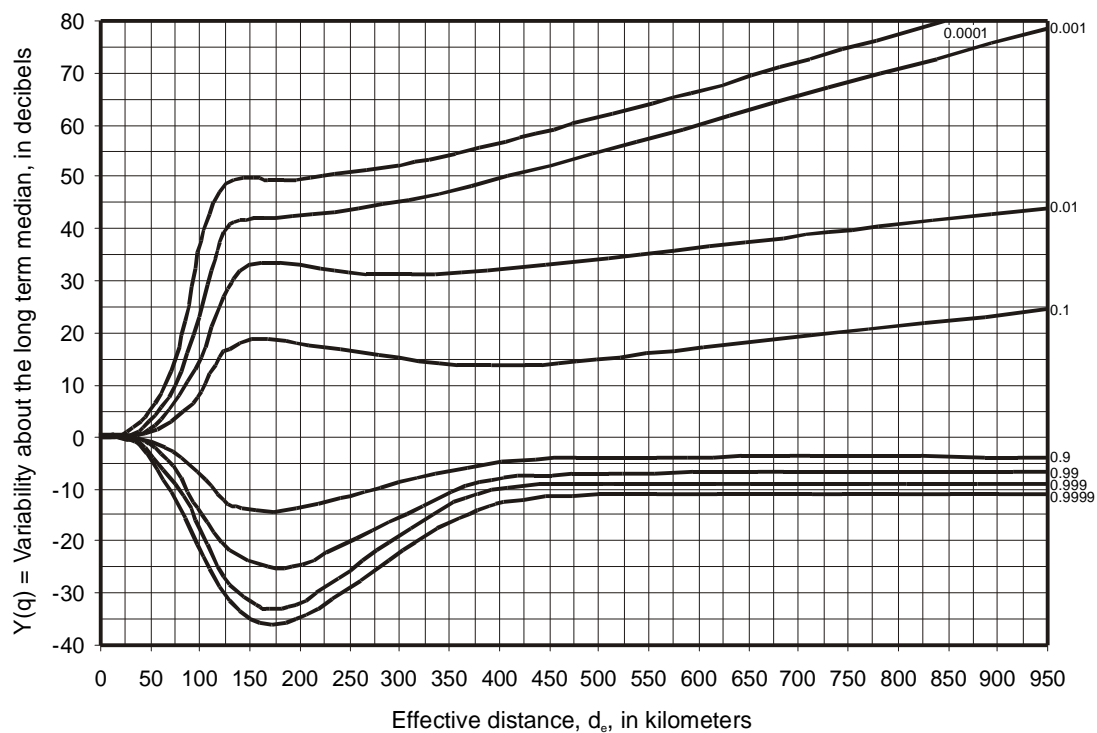
Figure 27: Maritime Temperate Climate Oversea 150 - 250 MHz
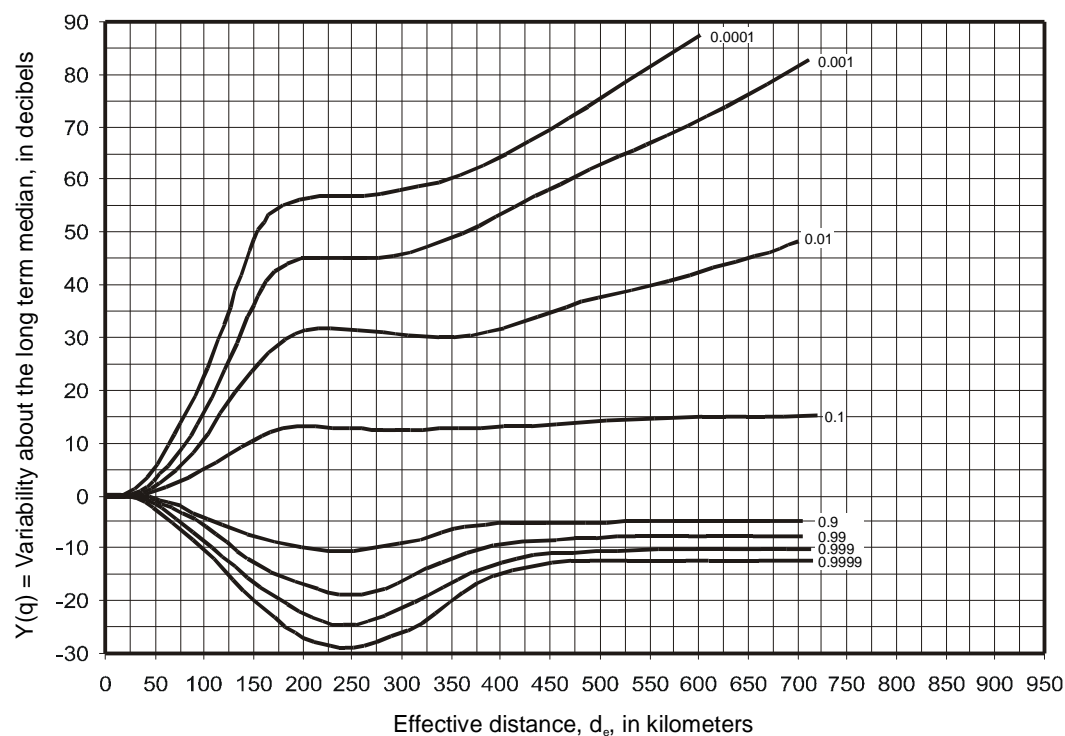
Figure 28: Maritime Temperate Climate Overland 450 - 1000 MHz
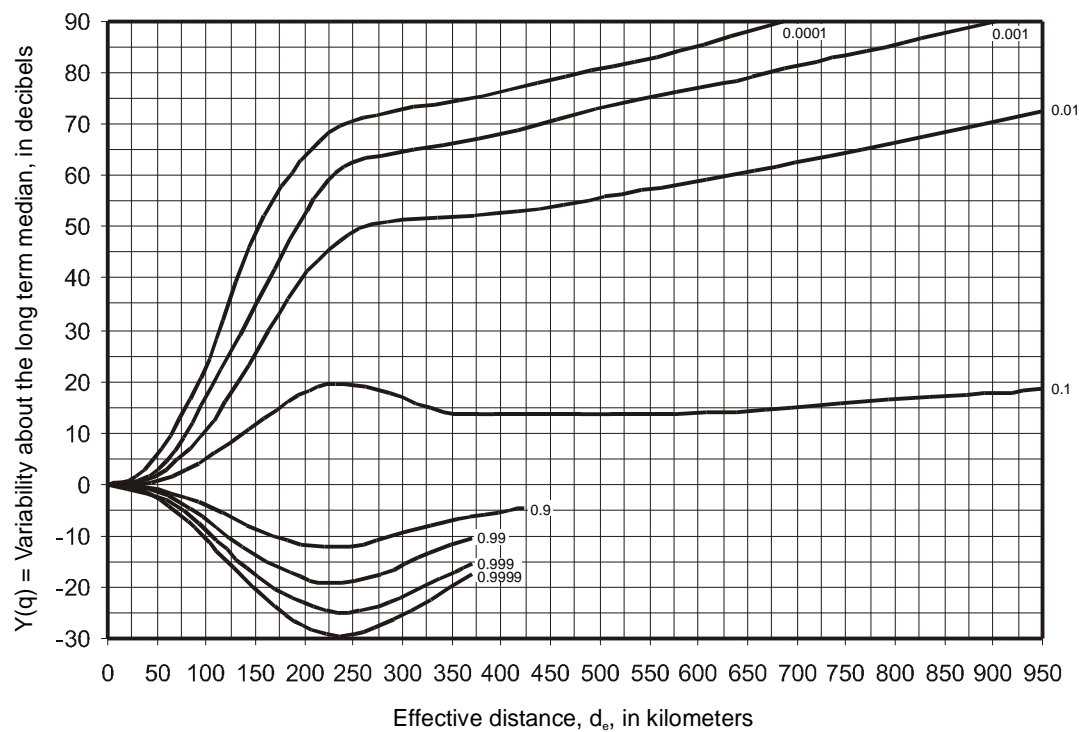
Figure 29: Maritime Temperate Climate Oversea 450 - 1000 MHz
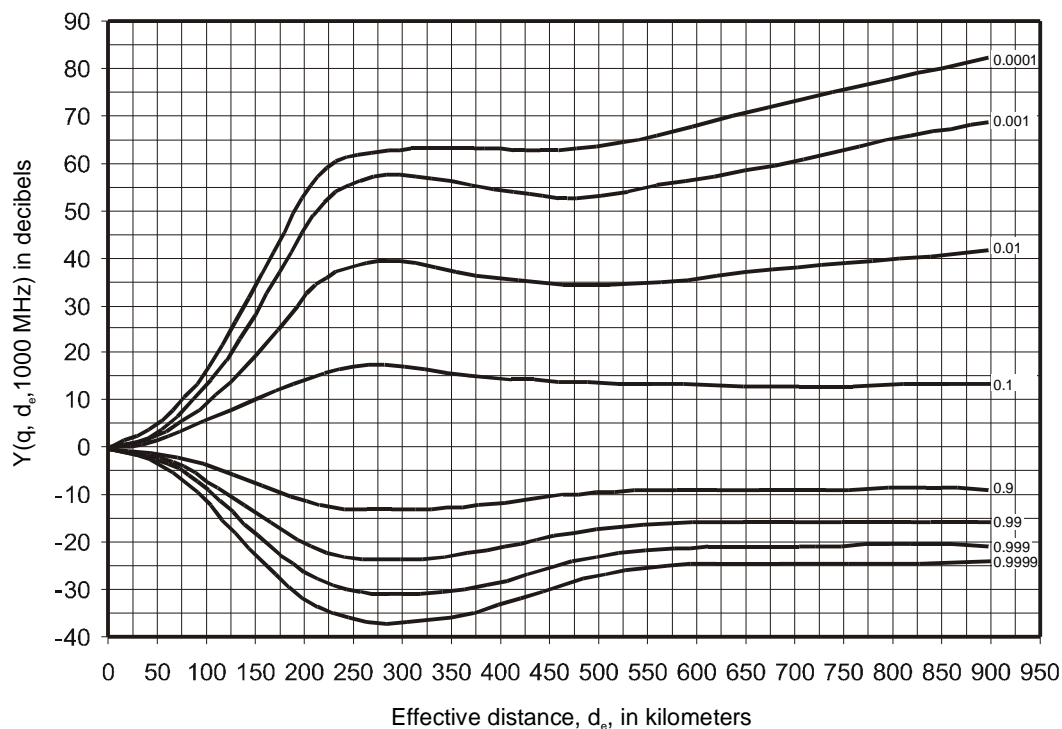
Figure 30: Climate 4 - Maritime Subtropical Overland
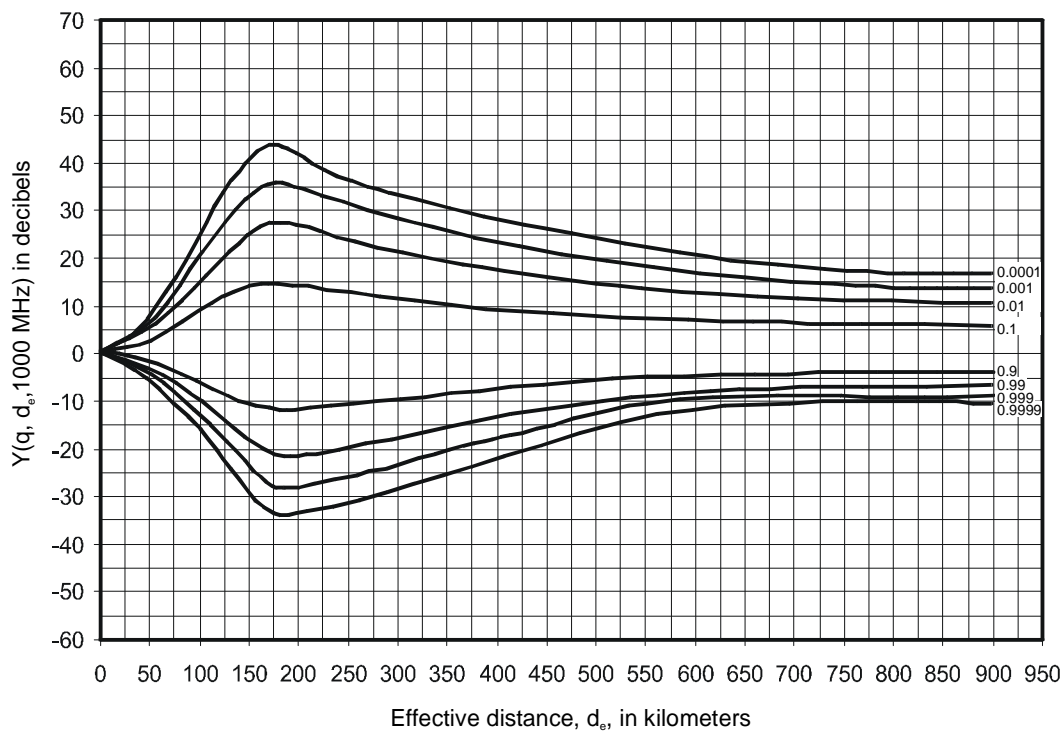
Figure 31: Climate 6 - Desert Sahara
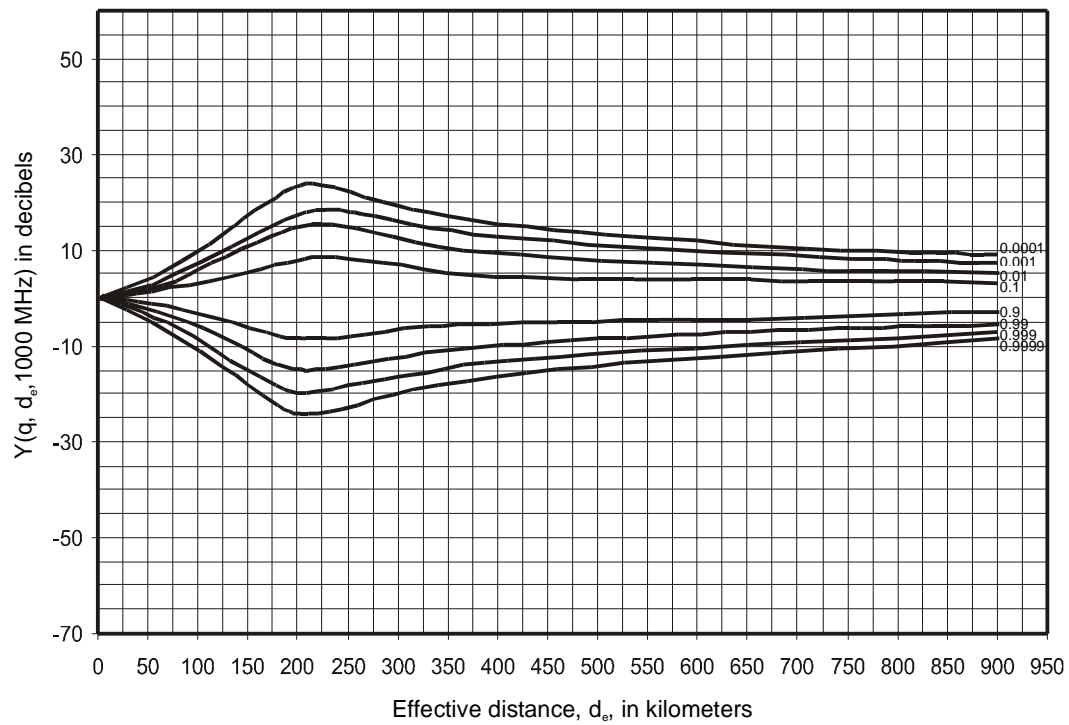
Figure 32: Climate 7, Equatorial
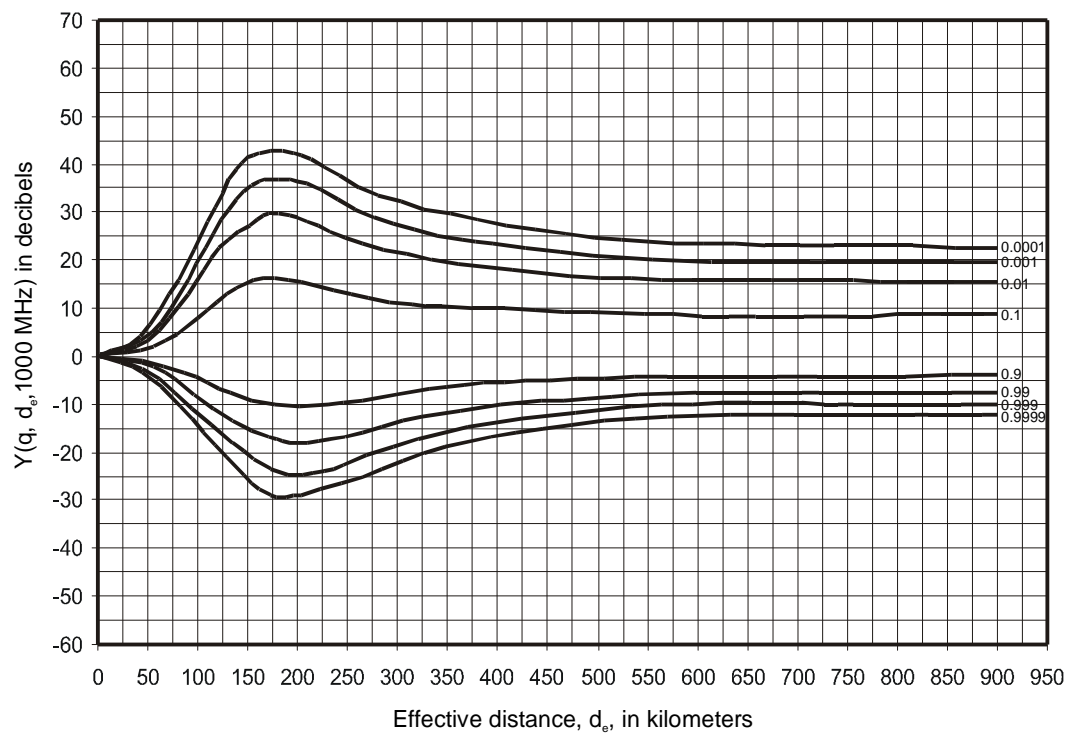
Figure 33: Climate 8, Continental Subtropical
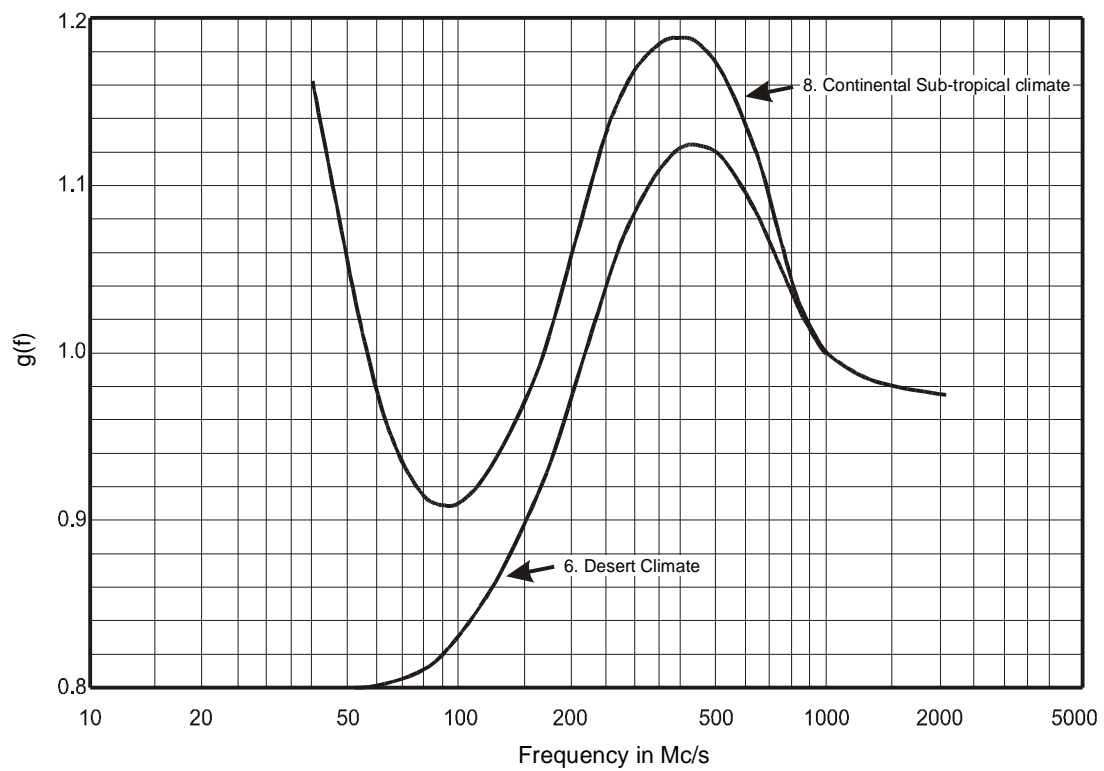
Figure 34: The Factor g(f) - g(f) = 1 for climates 4, 5 and 7

REFERENCES

1.   Transmission Loss Predictions for Tropospheric Communication Circuits
          Technical Note 101
          Referenced AD 687 820
          National Technical Information Service
          US Department of Commerce
          Springfield, Virginia
          22151

2.   Longley A.G. and Reasoner R.K.
          Comparison of Propagation Measurements with Predicted Values in the 20 to 10,000 MHz Range
          ERL 148-ITS 97
          Institute for Telecommunication Sciences, Boulder, Colorado January 1970

3.   Prediction of Tropospheric Radio Transmission Loss Over Irregular Terrain
          A Computer Method 1968
          A. G. Longley and P. L. Rice
          ESSA Technical Report ERL 79-ITS 67
          Reference AD 676874
          National Technical Information Service
          US Department of Commerce
          Springfield VA 22151

4.   Norton K.A., Rice P.L. and Vogler L.E.
          The Use of Angular Distance in Estimating Transmission Loss and Fading Range for Propagation
          through a Turbulent Atmosphere over Irregular Terrain.
          Proc IRE Vol. 43, October 1955, pp 1488-1526

5.   CIR Report 238-5 Section 3

6.   CCIR Report 569-3, 1984, section 4

7.   Microwave Radio Obstruction Fading
          A. Vigants
          Bell System Technical Journal
          Volume 60 July-August 1981

8.   Multiple Knife Edge Diffraction of Microwaves
          Jacques Deygout
          IEEE Transactions on Antennas and Propagation
          Vol. AP-14, No 4, July 1966 pp 480 - 489

9.   An Experimental Study of Wave Propagation at 850 MHz
          J. Epstein and D.W. Peterson
          Proc IRE Vol 41, 1953, pp 595-611.

10.   Radio Wave Propagation
         A. Picquenard
         Wiley, New York, 1974
         Page 296

11.   Radio Propagation Fundamentals
         Kenneth Bullington
         Bell System Technical Journal
         Volume XXXVI May 1957 Number 3

12.   Mobile Communications Engineering
         W.C.Y. Lee
         McGraw Hill

13.   P.L. Rice
         1971 IEEE Mountain-West conference record
         pp 1-10.

REFLECTION ANALYSIS

OVERVIEW

The Reflection module is used to analyse a single specular reflection on a path.The analysis is based on a user define reflective plane. Before using the Reflection module, determine the reflective characteristics of the path in the Multipath module. This step will also help identify the start and end points of the reflective plane. It is not possible to define a reflective plane on a path whose geometry will not support a specular reflection. In these cases, it is <u>not</u> necessary to carry out a reflection analysis.

The primary uses of the Reflection module are:

*   To determine the receive signal variations due to a specular reflection.

*   To set the antenna heights for an odd Fresnel number clearance on paths with excess clearance.

*   To determine the optimum vertical antenna spacing when space diversity is used to avoid signal nulls on a reflective path.

*   To determine the dispersive characteristics of a path (amplitude and delay of the reflected signal).

*   To ensure that a signal null does not occur at the median value of K.

*   To evaluate the effects of tilting the antennas vertically to reduce the reflected signal amplitude.

The initial screen display will be blank if a calculation has not been made. The calculations are retained when changing between modules and are also saved in the Pathloss data file.

The basic procedure is outlined and described in detail in the following paragraphs:

*   Define the reflective plane. All calculations are based on this definition.

*   Open the Variable dialog box and select one of the following variable parameters:

        Site 1 antenna height   Site 2 antenna height
        frequency   earth radius factor (K)   tide level

*   Enter the start and end values and the values of the constant parameters.

*   When the entries are complete, click the OK button to start the calculation. A maximum of four calculations can be simultaneously displayed.

*   The following parameters can be modified without repeating the calculation:

        terrain roughness   ground cover - clearance loss
        antenna 3 dB beam widths   divergence
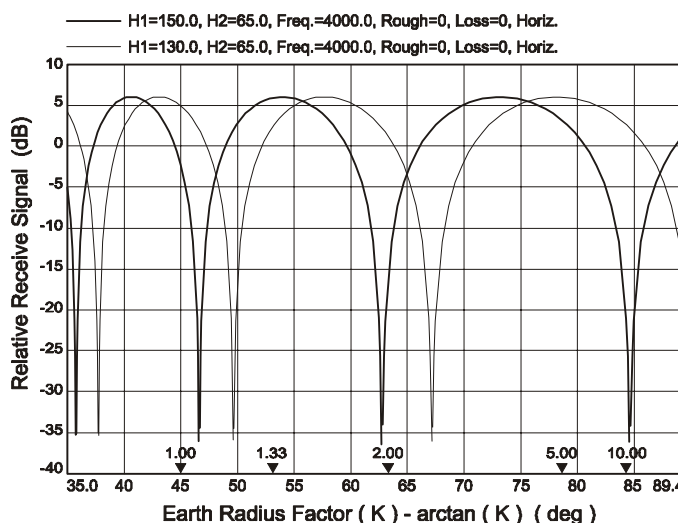
- These parameters affect the amplitude of the reflected signal. The results can be compared with those using only the theoretical reflection coefficient.

- The amplitude and delay of the reflected signal can be further analysed in the Dispersion data entry form.

REFLECTIVE PLANE DEFINITION
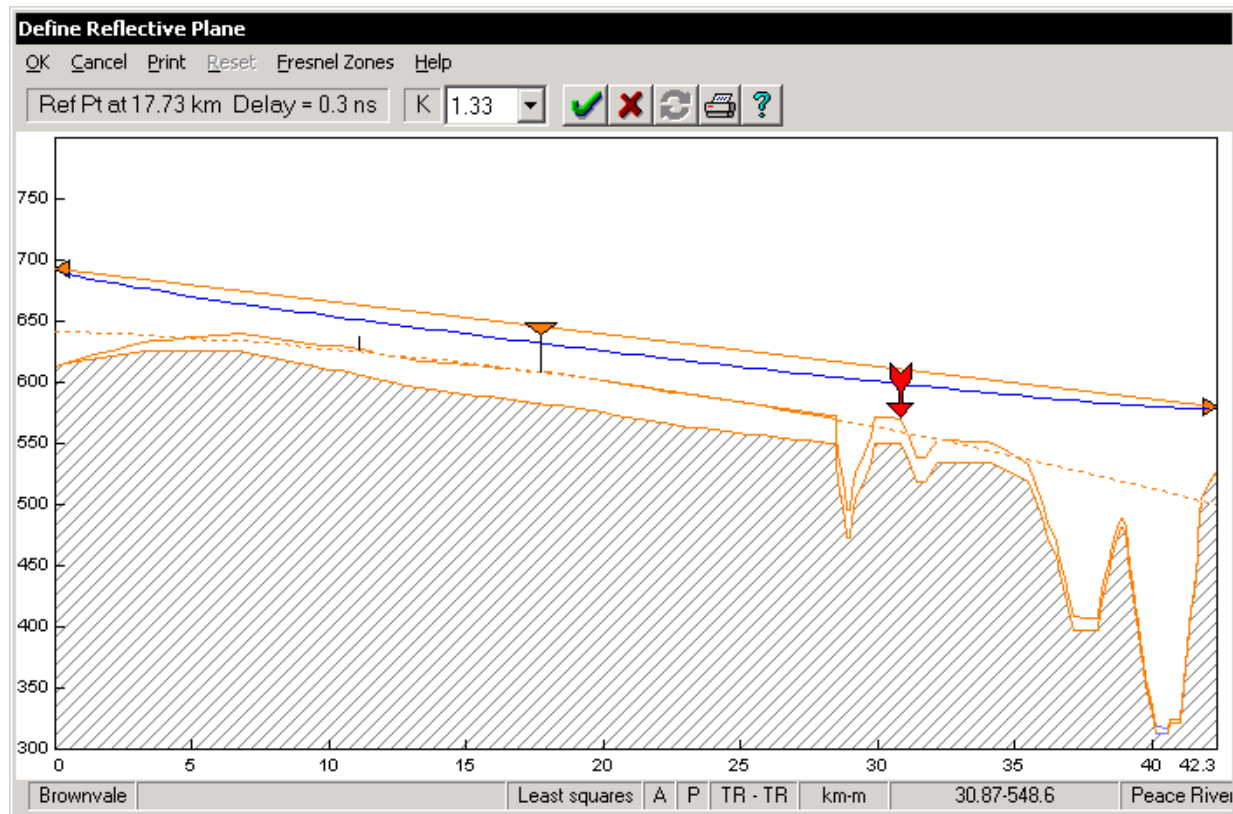
Select Define Plane from the Reflection menu bar to bring up the reflective plane calculation display. The shaded profile represents the flat earth profile. The upper profile is drawn for the earth radius factor displayed on the control bar. The antenna heights correspond to the antenna combination displayed on the status bar.

Control Bar

If a reflective plane has been defined, the control bar shows the location of the reflection point and the relative delay of the reflected signal. A new value of K can be selected and the display will automatically update without redefining the plane. The control bar also includes buttons corresponding to the menu items.

Status Bar

The following display and controls are included on the status bar:

- Site names (information only).

- Measurement system (information only).

- Plane definition method (least squares shown in the example display above). Click the left mouse button on this box to select the plane definition method.

- Cursor control (A and P on the example display above). Click the left mouse button to change the arrow and cursor movement attributes.

- Antenna combination. If the antenna configuration has more than one antenna combination, click on this box to select another antenna combination.

- Cursor location. Click the left mouse button on the cursor location box for additional information on the selected point.

Procedure

A plane is defined as follows:

- Place the arrow at one end of the reflective plane and click the right mouse button or press the F1 key. The arrow will change color to indicate that it has been selected. The reset button will cancel the selected point.

- Place the arrow at the opposite end of the reflective plane and click the right mouse button or press the F1 key again.

- To redefine a plane, just repeat the above two steps over the existing plane.

- Click the OK button to accept the reflective plane. The Cancel button cancels all changes made during this session. If a reflective plane had been previously defined, the Cancel button will restore the original definition.

Plane Method

Three methods are available to define a reflective plane (least squares, 2 point line and constant elevation). The current method is displayed on the status bar. Click the left mouse button on the reflective plane method box in the status bar to bring up the Reflective Plane Method dialog box.
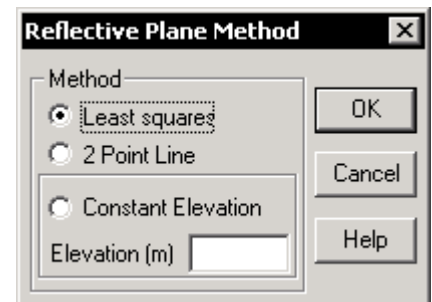
Least Squares

The plane is derived from a two term least squares fit of the form $y = a \cdot x + b$, using 50 uniformly spaced points interpolated over the end points of the reflective plane.

2 Point Line

The reflective plane is derived from the two end points which define the plane. The reflective plane also takes the form $y = a \cdot x + b$.

Constant Elevation

The plane is drawn at a constant elevation ($y = $ Elevation).

Note that the 2 point line and constant elevation methods are only available in the Reflection module. The least squares method is used in all other modules which use reflective planes.

Error Messages

The reflective plane is determined as described above and displayed for the selected value of the earth radius factor. The section between the defined plane end points are drawn as a solid line. The plane is extended to the end points of the profile using dotted lines. The reflection point location is then calculated and displayed. The control bar now shows reflection point location and the relative delay of the reflected signal in nanoseconds.

Effective antenna heights are determined by extending the reflective plane to the ends of the profile. The effective antenna heights are the heights of the antennas above this plane.

The following error messages may appear:

- The plane is non line of sight at the specified values of K and antenna heights. Select another value of K on the control bar.

- The plane elevation at Site 1 is higher than the antenna height.

- The plane elevation at Site 2 is higher than the antenna height.

- The reflection point is outside the defined limits of the plane.

- The reflection point could not be located. The algorithm failed to locate the reflection point. This can occur if the reflection point is very close to one of the sites. Increase the antenna heights or change the reflective plane.

Reflective Plane Considerations
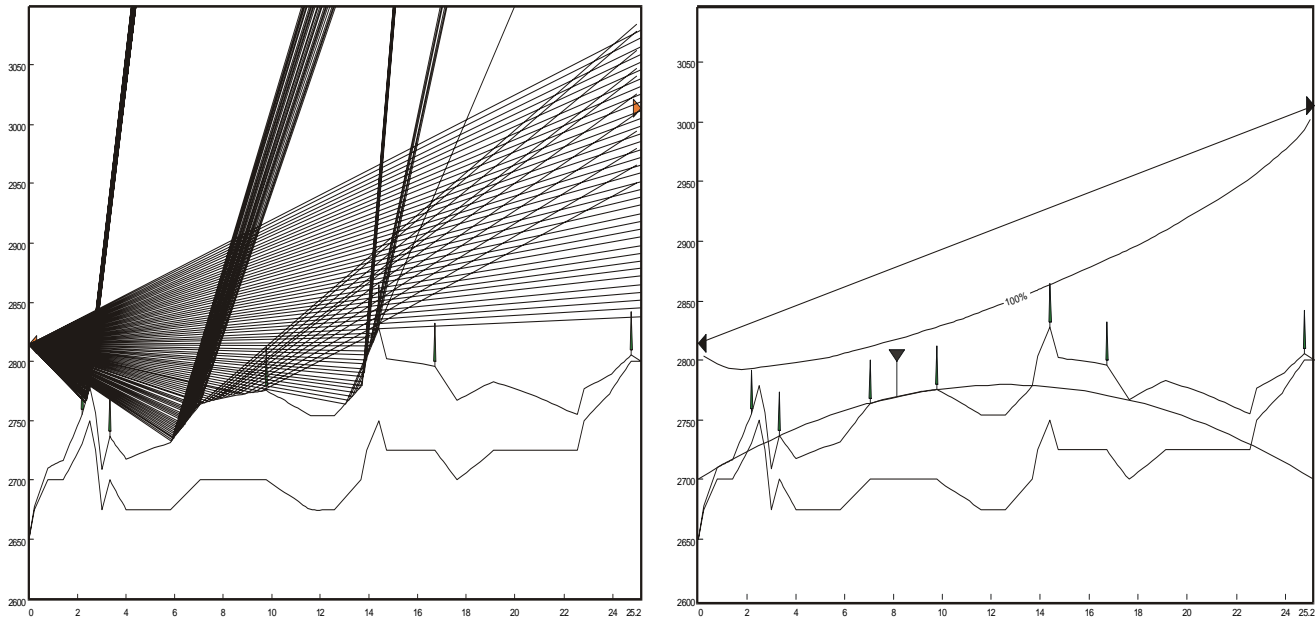
On over water paths, or paths which are predominately flat, the selection of the end points is straightforward. On other paths, some judgement is required. In many cases, the multipath module will indicate the extents of the reflection area. In the above example of a profile with no easily recognizable reflective region, the ray trace shows that reflected signals from the area between 10 and 15 kilometers are directed at the receive antenna. Accordingly, the reflective plane has been defined over that area.

In other cases the following guidelines can be used:

- Draw a 100% first Fresnel zone reference and note the extent of the terrain closest to this Fresnel zone reference.

- Place the cursor at the center of this extent and press the Ins key to display the terrain point data. Note the clearance to the first Fresnel zone ratio (C/F1).

- Using this value as a guide, draw additional Fresnel zone references until approximately 50% of the Fresnel zone is below the terrain.

- Define the end points of the reflective plane at the first and last intersections of the Fresnel zone reference with the terrain.

- Draw 100% first Fresnel zone references to the reflection point. The intersections of the Fresnel zone with the terrain represent the area along the profile required to support a specular reflection. The end points of the reflective plane should encompass this area.

TERRAIN ROUGHNESS

Select Modify - Terrain Roughness from the menu bar. The theoretical reflection coefficient assumes a smooth uniform surface over the terrain. Terrain roughness accounts for the actual variations in the terrain and reduces the magnitude of the reflection coefficient. Note that terrain roughness does not account for ground cover such as trees and vegetation on the path. These effects are treated separately in the Modify Parameters selection.

In most cases, the path profile will not contain sufficient detail to determine the actual terrain roughness and a field inspection may be required. In this case, an estimate of terrain roughness can be entered directly in the Modify Parameters dialog box.

The terrain roughness display uses the flat earth profile. The antenna heights correspond to the antenna combination displayed on the status bar. The reflective plane is also shown on the display.

The following steps describe the terrain roughness calculation:

- Draw 100% first Fresnel zone references to the reflection point. The intersections of the Fresnel zone with the terrain represent the approximate extent of the profile required to support a specular reflection. The terrain roughness should be calculated over this region.

- Place the cursor at one end of the region and press the F1 key or click the right mouse button.

- Place the cursor at the opposite end and press the F1 key or click the right mouse button again.

A least squares fit of the form $y = a \cdot x + b$ is calculated over the selected interval. The elevations, with respect to this least squares fit are determined at 50 equally spaced points. The terrain roughness is calculated as the standard deviation of these elevations.

To redefine a plane, just repeat the above steps over the existing terrain roughness calculation. Click the OK button to accept the terrain roughness or the Cancel button to ignore all changes made during this session. If a terrain roughness calculation had been previously defined, the Cancel button will restore the original definition.

VARIABLE PARAMETERS

The variations in receive signal due to a specular reflection can be calculated as a function of any of the following variable parameters:

- Site 1 antenna height
- Site 2 antenna height
- earth radius factor (K)
- frequency
- tidal changes on coastal paths

Enter the start and end values and the values of the fixed parameters. Fixed antenna heights can be set by clicking on the Antenna Combination button.

Click the OK button to carry out the calculation. The current values of terrain roughness, ground cover - clearance loss, antenna 3 dB beam widths and divergence are used. These can be changed at any time without repeating the calculation.

Typically, the analysis involves several values of the fixed parameters. For example, in a space diversity application, the reflection analysis is used to verify that simultaneous signal nulls do not occur on the main and diversity antennas at any value of K and that at K = 4/3, the signals on both antennas are near the free space value. The earth radius factor is the variable and the calculations are carried out for the following antenna combinations:

- Site 1 main antenna to Site 2 main antenna
- Site 1 main antenna to Site 2 diversity antenna
- Site 2 main antenna to Site 1 diversity antenna

A maximum of four calculations can be displayed. If the reflection point moves outside the defined plane limits during a calculation, the trace is drawn as a gray dotted line. The calculation will not proceed under the following situations.

- The plane is non line of sight for all values of K.
- The plane is non line of sight for all values of the site 1 antenna height.
- The plane is non line of sight for all values of the site 2 antenna height.
- The plane is non line of sight from low to high tide.
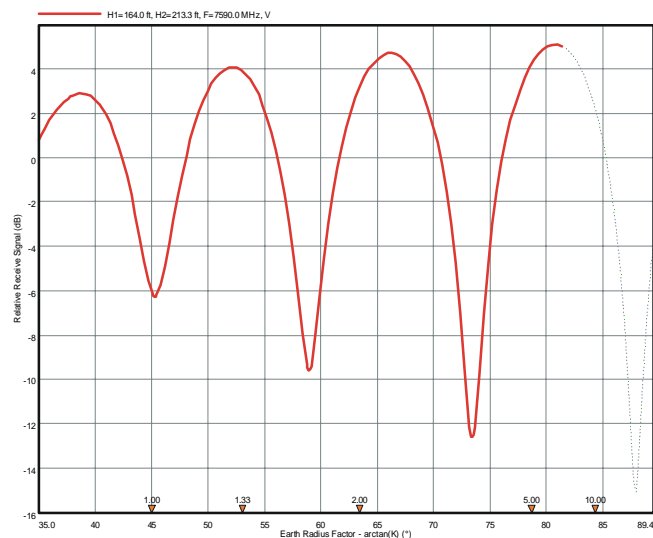
MODIFY REFLECTION PARAMETERS

Terrain Roughness

Terrain roughness can be calculated using the Roughness menu selection. In many cases, the elevation detail on the path profile is inadequate for this purpose; and it is necessary to enter the terrain roughness determined by a physical inspection of the path.

Ground Cover - Clearance Loss

The amplitude of the reflected signal is reduced by ground cover on the path. Estimates of these losses are:

0 to 1 dB   water, desert or salt flats

1 to 3 dB   fields with low vegetation or low grass

3 to 6 dB   sage brush, fields with high vegetation or high grass

8 to 15 dB   partially wooded areas including trees along roads which are perpendicular to the path

> 15 dB   heavily wooded areas

In addition to the ground cover, the clearance on the paths between the reflection point and each antenna must be considered. If the clearance on the reflected paths is less than 0.6F1, then the additional loss must be taken into account. This can only be analysed in the Diffraction module.

Antenna Beam Widths

Depending on the path geometry, the antenna discrimination may reduce the reflected signal amplitude. Enter the <u>total</u> vertical 3 dB beam widths of the antennas. If a zero is entered or the field is left blank, the antenna beam widths will not be used in the calculation.

Antenna Downtilt

To reduce the null depth produced by a reflected signal, it is common practice to tilt the antennas upwards. This increases the antenna discrimination to the reflection point; however, there will be some loss of received signal due the orientation loss. The antennas are assumed to be oriented at K = 4/3. To tilt an antenna upwards, you must enter a negative value (negative downtilt equals uptilt). If this field is left blank, the antenna downtilt will not be used in the calculation.

Divergence

Divergence is the scattering of a reflected signal due to the curvature of the earth. A graphic illustration of divergence is given in the Multipath module. The effect is to reduce the reflected energy at low values of K. At large values of K, divergence has no effect. If K is negative, then divergence becomes convergence and the amplitude of the reflected signal increases.

Show Perfect Reflector Results

The effects of terrain roughness, ground cover - clearance loss, antenna beam widths and divergence can be shown by displaying the unmodified results along with the actual results. The unmodified results consider only the theoretical reflection coefficient.

DISPERSION ANALYSIS

Select Dispersion from the menu bar. The dispersion analysis worksheet calculates the loss and delay of the reflected signal. These values determine the dispersive effects of a specular reflection. The calculation uses the reflective plane definition and the following parameters in the Modify Parameters selection:

Dispersion Analysis		
OK Cancel Help		
	Brownvale	Peace River
Antenna height (m)	79.20	54.00
Antenna 3 dB beamwidth (°)	1.40	1.40
Vertical angle (°)	-0.04	0.26
Antenna Downtilt (±°)	-0.25	-0.25
Orientation Loss (dB)	0.35	0.35
Discrimination Angle (°)	0.37	0.34
Discrimination (dB)	0.76	0.66
Earth Radius Factor K	1.33	
Frequency (MHz)	5882.50	
Polarization	Vertical	
Reflection Point Location (km)	18.75	
Reflection loss (dB)	5.25	
Reflection Delay (ns)	0.32	
Peace River Orientation Loss (dB) :		

- terrain roughness

- ground cover - clearance loss

- divergence

The following input parameters are local variables in the dispersion analysis worksheet and have no effect on the corresponding parameters outside the worksheet:

- antenna heights

- earth radius factor

- frequency

- polarization

The antenna 3 dB beam widths and downtilts values are global variables. If these are changed, the reflection calculations will be updated when the Dispersion Analysis worksheet is closed.

Note that both the antenna 3 dB beam widths and downtilts are "not included" parameters. If the letter X is entered for a value or the F3 key is pressed, these values will not be used in the calculation.

The following parameters are calculated:

- antenna discrimination angles

- antenna discrimination

- reflection point location

- reflection loss in dB

- reflection delay in nanoseconds

If the reflected signal delay is greater than 10-20 nanoseconds, performance problems on high capacity systems can occur unless the reflected signal amplitude is at least 40 dB below the direct signal. At very long delays, the path may not be workable.

REFLECTION OPTIONS

Grid

This option adds or removes horizontal and vertical grid lines on the reflection analysis display.

Vertical Scale

If the "Auto" option has been checked, the program will determine the vertical scale of the display; otherwise, the scale will be established by the maximum and minimum values. This feature is useful in comparing changes in various options.
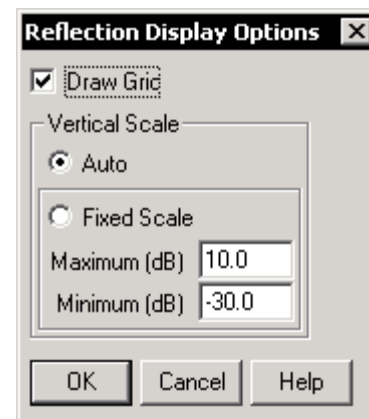
REPORTS

Null Depth

Only the data at the signal nulls is printed. The actual null depth is calculated.

Variable Parameter : Earth Radius Factor K

Reflective plane defined between 11.52 and 28.27 km (Least Squares)

Brownvale Antenna 3 dB Beamwidth (°)   1.40

Peace River Antenna 3 dB Beamwidth (°)   1.40

Terrain Roughness (m)

Ground Cover - Clearance loss (dB)

Use Divergence   Yes

Brownvale Antenna Height (m)   79.20

Peace River Antenna Height (m)   54.00

Frequency (MHZ)   5882.50

Polarization   Vertical

K	Location	Reflection Loss		Reflection Delay		Null Depth
	km	%	dB	rad	ns	dB
1.10	18.71	43.75	5.00	9.40	0.25	7.18
1.92	18.31	26.26	2.65	15.69	0.42	11.62
4.53	17.91	13.23	1.23	21.97	0.59	17.57

Reflection

All data in the reflection analysis is printed. Note that the number of pages in the report is displayed on the caption. There may be in excess of 1000 points in the calculation. The actual signal nulls may be deeper than shown on the report. The variable parameter may not fall exactly on the null.

Dispersion

This report prints the Dispersion worksheet data.

TWO RAY OPTICS

Reflection analysis is based on two ray optics and is limited to a single specular reflection. The receive signal is the vector addition of the direct signal and the reflected signal.

The amplitude of the reflected signal depends on:

- theoretical reflection coefficient
- terrain roughness
- divergence
- ground cover over the reflection surface
- additional loss due to lack of clearance between the reflection point and the antennas
- antenna discrimination

The phase difference between the direct and reflected signals depends on:

- the difference in path lengths between the two signals
- the phase shift which occurs on reflection

The resultant signal is given by:

$$A \;=\; 10 \cdot \log\left[1 + R^2 - R\cos\left(\frac{2\pi\Delta r}{\lambda} - C_{v,\,h}\right)\right] \tag{1}$$

R	reflected signal amplitude
λ	wavelength
Δr	difference in path length between the main and reflected signal paths expressed in the same units as the wavelength
$\pi\text{-}C_{v,h}$	phase shift which occurs on reflection

The subscripts v and h refer to vertical and horizontal polarization.

Equation (1) is valid on line of sight paths for frequencies greater than 30 MHz. As the clearance approaches grazing, two ray optics results in an unrealistically high loss.

THEORETICAL REFLECTION COEFFICIENT

The theoretical reflection coefficient is a complex number consisting of a magnitude and an angle and depends on:
- frequency
- polarization
- grazing angle (angle of incidence or angle of reflection)
- relative surface dielectric constant (ε)
- surface conductivity (σ mhos /meter)

The magnitude of the reflection coefficient R_h and R_v and the phase delay $(\pi - C_h)$ and $(\pi - C_v)$ for horizontal and vertical polarization is given by Equation (2). This is based on Technical Note 101 (III-3).

$$x = 1.80 \cdot 10^4 \cdot \frac{\sigma}{f_{MHz}}$$

$$q = \frac{x}{2p}$$

$$2p^2 = \sqrt{\varepsilon - (cos^2 \Psi)^2 + x^2} + (\varepsilon - cos^2 \Psi)$$

$$b_v = \frac{\varepsilon^2 + x^2}{p^2 + q^2}$$

$$b_h = \frac{1}{p^2 + q^2} \tag{2}$$

$$m_v = \frac{2(p\varepsilon + qx)}{p^2 + q^2}$$

$$m_h = \frac{2p}{p^2 + q^2}$$

$$R_v^2 = \frac{1 + b_v sin^2 \Psi - m_v sin^2 \Psi}{1 + b_v sin^2 \Psi + m_v sin \Psi}$$

$$R_h^2 = \frac{1 + b_h sin^2 \Psi - m_h sin^2 \Psi}{1 + b_h sin^2 \Psi + m_h sin \Psi}$$

$$\pi - C_v = tan^1 \left(\frac{x sin \Psi - q}{\varepsilon} \right) - tan^1 \left(\frac{x sin \Psi + q}{\varepsilon sin \Psi + p} \right)$$

$$\pi - C_h = tan^1 \left(\frac{-q}{sin \Psi - p} \right) - tan^1 \left(\frac{q}{sin \Psi + p} \right)$$

ε relative dielectric constant
σ surface conductivity
Ψ grazing angle in radians (angle of incidence or angle of reflection)

The phase shift on reflection is very near 180 degrees (radians) on most radio paths. As the grazing angle approaches the Brewster angle in the range 5 to 11 degrees, the phase shift rapidly changes for π to $-\pi$ radians. This path geometry is rarely encountered in practice.

Table 1: Ground Characteristics

Ground Type	Conductivity (σ) (mhos per meter)	Relative Dielectric Constant ($\in$)
Poor Ground	0.001	4
Average Ground	0.005	15
Good Ground	0.020	25
Salt Water	5.000	81
Fresh Water	0.010	81

The surface dielectric constant and the surface conductivity are determined by the ground types specified in the terrain profile as shown in Table (1).

TERRAIN ROUGHNESS

The magnitude of the theoretical reflection coefficient, $R_{h,v}$ in Equation (2) is based on a smooth surface over the area of the reflection. Typically, $R_{h,v}$ is in the range 0.9 to 0.99, which will result in receive signal nulls of 20 to 40 dB.

The reflection coefficient is modified to account for terrain roughness as shown in Equation (3) below.

$$R_e = R_{h,v}e^{-\left(0.6 \cdot sin\, \Psi \cdot \frac{\Delta_h}{\lambda}\right)} \tag{3}$$

R_e	effective reflection coefficient
λ	wavelength
Δ_h	terrain roughness expressed in the same units as the wavelength
Ψ	grazing angle in radians (angle of incidence or angle of reflection)

Note that the effect of terrain roughness depends on the sine of the grazing angle (Ψ). At very low values of Ψ, the sine is zero and terrain roughness has no effect. Even a very rough surface is reflective. This phenomenon is often observed while driving on paved roads. The road in the distance appears as a mirror reflecting light. The road surface is reflective to light at low grazing angles.

The terrain roughness is defined as the standard deviation of the terrain relative to a smooth curve within the limits of the reflection area. This is the same definition as used in the Microwave Worksheet; however, no limits are placed on the value of the terrain roughness. If the path is over water or salt flats, then a value of zero should be used for the terrain roughness which represents the worse case.

Note that the effective reflection coefficient is a function of frequency (λ). The effect will be greater at the higher frequencies. In estimating a value of the terrain roughness, only the terrain should be considered. Do not attempt to account for ground cover (trees or foliage) using terrain roughness. These effects are described under Ground Cover Effects.

DIVERGENCE

Divergence is defined as the scattering of a reflected ray due to the curvature of the earth. The effect is to slightly reduce the amplitude of the reflection coefficient for small values of K. Divergence has no effect at large values of K. If K is negative, divergence becomes convergence and the amplitude of the reflection coefficient increases.

The divergence factor is given by:

$$D = \frac{1}{\sqrt{1 + \dfrac{2 \cdot d_1 \cdot d_2}{K \cdot a \cdot d \cdot \tan(\Psi)}}} \tag{4}$$

d_1 distance from Site #1 to the reflection point
d_2 distance from Site #2 to the reflection point
d path length
a earth radius
K effective earth radius factor
Ψ grazing angle (angle of incidence or reflection)

The reflection coefficient is modified as R = D Re.

GROUND COVER EFFECTS

Trees and foliage in the area of the reflected signal can significantly reduce the reflected signal amplitude and the subsequent variations in the receive signal. An estimate of the ground cover loss is critical in determining the requirement for space diversity to handle specular reflections.

Table (2) provides approximate values of the loss for several types of ground cover.

Table 2: Ground Cover Loss

Ground Cover	Loss
water, desert or salt flats	0 to 1 dB
fields with low vegetation and low grass	1 to 3 dB
sage brush, fields with high vegetation and high grass	3 to 6 dB
partially wooded areas including trees along roads which are perpendicular to the path	8 to 15 dB

REFLECTED PATH CLEARANCE

Additional loss to the reflected path will occur if there is less than 60% first Fresnel zone clearance between an antenna and the reflection point. This analysis must be carried out separately in the Diffraction module.

ANTENNA DISCRIMINATION

Additional loss to the reflected signal will result from the antenna discrimination, provided that the angle difference between the orientation angle and the angle to the reflection point is sufficiently large. The antenna discrimination is calculated as:

$$u = \sqrt{\frac{1.0 + cos\left(\frac{\pi \cdot \theta}{bw}\right)}{2}}$$

$$for\ \theta \le bw$$

(5)

$$u = \frac{sin\left(\frac{bw}{2}\right)}{\sqrt{2} \cdot sin(\theta)}$$

$$for\ \theta > bw$$

$$U_{dB} = 20 \cdot log(u)$$

$u,\ U_{dB}$	antenna discrimination
θ	antenna discrimination angle (radians)
bw	total 3 dB beam width of the antenna (radians)

It is assumed that the vertical antenna orientation was carried out for an effective earth radius of K = 4/3. As K changes, the angle of arrival will also change resulting in an orientation loss. If the antennas are tilted upwards, additional orientation loss will occur to the main signal.

The effect can be graphically illustrated using the Formats selection in the Multipath module.

MULTIPATH OPERATION

OVERVIEW

The Multipath module uses ray tracing techniques to analyze propagation and ground reflections on line of sight paths. Select Module - Multipath from the menu bar to access this module. The ray trace is automatically generated on entry. Two methods of operation are provided.

Variable Gradient

A flat earth profile representation is used to display the ray trace. The rays follow curved paths in accordance with the relationship between K (dN/dH) and elevation which is specified in the Gradient data entry form. No further analysis is available using this method. The variable gradient display is used to illustrate propagation anomalies such as ducting and radio holes.

Constant Gradient

The profile is displayed using an effective earth radius and all rays follow straight lines in this representation. The program tracks the rays, recording the distance traveled for both direct and reflected rays. The antenna discrimination based on the antenna beam width is taken into account in the ray trace. When the ray trace is complete, the receive signal versus elevation at Site 2 can be calculated.

On terrain profiles which support a single reflection, the results are equivalent to those obtained in the Reflections module.

Profile Formats

The Multipath module also includes a generalized display of profile formats which illustrates the possible methods of representing a path profile. The central ray is drawn for several common values of K.

VARIABLE GRADIENT RAY TRACE

A number of rays are drawn about the central ray over a user defined angle. The path of the ray is determined by a user defined refractivity gradient versus elevation relationship. This method is used to demonstrate ducting and other atmospheric propagation anomalies. The diagram on the right shows an extreme example of a duct formed between a sub-refractive and super-refractive layer. The effect is a space wave fadeout at Site 2.

Select Method - Variable Gradient from the Multipath menu bar to bring up the Variable Gradient dialog box. The ray trace will be automatically generated when this dialog is closed.

The following entries are required:
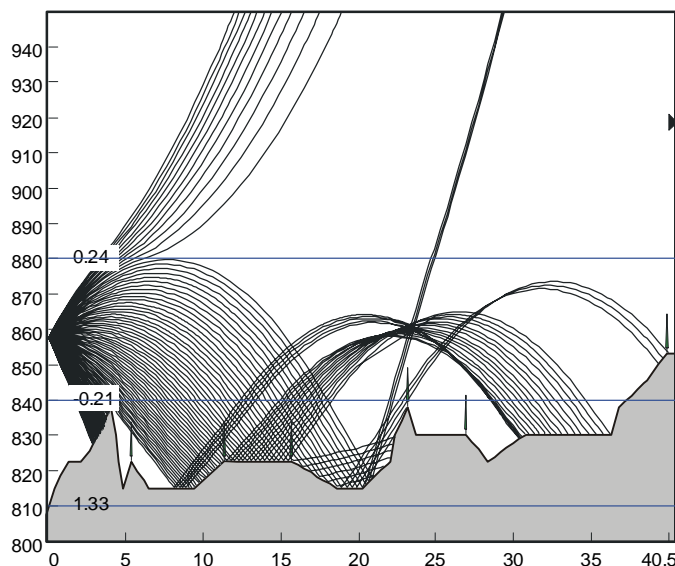
Number of Rays

This is the number of rays on either side of the central ray. For example, if 50 rays are specified, the total number of rays drawn will be 2 x 50 + 1.

Total Display Angle

All rays will be contained within the total display angle. For example, suppose that the number of rays has been set to 50, and the total display angle is 2 degrees. The ray trace will generate 50 rays in a one degree segment above the central ray and another 50 rays in the one degree segment below the central ray. Depending on the path length, some experimentation may be required to produce the desired display.

Antenna Orientation K

The antenna orientation K determines the angle of departure of the central ray. Normally, this is set to the median value of K (4/3).

Site 1 and Site 2 Antenna Heights

The antenna heights can be directly entered. If the antenna configuration supports multiple combinations, click the Antenna Combination button to select a new combination of main and diversity antennas. Note that the antenna heights are local variables in the Multipath module and any changes made to the antenna heights here are lost when the Multipath module is closed.

Ground Reflections
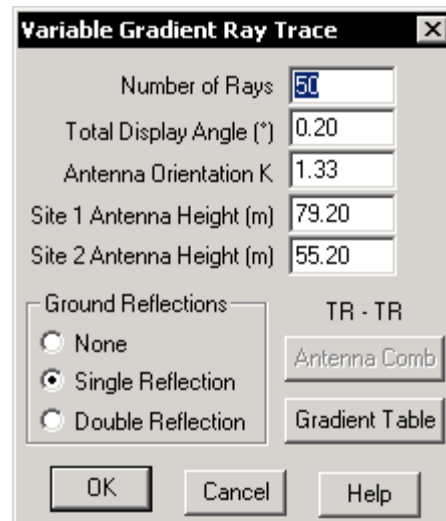
The maximum allowable number of reflections is set as desired to improve the readability of the display.

Reflections can also be selectively inhibited along the profile.

Gradient Table

The Gradient data entry form specifies the relationship between K or dN/dH and elevation. This data determines the variable gradient ray trace characteristics. Up to five elevations can be specified. To erase an entry, press the F3 key or enter the letter 'X' for the value. The data is automatically sorted in terms of elevation when the form is closed. The gradient can be specified in terms of K or dN/dH. The opposite format is automatically calculated.

A single entry is treated as a constant gradient. Multiple entries are treated as layers with constant gradients. In the above gradient table example, the ranges are defined as follows:

Elevation	K
Below 810 meters	1.33
810 to 840 meters	1.33
840 to 880 meters	-0.21
Above 880 meters	+0.21

Note that parameters such as frequency and polarization are not included in the Variable Gradient dialog box. Only the ray trace display is provided using this method.

CONSTANT GRADIENT RAY TRACE

The constant gradient ray trace is used to determine the reflective characteristics of the path. All rays are straight lines in this display. The first ray starts at the end antenna height specified in the Constant Gradient dialog box and continues in a clockwise direction until it covers 80 percent of the path. The angle between the rays is determined by the program. Note that not all rays are displayed on the screen; otherwise, the density would obscure the behavior of the ray trace. Once the ray trace is complete, the height gain characteristics of the path can be calculated.
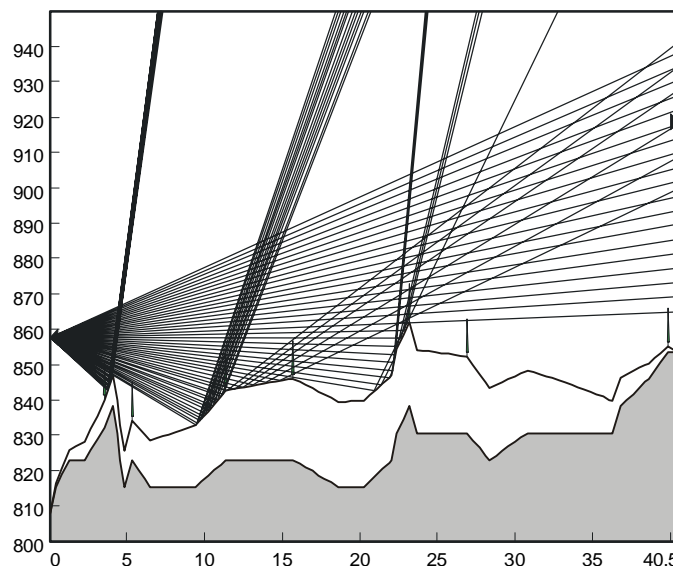
Select Method - Constant Gradient from the Multipath menu bar to bring up the constant gradientdialog box. Complete the entries and options and Click the OK button to generate the ray trace. The following entries are required:

Site 2 Start and End Antenna Heights
The default start antenna height is the minimum antenna height. The default end antenna height is the tower height. The first ray will terminate at the end antenna height.

Site 1 Antenna Height
This is the point of origin of the ray trace. If the antenna configuration supports multiple antenna combinations, click the Antenna Combination button to set the Site 1 antenna height to the main or diversity height. Note that the antenna heights are local variables in the Multipath module and any changes made to the antenna heights here are lost when the Multipath module is closed.

Antenna 3 dB Beam Widths
These are the total 3 dB beam widths (both sides of the main lobe) of the Site 1 and Site 2 antennas. The beam widths affect the amplitude of reflected rays received at Site 2 due to the antenna discrimination.

Frequency

Enter the frequency in MHz. This is the global value of frequency and will be changed throughout the program.

Earth Radius Factor (K)

This sets the constant gradient for the display. The multipath display shows the flat earth profile and an upper profile derived from the specified earth radius factor.

Include Ray Densities

This is equivalent to divergence defined as the scattering of reflected rays due to the curvature of the earth. The effect can seen on the constant gradient ray trace example display above. Note that the density of the direct rays arriving at Site 2 (number of rays per unit of elevation) is greater than the reflected ray density.

Including the ray densities, effectively reduces the reflected energy at low values of K and has no effect at high values of K.

Polarization

Select either horizontal or vertical polarization. Polarization is a global variable throughout the program. The polarization affects the amplitude of the reflected rays.

Ground Reflections

The maximum allowable number of ground reflections is set as desired to improve the readability of the display. The "None" selection serves no purpose in a constant gradient ray trace. Reflections can also be selectively inhibited along the profile as described in the following paragraph.

Height Gain Calculation

Once the constant gradient ray trace is complete, the Height Gain menu selection is enabled and the relative receive signal at Site 2 can be determined as a function of elevation. The user is prompted to enter the height increment for this calculation.
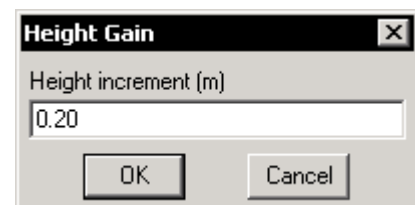
As each ray is traced, the length traversed along the path is calculated. If ground contact occurs, the complex reflection coefficient is calculated based on the grazing angle, frequency, polarization, and the type of terrain. When the ray arrives at Site 2, the angle of arrival and the elevation are recorded. A record for each ray is created containing the following data:

- number

- classification

- 0 - direct path

  1- single ground reflection

  2 - double ground reflection

- arrival angle at Site 2

- elevation at Site 2

- amplitude at Site 2. For a direct path, the amplitude is determined by the Site 1 antenna 3 dB beam width. In the case of a reflected wave, the amplitude is reduced by the reflection coefficient.

- path length traversed by the ray.

- the additional delay produced by a ground reflection.
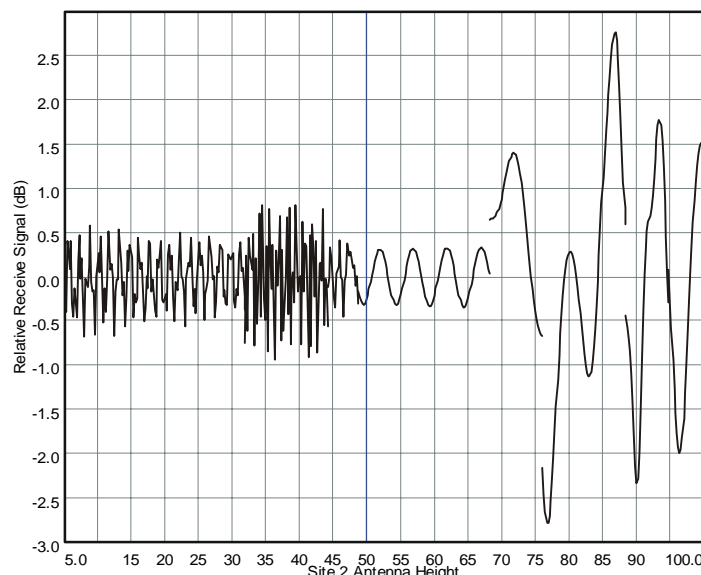
The ray records are separated into subsets, according to the ray classification and the angle of arrival. For direct path rays, the angle of arrival is not considered as the Site 2 antenna is assumed to be exactly oriented at the Site 1 antenna.

Range data records are developed from these subsets by associating sequential ray numbers, in each subset, with an elevation range at Site 2. The result is a series of independent ray records which exist over a certain elevation range at Site 2. Each range data record is examined to determine if the elevation difference between successive rays is consistent and any extreme deviations are discarded.

The height gain diagram is developed by calculating the relative receive signal between the start and end antenna heights at the specified height increment.

The magnitude and phase at specific elevations are determined by interpolating the applicable range data records and adding the Site 2 antenna discrimination. The received signal is calculated by the vector addition of these values. The display may show several discontinuities where a different number of rays are used in the vector addition.

No assumptions are made outside of the data ranges. If a given elevation is spanned by a single range, the magnitude is determined by the Site 1 antenna beam width.

If the resolution is too coarse, select Height Gain on the menu bar again and enter a smaller height increment.

INHIBIT REFLECTIONS

Reflections can be selectively inhibited over any portion of the profile. Select Operations - Inhibit Reflections or press the F7 key. The ray trace is canceled the arrow appears on the display and its location is displayed on the status bar.

Move the cursor to one end of the segment over which reflections will be inhibited and press the F1 key or the right mouse button. If the first point is selected in error, press the F8 key or click the reset button. Repeat for the opposite end of the segment.

The profile is redrawn showing a dotted line over the inhibited segment. A ray will not be reflected in this segment in either the constant or variable gradient ray trace modes.

To reset the profile to normal, select Operations - Cancel Inhibit Reflections or hold down the Ctrl key and press the F7 key.

REVERSE PROFILE

The ray trace starts at the site on the left side of the screen (Site 1). To view ray trace from Site 2, provision has been made to reverse the profile. All data including site names, coordinates, antenna heights and the worksheet are reversed.

PROFILE DISPLAY FORMATS

Profile Display Formats illustrate different representations of a path profile and shows the path followed by a ray for several values of the earth radius factor K. For small distances on the earth, a parabola is used to represent the earth in radio wave propagation analysis. Refer to the Multipath Reference section of the manual.

The initial display shows the profile drawn on the earth with Site 1 at the apex of the parabola. The Site 1 antenna is oriented horizontally. The earth is drawn with K = 1 which constitutes a true earth. This is the perspective for a person standing at Site1.

Four rays are drawn with the following values of K

K = 4/3	standard atmosphere
K = 2/3	sub refraction
K = infinity	super refraction
K = 1	true earth

The ray with the same value of K as the profile display will be a straight line. All other rays are curved lines.

The Profile Display Formats dialog box provides the following options:

View

The profile can be displayed from Site 1 or 2 or it can be centered on the parabola. The latter is the representation used in the Pathloss program.
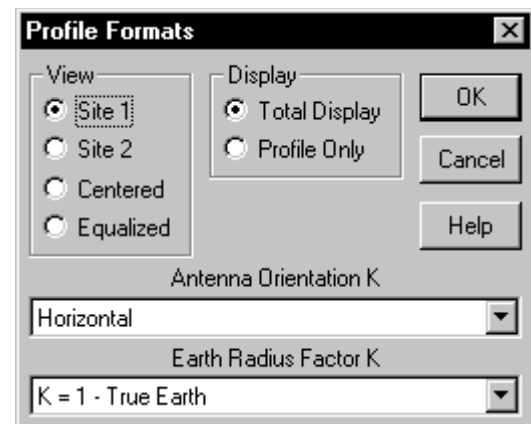
In the equalized display, the profile is positioned on the parabola so that the line between the Site 1 and 2 antennas is horizontal. Note that this is not possible if the earth radius factor is large. The Diffraction Module uses this option to assist in defining the radius of an obstacle.

Display

Both sides of the parabolic earth representation can be shown, or the display can be limited to the profile. The former is used to illustrate the concept. The latter is the working profile display.

Antenna Orientation K

Initially, the Site 1 antenna will be oriented horizontally. The antenna can be oriented for any of the four values of K. The option for "All K values" produces the classic profile display which is impossible to achieve in practice.

Earth Radius Factor K

The parabolic earth is drawn using the earth radius factor K. The ray with the same value of K will be drawn as a straight line.

MULTIPATH REFERENCE

EARTH RADIUS REPRESENTATION

For small distances relative to the earth radius, the parabolic representation of the earth given by Equation (1) is used.

$$h = -\frac{\gamma}{2} \cdot d^2$$
$$\gamma = \frac{1}{a}$$

(1)

h   elevation above sea level
d   distance
γ   earth curvature
a   actual earth radius (6375 Km)

The path followed by a radio wave is governed by the vertical gradient of the index of refraction. Under normal propagation conditions, the density of the earth's atmosphere decreases uniformly with increasing elevation. Radio waves, in this case, will bend downwards toward the denser medium.

The earth radius in Equation (1) can be replaced by an effective earth radius (K·a) so that radio waves can be represented as straight lines. This transformation is valid only for a constant vertical gradient of the index of refraction. This assumption is valid for radio paths within one kilometer of the earth's surface.

This effective earth radius model simplifies the basic path geometry. Parameters such as grazing angles, and path clearance can be calculated using plane geometry.

The following paragraphs provide a basic derivation of the effective earth radius model. This representation is used in the Pathloss program.

REFRACTION

When a ray passes through two mediums with different refractive indexes, the ray is bent in the direction of the medium with the larger refractive index, in accordance with Snell's law.

$$\eta_1 \cdot sin(\theta_1) = \eta_2 \cdot sin(\theta_2)$$ (2)

The refractive index, η, of a medium is defined as the ratio of the velocity of light in a vacuum to the velocity of light in the medium. The index of refraction is a dimensionless number and does not exceed 1.00045 at sea level. For convenience, the refractive index is usually expressed as refractivity, N, defined as:

$$N = (\eta - 1) \cdot 10^6 N - units$$ (3)
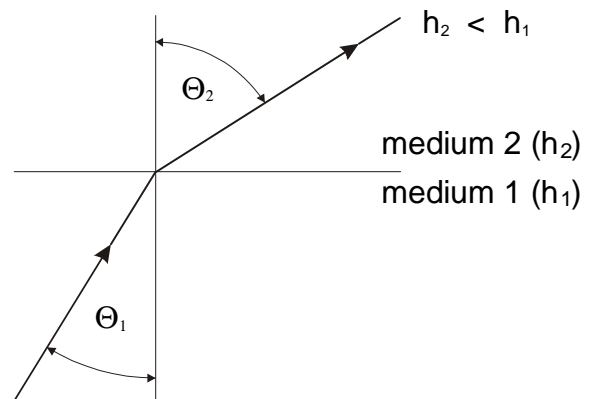
Figure 1: Refraction

The radio refractivity of air for frequencies up to 30 GHz is given by:

$$N \ = \ 77.6 \cdot \frac{\rho}{T} + 3.73 \cdot 10^5 \cdot \frac{\varepsilon}{T^2} \tag{4}$$

ρ total atmospheric pressure in millibars

ε partial pressure due to water vapor in milli-bars

T absolute temperature in degrees Kelvin

T and ε normally decrease with elevation. ρ always decreases with elevation.

The concept of radio wave bending is illustrated in Figure (2). In the upper diagram, the atmosphere is shown as discreet layers with refractive indexes $\eta_1 .. \eta_5$. In the lower diagram, the atmosphere has a continuous variation or the refractive index. The diagram represents propagation through a horizontally stratified atmosphere.
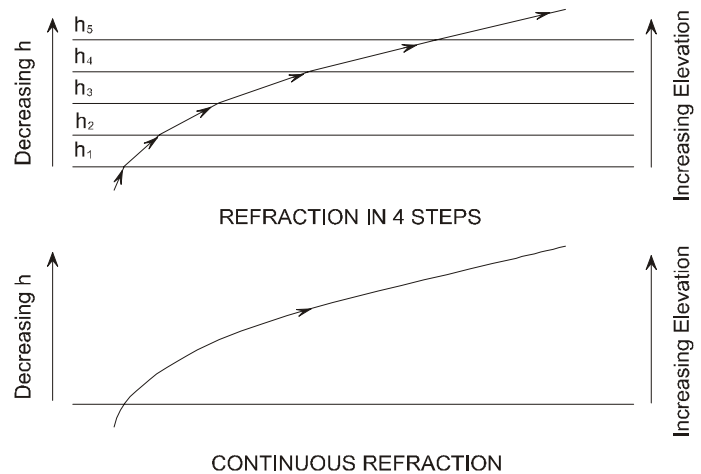
Figure 2: Flat Earth Refraction

Refractivity Gradient

The refractivity gradient is the slope of the refractivity versus elevation curve:

$$Refractivity\ Gradient \ = \ \frac{\Delta N}{\Delta h} \tag{5}$$

An example of a constant refractivity gradient which represents normal propagation conditions is shown in Figure (3).
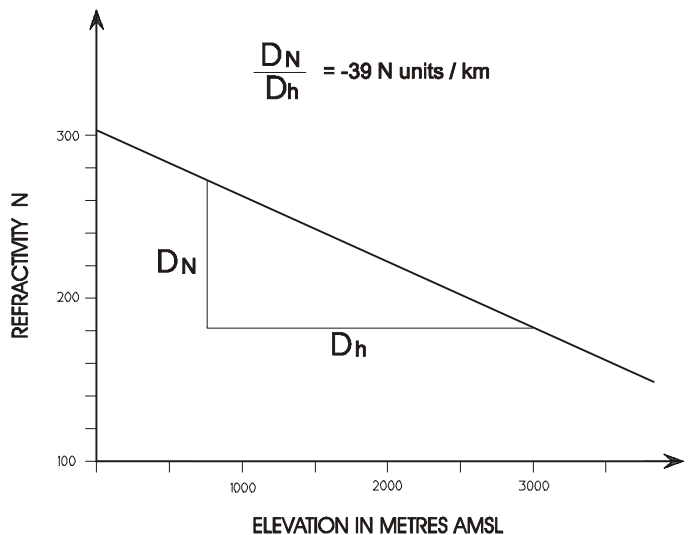
Figure 3: Refractivity Gradient

PATH PROFILE FORMATS

Physical Earth Profile

Figure (4) shows a physical representation of a path profile using the representation given by Equation (1). The ray path curvature is based on the refractivity gradient shown in Figure (3). The initial angle of the ray is assumed to be zero (horizontal).

Figure 4: Physical Path Profile

Effective Earth Radius Profile

In Figure (5), the earth radius, a, is replaced by an effective earth radius, a_e, defined as:

$$a_e = K \cdot a$$

$$(6)$$

$$K = \left(1 + \frac{\left(\frac{\Delta N}{\Delta h} \right)}{157} \right)^{-1}$$
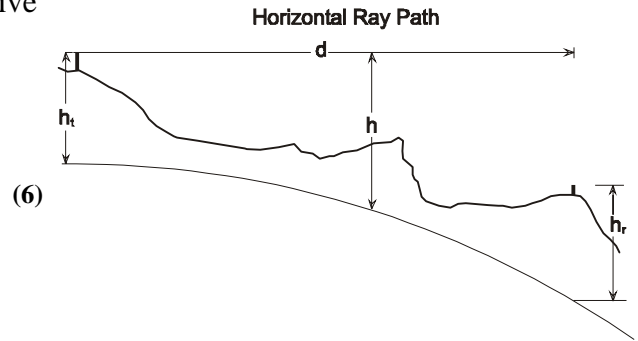
Figure 5: Effective Earth Radius Profile

The ray is now represented as a straight horizontal line. The profile is drawn in a rectilinear format which implies the following assumptions:

- The distance along the ray path is equal to the great circle arc distance.

- Elevations perpendicular to the earth are equal to their rectilinear values.

The elevations with respect to the ray path are given by:

$$h - h_t + \frac{d^2}{2 \cdot K \cdot a} \qquad (7)$$

The usual terrain profile representation is obtained by applying a transformation to Equation (7) so that the display is relative to the end points of the profile. The final display is shown in Figure (6).

The elevation, h, is given by:

$$h = \frac{d_1 \cdot d_2}{2 \cdot a \cdot K}$$

$$h = \frac{d_1 \cdot d_2}{12.75 \cdot K}$$

$d_{1/2}$ *in kilometers*

h *in meters*   **(8)**

$$h = \frac{d_1 \cdot d_2}{1.5 \cdot K}$$

$d_{1/2}$ *in miles*

h *in feet*
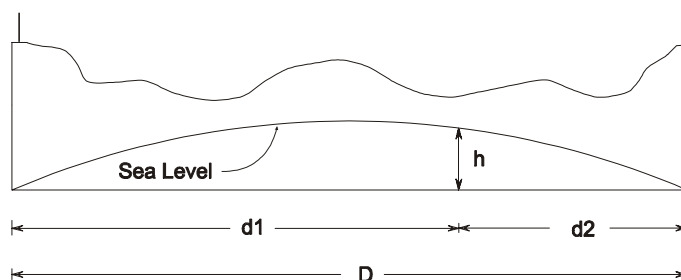
Figure 6: Path Profile Format

RAY TRACING

The ray tracing algorithm is based on the following assumptions:

- The atmosphere is separated into horizontal layers. Within a layer the refractivity gradient is constant.
- Variations along the path and transverse to the path are negligible.

Within a layer, a ray follows a parabolic path given by:

$$y = a + m \cdot x - \frac{\gamma}{2} \cdot x^2$$

$$\gamma = \frac{\Delta N}{\Delta h} + 157$$

           (9)

The constants, *a* and *m* in Equation (9) are determined by the initial conditions. At the start, *a* is equal to the transmit antenna height and the slope *m*, is determined by the vertical antenna orientation angle.

Multipath Fading

The effects of the above example on a 65 kilometer path are shown in Figure (7). The transmit antenna lies between a subrefractive layer below and an elevated superrefractive layer above. The direct rays pass between these layers to the receive antenna. Rays with a higher take-off angle reach the elevated layer and are bent back towards the earth. Some of these rays also reach the receive antenna. Rays with a lower take-off angle reach the subrefractive

Figure 7: Multipath Propagation

layer and are bent back up. Some of these rays also reach the receive antenna. The receiver thus sees three different waves that have reached it by three different paths. Since the paths have different optical lengths, the waves will interfere with each other. Depending on the exact optical lengths and frequency, the interference will be destructive or a signal enhancement will result. Slight changes in the structure of the atmosphere will usually produce extreme variations in the receive signal. Under such conditions, short duration deep fades are expected and the receiver is experiencing multipath fading. Ground reflections have been inhibited in this display, but these will actually constitute a fourth signal at the receiver.

Inversion Layer

Figure (8) shows an example of an inversion layer. Rays with a high take-off angle miss the layer entirely and end up far above receiver. Other rays with a lower take-off angle enter the layer and are bent downward to the earth. There is a large region that does not receive a direct ray. Therefore, the receiver has lost contact with the transmitter and is experiencing a space wave fade. The affected area is referred to a radio hole.
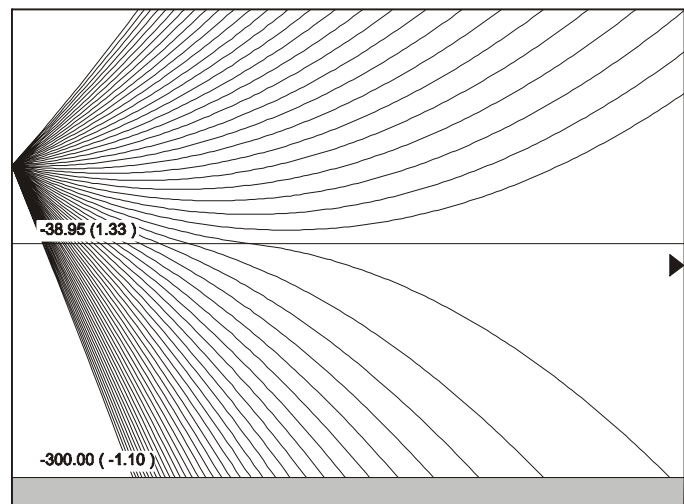
Figure 8: Inversion Layer

Figure (9) shows a example of an inversion layer but with ground reflections enabled. In this case, the transmit antenna is inside the layer and all rays are bent downward. The example assumes that the antennas were initially oriented during average propagation conditions (K = 4/3). The receiver will only receive rays which have been reflected one or more times off the ground.
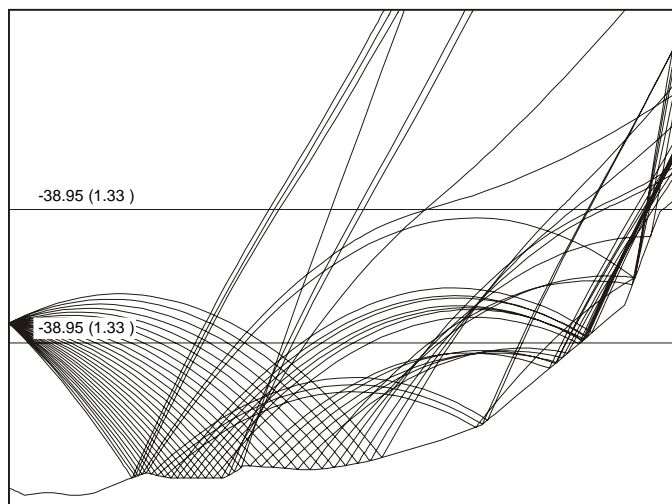
Figure 9: Inversion Layer with Ground Reflection

NETWORK

NETWORK OVERVIEW

The basic functions of the Network module are listed below:

- provides a geographic representation of the sites in a network

- provides the interface to the intra system interference calculations

- provides access to the design modules for individual Pathloss data files

- calculates topographic map crossings

The Network module can be used as the starting point to design the individual radio links in a project. Alternately, Pathloss data files can be imported directly into the Network module.
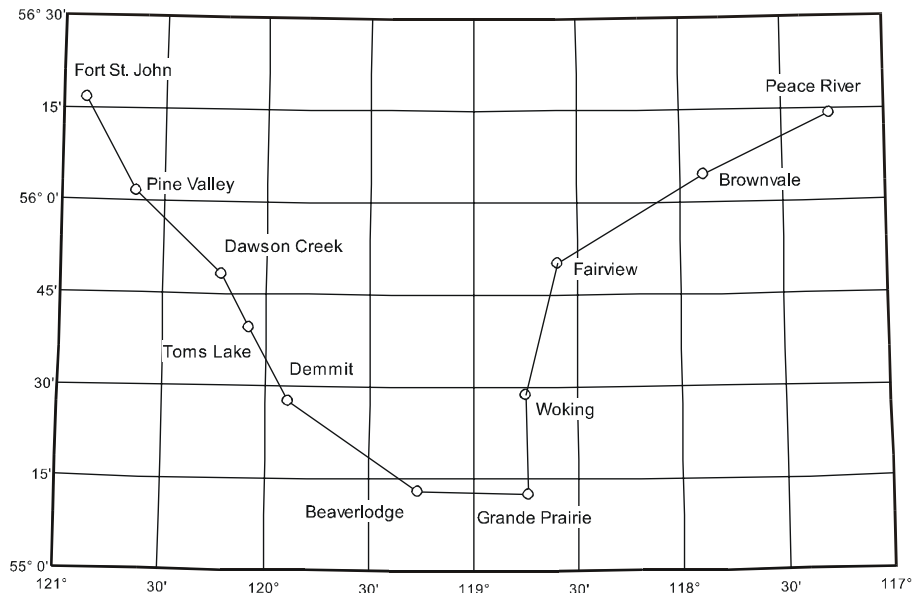
The network can be arranged in layers for both the sites and the links. A site layer could be used to represent optional routing designs, different owners or geographical regions. A link layer could be used to represent a frequency band. A maximum of six site layers and six link layers are available. Interference calculations only consider links on visible layers which allows a selective analysis of the network.

Basic Operation

The following is a typical design procedure for a multihop system using the Network module as a starting point.

- Enter the site names and coordinates of the proposed sites into the Site List. These are the required data entries. Call signs will be required to calculate interference. Decide on a naming convention for temporary call signs and enter a unique call sign for each site. If the site elevations are available and you will be developing the terrain profiles from topographic maps, these should also be entered. When the Site List is closed, the sites will be displayed.

- Set the Map Reference to correspond to the topographic maps that will be used in the design.

- Link up the sites. Place the cursor on a site legend and while holding the left mouse button down, move the mouse to the adjacent site. Release the left mouse button to complete the link. Note that the order of the sites is set by the first site selected. The first site becomes Site 1 and the second site becomes Site 2 in the data file.

- Move the site name labels and set the site legend and link display attributes as desired.

- If topographic maps will be used to generate the profiles, determine the map crossings. Click the right mouse button on a link and select Map Crossings to generate a crossing report.

- Access the Terrain Data module with one of the links. Click the right mouse button on the link and select Terrain Data. Generate the terrain profile from a data base or topographic maps and proceed with the link design using the various design modules in the program.

- When the link data file (Pathloss file) is saved, the file name will be automatically registered in the associated Network data file.

- Repeat the above sequence until Pathloss data files are available for all links on the system.

Within the Network module, there are two ways of accessing the various design modules in the program. You can click the left mouse button on a link and select the desired design module. Remember that only one Pathloss data file can be loaded into memory at a time. If the Pathloss data file is already in memory, then the program will switch to the design module. Otherwise, the file will first be loaded and then switched to the design module.

Alternately, you can click Module - [design module] on the Network menu bar. This operation switches to the design module using the currently loaded Pathloss data file.

Note that there is a duplication of data in the Network file and the Pathloss data files. Each contain the site names, call signs, coordinates and elevations. Furthermore, a change in one of these could affect several Pathloss data files. As the design proceeds, the site data in the Network is compared against the data in the current Pathloss file. When switching between the network and one of the design modules, the Data Changed dialog box will appear if the data does not match. If "Use Network" is selected, the Pathloss file data will be changed to the network data. If "Use Pl4 File" is selected the network data will be changed to the Pathloss file data.
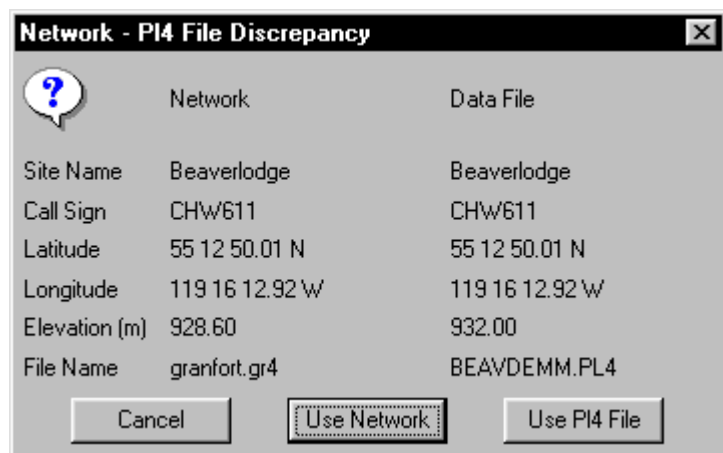
Provision is also made to update all of the Pathloss data files in the Network module to the data in the Site List.

Network Data File
A network data file essentially consists of a list of sites with the following parameters:

site name	call sign
latitude	elevation
longitude	display attributes

In addition, the site list contains a reference to a table of links for each site. This link table contains the following additional information:

- the index of the site to which it is linked

- the full file name of the pathloss data file associated with the link

- the link display attributes

- the reversal status of the pathloss data file

Merging Network Files

You can merge several Network data files together. Click Files - Merge on the Network menu bar and select the Network data file to merge with the current display. Problems may occur if the files represent widely separated areas.

Move /Copy Network Files

In a large project, there will be 500 or more Pathloss (pl4) files associated with the network. These could be located in different directories along with files which are not part of the current network. The move /copy function will either move or copy all relevant files to a single new directory. The operation will not proceed if a pl4 file would be overwritten (same pl4 file name in different directories).
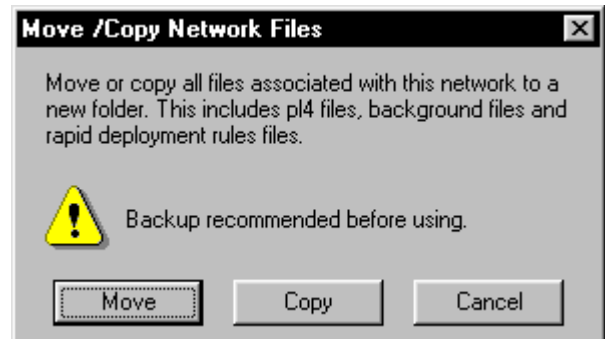
MapInfo Exchange Format

Sites, links and the grid can be exported to MapInfo using the MapInfo drawing exchange format. Two files are created for each export with the suffixes mif and mid. Select Files - MapInfo Export and select the required type (sites, links or grid). The following data items are transferred in the mid file:

Sites   site name, call sign, elevation

Links   site names, geographic coordinates and the link label

Grid   axis labels

DEFAULTS

Display attributes such as the site legend, the links between sites and the site name label can be individually set or can be set to the defaults for all new additions.

Site Legend

Select Defaults - Site Legend from the Network menu bar to set the default site legend. Double click the left mouse button on a site legend to set the attributes for that legend. The legend options are the size, shape (circle, square or triangle), and color. The legend can be a solid object or outline. All of the reset operations act only on visible layers. The shape, color or size can be selectively reset or all of the site legend attributes can be reset with the Reset all button.
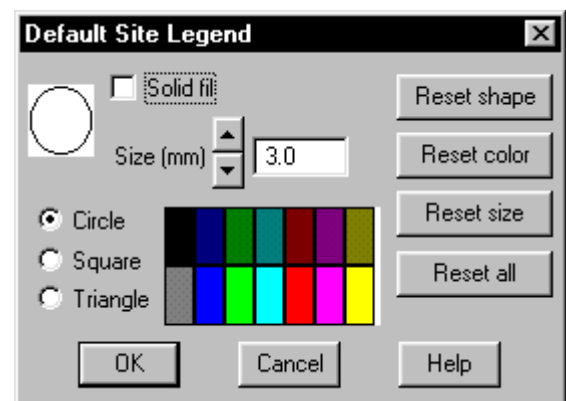
Site Name Attributes

Select Defaults - Site Name Attributes from the Network menu bar to set the default site name attributes. Double click the left mouse button on the site name label to set the individual attributes for this site. To move a site name label, place the cursor on the label, hold down the left mouse button and move the label to the desired location. You can set the point size, color and the style (bold - italic) for the label. The site label can include, the site name, call sign, coordinates and elevation. If all of the site name labels have been hidden and you wish to restore only a few, then double click on the site legend. The same selections are available here.

The site labels use the Titles font which is common to all modules in the Pathloss program. Select Configure - Fonts - Titles from the menu bar to change the basic font. The point size, color and style will not be affected.

The Default Position button resets the placement of all site names to the default position on creation.

Link Attributes

Select Defaults - Link Attributes from the Network menu bar to set the default link attributes. Click the right mouse button on the link and select Link Attributes from the popup menu. You can set the line thickness, color and style (solid, dashed or dotted). Note that the Windows Graphic Device Interface may not support thick dashed or dotted lines.

The individual Link Attributes Dialog box includes a delete button. If you delete a link which includes a reference to a Pathloss data file, you must import the Pathloss data file again to establish the reference. If you just redraw the link, there is no way to re-establish the reference to the Pathloss data file.
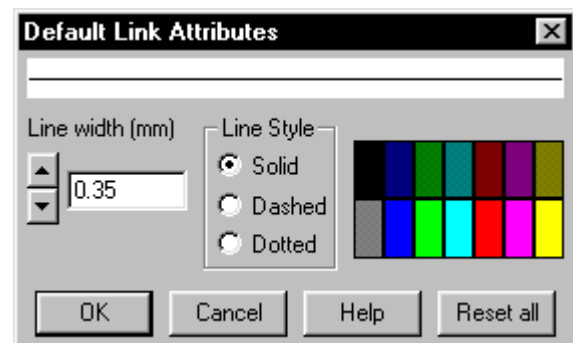
It is also possible to delete a link from the popup menu when you click the right mouse button on a link or from within the Link List grid display. The same considerations apply in all cases.

Axis Attributes

Select Defaults - Axis Attributes to set the axis attributes. The point size, color and style (bold and italic) can be set.

The latitude - longitude labels use the Axis font which is common to all modules in the Pathloss program. Select Configure - Fonts - Axis from the menu bar to change the axis font face. The point size, color and style will not be affected.

Map Reference

Select Map Reference on the Network menu bar to set the spacing between the latitude and longitude grid lines. These settings determine the map crossings. There are three predefined map scales:

Canada 1:50,000   Lat inc 15'   Long inc 30'

Canada 1:250,000   Lat inc 1°   Long inc 2°

USA 1:24,000   Lat inc 7.5   Long inc 7.5'

If one of these are selected, the map name is given on the map crossing report.

For all other scales, you must specify the scale, latitude increment, longitude increment and the units used for the increment (degrees or minutes).

The overall extents of the drawing are set to multiples of the latitude - longitude increments which will enclose the sites. This is the case, even if the grids are not displayed on the drawing.

Network Link Labels

The labels can be either in a free format or fixed format using the Pathloss file data associated with the link.

If a Pathloss file is not associated with a link, only the free format label is available.

To set an individual link label, click the right mouse button on a link and select Label from the drop down menu to access the Label dialog box for that link.

To set a default label specification for all links, select Defaults - Labels on the network module menu bar.

Free Format

When this option is selected, the user directly enters the label text. This must be carried out for each link label. There is no default free format label.
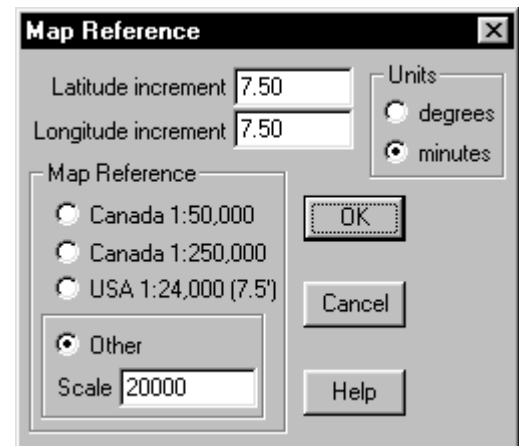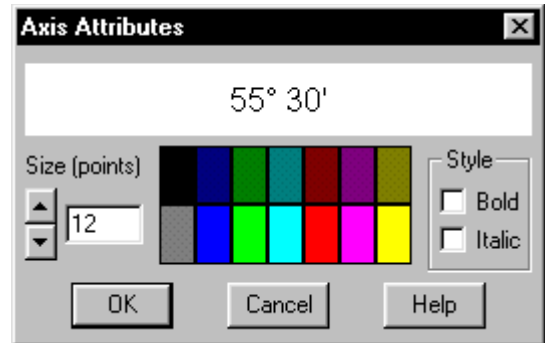
Fixed Format

The fixed format is in effect when one or more of the following options are checked:

TX frequency	Channel ID
Polarization	Distance

The label format is displayed but cannot be edited. In this mode, the label is formatted using Pathloss file data on disk. A file in memory will not used. The file must first be saved. This format is not available if there is a file association or the link does not exist.

The TX frequency, channel ID and the polarization are taken from the first entry in the TX channel assignments. The file must be a microwave application to use these parameters. The distance is the calculated path length based on the coordinates.

If the file data is changed, the labels are not automatically updated. To update the labels, select Defaults - Labels and click the Update Labels button. The Pathloss data files associated with the links will be read and the labels will be updated using the existing label format specification. The Reset All button will also update the labels; however, all label specifications will first be reset to the default values before updating.
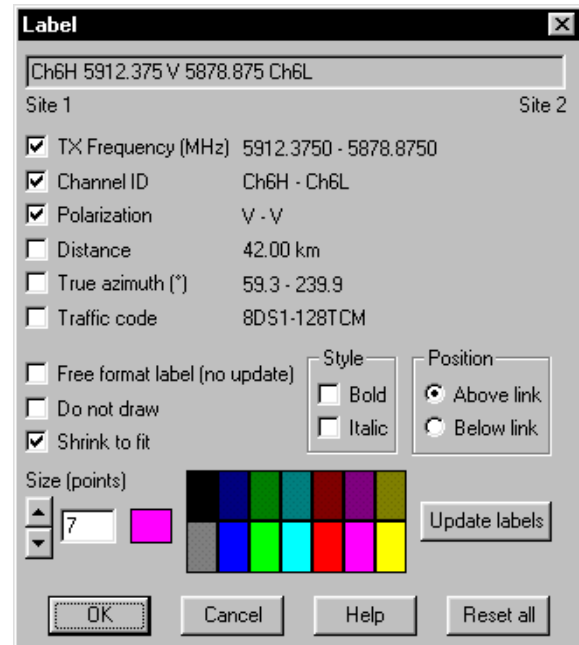
Shrink to Fit

When this option is selected, the program will attempt to fit the label on the link starting with the specified font size. If the label does not fit on the link, the font size will be successively reduced until the label fits. The font size will then be changed to the final size. If the font size reaches zero, the label will not be drawn.

Coverage Attributes

Select Defaults - Coverage Attributes. Area coverage plots can be imported into the network display. These are displayed as solid coverage areas. The radial line display is not supported in the network. You can set the colors, switch the various signal levels on and off and set the fill to either a solid or hatch fill. The latter provides a limited transparency effect when the network display has a terrain background. The line widths and styles are not used in this display. To change the color of a signal range click on the line in the Line Attributes group box. The link will appear in the Edit Line group box. Select one of the stock colors or used the RGB color bars to set the color. The settings will be common to all imported coverage plots.
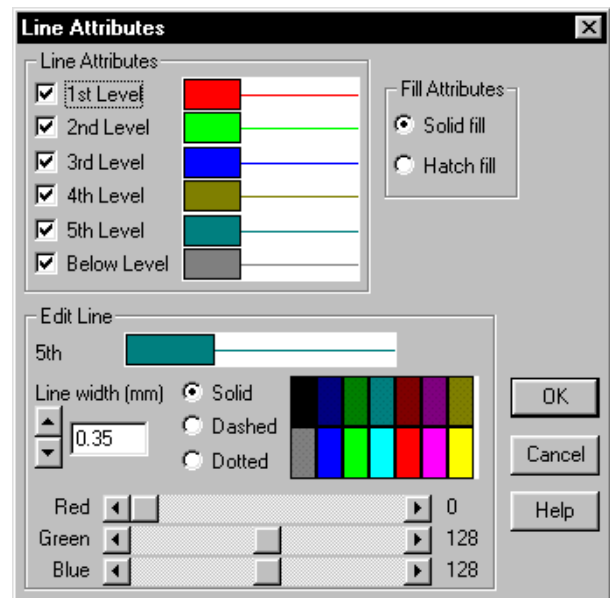
PAGE SETUP

Network Display Scale

The scale of the network display is automatically determined from the geographic extents of the sites and the current printer page size and orientation. The complete drawing extents are determined by the map reference even if the map grid is not displayed.

In the "arbitrary scale - fit to page method", the site legends, site names and the latitude - longitude labels are drawn to absolute dimensions. If the site legend dimension has been set to 4 mm, the drawing will be printed with a 4 mm legend independent of the scale of the overall drawing.

This system works well when the number of sites are small and the drawing can be printed on a single, letter size page. With a large number of sites, the drawing is usually plotted on large format paper.
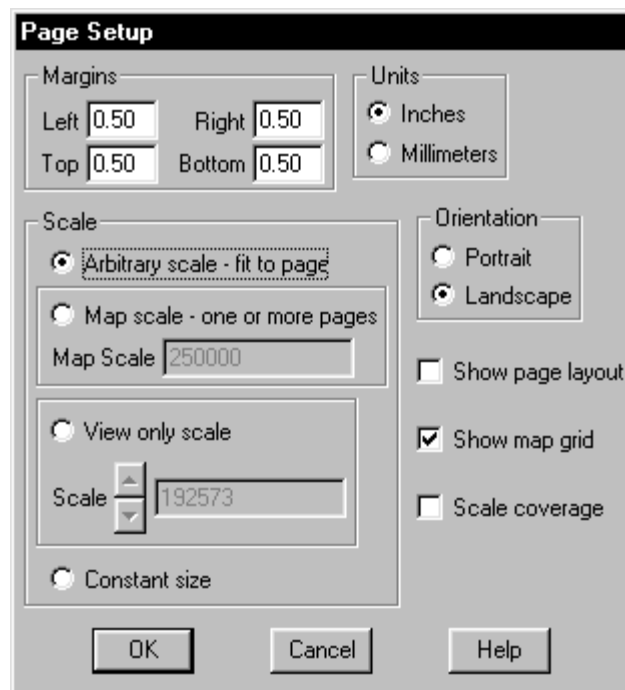
The latter method is required for a large number of sites. When the total network is displayed, the text will be too small to read, however, when the display is zoomed, to view a selected area, the drawing appears normal. The scale is set in the Page Setup dialog box.

Select Print - Page Setup to set the print and display options. The margin setting only applies to the Arbitrary scale fit to page method.

Select the page orientation (Portrait or Landscape) which best fits the network display.

The map grid lines may be switched off; however, the overall drawing scale is unaffected.

The Show page layout option shows the relation of the drawing to the paper dimensions.

The Scale coverage option determines the extents of the drawing when an area coverage display is added to the drawing. If the Scale coverage is checked, the extents of the coverage will be taken into account in sizing the drawing.

Scale

Changes to the scale method automatically update the display as the changes are made.

Arbitrary Scale - fit to page

In this method, the drawing scale is automatically determined to fit the selected printer page size and page orientation. The specified page margins are taken into account. The site legends, site names and the latitude longitude labels are drawn to absolute dimensions. If the site legend dimension has been set to 4 mm, the drawing will be printed with a 4 mm legend independent of the scale of the overall drawing. This method is suitable for a small number of sites.

Map scale - one or more pages

This option allows the network display to be printed for a specified scale using multiple pages. If more than 50 pages are required to print the drawing, an error message is issued and the display reverts to the Arbitrary scale - fit to page method. The specified margins are not used in this option.

Use the Show page layout option to determine the number of pages required.

View only scale

This method is used for drawings which contain a large number of sites. Suppose the network display contained 100 sites and the printer is set for an 8.5 x 11 inch paper size. If the site name labels were set to 10 point, both the screen display and the printed page would be unusable, as the site names would overlap each other. The solution is to create an artificial scale which will shrink the size of the site names to a size which is useable only when the display is zoomed. Click the scale up - down controls to achieve a useable display. In this mode, the drawing can be printed; however, the margin settings are ignored.

Constant Size

The size of the text and site legends is constant and independent of the zoom. In the unzoomed state, a dense network will have overlapping name and legends. When the display is zoomed, the display becomes usable. On networks with a large number of closely spaced sites, this scaling method may be the most practical.

DISPLAY ZOOM
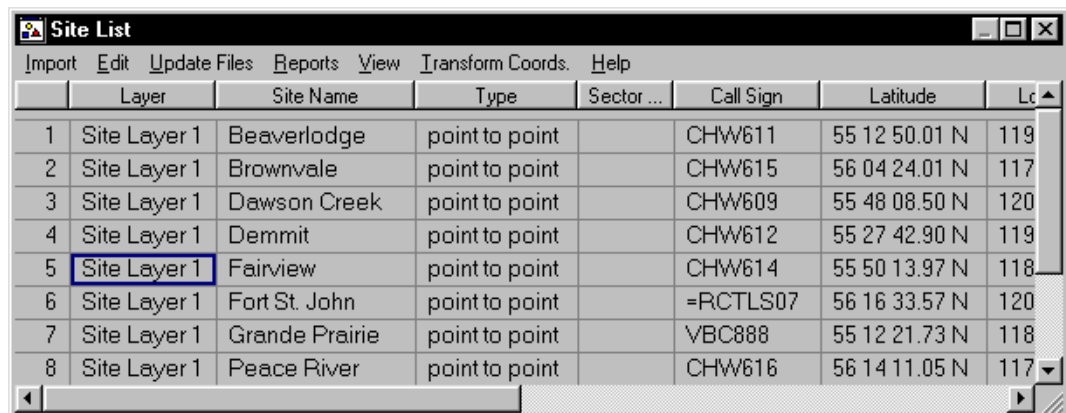
Place the cursor on one corner of the area to be zoomed. Hold down the Ctrl key and the left mouse button and move the cursor to the diagonally opposite corner of the zoom area and release the mouse button and Ctrl key. The zoomed area will remain in effect if you switch between the various design modules in the Pathloss program.

To reset the display, hold down the Ctrl key and click the right mouse button.

SITE LIST

The Site List uses a standard grid data entry display. Refer to the General Program Operation section for details on the grid display. Additional points on the Site List are:

	Layer	Site Name	Type	Sector ...	Call Sign	Latitude	Lo
1	Site Layer 1	Beaverlodge	point to point		CHW611	55 12 50.01 N	119
2	Site Layer 1	Brownvale	point to point		CHW615	56 04 24.01 N	117
3	Site Layer 1	Dawson Creek	point to point		CHW609	55 48 08.50 N	120
4	Site Layer 1	Demmit	point to point		CHW612	55 27 42.90 N	119
5	Site Layer 1	Fairview	point to point		CHW614	55 50 13.97 N	118
6	Site Layer 1	Fort St. John	point to point		=RCTLS07	56 16 33.57 N	120
7	Site Layer 1	Grande Prairie	point to point		VBC888	55 12 21.73 N	118
8	Site Layer 1	Peace River	point to point		CHW616	56 14 11.05 N	117

- The column buttons will sort the data in an ascending order. For example, click the Site Name header button to sort the sites alphabetically. Click the Latitude header button to sort the sites in ascending latitude.

- The Add and Edit forms include the grid coordinates in addition to the geographic latitude and longitude coordinates. Both the grid coordinate format and the latitude longitude data entry format can be set under Configure - Geographic defaults on the Network menu bar.

Edit Item 1	
OK Cancel	
Site Name	Beaverlodge
Sector number	
Call Sign	CHW611
Latitude	55 12 50.01 N
Longitude	119 16 12.92 W
Elevation (m)	928.60
Structure Height (m AMSL)	
Easting (km)	355.557
Northing (km)	6120.729
UTM zone	11N

When the Site List is closed, the network display is always reformatted for a full screen display if there are 10 or less sites. For a larger number of sites the must be done manually. Select Site Data - Reset Display

Import

Data can be imported into the network display in the following forms: Pathloss data files, text site files, text link files, and from a site data base. Coverage files (prd4) can also be imported to analyse multi site coverage.

Import Pathloss Data File

Select Import - Pathloss File from the Site List menu bar. A Pathloss data file is imported as a complete link. In this case, the open file dialog box is a multi-select list. Hold down the shift or Ctrl key and select the files to be imported. The pathloss file name is saved and you can select a design module for the file by clicking the left mouse button on its link.

When a Pathloss file is imported into the site list, the program first checks to see if the sites already exist based on the geographic coordinates. A duplicate site will not be added. If a link does not exist, it will be added using the default link attributes. The Pathloss file name will always be added to the link and will overwrite any existing file name reference.

Import Site Text File

Select Import - Text File from the Site List menu bar. Define the field numbers for the site name, call sign, latitude, longitude and elevation. If the call sign or elevation does not exist in the file, the field number must be blank. Coordinates can be in geographic or grid format. If "Use grid coordinates" is checked, the conversion will be carried out using the current grid coordinate system and datum.

The fields must be delimited. This means that each field must be separated by a unique character. The default field delimiter character is a comma.

Select the format of the coordinates and the hemisphere sign convention used in the file. Errors in these settings can place the site in the opposite hemisphere. Set the units for the elevation (feet or meters).

Click the Import button and select the file name to import. Only sites can be imported. The links must be drawn separately.

Import Link Text Files

This feature imports complete links into the Pathloss program and will generate the Pathloss data files and create terrain profiles.

In conjunction with the CSV report feature, this provides a two way interface with an external database.

This feature reads site and link information from delimited text file. The file format must be one link per line. Each line contains site 1 and site 2 information. A link will be created if two site names and their coordinates are imported. If one site name and coordinates are on the line, the operation is similar to the import site text file selection.

The import link text file is accessible from the site data entry form in the network or map grid modules. Select Import - Link Text File.

The first step will be to create a link definition file which defines the fields in the file to be imported. Initially the file contains all of the field descriptors available for import without any field numbers. The editing procedure consists of assigning a field number to the relevant descriptors. One or more spaces separate the descriptor from the field number as follows:

S1_SiteName 4   You can save this file and edit the fields numbers externally or carry this step out directly in the dialog.

The available field descriptors are shown below. Each descriptor is prefixed with S1_ or S2_ indicating site 1 and site 2. The descriptors can be in any order. A field descriptor without a field number will be ignored. Field descriptors which are not used can be deleted. The same field number could be assigned to different descriptors. For example the S1_RadioModel and S2_RadioModel would normally be assigned the same field number. Descriptors marked with an * will only be read if the save Pathloss file option is checked.

SiteName	site name - 23 characters
CallSign	call sign - 15 characters
StationCode	* station code - 15 characters
State	* state - 15 characters
OwnerCode	* owner code - 15 characters
OperatorCode	* operator code - 15 characters

Latitude	latitude in single field
Longitude	longitude in single field
LatitudeDeg	separate field for latitude degrees
LatitudeMin	separate field for latitude minutes
LatitudeSec	separate field for latitude seconds
LongitudeDeg	separate field for longitude degrees
LongitudeMin	separate field for longitude minutes
LongitudeSec	separate field for longitude seconds
Easting	grid coordinates
Northing	grid coordinates
UTM zone	UTM grid coordinates only
Elevation	site elevation AMSL (feet or meters)
TowerHeight	* tower height AGL (feet or meters)
AntennaModel	* antenna model - 23 characters
AntennaCode	* antenna code - 15 characters
AntennaDiameter	* antenna diameter (feet or meters)
AntennaHeight	* antenna height AGL (feet or meters)
AntennaGain	* antenna gain (dBi)
TXLineType	* transmission line model
TXLineLength	* transmission line length (feet or meters)
TXLineLoss	* transmission line loss (dB)
ChID1	* 1st transmit channel id - 7 characters
TXFreq1	* 1st transmit frequency (MHz)
Pol1	* 1st transmit channel polarization
ChID2	* 2nd transmit channel id - 7 characters
TXFreq2	* 2nd transmit frequency (MHz)
Pol2	* 2nd transmit channel polarization
ChID3	* 3rd transmit channel id - 7 characters
TXFreq3	* 3rd transmit frequency (MHz)
Pol3	* 3rd transmit channel polarization
RadioCode	* radio code - 15 characters
RadioModel	* radio model - 23 characters

EmDesig	* emission designator - 15 characters
TXpower	* transmit power (dBm)
TXloss	* transmit loss (dB) - assigned to other transmit loss
RXloss	* receive loss (dB) - assigned to other receive loss
RXthresLvl	* receive threshold level (dBm)
RXthresCrt	* receive threshold criteria - 15 characters

Latitude - Longitude Options
If the coordinates are specified as latitude and longitude and a single field is used for each, (S1_Latitude, S2_Latitude, S1_Longitude, S2_Longitude) the following options are available:

The coordinates can be expressed as a decimal (49.12345) or in degrees minutes and seconds separated by a spaces, dash or other characters (49 07 24.42 N). In the latter format, the letters N and S can be used with latitudes and E and W with longitudes to identify the hemispheres. In the absence of a letter and in the decimal coordinate format, it is necessary to specify the sign convention for the coordinates:

Latitude - positive north or south

Longitude - positive east or west

It separate fields are used for degrees minutes and seconds, use the LatitudeDeg, LatitudeMin, LatitudeSec, LongitudeDeg, LongitudeMin, LongitudeSec fields. The sign convention options will determine the hemisphere.

If the import file uses grid coordinates, use the Easting and Northing descriptors. These will be converted to latitude and longitude using the current settings in the Geographic Defaults section. The following parameters are used:

The ellipsoid defined by the datum or ellipsoid selection.

The grid coordinate system. If UTM coordinates are specified, then the zone descriptor must be used.

The following options must be set for grid coordinate systems.

Grid Units - meters or kilometers

Hemisphere - northern or southern

Field Delimiter
Specify one of the field delimiters or check the other box and enter the field delimiter character.

Text Qualifier
This is not used at present. All quotation marks in text fields will be removed.

Units
Check either meters or feet. This applies to elevations, antenna heights, antenna diameters, transmission line lengths and tower heights.

Polarization

The following options for polarization are used:

Vertical polarization is designated by V or v, horizontal by H or h

Vertical polarization is designated by 1 or TRUE, horizontal by 0 or FALSE

Vertical polarization is designated by 0 or FALSE, horizontal by 1 or TRUE

Save Pathloss Files

This option will create pathloss data files. As a minimum, the imported line must contain two valid site names and two sets of coordinates. The file names can be created from the call signs or the site names. A terrain profile will be generated if a terrain database has been configured.

Import Coverage Files

Coverage files (Prd4) are created in the Coverage module. Select Import - Prd4 File from the Site List menu bar. Load the required Prd4 file. The last four columns of the Site List show the display the status of the Prd4 Files. The Show column check boxes allow the user to selectively display coverage for different sites. The LOS (line of sight) check boxes switch the display from signal coverage to line of sight display. The Prd4 file column displays the coverage file name. This cannot be edited.

It is possible to generate a complete coverage display directly in the Network module. Double click on a site legend. Then click the Area Coverage button. The procedure is described in the Area Coverage section of the manual.

Import from the Site Database

Sites and links can be imported from the site database. Refer to the section Summary - Site Database for details.

MapInfo Import

Sites and Links can be imported in the MapInfo drawing exchange format. The import does not read legend or line color /styles. In a site import, the site name must be the first field in the mid file. In a link import, the site names must be in the first two fields of the mid file.

Mark Sites

The mark site feature closes the site list and draws a 0.5 inch blue circle on the site which was selected in the site list. This is used to identify the location of a site on a network with a large number of sites. Note that mark will persist until the site name is moved. This allows the user to zoom the display to locate the site in case it was overwritten on a very dense network.

Reset Site Type and Sector Numbers

Sites are designated as point to point, point to multipoint and remote. Sector numbers are assigned to the latter two categories. The reset feature is used in conjunction with the Sections feature described later in the section. All sites in the Site List will be reset. If a sub network is active, then the site list display can be limited to show site in the sub network only.
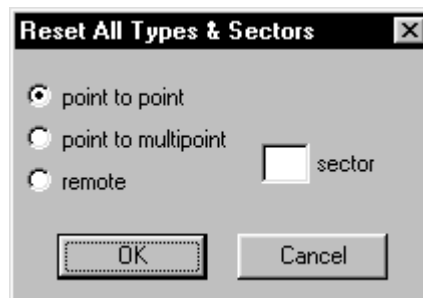
Update Files

Several Pathloss data files may contain the same information as in the Site List. Provision is made to update all files. A prompt is issued for each change encountered. This is the only method available to guarantee that the Pathloss file data agrees with the network data.
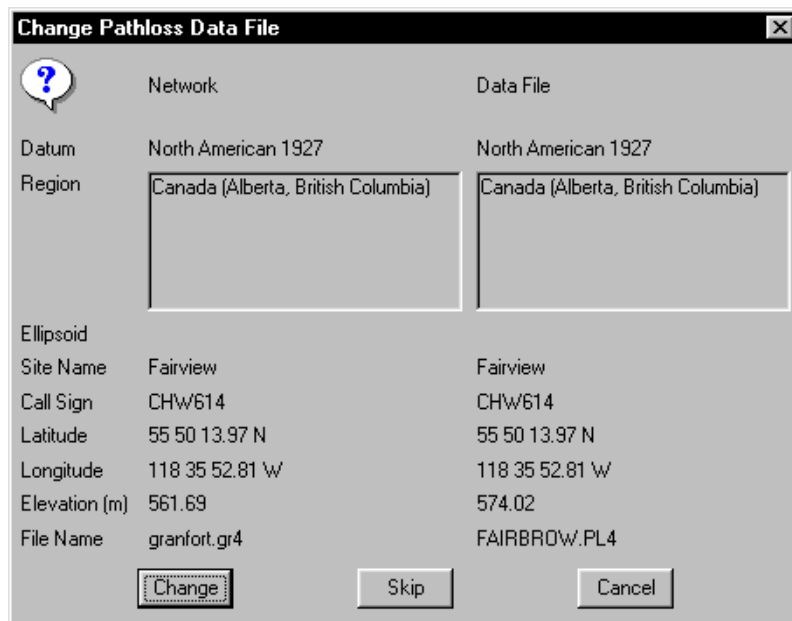
Site Layers

The site layers are set in the Site List. Double click on the layer field and set the layer. This operates in conjunction with the Layers dialog box.

LAYERS

The layers dialog box is accessed from the Network menu bar and displays both the site and link layers. Each layer can be given a descriptive name. The layer is visible if the associated box is checked.

Site layers are defined in the Site List and link layers are defined in the Link list.

The active site and link layers are set in this dialog box. The active layer is always visible and is the default layer for the next site or link which is added to the network.

If the Maintain maximum drawing size option is checked, the overall drawing extents are determined by all sites, whether they are visible or not. If this option is not checked, the drawing extents are determined by the visible sites.
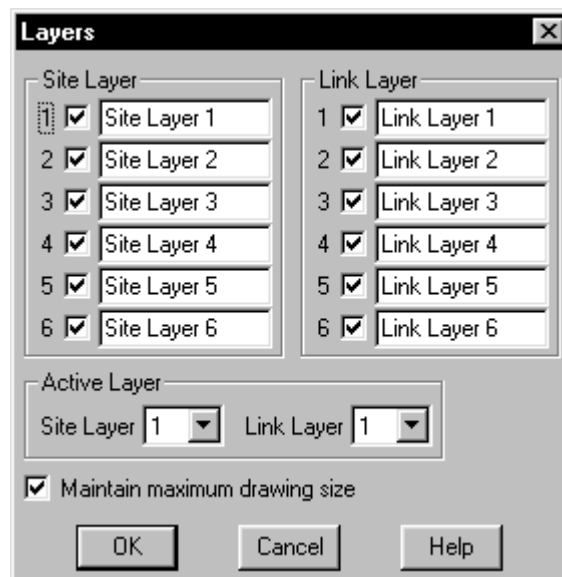
LINK LIST

The Link List simply shows the links and the associated Pathloss data file name. The list cannot be edited. The list can be sorted by clicking on the column header. Any of the design modules for the selected link can be accessed from the module menu selection. The Link List includes the layer selection. Double click on the layer field and select the layer for the link.

NETWORK DISPLAY BACKGROUNDS

A terrain image can be used as a background in the network display. A terrain database must be configured for this option. Select Site Data - Create Background. The process is automatic. Elevations are read from the database for each pixel on the display. The network display should be maximized for the best results. The following points should be noted:

- The network display uses a symmetrical projection based on the extents of the sites. This is accomplished by creating an arbitrary central meridian at the exact centre of the display. The background is formatted for this projection. If the extents of the display are changed by adding a new site or by changing the map reference, the background projection will not be valid and it is automatically erased.

- If the display is zoomed, the background will be zoomed with a reduction in resolution. In this zoomed state, the resolution can be increased to the screen pixel size with the Zoom Background menu selection. The drawing on the right is a zoomed background for an ESRI GRIDASCII terrain database with embedded building data. In conjunction with the Add Site feature described below, the user can design a network of sites located on building tops. If the display is scrolled or the zoom is changed the display reverts to the original background.
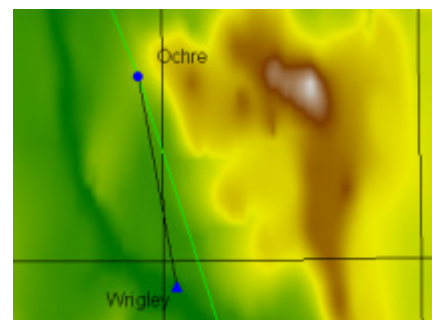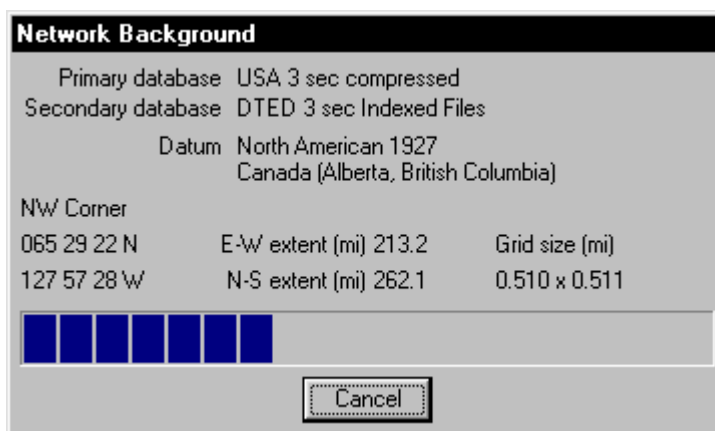
Add Site

Select Site Data - Add Site to add a new site directly on the network display. In conjunction with the network background, this feature will be useful in the initial planning stages. A site marker is shown on the display. Click the left mouse button on the display to move the marker to the cursor location, or hold the left button down and drag the marker to the desired location. The keyboard cursor keys can also be used to position the marker with a one pixel resolution. In many cases, it may be useful to zoom the display and background when adding a new site. When the marker is in position, click the Add Site button and enter the site name.
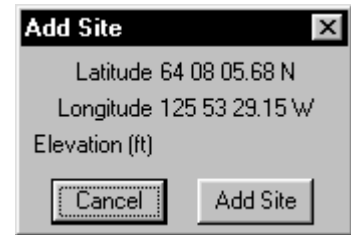
Colour Legend

Select Site Data - Colour Legend to display the colours for the elevations used on the display.

The background display can be temporarily removed with the Show Background menu selection. The Create Background menu selection will be disabled under the following conditions:

- a terrain database has not been configured
- the network file has not been saved

The create background feature will generate two files in the same directory as the network file using the network file name and the extensions bmp and bkg. The bmp file is a windows bitmap and the bkg file contains the elevations which appear when the Add Site dialogue is active.
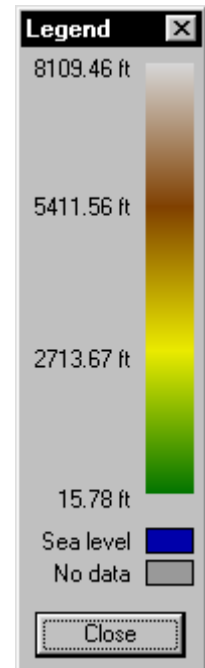
NETWORK OPERATIONS

On any project involving more than several sites, the network module should be used as the front end of the program. Start the project by entering (or importing) sites into the Site List. Once the sites have been entered, link up the sites to form the network. Use the network display to access the various design modules. The network will manage all data changes.

Moving Pathloss Data Files

Suppose a network drawing has been constructed. Each link references a pathloss file name by its full path name (directory and file name). If for some reason the Pathloss data files were moved to another directory, you would not be able to access the data files by clicking on the link. The solution is to re-import the pathloss data files into the Site List again over top of the existing sites. The existing drawing attributes (colors, line styles and legend sizes) will not be affected. During the import, the program checks if the site exists and will not add the site again or change any of the attributes. If the link exists, only the new file name association will be made.

Overlapping Sites and Links

As the number of sites increase, there is always the possibility that sites and links will overlap. When the mouse is clicked on a link, the program checks for overlapping links and creates a link selection if multiple links are detected.

Similarly, if the left mouse button is double clicked on a site legend, which has overlapping sites, a selection list is presented.
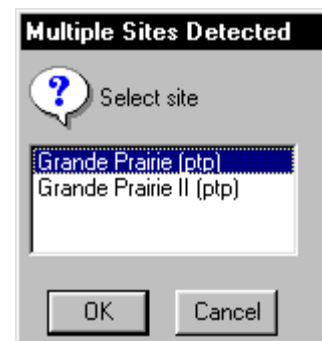
When two sites are joined, and multiple sites exist, a link selection list is presented. It is possible to join two overlapping sites; however, in the current release, the link cannot be selected.

Adding Multiple Links Between Two Sites

To allow for situations where an existing system is being over-built or a temporary link is required, multiple links and the associated Pathloss data files are required. The first link between two sites can be implemented by any of the following methods:

- Place the cursor on the first site - hold down the left mouse button and drag the mouse to the second site. This method will only work if a link does not exist between the two sites.

- Import a link from a Site Database.

- Merge two network data files.

- Import a Pathloss data file into the Site List. Select Site Data - Site List and then select Import - Pathloss File. This brings up a multi-select File Open dialog box. Select the required files and click open. Multiple links can only be created using the Import Pathloss File method.
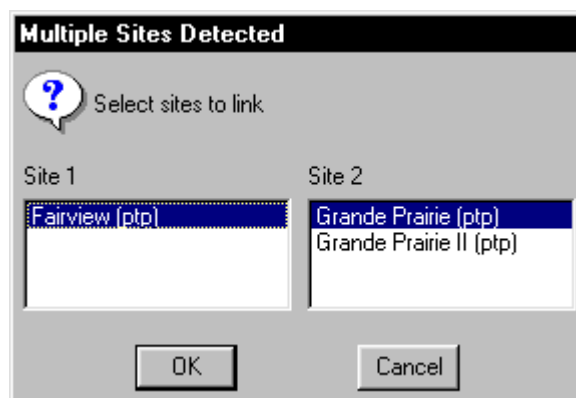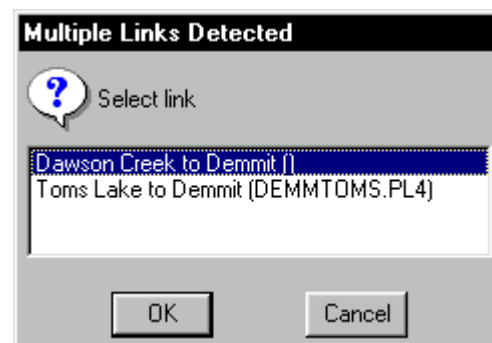
The sequence of operations used to import a Pathloss file is described below.

The coordinates of the two sites in the Pathloss data file are compared with those in site list to determine if the site exists. If the difference between the two latitudes and longitudes is less than $2.777778 \; 10^{-6}$ degrees (0.01 seconds), then the existing site will be used. The site name, call sign and elevation in the site list are not changed. Otherwise, a new site will be added.

The program then checks for an existing link between the two sites using the following criteria:

If the existing link does not have a pathloss (pl4) file name associated with it or the associated file cannot be found, then the name of the file being imported will be used. No changes are made to the link attributes (line style and color). If the pathloss files were moved to another directory, then the user would simply re-import the files to re-establish the correct file name association.

If the file name associated with existing link is the same as the file name being imported, no action is taken, otherwise, a new link will be added.

A word of caution is necessary when the files are located on a shared network drive. The check for the same file name is based on a simple string comparison. If the network drive has been mapped, then two different file names for the same file are possible. As an example, the UNC file name \\SERVER\PROJECT\REGION_1\link_1.pl4 could be the same file as J:\REGION_1\link_1.pl4. In this case a duplicate link would be created.

Deleting an Existing Link

If either site is deleted in the site list, the corresponding link will be automatically deleted. To delete the link only, click the right mouse button on the link and select the Delete menu item. The pathloss data file (pl4) associated with the link is <u>not</u> deleted.

AREA COVERAGE CALCULATIONS IN THE NETWORK MODULE

An area coverage analysis can be carried out directly in the network module. Double click on the site legend that the coverage analysis will be carried out on. Click the area coverage button. The procedure is exactly the same as a new coverage project described in the Area Coverage section of the manual.

- you will be prompted for the name of the coverage project in a save file dialog box.

- a sequence of dialog boxes will appear for the terrain profile, diffraction calculations and the equipment parameters.

When the coverage calculation is complete, the results are automatically displayed
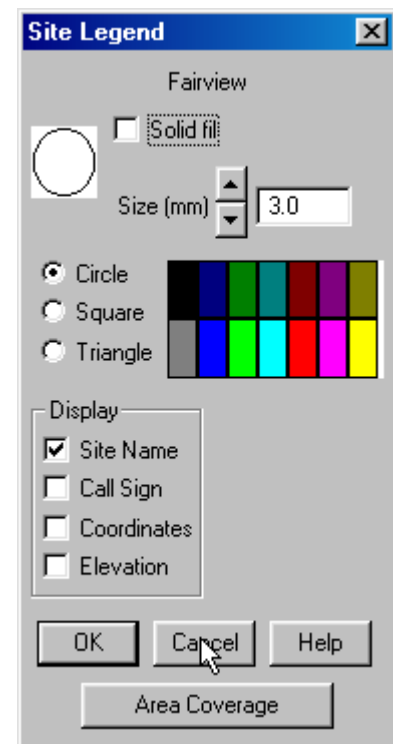
SECTION PERFORMANCE OBJECTIVES

This feature is accessible in the network module. Select Sections - Objectives.

The procedure is as follows:

Define the links in the section. This definition consists of selecting the links, defining the order that they are arranged and defining the order of the sites in a link. The easiest way to do this is to minimize the Section Performance Dialog and select the individual links in the order that they will appear by clicking the left mouse button on the link. The first click selects a link - the second click removes the link from the section. You can reverse some of the links or change the order if required by returning to the Section Performance dialog box.
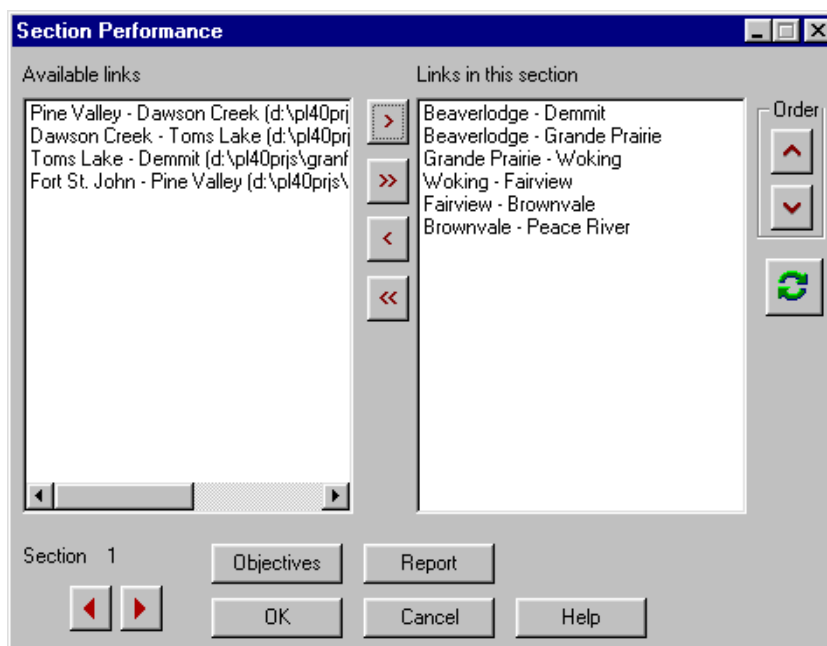
In the second method links are selected by moving them from the available links list box to the selected links list box. You can remove a selected link by hiliting the link and then moving the link back to the available links list.

Any number or sections with any combination of links in a section can be defined. The only restriction is that a link must have a valid pl4 file association. Each section definition will have its own set of performance objectives.

Objectives will be reference to either the present section definition or a hypothetical reference path. The length of the HRP must be specified in kilometers.

Select the calculation method for the objectives (G.821, G.826 or Annual time below level). It is assumed that the associated pl4 files have been configured for the same option. If objectives are not specified, then the report will only contain the calculated performance.

SUB NETWORK OPERATIONS

The concept of a sub network simplifies operations on a large network and automates certain routine task such as path profile generation and equipment data entry.
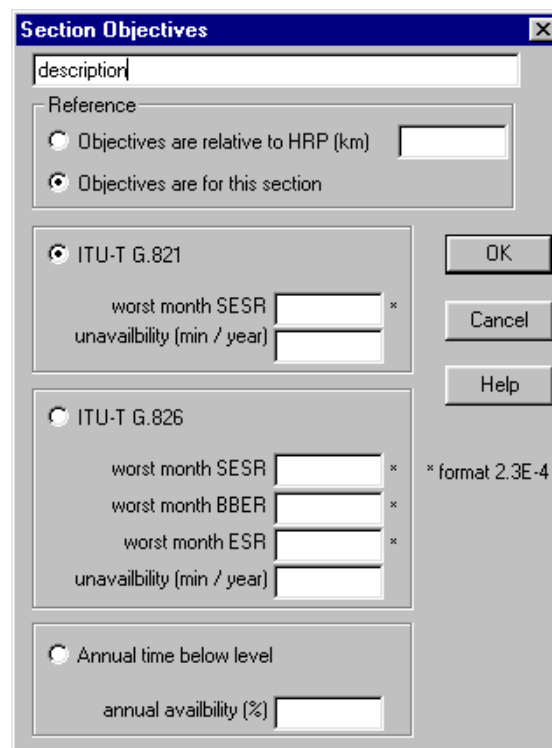
Sub Network Definition

In the network module, select Sections - Sub Network Operations. There are two methods to define a sub network.

- Select the required links from the Available links list and move these to the Sub network links list.

- Click on the desired links in the network display. You can minimize the dialog box for this purpose.

Note that only links can be placed in a sub network. There is no provision to add individual sites. Once the link definition is complete, check the Activate sub network option and Click OK to close the dialog box. The sub network is always saved when OK is clicked.
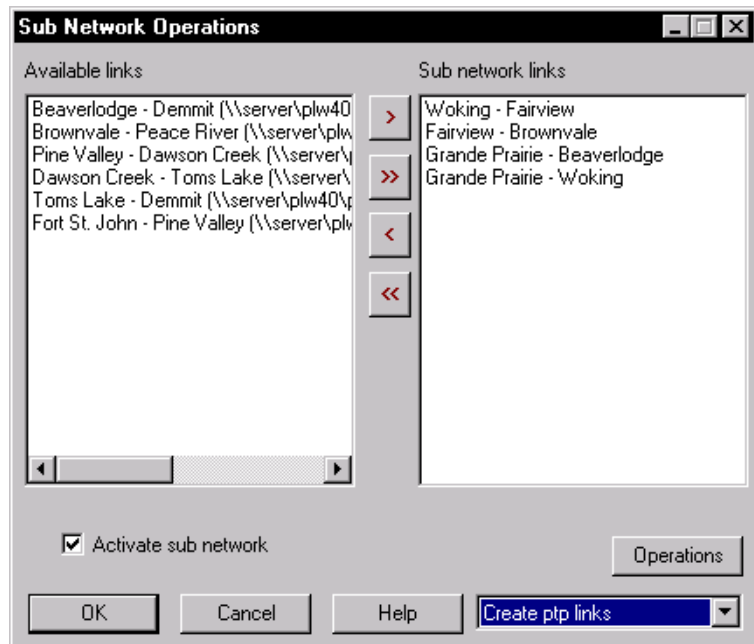
The network display is resized to show only the sub network links. All network operations are now limited to these links. You can return to the Sub Link Operations dialog at any time and deactivate the sub link.

Interference Calculations on a Sub Network

An intra system interference calculation has two new options when a sub network has been defined and is activated.

Sub network intra system interference
In this option, the interference calculation is carried out for only the sites in the sub network. All other sites are ignored.

Sub network against network interference
Each interference case must involve one TX or RX in the sub network with one RX or TX in the remaining network display. All TX and RX combinations of the sub network are excluded. Similarly all TX and RX combinations in the remainder of the network are also excluded.

The Analyse current file option can be used in a sub network.
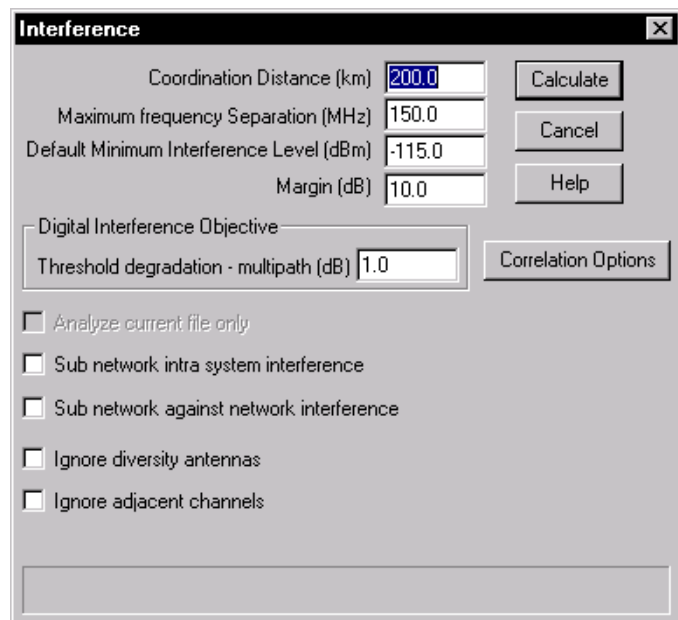
Point to Point Profile Generation

This function creates Pathloss data files (pl4) for all links defined in the sub network. Equipment data entry is based on a template Pathloss data file.

In the Sub network definition dialog, select "Create ptp links" and click the operations button.

Select the template file to be used to generate the new Pathloss data files. All equipment parameters, and calculation settings including the rain region will be use.

The template file can be a file on disk or the current file loaded in memory. If a disk file is to be used, Click the Browse button to load the file.

The Pathloss file names can be based on either the site names or the call signs.

Check the Generate path profile box to create path profiles. A terrain database must be configured.

Click the OK button to generate the Pathloss data files.

Edit Frequency Plan

This operation is only applicable to microwave applications. Select the "Edit frequency plan" in the operations drop down list.

Hilite the desired links in the Sub network links list box.

Click the Operations button. The transmit channel data entry form will be brought up for each link in sequence. The changes will be automatically written to the associated Pathloss data files.

Sub network Link Layer

This operation sets the drawing layer for all links in the network.

Select Link Layer in the operations dropdown list and click the operations button. Set the link layer number as required.
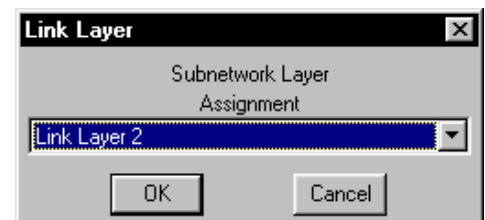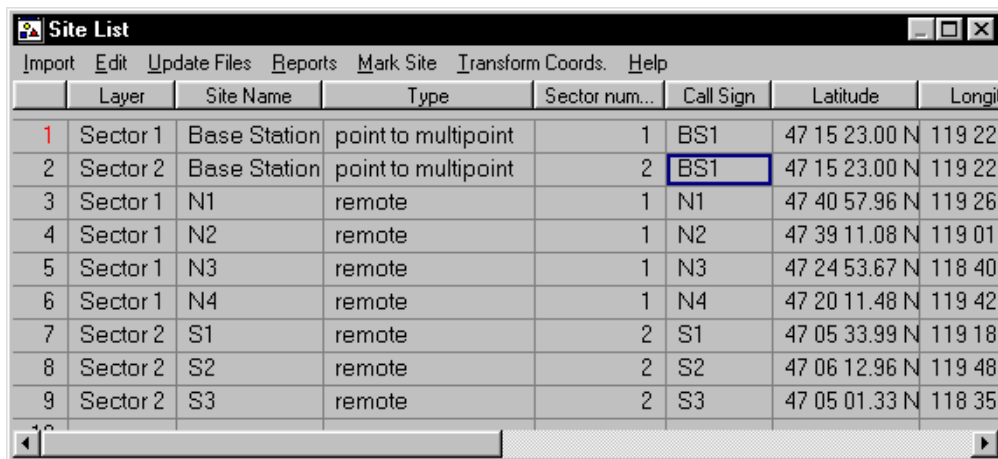
Point to Multipoint

This operation will generate point to mulitpoint Pathloss data files for all links defined in the network.

One site must be designated as a point to multipoint site; all others must be designated as remotes. The same sector number must be used for all sites. The following steps illustrate the creation, layout and design of a Point to Multi point network.
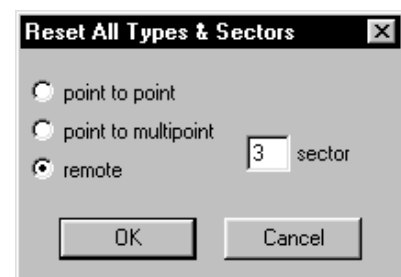
Step 1 - Entering Sites

Enter the site information into the Site List, this can either be entered as individual sites or you can import the data from a text file or existing Pathloss data files. Each site must be designated as either a PMP or a Remote site this is done by selecting and changing the value in the Type dropdown list.

	Layer	Site Name	Type	Sector num...	Call Sign	Latitude	Longit
1	Sector 1	Base Station	point to multipoint	1	BS1	47 15 23.00 N	119 22
2	Sector 2	Base Station	point to multipoint	2	BS1	47 15 23.00 N	119 22
3	Sector 1	N1	remote	1	N1	47 40 57.96 N	119 26
4	Sector 1	N2	remote	1	N2	47 39 11.08 N	119 01
5	Sector 1	N3	remote	1	N3	47 24 53.67 N	118 40
6	Sector 1	N4	remote	1	N4	47 20 11.48 N	119 42
7	Sector 2	S1	remote	2	S1	47 05 33.99 N	119 18
8	Sector 2	S2	remote	2	S2	47 06 12.96 N	119 48
9	Sector 2	S3	remote	2	S3	47 05 01.33 N	118 35

Assigning sector numbers and remote site identifiers can be simplified with the view menu selections in the site list. Select "show subnetwork only" and then select "reset site type". Set the site type to remote, enter the sector number and click OK. Manually change the hub site identifier to point to mulitpoint.

Reset All Types & Sectors
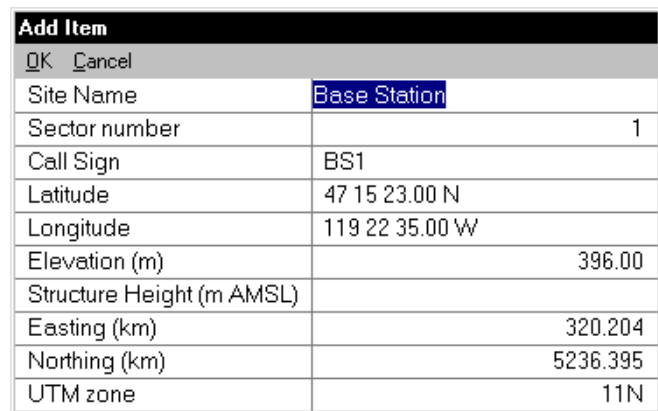
○ point to point
○ point to multipoint
● remote   [3] sector

OK   Cancel

Step 2 - Create Sectors

After all of the sites have been entered you must create additional base station sites for each Sector in that site. Click on the line number of the base station site that you wish to add an additional sector to. The line number will turn red as shown in the above figure. Click Edit, Add or type Crtl A. The Add Item dialog will appear with all the information entered. Change the sector number and click OK.

Add Item
OK Cancel

Site Name	Base Station
Sector number	1
Call Sign	BS1
Latitude	47 15 23.00 N
Longitude	119 22 35.00 W
Elevation (m)	396.00
Structure Height (m AMSL)	
Easting (km)	320.204
Northing (km)	5236.395
UTM zone	11N

Step 3 - Create Links

You may now connect the sites together. Click and drag a line from the base station to the remote site and release the button. You will have to pick which base station sector you wish to join to.

By now you should have your Sites entered defined as either Remote or Base Station and the links defined. The next steps create a template file and generate the Pathloss profiles.
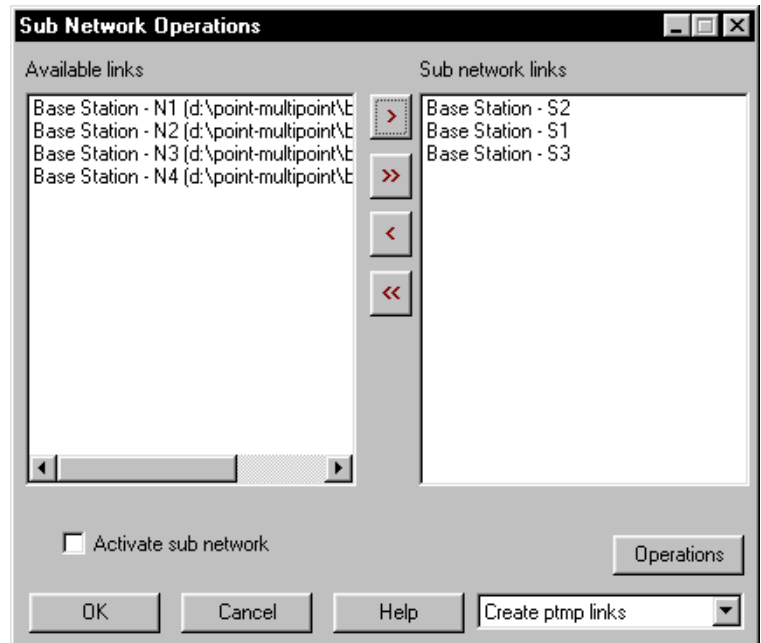
Step 4 - Create a Template

Before we can create any profiles we need to first have a template that has all the values used in the profile creation. Click on one of the links and go to the Worksheets module. In the Worksheet module you should

define all equipment and frequencies that will be used. You should also set the antenna heights for both sites. These values will be used in all of the Pathloss files generated.

Save this Pathloss file and return to the network module.

Step 5 - Profile Generation

In the network module click Sections and Sub Network Operations. Select all the links for the first sector either by selecting the links from the list in the left pane or by minimizing the dialog and selecting the links graphically on the screen. Once all of the links for that sector have been selected, bring the dialog back up and click Activate sub network. The display will update in the background showing only the defined sub network highlited in pink. Click the drop down list under the Operations button and select "Create Ptmp Links". Click Operations.
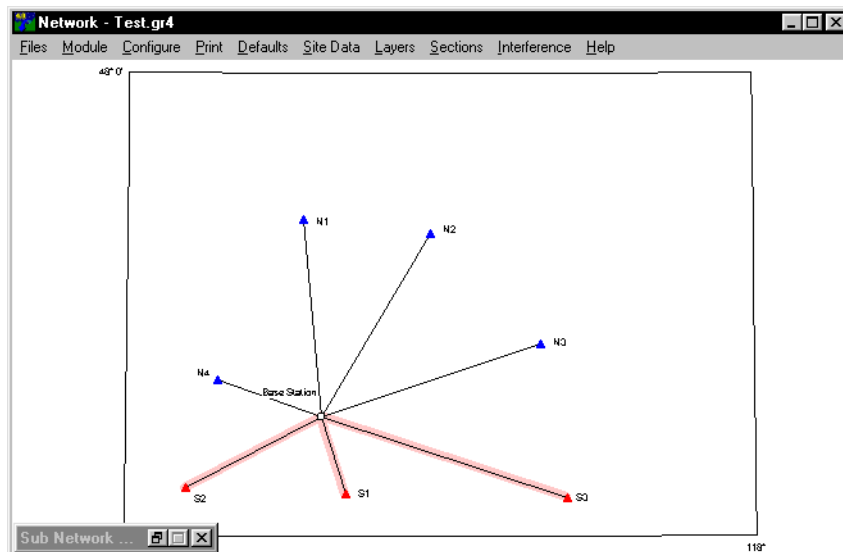
The Create Pathloss data files dialogue box will appear. Select the template file to use for the creation of the Pathloss files. This file is the Pathloss file that was created and saved in Step 4 above. Decide how you want the files named, either Site1-Site2.pl4 or CallSign1-CallSign2.pl4. If you have a terrain database setup, select Generate path profiles. The program will ask to overwrite the Template file, Click Yes or the template file will not have a path profile. The rest of the files created will prompt to confirm the save name and location.

Once all of the profiles have been generated for a sector, you can click "Activate Sub Network" again and then unselect all of the links.

Repeat Step 5 for each sector at the site.
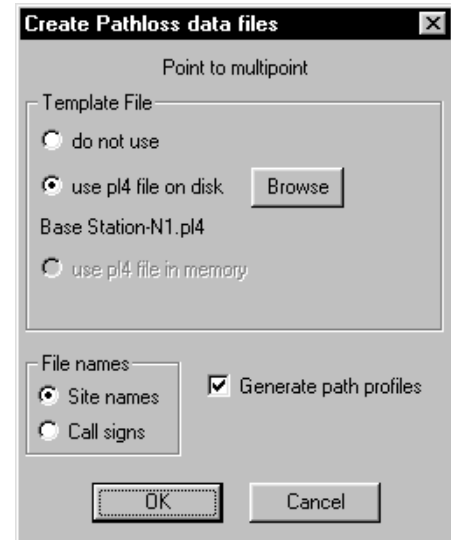
REPORTS

Several reports are available in the Site List. The format and number of these reports will change to meet special requirements. Select Help on the Site List menu bar for details of new reports.

Site List

This report prints out the contents of the site list.

Site Name	Call Sign	Latitude	Longitude	Elevation (m)
Woking	CHW613	55 28 47.00 N	118 44 50.00 W	925.6
Fairview	CHW614	55 50 14.00 N	118 35 48.00 W	574.0
Grande Prairie	VBC888	55 12 21.80 N	118 44 26.90 W	681.6
Beaverlodge	CHW611	55 12 50.10 N	119 16 08.10 W	928.6

Equipment Summary

This report prints out an equipment list and frequencies - polarization for each visible link.

Site Name	Woking	Fairview
Call Sign	CHW613	CHW614
Latitude	55 28 47.00 N	55 50 14.00 N
Longitude	118 44 50.00 W	118 35 48.00 W
Azimuth (°)	13.33	193.45
Elevation (m)	925.61	574.02
Path Length (km)	40.92	
Radio Model	OC-3 6GHz	OC-3 6GHz
TX power (dBm)	31.50	31.50
Antenna Model	HPX10-58W	HPX10-58W

Antenna Height (m)	79.20	55.20
TX Line Type	EWP63-59W	EWP63-59W
TX Line Length (m)	90.00	65.00
Frequency (MHZ)	5878.8750 - H	5912.3750 - H

CSV File

This report saves the report in a comma delimited file (CSV). There are two lines for each link. The first line in the file is a description of the fields in the list below:

Site Name,	Free Space loss (dB),
Coordinate site,	Net Path loss (dB),
Azimuth,	Radio model,
Antenna Model,	TX power (watts),
Antenna Height,	TX power (dBm),
Antenna Gain (dBi),	EIRP (dBm),
TX Line Type,	RX Threshold Level (dBm),
TX Line Length,	RX Signal (dBm),
TX Line loss (dB),	Thermal Fade Margin (dB),
Frequency (MHZ),	Effective Fade Margin (dB),
Polarization,	

This feature is intended as an interface to other programs and the format may change. The first line of the file describes each term.

Frequency Plan Report

In the Network module, select Site Data - Site List. Then select Reports - Frequency Plan. The format of the report is shown below:

Site 1	TX (MHz)	Ch ID	File Name	Ch ID	TX (MHz)	Site 2
Fairview	5912.3750V	LL6-6H	Fairbrow.pl4	LL6-6L	5878.8750V	Brownvale
Woking	5878.8750H	LL6-6L	Wokifair.pl4	LL6-6H	5912.3750H	Fairview
Grande Prairie	5912.3750H	LL6-6H	Beavgran.pl4	LL6-6L	5878.8750H	Beaverlodge
Grande Prairie	5912.3750H	LL6-6H	Granwoki.pl4	LL6-6L	5878.8750H	Woking
Beaverlodge	5878.8750H	LL6-6L	Beavdemm.pl4	LL6-6H	5912.3750H	Demmit
Brownvale	5878.8750V	LL6-6L	Browpeac.pl4	LL6-6H	5912.3750V	Peace River
Pine Valley	5878.8750H	LL6-6L	Dawspine.pl4	LL6-6H	5912.3750H	Dawson Creek
Dawson Creek	5912.3750V	LL6-6H	Tomsdaws.pl4	LL6-6L	5878.8750V	Toms Lake

Toms Lake   5878.8750V   LL6-6L   Demmtoms.pl4 LL6-6H   5912.3750V   Demmit

Fort St. John   5912.3750H   LL6-6H   Pinefort.pl4   LL6-6L   5878.8750H   Pine Valley

Map Crossing Report

Associated with the map reference, a map crossing report can be generated for a link. Click the right mouse button on the link for which the map crossings are required and select Map Crossings from the popup menu to generate a map crossing report. A sample section of a report is given below. The first site in the report is determined by the direction that the link was created.

	Pine Valley	Dawson Creek
Latitude	56 01 37.06 N	55 48 08.60 N
Longitude	120 38 09.66 W	120 12 58.10 W
True azimuth (°)	133.4271	313.7749
Elevation (m /ft)	804.7 /2640.1	775.8 /2545.3
Path Length (km /miles)	36.26 /22.53	
Datum	North American 1927	
UTM zone	10	10
Easting (km)	647.324	674.489
Northing (km)	6211.387	6187.379
Map #1 94 A/2 (Pine Valley)		
South West Corner	56 00 00.00 N	121 00 00.00 W
North East Corner	56 15 00.00 N	120 30 00.00 W
Crossing 1	56 00 00.00 N	120 35 06.75 W
	5.317 km west of the SE corner (4.19 in - 10.63 cm)	
	Accumulated Distance = 4.37 km (2.71 miles)	

CSV SITE AND LINK LIST REPORTS

A site and link list report is available as a comma or tab delimited file (CSV) in the network module. The reports are displayed using a spreadsheet program such as Excel. All data for these two reports are taken directly from the PL4 files. The network data is not used. All of the fields and their order in the report are set by the user.

CSV Site List

In the Network module, select Site Data - Site List. Then select Reports - CSV site list. A selection list is first presented to the user. Select items from the Available list box and transfer them to the Selected list box with the > button. The » button transfers all available items to the selected list.

To return items in the Selected list box, to the Available list, select the items and use the < button. The « double left button moves all selections back to the Available list box. The order of the selected items is set with the ^ and v buttons.
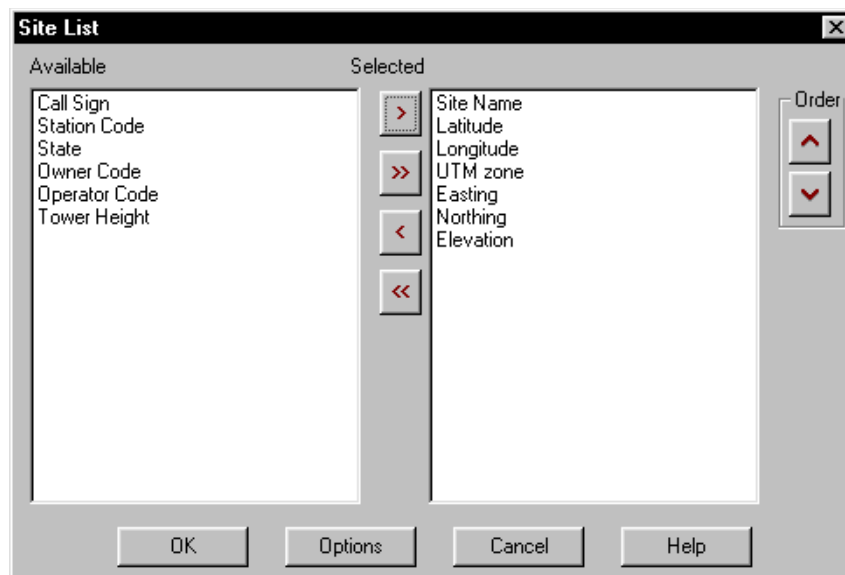
CSV Site List Options

Click the options button in the site list selection dialog to access the following settings:

Delimiter
The delimiter can be a comma or tab. If you are using this report with Excel, a comma must be specified.

Grid Units
If grid coordinates have been selected, these may be expressed in either kilometers or meters.

Write headers
The column headers will be written to the CSV file if this option is selected.
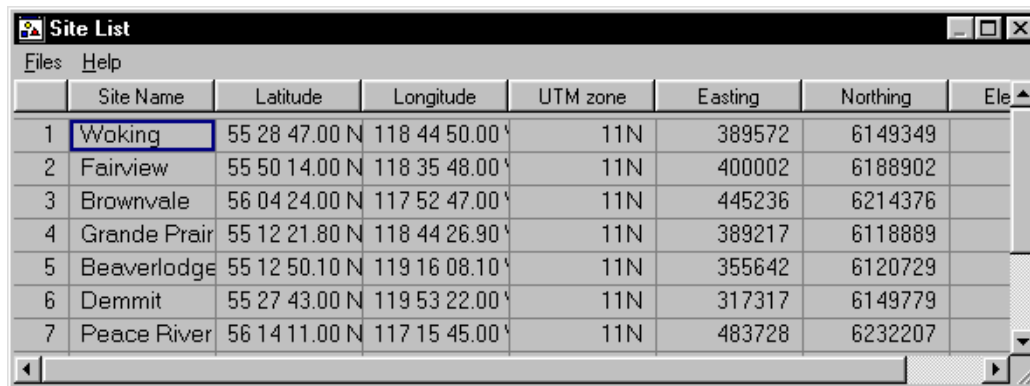
Coordinate format
Geographic coordinates can be formatted in degrees minutes and seconds or as a floating point number. If the latter format is selected, the sign convention for the hemisphere must be defined.
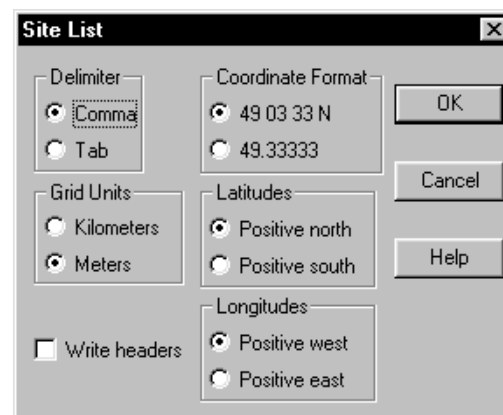
When the options and field selections are complete, click the OK button to display the report. The standard grid control is used for this purpose.

	Site Name	Latitude	Longitude	UTM zone	Easting	Northing	Ele
1	Woking	55 28 47.00 N	118 44 50.00 '	11N	389572	6149349	
2	Fairview	55 50 14.00 N	118 35 48.00 '	11N	400002	6188902	
3	Brownvale	56 04 24.00 N	117 52 47.00 '	11N	445236	6214376	
4	Grande Prair	55 12 21.80 N	118 44 26.90 '	11N	389217	6118889	
5	Beaverlodge	55 12 50.10 N	119 16 08.10 '	11N	355642	6120729	
6	Demmit	55 27 43.00 N	119 53 22.00 '	11N	317317	6149779	
7	Peace River	56 14 11.00 N	117 15 45.00 '	11N	483728	6232207	

The data cannot be edited; however, the columns can be sorted. Click on a column header to sort the data using this field as the sort criteria. The first click sorts the data in an ascending order. The second click sorts in a descending order.

Select Files - Save to save the report.

CSV Link List

In the Network module, select Site Data - Site List. Then select Reports - CSV link list. A selection list is first presented to the user. The report can be written using a single line or two lines for each link

Select items from the Available list box and transfer them to the Selected list box with the > button. The » button transfers all available items to the selected list box.

To return items in the Selected list box, to the Available list, select the items and use the < button. The « button moves all selections back to the Available list box. The order of the selected items is set with the ^ and ∨ buttons.
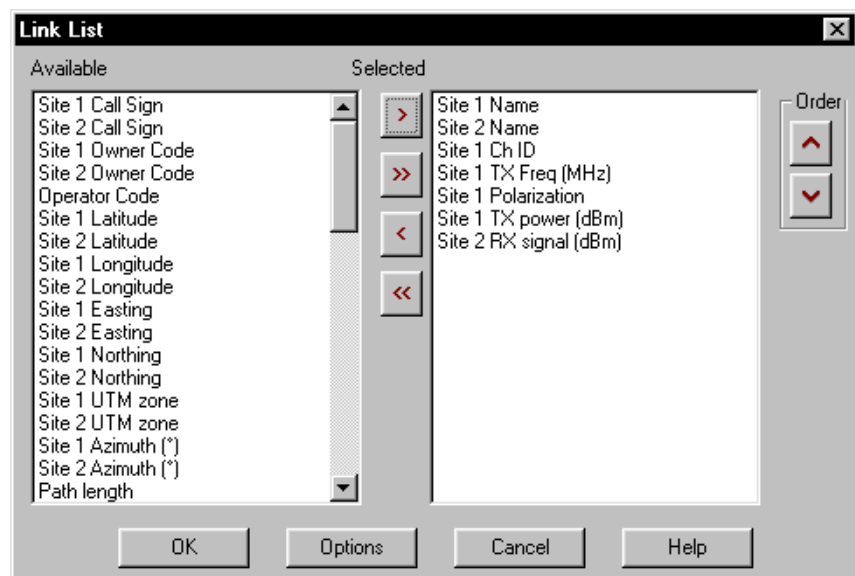
CSV Link List Options

Click the Options button in the Link List selection dialog to access the following link list report settings:

Delimiter

The delimiter can be a comma or tab. If you are using this report with Excel, a comma must be specified.

Grid Units

If grid coordinates have been selected, these may be expressed in either kilometers or meters.

Path length

The path length will be in either miles or kilometers as determine by the global measurements setting. If the path length in meters is selected, then the path length will be written in feet or meters.

Write headers

The column headers will be written to the CSV file if this option is selected.

Coordinate format

Geographic coordinates can be formatted in degrees minutes and seconds or as a floating point number. If the latter format is selected, the sign convention for the hemisphere must be defined.

Lines per link

The report can be written as one or two lines per link. If the one line per link option is used, then the user must define a criteria to determine which of the two sites will be Site1 (the first site).

When the options and field selections are complete, click the OK button to display the report. The standard grid control is used for this purpose.

The data cannot be edited; however, the columns can be sorted. Click on a column header to sort the data using this field as the sort criteria. The first click sorts the data in an ascending order. The second click sorts in a descending order.

Select Files - Save to save the report.

	Site 1 Name	Site 2 Name	Site 1 Ch ID	Site 1 TX Freq (MHz)	
1	Woking	Fairview	LL6-6L	5878.8750	
2	Fairview	Woking	LL6-6H	5912.3750	
3	Fairview	Brownvale	LL6-6H	5912.3750	
4	Brownvale	Fairview	LL6-6L	5878.8750	
5	Grande Prairie	Beaverlodge	LL6-6H	5912.3750	
6	Beaverlodge	Grande Prairie	LL6-6L	5878.8750	
7	Grande Prairie	Woking	LL6-6H	5912.3750	
8	Woking	Grande Prairie	LL6-6L	5878.8750	
9	Beaverlodge	Demmit	LL6-6L	5878.8750	

MAP GRID

OVERVIEW

An new site network display module named Map Grid has been added in the May 2001 program build. This operates in parallel with the existing network module. The network module uses a Transverse Mercator projection to display the sites. The longitude origin of this projection is set to the mid point of the east - west extents of the sites. This produces a display with symmetrical latitude and longitude lines. If a new site is added which changes the extents of the display, a new longitude origin is calculated. As such, this variable projection will not accommodate backdrops such as maps and ortho-photos.

The map grid module uses fixed projections to display the network sites with both backdrops and elevations. The backdrops can be in either a TIF or window bit map (BMP) format. The elevations must be in the Odyssey - Planet BIL format. The map grid elevation database setup is independent of the terrain database setup under Configure - Terrain data base. At this time, the same projection must be used for the both the backdrop and the elevations.
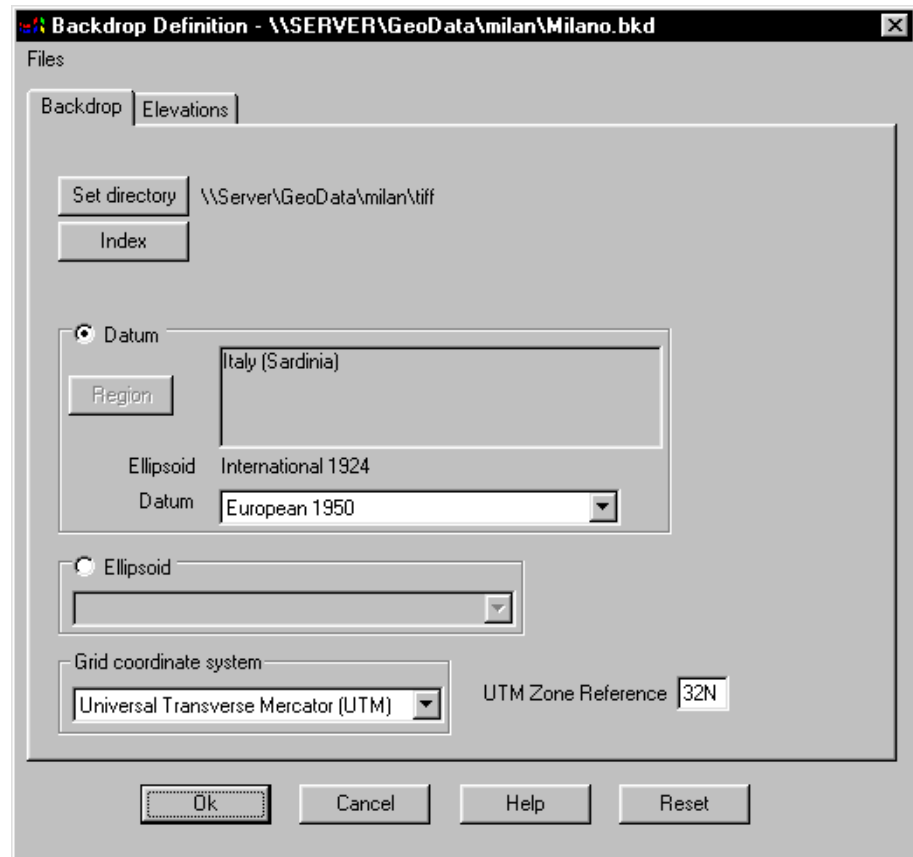
BACKDROP DEFINITION

Select Site Data - Backdrop to access the backdrop definition dialog. A backdrop definition consists of the following steps for both the image and elevation files. The procedure is identical for each.

1. specify the directory containing the image /elevation files
2. create an index for the image /elevation files
3. specify the map projection used by the image /elevation files
4. specify the datum or reference ellipsoid for the image /elevation files

Set Directory

Click the set directory button and point to the directory containing the image files. All image files must be located in this directory.

Image File Index
Click the Index button to access the grid data entry form. The following fields are available:

Image file name   95 characters maximum.

Show   any image file can be temporarily switched off.

Type   At this time only TIF and bitmap (bmp) image files are supported.

Edges   West, south east and north edges. These are expressed in kilometers and must corre-
                        spond to the selected map projection.

Cell size   optional entry (not used).

The data can be manually entered using the procedures described in the General Program Operation or im-
ported from a list or GeoTIF file.

Import List
Select Files B Import List. Specify the locations of the fields in the file
to be imported.

Two default options are provided for Planet and Odyssey image files.

Specify the units of the edges, click Ok and open the file containing the
index information.

GeoTIF File
GeoTIF files may contain the required information to create an index
entry for the file. Select Files B GeoTIF File and open the file.

There must be sufficient information in the file to determine the edges,
map projection and datum.

At present, only UTM projections and US State plane coordinates will automatically generate the index and
set the datum.
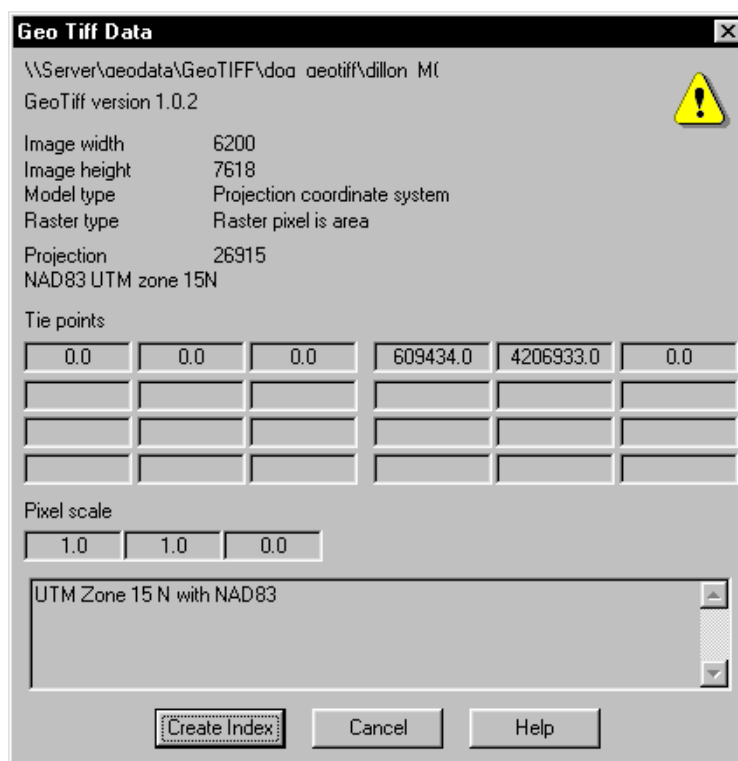
New List

The Import List and GeoTIF file procedures simply append the new entry to the existing index. Select Files B New List to erase the existing list.

TIFF to Bit Map Array

TIF files are sometimes supplied in large sizes in the range from150 to 200 megabytes or larger. A TIF file must first be converted to a bitmap. This can be very time consuming and places a strain on system resources. A provision has been made to convert a large TIF file into an array of bitmaps. The bitmaps will be saved in the same directory as the TIF file.

Select Files - Create bitmap array and enter the number of rows and columns. The index will be automatically updated with the bitmap data. Be sure to save the new backdrop file.

Bitmaps are not loaded into memory. Instead the bit map files are opened as memory mapped files. Significant performance improvements can be realized by using a number of smaller bitmaps instead of a single large TIF file.

Elevation File Index

Click the Index button to access the grid data entry form. The following fields are required for an elevation file entry:
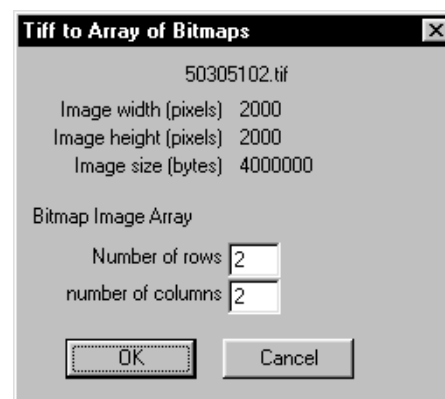
Map name   95 characters maximum.

Bytes / pixel   Some file formats contain the elevation and additional information. The default is 2 bytes per pixel which corresponds to a 2 byte integer elevation.

Bottom up   This setting specifies if the rows of elevations start at the south west corner or the north west corner. If the elevation views are upside down, then change this setting.

Byte order   The elevations are expressed as two byte integers. This setting determines if the most significant byte is first (SPARC) or the least significant byte is first (INTEL). If the wrong setting is used, the resulting elevations will be very large positive and negative numbers. The program will interpret these as no data values and nothing will be displayed.

Cell size   The horizontal resolution of the database expressed in meters.

Edges   West, south east and north edges. These are expressed in kilometers and must correspond
                     to the selected map projection.

Show   any elevation file can be temporarily switched off.

The data can be manually entered using the procedures described in the General Program Operation or im-
ported from a list file.

Import List
Select Files B Import List. Specify the locations of the fields in the file to
be imported.

Two default options are provided for Planet and Odyssey image files.

Specify the units of the edges, click Ok and open the file containing the in-
dex information.

Elevation File Conversion
The elevation files must be in the Odyssey - Planet BIL format. Several file
conversion utilities are available to convert other format to the BIL format.
Select Files - Convert in the Elevation index menu to access these conver-
sions.
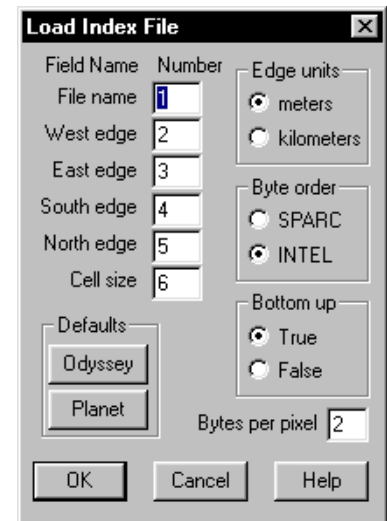
Datum - Ellipsoid Selection
The shape of the earth is not spherical. Rather it is more nearly an oblate ellipsoid of revolution which is
also called an oblate spheroid. This is an ellipse rotated about its minor axis.

The earth is not an exact ellipsoid. The geoid is the name given to the shape that the earth would assume if
all measurements were reference to mean sea level. This is an undulating surface which is within 100 me-
ters of a well fitting ellipsoid. Note that elevations and contour lines are referenced to the geoid. Latitude
and longitude and all grid coordinate systems are referenced to the ellipsoid.

The ellipsoid is defined by the semi major and semi minor axis. Alternately this can be expressed as the
semimajor axis and the flattening or eccentricity as defined by equation Equation (1) below:

$$B = A \cdot \frac{recf1}{recf} \tag{1}$$

where:

A   major axis
B   minor axis
recf   reciprocal flattening

Local Datums
Initially ellipsoids were fitted to the mean sea level surface over a particular region or country. These were
related to an initial point on the surface of the earth to produce a local datum. This initial point is assigned
a latitude, longitude, an elevation above the ellipsoid and an azimuth to some point. This initial point be-
comes the triangulation station Principio to which all ground control measurements will be referenced. The

latitude and longitude and elevation of all control points in the area are computed relative to this initial point and the ellipsoid.

An example of a local datum is the North American Datum of 1927 (NAD27) with the following parameters:

reference ellipsoid	Clark 1866
semi major axis	6378206.4 km
inverse flattening	294.9786982
origin	Meades Ranch in Kansas

Global Datums
Global datums use ellipsoids determined from satellite based survey methods and define a coordinate system used for the entire earth. The center of the reference ellipsoid is located at the mass center of the earth. An example of a global datum is the World Geodetic System of 1984 (WGS 84)

reference ellipsoid	WGS 84
semi major axis	6378137.0 km
inverse flattening	298.257223563
origin	mass center of the earth

In the Pathloss program, either a datum or ellipsoid can be selected. Selecting a datum indirectly defines the reference ellipsoid and since all conversions between geodetic and rectangular coordinates and the distance and azimuth calculations are based on the reference ellipsoid, the two choices may seem redundant.

A datum in the Pathloss program includes additional data to allow the transformation of geodetic coordinates between datums. In local datums, it is necessary to subdivide the area covered by the datum into smaller regions to improve the accuracy of the coordinate transformation.

Some local map projections do not have a corresponding datum. Several examples are:

Swiss National Grid - reference ellipsoid - Bessel 1841

Irish National grid - reference ellipsoid - modified airy

In these cases, an ellipse must be specified and there will be no provision to transform coordinates. For example geodetic coordinates in the WGS84 coordinates cannot be transformed to Swiss National grid coordinates; however the WG84 coordinates could be transformed to the European Datum of 1950

Note that in the current program build, the map projection and the datum / ellipsoid must be specified for both the image files and the elevation files. This generality will allow additional flexibility in a future build by allowing coordinate transformation between datums. The errors in these transformation will certainly be greater that the imagery / elevation data resolution and it will be necessary to provide procedures to match the imagery and elevation data.

The datum or reference ellipsoid selection must be the same for the site data, image, and elevation files. The same map projection must be used for the image and elevation files.

Map Projection

Select one of the map projections in the drop down list. The following projections are currently supported:

- UTM - Universal Transverse Mercator - The UTM zone must be specified.

- Swiss National grid   *

- UK Ordnance grid   *

- Irish National grid   *

- New Zealand grid   *

- Gauss Kruger

- US State Plane grid   *

- HGRS-87 Grid

- MGI Grid

The selection of any of the projections marked with an *, will automatically select the correct datum or ellipsoid.

The default projection is the same as that used in the network module. This is a Transverse Mercator projection referenced to a central meridian located at the center of the east - west extents of the sites. This selection effectively inhibits all of the imagery and elevation procedures in the Map Grid module.

OTHER CONSIDERATIONS

When the backdrop definition is complete, save the file using the file menu in this dialog box.

Click OK to close the backdrop definition dialog. The image files are loaded into memory and displayed. If the file loading is cancelled, then it will be necessary to recall the backdrop definition dialog and close it with the OK button again.

The current backdrop definition file will be automatically loaded again when the program is started again and the map grid module is entered.

If a network file whose extents are separated by 10 degrees from the extents of the imagery data, is loaded, then the map projection is automatically set to the default and the imagery and elevation features are inhibited.

CURSOR MODES

Pan and Zoom Controls

Click the   button to set the cursor to the pan mode. Hold the left mouse button down and drag the display to the new location. The display can also be moved with the cursor keys at any time.

Click the 🔍 button to set the cursor to the zoom mode. A left button click magnifies the display a preset amount and centers the display at the cursor location. A right button click reduces and centers the display. To zoom a specific area, hold down the left mouse button and drag the mouse to define the desired area. Three additional buttons affect the display as follows:

🔍 The backdrop image is displayed from the upper left corner with the same resolution as the image file.

📍 The extents of the site data is displayed.

🖼 The extents of the image files is displayed.

📊 The elevation view is switched off an on by clicking this button.

Link Mode Cursor

Click the 🔗 button to set the cursor to the link mode. This is the default cursor mode in the network module and is used to access the design modules, create links between two sites, and selectively set the link and site attributes.

VISIBILITY TESTS AND PROFILE GENERATION

Click the 📊 button to begin the visibility tests. Place the cursor at one location, hold down the left mouse button and drag the mouse to the second location.
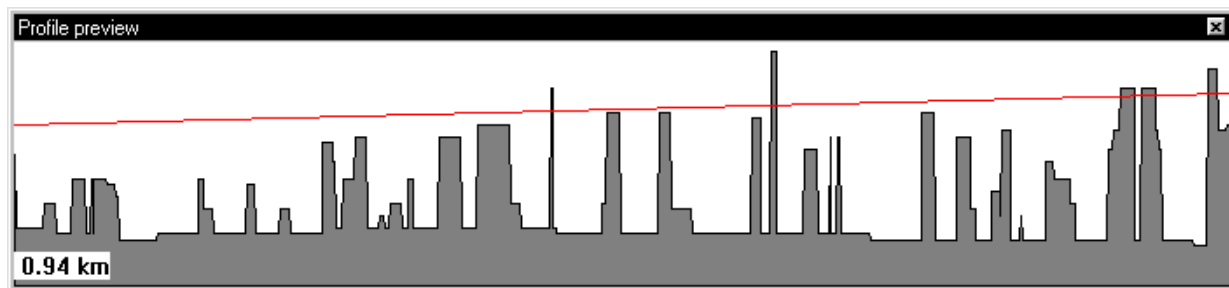
The progress of the profile is dynamically shown on the screen. To reset this display during the profile generation, click the right mouse button. When the left mouse button is released, a profile analysis display will

appear. This display allows you to change antenna heights, earth radius factor K and test the clearance using Fresnel zone references of the clearance display.
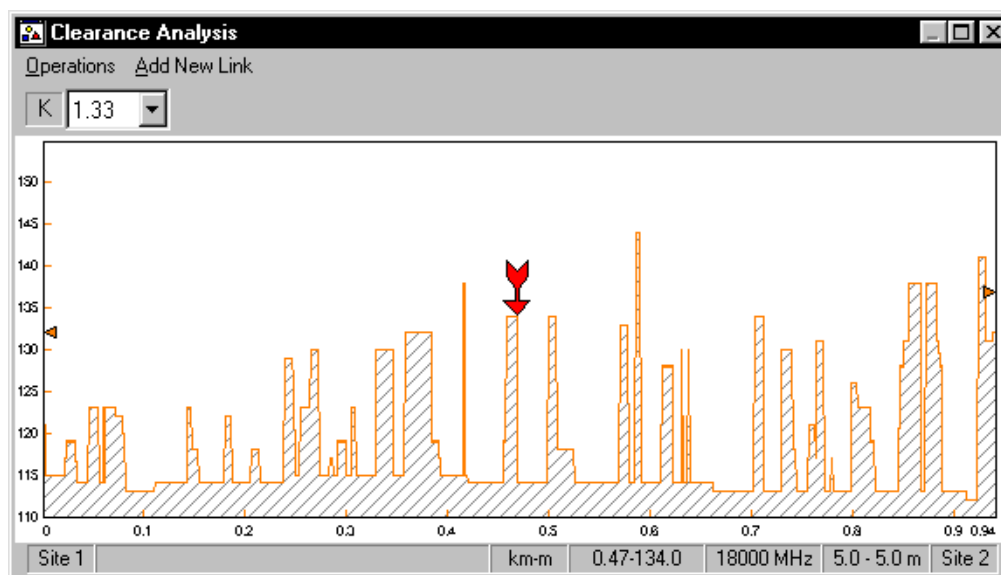
You can add this link to the site data list and save the data as a Pathloss pl4 file. If the two end locations were not between existing sites, you should change the site names from the default Site 1 and Site 2 names. To exit the profile generation mode, close the profile preview display, click the button again or change the cursor mode to the pan, zoom or link modes.

ELEVATION DISPLAYS

An elevation display can be generated at any zoom level which will overlay the image backdrop. The extents of the display always corresponds to the current display extents.

Select Site Data - Elevation view - Create.

The display is useful to resolve small elevation differences which may not be apparent from the image display.

An elevation legend is available under the same menu.

The elevation display will remain until it is reset.

Several display options are available. Select Elevation - View - Options.

The color can be either a graduated color ramp or a grey scale. The elevation display is overlaid on to the backdrop display. The raster operation code is SRCCOPY in the above drawing which hides the backdrop. The code ADSP-Dxax@ is a transparent copy which allows the backdrop to show through. If any code other than SRCCOPY, the elevation legend colors will not be correct.

ADD SITE AND MOVE SITE

Two similar operations allow the user to visually add a new site or move an existing site. Select Site Data - Add Site or Move Site

In the add site case, use the mouse to position the marker at the desired location.
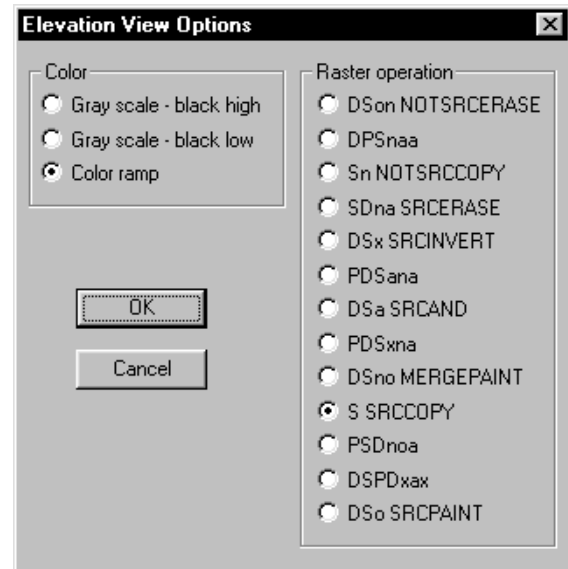
Click the Add site button and enter a name for the site.

In the move site case, first identify the site to be move by clicking the left mouse button on the site legend. Then move the site to the new location and click the OK button. Both of the displays show the elevation.

DEFINITIONS - GLOSSARY

Datum - Any numerical or geometrical quantity or set of such quantities specifying the reference coordinate system used for geodetic control in the calculation of coordinates of points on the earth. Datums may be either global or local in extent. A local datum defines a coordinate system that is used only over a region of limited extent. A global datum specifies the center of the reference ellipsoid to be located at the earth's center of mass and defines a coordinate system used for the entire earth.

Ellipsoid - The surface generated by an ellipse rotating about one of its axes.

Geocentric Coordinates - Cartesian coordinates (X, Y, Z) that define the position of a point with respect to the center of mass of the earth.

Geodetic Coordinates - The quantities of latitude and longitude that define the position of a point on the surface of the earth with respect to the reference ellipsoid. Also, imprecisely called geographic coordinates.

Geodetic Height - The height above the reference ellipsoid, measured along the ellipsoidal normal through the point in question. The geodetic height is positive if the point is outside the ellipsoid. Also known as ellipsoidal height, h.

Geodetic Latitude - The angle between the plane of the equator and the normal to the ellipsoid through the computation point. Geodetic latitude is positive north of the equator and negative south of the equator.

Geodetic Longitude - The angle between the plane of a meridian and the plane of the prime meridian. A longitude can be measured from the angle formed between the local and prime meridians at the pole of rotation of the reference ellipsoid, or by the arc along the equator intercepted by these meridians.

Geoid - The equipotential surface of the earth's gravity field approximated by undisturbed mean sea level of the oceans. The direction of gravity passing through a given point on the geoid is perpendicular to this equipotential surface.

Geoid Separation - The distance between the geoid and the mathematical reference ellipsoid as measured along the ellipsoidal normal. This distance is positive outside, or negative inside, the reference ellipsoid. Also called geoidal height; undulation of the geoid.

Horizontal Datum - A horizontal datum specifies the coordinate system in which latitude and longitude of points are located. The latitude and longitude of an initial point, the azimuth of a line from that point, and the semi-major axis and flattening of the ellipsoid that approximates the surface of the earth in the region of interest define a horizontal datum.

Reference Ellipsoid - An ellipsoid whose dimensions closely approach the dimensions of the geoid; the exact dimensions are determined by various considerations of the section of the earth's surface concerned. Usually a bi-axial ellipsoid of revolution.

Vertical Datum - A vertical datum is the surface to which elevations are referred. A local vertical datum is a continuous surface, usually mean sea level, at which elevations are assumed to be zero throughout the area of interest.

WGS 72 - World Geodetic System 1972. WGS 72 was the previous DoD standard earth-centered, earth-fixed world geodetic system. It was superceded by WGS 84.

WGS 84 - World Geodetic System 1984. A world geodetic system provides the basic reference frame, geometric figure and gravimetric model for the earth, and provides the means for relating positions on various local geodetic systems to an earth-centered, earth-fixed coordinate system. WGS 84 is the current DoD standard earth-centered, earth-fixed world geodetic system.

REFERENCES

1.   Topographic Engineering Center, TEC-SR-7,
        Handbook for transformation of DATUMS, PROJECTIONS, GRIDS, AND COMMON COOR-
        DINATE SYSTEMS, January 1996.

2.   Department of Defense, MIL-HDBK-850, Military Handbook B Glossary of Mapping, Charting,
        and Geodetic Terms, 21 January 1994.

INTRA SYSTEM INTERFERENCE

OVERVIEW

Intra system interference is calculated in the Network module. The calculation considers only the displayed layers. All sites and links which are not on an active layer will be ignored. The calculations use antenna and radio codes. An antenna or radio code is the data filename without an extension. These contain the parameters required for an interference calculation and are described in detail in this section. The minimum conditions to calculate intra system interference are listed below:

- Each link in the display must be associated with a Pathloss data file.

- Each antenna in the Pathloss data file must contain an antenna code.

- The worksheet data entries must be complete to the level of a receive signal calculation.

- Call signs are used as a unique identifier for a site. Each site in the Pathloss data file must have a unique call sign.

- The Pathloss data file must contain the transmit and receive channel assignments.

A radio code is optional; however, only the interfering level will be calculated without this file. A radio code is required to calculate filter improvement and threshold degradation.

The calculation uses database tables for the transmit and receive data, the interference data and for the calculation options. These tables are saved in the same directory as the network data file (gr4).

INTERFERENCE CALCULATION PROCEDURE

Select Interference - Calculate Intra from the Network menu bar. This operation will be unavailable under the following conditions:

- The database engine could not be initialized. This is an installation problem.

- The network data file has not been saved; and therefore, the directory to save the database tables cannot be determined. Just save the network data file.

The "Intra System Interference" dialog box sets the options for the calculation.

Coordination Distance

Interference is not calculated if the interfering path length is greater than the specified coordination distance.

Maximum Frequency Separation

Interference is not calculated if the difference between the interfering transmitter and victim receiver frequencies is greater than the specified maximum value.

Default Minimum Interference Level

The calculation will determine the interference objective using the 10-6 BER threshold level and the threshold to interference (T/I) ratio specified in the Pathloss data file. If this data is incomplete, the default minimum interference level will be used as the objective. Interference objectives are discussed later in this section.

Calculation Margin

The calculation margin sets a tolerance on the reporting of interference cases. If the interference level objective for the receiver under test is -104 dBm and the calculation margin is set to 10 dB, then all interference cases greater than -114 dBm (-104 - 10) will be reported.

Digital Interference Objective

The objective is specified in terms of the allowable receiver threshold degradation. For frequency coordination with other operators, the usual value is 1 dB; however, for intra system interference, the final criteria is determined by the increased outage times resulting from the actual threshold degradation.

The threshold degradation objective will be converted to an interference level objective for each receiver in the calculation.

Analyze Current File Only

If one of the pathloss data files has been loaded, this option will limit the interference calculation to this file. Each interference case will involve one of the sites in this file, either as an interferer or as a victim.

Sub Network Intra System Interference

If a sub network has been defined and activated, this option will limit the interference calculation to the subnetwork.

Sub Network Against Network Interference

If a sub network has been defined and activated, this option will calculate the interference between the sub network and the overall network. Each interference case will involve one site from the network and one site from the sub network either as an interferor or a victim.

Ignore Diversity Antennas

This option ignores all receive frequencies associated with a space diversity receive only antenna. In the initial frequency analysis, this option will reduce the number of cases by 50%. If the main and diversity antenna gains are different, then the final analysis should consider the diversity antennas.

Ignore Adjacent Channels

This option applies to 1 for N systems. Once the threshold degradation of the adjacent channels has been established, use this option to limit the number of interference cases.

Interference Calculation Directory

If the network file is saved in a shared directory located on a server, only one person will be able to run an interference calculation at any one time. The calculation uses database tables which are created in the same directory as the network file. This option allows the user to specify a private directory for the database tables.

Interference Calculation

Four data base tables are created for an interference calculation:

INTRA_RX.DB	receiver data read from the Pathloss data files
INTRA_TX.DB	transmit data read from the Pathloss data files
INTRADTA.DB	results of the interference calculation
IFN_OPTS.DB	options used in the interference calculation

These files are stored in the same directory as the network data file and will be overwritten each time a new calculation is made. The interference results corresponding to a network data file can be reviewed simply by loading the network data file.

The progress bar in the "Intra System Interference" dialog box operates in two stages. The first stage reads the Pathloss data files and creates the transmit and receive tables.

The fields in these tables are listed below:

Receiver Table Fields (INTRA_RX.DB)

sequence number	Pathloss file name
site name	call sign
latitude	longitude
adjacent site name	adjacent call sign
RX frequency	RX channel ID
RX polarization	RX antenna model
RX antenna code	RX antenna usage
RX antenna gain	RX antenna height
RX azimuth	RX loss
RX signal	RX radio code
RX thermal fade margin	RX traffic code

Cochannel threshold to interference (T to I) ratio

RX threshold corresponding to a BER of 10-6

station class (point to point, point to multipoint, point from multipoint)

> Note that transmit and receive tables are only created from Pathloss disk files. A file which is currently loaded into the program, is not used. Therefore, any changes made to a file must be saved before running an interference calculation. One exception to this is when the "analyze current file" has been selected. In this case only, the file data in memory will be used.

sector number (point to multipoint only)

Note that some duplication of data occurs in the Pathloss data file and the data contained in the RX antenna and RX radio codes. The values may be intentionally different. For example, the gain in the antenna code is usually the mid band gain. The Pathloss data file may contain the low or high end antenna gain. A similar situation occurs with the cochannel T to I ratio and RX threshold parameters. The Pathloss file data is always used in an interference calculation.

The receiver data is validated before it is added to the table. If the validation fails, an error message will be written to an error log file and the receiver will not be included in the calculation. The following validations are carried out:

- A call sign must be specified.

- A RX antenna code must be specified and the corresponding file must be found.

- A calculated receive signal level must exist.

- A receive channel assignment must be specified.

An error message will be logged if a RX radio code is specified but the file cannot be found; however, the receiver will be included in the calculation.

Transmit Table Fields (INTRA_TX.DB)

sequence number	Pathloss file name
site name	call sign
latitude	longitude
adjacent site name	adjacent call sign
TX frequency	TX channel ID
TX polarization	TX antenna model
TX antenna code	TX antenna usage
TX antenna gain	TX antenna height
TX azimuth	TX loss
TX power	TX APC range
TX radio code	TX traffic code

station class (point to point, point to multipoint, point from multipoint)

sector number (point to multipoint only)

As in the case of the receiver fields, some duplication of data occurs in the Pathloss file and the data contained in the antenna and radio codes. The transmit power is always the value in the Pathloss data file.

The transmit data is validated before it is added to the table. If the validation fails, an error message will be written to an error log file and the transmitter will not be included in the calculation. The following validations are carried out:

- a call sign must be specified

- an antenna code must be specified and the corresponding file must be found

- the transmit power must be specified

- a transmit channel assignment must be specified

An error message will be logged if a radio code is specified but the file cannot be found; however, the transmitter will be included in the calculation.

INTERFERENCE CALCULATION

The progress bar is reset for the interference calculation.

Each receiver record is tested against all transmitter records. The calculation sequence and the logic used to discard interference cases are described in the following steps:

Checks are carried out as the calculation proceeds to eliminate an interference case. The initial checks to clear a potential interference case are listed below:

- The difference between the transmitter and receiver frequencies is greater than the specified maximum.

- The transmitter is located at the same station as the receiver.

- The transmitter is associated with the receiver under test.

- The interfering path length is greater than the specified coordination distance. The path length is calculated from the receive and transmit coordinates.

- The receiver is a hub or remote on a point to multipoint system and the transmitter is a hub or remote in the same sector.

Receiver Noise Threshold

The receiver noise threshold is calculated from the following parameters:

- receiver static threshold for a 10^{-6} bit error rate (Trx dBm)

- cochannel threshold to interference ratio for like modulation (T_Ic dB)

By definition of the T to I measurement, an interfering signal which is T_Ic dB below the receiver threshold level (Trx dBm) will degrade the receive threshold by exactly 1 dB. Therefore, the receiver noise threshold (Nrx) is given by the equation:

$$Nrx = Tr - T\_Ic + 5.868 dBm \tag{1}$$

The receiver noise threshold is used to calculate the interfering level objective as follows:

$$I_{obj} = 10 \cdot \log_{10}\left(10^{\frac{Nrx}{10}} \cdot \left(10^{\frac{Tdo}{10}} - 1 \right)\right) \tag{2}$$

where:

T_{do} is the allowable threshold degradation specified in the Interference dialog box.

This interference level represents the total power in the victim receiver passband which will degrade the receiver threshold by the specified amount. At this point, the frequencies and the bandwidths of the interfering transmitter and victim receiver are not considered. These will be used later to calculate the filter improvement.

If the receiver noise threshold is not available due to missing data, the default minimum interfering level will be used as the objective.

Free Space Loss Interfering Signal

The free space loss interfering signal level is calculated as follows:

I_{fs} = TX power + TX antenna gain + RX antenna gain - TX loss - RX loss - free space loss.

If I_{fs} is less than (I_{obj} - calculation margin), the interference case is not reported.

Antenna Discrimination

The effects of the transmit and receive antenna discriminations are now considered:

- Calculate the antenna discrimination angles for the TX and RX antennas.

- Calculate the antenna discrimination for the TX and RX antennas. This calculation uses the antenna data files.

- Calculate the interfering signal levels for all combinations of TX and RX antenna polarizations.

Antenna discrimination is characterized by the four polarization combinations HH, HV, VV, and VH. The first letter is the polarization of the antenna under test. The second letter is the polarization of the signal being received or transmitted. For example, the term HV is the response of a horizontally polarized antenna to a vertically polarized signal.

At first glance, the total antenna discrimination would be obtained by adding the appropriate polarization combinations of the interfering transmit antenna and the victim receiver antenna. Unfortunately, this is not the case, as the ratio of horizontal and vertical polarized signals is unknown.

The following polarization combinations are determined and the minimum value is assigned as the total antenna discrimination:

Tx H Rx H (HH)	HH	HH
	HV	HV
Tx H Rx V (HV)	HV	VV
	HH	VH
Tx V Rx V (VV)	VV	VV
	VH	VH
Tx V Rx H (VH)	VH	HH
	VV	HV

An example of this analysis is given below for a free space loss interfering signal level of -38.59 dBm. The first letter in the polarization combination is the transmit polarization; the second letter is the receive polarization.

Antenna Discrimination	HH	HV	VV	VH
Interfering TX	0.00	32.00	0.00	32.00
Victim RX	65.00	69.00	67.00	69.00
Total Discrimination (dB)	65.00	69.00	67.00	69.00
Interfering Signal (dBm)	-103.59	-107.59	-105.59	-107.59

If the interfering level for the specified polarization is less than (I_{obj} - calculation margin), then the interference case is rejected.

If this is a cochannel case (same transmit and receive frequencies) and the TX and RX traffic codes are the same, the calculation for this interference case is complete.

Filter Improvement

Radio data files are required to calculate the filter improvement. If a radio data file does not exist for the victim receiver, the calculation terminates.

> If the interfering transmitter is an analog radio, the filter improvement is read from the victim receiver selectivity curve.
>
> The traffic code format for an analog radio is expressed as [capacity]-ANALOG. Eg
>
> 600CH-ANALOG
>
> The capacity prefix (600CH) is ignored

If the interference analysis reaches this stage, the next step will depend on the specific data available in the transmit and receive radio data files. The radio data file format allows for a matrix of T to I curves or interference reduction factor curves.

The program examines the traffic code of the interfering radio and first determines if the correct interference reduction factor curve is available. The filter improvement (or in some cases filter degradation) is read directly from the appropriate curve. The two IRF curves shown below both belong to a 2E1 capacity radio. The curve on the left shows the filter improvement due to a 2E1 interfering signal. The curve on the right shows the filter improvement due to a 16E1 interfering signal.
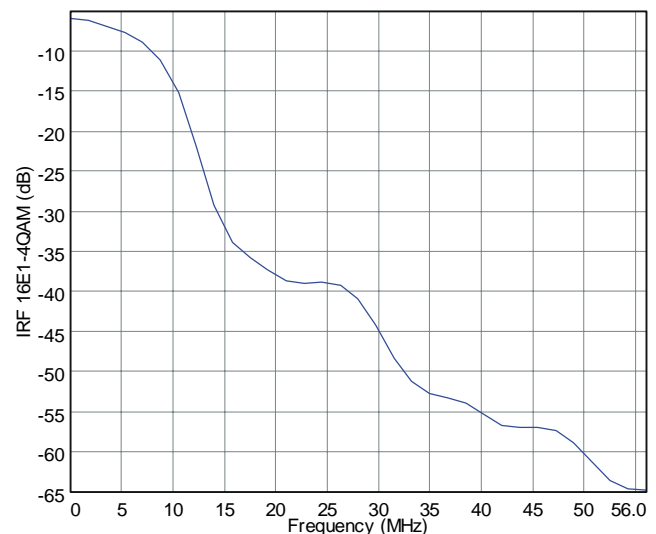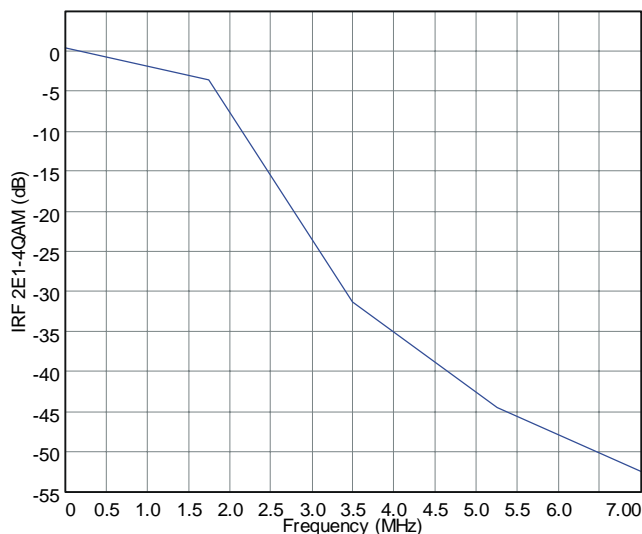
With a zero frequency offset, there would be effectively a zero improvement for a 2E1 interfering signal and about a 6 dB improvement for a 16E1 interfering signal with a much larger bandwidth.

The equivalent computation for a radio with a matrix of T to I curves is shown below. Both curves belong to a 2E1 capacity radio.
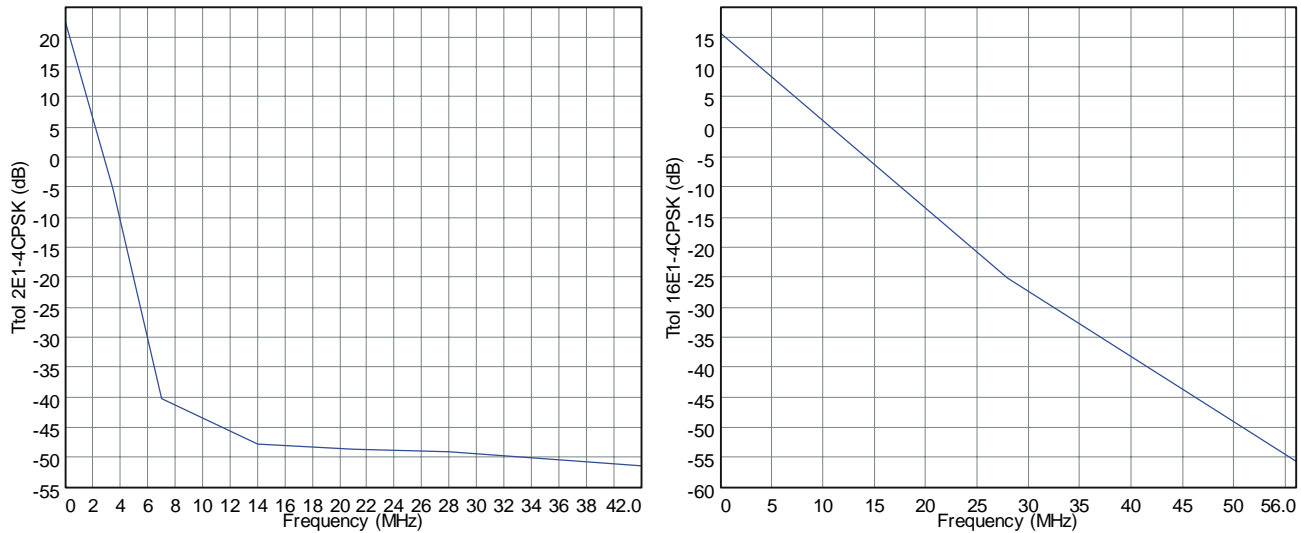
With a zero frequency offset, the filter improvement due a 2E1 interfering signal would be the cochannel T-I value for the same modulation and capacity (22.4 dB) minus the value at 0 frequency offset (also 22.4 dB) which results in zero improvement.

For the case of a 16E1 interfering signal with a zero frequency offset, the improvement would be the co-channel T-I value for the same modulation and capacity (22.4 dB) minus the value at 0 frequency offset read from the TtoI_16E1 curve (15.5 dB) resulting in a 6.9 dB improvement.

A typical T-I matrix is shown in the table below. This represents a radio product line available in four channel capacities. Four radio data files are used; one for each traffic capacity. Each radio file contains four T to I curves. The like modulation case is shaded in the table. The 2E1 radio, for example, would contain a 2E1 into 2E1 (like modulation) 4E1 into 2E1, 8E1 into 2E1 and 16E1 into 2E1.

Table 1: Interfering Transmitter Channel Capacity

	Interfering Transmitter Channel Capacity			
R e c e i v e r	2E1 TtoI_2E1-4FSK	4E1 TtoI_4E1-4FSK	8E1 TtoI_8E1-4FSK	16E1 TtoI_16E1-4FSK
	2E1 TtoI_2E1-4FSK	4E1 TtoI_4E1-4FSK	8E1 TtoI_8E1-4FSK	16E1 TtoI_16E1-4FSK
	2E1 TtoI_2E1-4FSK	4E1 TtoI_4E1-4FSK	8E1 TtoI_4FSK	16E1 TtoI_16E1-4FSK
	2E1 TtoI_2E1-4FSK	4E1 TtoI_4E1-4FSK	8E1 TtoI_8E1-4FSK	16E1 TtoI_16E1-4FSK

If the required T to I or interference reduction factor curve is not available, the filter improvement will be calculated by convoluting the spectrum of the interfering transmitter against the victim receiver selectivity.

There are two levels of default for both the transmitter and receiver.

If the transmitter radio data file includes a measured transmit spectrum, this will be used; otherwise, the default emission mask is used. In both cases, the data is normalized, so that the area under the curve is unity as shown in Equation (3) .

$$\int P_I(f)df \; = \; 1 \tag{3}$$

where $P_I(f)$ is the power spectral density of the interfering transmitter. This normalization was carried out when the ASCII radio data file was converted to the binary format.

In the case of the receiver, the decision on the curve to be used for receiver selectivity was made when the ASCII file was converted to the binary format. If a T to I curve for carrier wave modulation (CW) was available, this would be used. The second choice was a composite receiver selectivity curve including the RF, IF, and baseband (Nyquist) filtering. The third choice was the default receiver mask. A RX_SELECTIVITY_CALC curve was created which was optimized for the convolution process by using a variable point density concentrated around the receiver passband.

The receiver selectivity and interfering power spectral density are convoluted together to calculate the filter improvement *FI* as follows:

$$FI \; = \; 10 \cdot log10(\int H_r(f) \cdot P_i(f + \Delta f)df) \tag{4}$$

where:

Δf	interfering frequency - receiver frequency
$H_r(f)$	receiver selectivity (RX_SELECTIVITY_CALC curve)
$P_i(f)$	power spectral density of the interfering transmitter

If the filtered interfering level is less than (I_{obj} - calculation margin), then the interference case is rejected.

Threshold Degradation

If a receiver noise threshold level is available, the threshold degradation will be calculated using the following formula.

$$Td \; = \; Nrx - 10 \cdot log_{10}\left(10^{\frac{Nrx}{10}} + 10^{\frac{Ifl}{10}} \right) \tag{5}$$

where

Td	threshold degradation (dB)
Nrx	receiver noise threshold (dBm)
Ifl	interfering signal level (dBm)

The composite threshold degradation is calculated in the same manner using the power sum of all interfering signals.

INTERFERENCE REPORTS

Interference Summary Report

Select Interference - Reports - Summary from the Network menu bar. This report prints the options used in the interference and a brief summary of all cases. The format is shown below:

Coordination Distance (km)	400.00
Maximum frequency Separation (MHZ)	150.00
Default Minimum Interference Level (dBm)	-115.00
Margin (dB)	10.00
Threshold degradation objective (db)	1.00
Total number of cases calculated	50

Calculation made on Wednesday, August 19 1998 05:50:00 PM

Case 1	Victim RX	Interfering TX
	Dawson Creek	Toms Lake
Coordinating Station	Toms Lake	Demmit
Antenna Model	HPX8-58W	HPX8-58W
Discrimination Angle (°)	0.00	181.02
Frequency (MHZ)	5878.88 V	5878.88 V
V-I Distance (km)	18.31	
Antenna Discrimination (dB)	67.00	
Interfering Signal (dBm)	-97.85	
Objective (dBm)	-113.00 (-15.15)	
Threshold Degradation (dB)	9.65	

The objective shows the interference level objective and the difference between the objective and the actual interfering level.

Interference Cross Reference Report

This report serves as a cross reference to the case detail report described in the following paragraph. It contains a highly abbreviated single line listing for each interfering transmitter and is used as an aid in navigating through the case detail report. Each victim receiver is considered a case. Each transmitter interfering with this receiver is considered as a sub case. This is the same numbering system as used in the case detail report. This report must be printed in landscape mode. A sample of this report is given below using the following legends:

obj	Interference objective level (dBm)
v-i	Victim to interferer path length (km)
tad	Total antenna discrimination (dB)
ifl	Interfering signal (dBm)
td	Threshold degradation (dB)

Case 1   Beaverlodge (Demmit), HPX10-58W, 5912.3750H, obj = -113.0

         1-1   Fort St. John (Pine Valley), HPX8-58W, 5912.3750H, v-i = 156.0,

tad = 64.0 (i -11.7° v 14.6°), ifl = -111.0 (-2.0), td = 1.5

1-2   Grande Prairie (Beaverlodge), UHX10-58W (R), 5912.3750H, v-i = 33.6,

tad = 68.0 (i 0.0° v -214.0°), ifl = -102.6 (-10.4), td = 5.8

The first line summarizes the victim receiver in the following format:

     case number

     RX site name

     coordinating site in ( )

     antenna model

     RX frequency - polarization

     interfering signal level objective

The following lines provide details for each interfering transmitter in the following format:

     case - sub case number

     TX site name

     (coordinating site)

     antenna model

     TX frequency - polarization

     interfering path length

     total antenna discrimination (interferer discrimination angle, victim discrimination angle)

     interfering signal level (difference between objective and interfering signal levels)

     threshold degradation

Use the "go to case number button" in the case detail report to access the desired case number in the cross reference report.

Interference Case Detail Report

Select Interference - Reports - Case Detail from the Network menu bar. This report arranges the interference results into cases and sub-cases. A case is one receiver. A sub-case is a transmitter which is causing interference in that receiver. The screen display shows the results of one case-sub-case at a time. The ▼ and ▲ buttons on the report control bar change the interference case. The ▶ and ◀ change the sub-cases.

The go to case number button ⬛ is used in conjuction with the cross reference report to access specific interference cases.

The display for the last sub-case shows the interference levels and the composite threshold degradation due to all sub-cases.
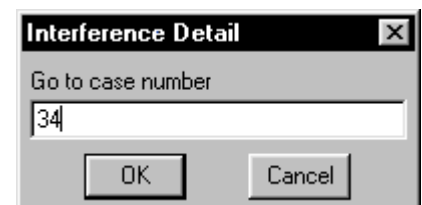
The print and copy buttons print /copy all sub-cases for the displayed interference case. To print all inter-ference cases (and sub-cases), Select Files - Print All Cases from the Interference report menu bar.

View

The transmit and receive antenna and radio files for the displayed case - sub-case can be displayed. Select View on the Interference Menu bar. The antenna discrimination angle is shown on the antenna display and the frequency difference is shown on the radio display.

OHLOSS Calculation

If the present case is a candidate for an OHLOSS cal-culation, the OHLOSS menu item and the associated button will be enabled. A terrain data base must be available for this calculation.

The "Generate Profile" dialog box shows the terrain data base configuration and the parameters to be used to create the profile. If the profile is not completely generated, a profile status message is displayed and the calculation is aborted.
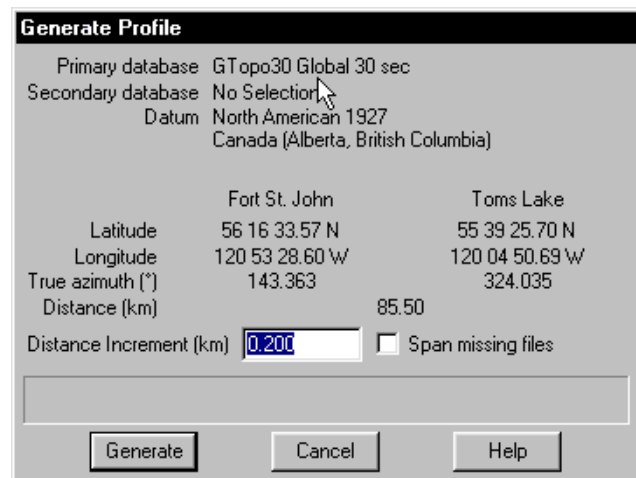
If the profile is line of sight at an earth radius factor of K = 4/3, a message is displayed and the OHLOSS cal-culation is not carried out; otherwise, the OHLOSS re-sults are displayed.

The following parameters can be changed directly in this dialog box.

- diffraction algorithm
- climatic region
- short term time percentage
- long term time percentage

Click the OK button incorporate the results into the inter-ference report.

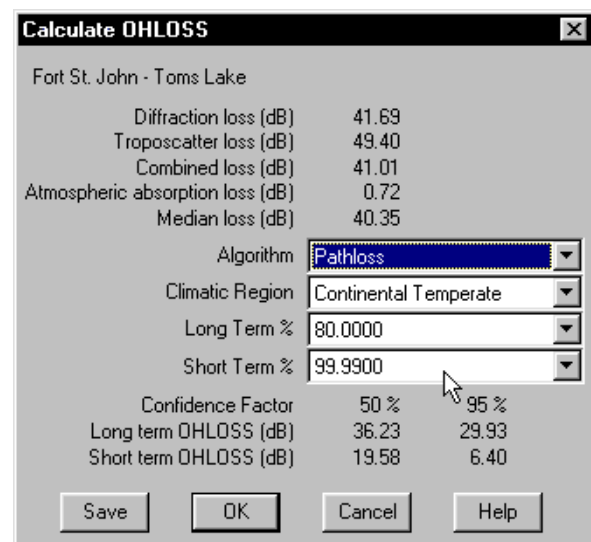The OHLOSS profile can be saved for subsequent analy-sis.

Modify Interference Parameters

Select Modify from the Interference Report menu bar to bring up the "Modify Interference Parameters" dialog box for the present case - sub-case. If OHLOSS is not applicable to this case, the these entries will be disabled.

This dialog box also allows a user to ignore the present interference case. If there are any cases which have been previously ignored, then you can also restore all of the ignored cases.

The fade correlation can be edited in this dialog.

When the dialog box is closed with the OK button, the interference case is recalculated for the modified values. Other changes such as polarization, antenna type or ATPC must be carried out by changing the Pathloss data files and repeating the calculation.

An example of a complete interference sub-case is shown below:

	Victim RX	Interfering TX
	Fort St. John	Toms Lake
	=RCTLS07	=RCTLS10
Latitude	56 16 33.67 N	55 39 25.80 N
Longitude	120 53 23.42 W	120 04 45.70 W
Azimuth (°)	150.26	332.07
Coordinating Station	Pine Valley	Dawson Creek
	=RCTLS08	=RCTLS09
Antenna Model	HPX8-58W	HPX8-58W
Usage	TR	TR
Code	a1992	a1992
Antenna Height (m)	37.20	37.20
Antenna Gain (dBi)	40.80	40.80
Polarization	Horizontal	Vertical
Discrimination Angle (°)	-6.90	-8.03
Radio Model	MDR-6706-8	MDR-6706-8
Traffic code	8DS1-128TCM	8DS1-128TCM
Code	6706_8CD	6706_8CD
TX - RX loss (dB)	3.79	2.79
TX Power (dBm)		29.00
APC Range (dB)		
T to I Cochannel (dB)	34.00	
RX Threshold BER 10-6 (dBm)	-79.00	
Frequency (MHZ)	5878.8750	5878.8750
Channel	CH 6	CH 6
V-I Distance (km)	85.49	
V-I Free Space loss (dB)	146.49	

Antenna discrimination	HH	HV	VV	VH
Interfering TX	29.00	46.00	28.38	46.00
Victim RX	29.00	44.19	27.31	45.79
Total discrimination (dB)	58.00	73.31	55.69	72.57
Interfering Signal (dBm)	-100.47	-115.79	-98.17	-115.04
Performance Degradation				
Objective (dBm)		-113.00		
RX Signal (dBm)		-34.77		
Noise Threshold (dBm)		-107.00		
Interfering Signal (dBm)		-115.04		
Frequency Separation (MHZ)		0.00		
Filter Improvement (dB)		0.00		
Other loss (dB)				
Short Term - Long Term (%)		80.0000	99.9900	
OHLOSS (dB)		38.85	17.02	
Adjusted Interfering Level (dBm)		-153.88	-132.06	
C to I (dB)		119.11	97.29	
Threshold Degradation (dB)		0.00	0.01	

An example of the composite threshold degradation for the interference case is given below:

Composite performance degradation			
Interfering Signal (dBm)		Long term	Short term
Toms Lake		-153.88	-132.06
Beaverlodge		-110.93	
Pine Valley		-100.68	-100.68
Composite level (dBm)		-100.29	-100.68
Threshold Degradation (dB)		7.55	7.23

High - Low Violations Report

This report provides a listing of all transmit frequencies used in the interference analysis. A sample format is shown below:

| TX	RX		
Fort St. John	Pine Valley	5912.3750H	LL6-6H
Pine Valley	Fort St. John	5878.8750H	LL6-6L
	Dawson Creek	5878.8750H	LL6-6L
Dawson Creek	Toms Lake	5912.3750V	LL6-6H
	Pine Valley	5912.3750H	LL6-6H

The transmit sites are shown in the first column. The receive site, frequency, polarization and channel identifier are shown in the following columns respectively. The channel identifier naming convention is used to determine if both high and low frequencies exist at a site and this will be flagged accordingly. The last letter of the channel ID must be either H or L (high or low); otherwise, a bad channel ID will be flagged.

INTERFERENCE AND DESIRED PATH FADE CORRELATION

OVERVIEW

If an interfering signal follows the same path as the desired signal, the two signals can be considered to be correlated to some degree. The interfering signal will experience fading at the same time as the desired signal; thereby reducing the effect of the interference.

Spatially Correlated

This is the case for both rain and multipath fades; however, the degree of correlation for these two conditions will be different. In the case of a multipath fade, it is realistically assumed that only one fade will exist at any instance in time in an area due to the characteristics of deep fading. Multipath fades are short in duration and highly localized in an area. Rain fades on the other hand are of longer duration, are relatively frequency independent in a given band and can extend over a wide area.
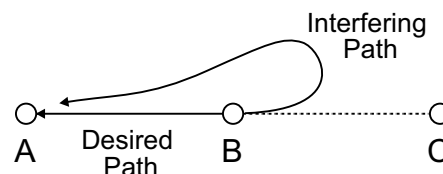
To handle this fade correlation, the May 2001 program build considers the interference fade margin and threshold degradation for both rain and multipath separately under the assumption that rain and multipath fading are mutually exclusive events. Provision is made to edit the rain - multipath fade correlation and to assign default values for this correlation at the start of an interference calculation.
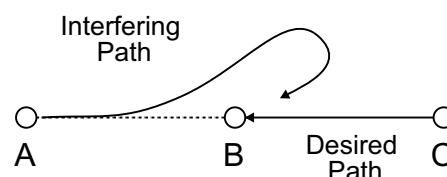

Spatially Uncorrelated

The base interference calculation is always carried out and retained. The effect of rain and multipath correlation does not change the base calculation.

An example of a correlated fade would be a multi hop two frequency plan system with sites designated as A, B and C. The receiver at site A whose associated transmitter is located at site B, will be interfered by the transmitter also at site B transmitting to site C. The carrier to interference ratio is completely determined by the front to back ratio of the interfering transmit antenna. Since both the desired and interfering signals follow the path from B to A, the following considerations can be made.

- Rain will attenuate the desired and interfering signals equally if the polarizations are the same for both signals. The polarization of the interfering signal is indeterminate off boresight and can be considered to be circular at discrimination angles greater than 90 degrees. Therefore, the fading could be considered as completely correlated and the case could be ignored.

- The degree of correlation between the desired and interfering signal fades due to multipath will depend on the antenna heights of the desired and interfering transmitters at site B. Polarization will affect the correlation to a lesser degree. For equal antenna heights, the fading can be considered to be correlated; otherwise a partial correlation situation exists.
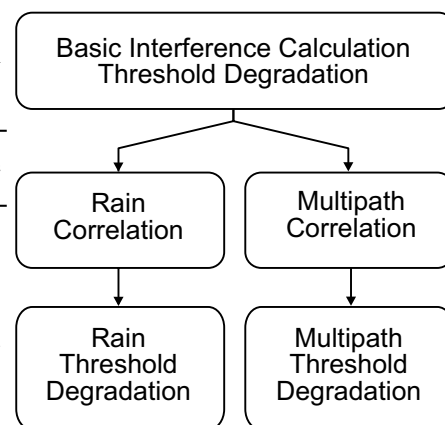
ADJACENT CHANNEL FADE CORRELATION

A one for N systems is a specialized case of correlation. From a multipath standpoint, the frequency difference between the desired signal and the adjacent channel interferer, is small enough to offer some multipath fading correlation. This correlation combined with the filter improvement is usually sufficient to clear the case. At frequency separations of two or more adjacent channels, the filter improvement is sufficient to ignore the interference.

From a rain fade standpoint, the interfering and desired paths are completely correlated and the interference can be ignored.

ATPC CONSIDERATIONS

An interference detail report shows the carrier to interference ratio. Prior to the May 2001 build, the C/I was always calculated with the receive signal at the maximum power and the interfering signal at the minimum power when ATPC was specified. The C to I calculation now depends on the spatial correlation as follows

Uncorrelated   minimum receive signal - minimum interfering signal

Correlated   minimum receive signal - maximum interfering signal

DEFAULT PROGRAM SETTINGS

At the start of an interference calculation, default correlation values can be assigned to the calculation. In the Network module select - Interference - Calculate Intra to bring up the interference dialog box.

Click the Correlation Options button to set the defaults. Four categories of correlation available including uncorrelated for both multipath and rain. The user can choose to ignore the interference or to specify a value for the correlation. Remember that any setting here does not affect the base calculation.

EDITING CORRELATION

The correlation can be edited on a case by case basis in the Modify Interference Parameters dialog. This can be accessed from the case detail report under the Modify menu selection.

The antenna heights are shown under the designations:

itx   interfering transmitter

atx   victim receiver adjacent site transmitter

The correlation can also be edited directly in the Network display. Select Interference - Edit Correlation. The organization is the same as that used in the case detail report. Each receiver is a case. Each interferer into that receiver is a sub case. The interference path is shown on the network display which helps to assign values to the correlation. The arrows on the left changes the receiver (case) and the arrows on the right change the interfering transmitter (sub case).

The frequencies and polarization are shown along with the antenna heights using the same nomenclature as described above. In addition the following parameters are given:
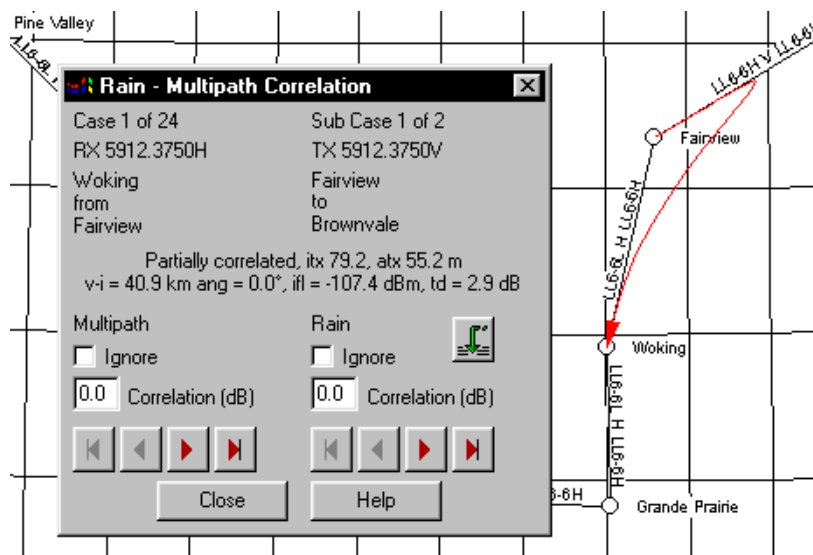
v-i   victim to interferer path length

ang   the discrimination angle at the victim receiver

ifl   interfering signal level

td   threshold degradation

The ![button] button allows the user to go to a specific case number. The cross reference report can be used as an overall index.

View Error Log

As the interference calculation proceeds, a record is made of any problems which prevent the calculation of an interference case from running to completion. The results are written to the file "INTRFERR.LOG" in the same directory as the network data file. Typical errors are:

• an antenna code has not been specified in a Pathloss data file

• an antenna data file (mas) could not be found or encountered a file read error

• a radio data file (mrs) could not be found or encountered a file read error. A missing radio code in a Pathloss data file is not considered an error. The interference calculation may not be complete.

• different call signs for the same site were found in several Pathloss data files.

To view the file, select Interference - View Error Log from the Network menu bar. The Windows Notepad is used to view the file and must be available on the system.

Update Pathloss Files

The composite threshold degradation of each receiver is determined in an interference calculation. This is corrected for multipath and rain correlation. These values can be transferred to the Pathloss data files to determine the actual degradation in performance. Select Interference - Update Pathloss Files - Update threshold degradation. A second option is provided to remove threshold degradation from the Pathloss files.

SITE DATABASE INTERFERENCE CALCULATIONS

Interference calculations using the site database are identical to the intra system interference calculations made in the Network module.

PROCEDURE

Select SDB - Interference to initiate an interference calculation. The link to be coordinated against the site database must be validated for interference. If the red × mark is displayed on the status bar, the link is not valid and the calculation will not be made. Click on the red to display the missing information. The following data is a prerequisite for an interference calculation:

This must be a microwave application. No provision is made for VHF-UHF links.

- Call signs must exist for both sites.

- Coordinates must exist for both sites.

- The design frequency must be specified.

- The antenna code must be specified for each antenna used.

- The data entry in the Summary or Microwave worksheet module must be complete to the point of a receive signal calculation.

- The transmit channels must be specified.

The calculation starts by creating four new database tables for the interference calculation. These tables are stored in the current database directory. Existing tables are overwritten each time a new calculation is made. The table names and usage are listed below:

TXMDBIFR.DB	transmit data in the Summary module link
RXMDBIFR.DB	receiver data in the Summary module link
DTMDBIFR.DB	results of the interference calculation
OPMDBIFR.DB	options used in the interference calculation

The interference calculation is carried out in two steps. The first step analyzes the transmitters in the Summary module against all receivers in the site database. The second step analyzes all transmitters in the site database against the receivers in the summary module.

Coordination Distance

The coordination distance is the maximum distance between an interfering transmitter and the victim receiver. An interference case is not reported if this distance is exceeded.

Maximum Frequency Separation

An interference case is not reported if the frequency difference between the interfering transmitter and victim receiver is greater than the specified maximum frequency separation.

Margin

The margin limits the number of interference cases reported. Each interference calculation establishes an interference level objective based on either the default minimum interference level or the level derived from the specified threshold degradation objective. If the calculated interference level is less than the objective by the specified margin, the interference case is not reported.

Default Minimum Interference Level

The default minimum interference level is used when sufficient radio data is not available to determine the receiver noise threshold level. This is calculated from the receive threshold for a BER of 10-6 and the co-channel T to I ratio. In the site database, this information is contained in the radio data file as referenced by the radio code. In the summary module this is calculated from the receiver data entered in the Microwave Worksheet module.

If the radio data is not available, an interference case will not be reported if the interfering level is less than the specified default minimum level minus the margin (described above).

Threshold Degradation

The interference level objective is calculated from the specified threshold level degradation. This calculation requires the receive threshold for a BER of 10-6 and the cochannel T to I ratio. These are obtained from the radio code in the site data base and the receiver data in the Summary module. If these parameters are not available, the default minimum interference level is used.

Interference Calculation

The steps described below are carried out for each transmitter and receiver in the Summary module.

- the TXMDBIFR.DB and RXMDBIFR.DB database tables are created and filled with the transmit and receive data in the Summary module.

- The OPMDBIFR.DB option table is created using the options set in the Interference dialog box. The time of the calculation is also saved in this table.

- A frequency range is set on the transmit channel table in the site data base using the specified maximum frequency separation. Only those channels within this frequency range are analyzed.

- The coordinates of a bounding rectangle are calculated using the site coordinates and the maximum coordination distance. A filter is set on the site table so that only sites whose coordinates are within these bounds are visible.

- All other details of the interference calculation are identical to the Intra System Interference calculation at the beginning of this section. The interference results are tabulated in the DTMDBIFR.DB file.

View Error Log

As the interference calculation proceeds, a record is made of any problems encountered which prevents an interference level calculation. Some typical errors are listed below:

- An antenna code has not been specified in the site database.

- The antenna data file (*.mas) for an antenna code could not be found or encountered a file read error.

- The radio data file (*.mrs) for a radio code could not be found or encountered a file read error. A missing radio data file does not constitute an error. The interference calculation will be incomplete in the report.

These errors do not terminate the overall calculation. When the calculation is complete, the results are saved in the file MDB_ERR.TXT in the site database directory.

To view the file, select SDB - View Error Log from the Summary module menu bar. The Windows Notepad is used to view the file and must be available on the system.

Interference Report

Select SDB - Report to display the results of an interference calculation. The report represents the last interference calculation carried out on the selected site database.

The results are presented as individual interference cases. The cases follow the sequence below:

Victim RX   Interfering TX

Summary module Site 1 receivers Site database transmitters
Summary module Site 2 receivers Site database transmitters
Site database receivers   Summary module Site 1 transmitters
Site database receivers   Summary module Site 2 transmitters

The print and copy buttons on the report control bar print or copy the selected case only. To print all cases, select Files - Print all cases on the report menu bar.

An example of an interference case report is given below:

Coordination Distance (km)	200.00
Maximum frequency Separation (MHZ)	150.00
Default Minimum Interference Level (dBm)	-115.00
Margin (dB)	10.00
Threshold degradation objective (db)	1.00
Total number of cases calculated	8
Number of cases ignored	0

Calculation made on Saturday, August 15 1998 03:34:00 PM
Case 1 - Grande Prairie from Woking

	Victim RX	Interfering TX
	Grande Prairie	Beaverlodge
	VBC888	=RCTLS12
Latitude	55 12 21.80 N	55 12 50.10 N
Longitude	118 44 26.90 W	119 16 08.10 W
Azimuth (°)	359.24	91.27
Coordinating Station	Woking	Grande Prairie

	=RCTLS13		VBC888	
Antenna Model	UHX10-58W		HPX8-58W	
Usage	TR		TR	
Code	a2008		a1992	
Antenna Height (m)	78.50		50.00	
Antenna Gain (dBi)	42.10		40.80	
Polarization	Horizontal		Horizontal	
Discrimination Angle (°)	-87.53		0.00	
Radio Model	MDR-6706-8		MDR-6706-8	
Traffic code	8DS1-128TCM		8DS1-128TCM	
Emission Designator	2M44D7WET		2M44D7WET	
Code	6706_8CD		6706_8CD	
TX - RX loss (dB)	5.89		3.43	
TX Power (dBm)	29.00			
APC Range (dB)				
T to I Cochannel (dB)	34.00			
RX Threshold BER 10-6 (dBm)	-79.00			
Frequency (MHZ)	5878.8750		5878.8750	
Channel	CH 6		CH 6	
V-I Distance (km)		33.63		
V-I Free Space loss (dB)		138.39		
Antenna discrimination	HH	HV	VV	VH
Interfering TX	0.00	32.00	0.00	32.00
Victim RX	69.72	74.00	69.82	74.00
Total discrimination (dB)	69.72	74.00	69.82	74.00
Interfering Signal (dBm)	-105.52	-109.81	-105.63	-109.81
Performance Degradation				
Objective (dBm)	-113.00			
Noise Threshold (dBm)	-107.00			
Interfering Signal (dBm)	-105.52			
Frequency Separation (MHZ)	0.00			
Filter Improvement (dB)	0.00			
Other loss (dB)				
Adjusted Interfering Level (dBm)	-105.52			
Threshold Degradation (dB)	3.81			

AREA COVERAGE

OVERVIEW

The area coverage module creates signal range and line of sight displays for both microwave and VHF-UHF applications using a terrain database. The calculations use a three step sequential process as illustrated in Figure 1.

The results of each step are saved in three files using fixed file name suffixes.

Step 1   creates a Ter4 file containing the radial profiles (distance - elevation along azimuths).

Step 2   creates a Cvg4 file containing the diffraction loss results of the Ter4 file.

Step 3   creates a Prd4 file containing the final processed coverage results.

A new project would create all three files. Additional analysis at the same site can start with the Ter4 or Cvg4 files. All related files in a coverage project should be located in the same directory.

Figure 1: Area Coverage Calculation Steps

Multi Site coverage displays are created by loading Prd4 files into the Site List in the Network module.

Check the application type before selecting the Coverage module. If this is a microwave application, only microwave antennas and the microwave worksheet can be used. If a VHF-UHF application has been selected, then VHF-UHF antennas and the VHF-UHF worksheet will be used.

STEP 1 - GENERATE RADIAL PROFILES

Select Files - New Project to access the Generate Radial Profiles dialog. This is the first step in creating a new coverage project. A terrain data base is required for this step. If the New Project menu selection is disabled, check that a terrain data base has been selected (Select Configure - Terrain Data Base).

A save file dialog is used to specify the project name. The suffix Ter4 will be automatically added to the file name.
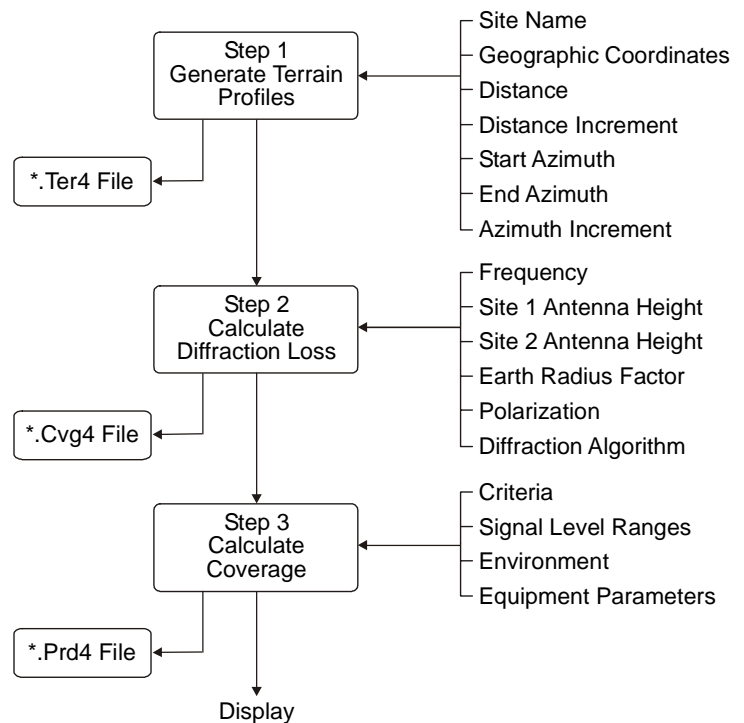
The dialog shows the primary and secondary data bases that will be used to create the profiles and the datum and the specific region for the datum. It is important to have the datum and region correctly specified. The program will transform the site coordinates to correspond to the database datum, if required. If an ellipsoid is specified, this transformation cannot take place.

Complete the required entries in the Generate Radial Profiles dialog. The S1 and S2 buttons transfer the site name and coordinates of the current Pathloss data file.

Decide the overall resolution of the display. This is determined by the distance increment and the azimuth increment. The distance increment is the spacing between distance - elevation points along the radial profiles. Subsequent diffraction loss calculations will be made at these points. The azimuth increment is the angular spacing between radials. A preliminary study might use a 5° increment and a 1° increment for the final presentation. The choice affects the processing time.

If the Delay processing option is unchecked, the terrain profiles will be generated immediately when the Next button is clicked; otherwise, the generation will be delayed until the subsequent steps are completed. You can return to the Generate Radial Profiles dialog; however, once the profiles have been created, the entries can no longer be edited.

Click the Next button to go to the second step

STEP 2 - CALCULATE DIFFRACTION LOSS

Step 2 calculates the diffraction loss at each point in the radial profiles generated in step 1. The following parameters are required to completely define the diffraction loss calculation:

Base and mobile antenna heights

Frequency and polarization

Earth radius factor (K)

Diffraction algorithm

The S1 and S2 buttons can be used to transfer the antenna heights and frequency of the current Pathloss data file into the dialog. S1 assumes that the base station is Site 1 and conversely for the S2 button.

Normally, both signal range and line of sight displays are processed. If the line of sight only option is checked, diffraction loss will not be calculated. Each point is examined for line of sight. In this case, the frequency, polarization and the diffraction algorithm are not used. This option allows the user to specify a fixed tree / structure height along the path. Be sure that the mobile antenna height is greater than this structure height; otherwise, there will be no line of sight anywhere.

If the Delay processing option is not checked, the diffraction loss calculation will proceed immediately when the Next button is clicked; otherwise, the calculation will be delayed until the coverage parameters are specified in the third step.

The following parameters are determined at each point along the radial profiles in the diffraction loss calculation:

- Free space loss.

- Diffraction loss on line of sight paths with less than 60% first Fresnel zone clearance or combined diffraction and tropospheric scatter loss on obstructed paths.

- Vertical angle to the mobile antenna. If the path is non line of sight, the horizon angle is used.

- Effective distance. This is used to calculate time variability.

- Elevation of the point.

- Clutter - this is not used at present.

- Line of sight flag.

Click the Next button to go to the third step to specify the equipment parameters and signal criteria. If this is a line of sight only calculation, no further data entry is required and the calculation will run to completion immediately. This is effectively a two step process.

STEP 3 - CALCULATE COVERAGE

Step 3 specifies the signal criteria and levels, the equipment parameters and the environment variables for the final calculation.

Criteria
The criteria can be any of the following:
- receive signal in µvolts

- receive signal in dBm

- fade margin

- field strength in µvolts / meter

A maximum of five signal level ranges can be specified. The 1st level is the highest signal. A blank level entry will be ignored. The final display will have the number of specified levels plus one; the last one being signals less than the lowest specified level.

Equipment Parameters
Coverage calculations normally use the path with the lowest fade margin (the inbound or outbound path). This is determined in the worksheet module. Use the S1-TX or S2-TX button to transfer the required worksheet data into the dialog. Note that the choice of S1-TX or S2-TX buttons only affect the parameters: TX power, RX sensitivity, TX and RX loss. The site 1 antenna (gain, code and mechanical downtilt) will always be used for the base station. If an antenna code is not specified, the antenna is assumed to be omnidi-

rectional. The antenna has a constant gain in all directions and the effects of the vertical angle are not considered. If an antenna code is specified, the base station antenna azimuth must also be specified. Note that this is the azimuth of the antenna mechanical boresight. Note that the mechanical boresight does not always correspond to the direction of maximum gain. For example, the maximum gain of a stacked dipole antenna, with a half wavelength antenna to mast spacing, is at $\pm 90°$ to the mechanical boresight.

The mobile antenna is assumed to be perfectly oriented towards the base station antenna. The horizontal and vertical patterns of the mobile antenna are not considered.

Click the Code Index button to load an antenna code. The code index dialog will correspond to the current application setting (microwave or VHF-UHF). Antenna gains are always expressed in dBd in this dialog. If this is a microwave application, the antenna gains will be 2.15 dB less than the isotropic antenna gain. Click the View button to display the antenna pattern.

Antenna Response

In general, the antenna data files do not contain sufficient data to determine the three dimensional response to an incoming signal at arbitrary horizontal and vertical angles, θ_H and θ_v relative to the mechanical boresight of the antenna. The procedure for calculating the response of microwave and VHF-UHF antennas is described below. In the following descriptions, the horizontal and vertical patterns are denoted by $G_H(\theta)$ and $G_V(\theta)$ respectively.

Mechanical Downtilt

In the pathloss program, the sign convention for vertical angles is positive for angles above the horizon and negative for angles below the horizon. A positive downtilt, however, means that the antenna boresight is pointing down to the ground.

The effects of mechanical downtilt are accounted for by modifying the vertical angle θ_V. The effect is to increase the vertical angle at the front of the antenna and decrease the vertical angle at the rear. At 90° off of boresight,$(\theta_V = 90°)$ mechanical down tilt has no effect. The modification is given by the following equation.

$$\Delta\theta = \frac{\theta_{MD}}{90} \cdot (90 - \theta_H) \text{ for } 0 \leq \theta_H \leq 180$$

$$\Delta\theta = \frac{\theta_{MD}}{90} \cdot (-270 + \theta_H) \text{ for } 180 \leq \theta_H \leq 360 \tag{1}$$

$$\theta_{Vmod} = \theta_v + \Delta\theta$$

where:

θ_{Vmod}	is the modified vertical angle
$\Delta\theta$	is the correction to the vertical angle
θ_{MD}	is the mechanical downtilt angle (positive down)
θ_H	is the azimuth angle relative to the antenna boresight

Note that the microwave antenna data files (*.mas) used in the Pathloss program are radiation pattern envelope files. Only the peaks of the side lobes are considered. In addition, most microwave antenna patterns do not specify the vertical plane data. Those that do, only provide data in the range ±5 degrees about the boresight. If a vertical pattern is not available in the antenna data file, then it is assumed that the pattern is rotationally symmetric and the horizontal pattern data will be used for both the horizontal and vertical response.

The following procedures are used for omnidirectional and directional antennas.

Omnidirectional Antennas

It is assumed that the vertical pattern of an omnidirectional is rotationally symmetric. The response,

$$R_{dB} = G_H(\theta_H) + G_V(\theta_V) \tag{2}$$
$$G_H(\theta_H) = 0 \quad \text{for an omnidirectional antenna}$$

Directional Antennas

It is assumed the field distributions are separable into two orthogonal components. The response, R_{dB} is given by Equation (3) below

$$\Omega = sin^{-1}(cos(\theta_H) \cdot sin(\theta_V)) \tag{3}$$
$$R_{dB} = G_H(\theta_H) + G_V(\Omega)$$

In Equation (3), and effective vertical angle, Ω is first determined. The vertical response is read from the antenna data file, $G_V(\Omega)$.

Environment Parameters

In the previous step, the diffraction loss was calculated on line of sight paths with less than 60% first Fresnel zone clearance. On obstructed paths, both diffraction loss and tropospheric scatter loss were calculated and combined together to produced a combined loss. This is referred to as a reference loss which by definition is valid for 50% of the time and 50% of the locations. The environment section allows the user to select higher time percentages for the time and location variabilities.

Time Variability

Refer to the Diffraction Loss technical reference section of this manual for details of the time variability calculation. The time variability depends on an effective distance parameter and the selected climatic region. The calculation uses digitized curves shown in the Diffraction Loss technical reference instead of the curve fit approximations. This allows an accurate interpolation of the time percentages for all climatic regions. The effect of specifying a time percentage greater than 50% is to increase the loss: and therefore, reduce the coverage area.

A median loss correction factor is first added to the combined diffraction - tropospheric scatter loss. If the time variability is specified to be 50% or less, the time variability is zero; otherwise, the value is read from the time variability curves and added to the loss.

Location Variability

The additional loss due to location variability is determined by the product $Z \cdot \sigma$ where Z is the standard deviate unit and σ is the standard deviation of a log normal probability. Standard deviates for several time percentages are shown in Table (1) on the right. The standard deviate is calculated from the following equation:

$$Z(x) = \frac{1}{2} erfc\left(\frac{\mu - x}{\sqrt{2} \cdot \sigma}\right) \qquad (4)$$

where *erfc* is the complimentary error function. And the mean value μ, is normalized to zero.

Select one of the location regions. This sets the standard deviation, σ to one of the following values:

Metropolitan	σ = 12 dB
Urban	σ = 10 dB
Suburban	σ = 8 dB
Woodland	σ = 6 dB
Open Terrain	σ = 4 dB

Table 1:

Standard Deviate Unit (Z)	
Reliability Required	Z
50%	0.00
70%	0.52
80%	0.84
85%	1.04
90%	1.28
95%	1.65
97%	1.88
99%	2.33

Enter the time percentage and the log normal loss will be displayed. This loss will be added to all points in the coverage display. Log normal shadowing is assumed to be frequency and distance independent.

Clutter

A fixed clutter loss can also be included in the calculation. To some extent this factor overlaps with the location variability and in general, the two factors <u>should not</u> be used together. One example where both location variability and clutter are valid would be an area coverage calculation inside the vehicles of a public transit system. Suppose the vehicle shielding was measured to be 12 dB. This value would be directly entered into the clutter field. The location variability would account for the factors outside the vehicle.

Clutter	
OK Cancel Help	
Clutter type	Wood buildings
Distance to clutter (ft)	10.00
Height above antenna (ft)	5.00
Depth on path (ft)	12.00
Width across path (ft)	5.00
Clutter loss (dB)	7.59
Press Enter to Select :	

Click the C button to bring up the clutter worksheet. This can be used to determine typical expected values of clutter in a particular environment.

When the coverage parameters have been specified, click the Finish button to process the radial data and display the results.

COVERAGE DISPLAY

A calculation can be drawn as either radials or as a solid colored display. The selection for both line of sight and signal calculations is made in the Display menu. This menu includes the additional selections described below:

Page Display

The Page Display menu selection toggles the display mode between a page lay-out display and a coverage display. The drawing can only be printed in the page display mode. In this mode, the display is relative to the paper edges and shows the title block. To set the page display options, select Print - Page Setup on the menu bar.
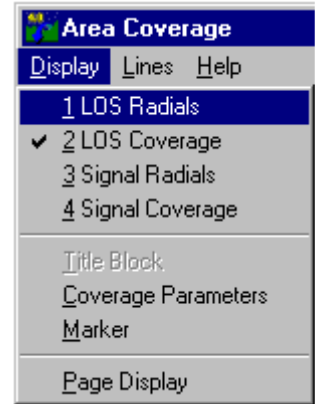
The following operations are carried out in the page display mode:

*   Shift the coverage display on the page. Hold down the shift key and press the left mouse button. Drag the coverage display to the desired location on the page.

*   Double click the left mouse button on the title block outline to view the title block. The outline will not be shown if the title block will be printed on a separate page or the title block is not used. These options are set in the Page Setup dialog.

*   The display can only be printed in the page display mode.

*   The title block can be copied to the clipboard.

If the page display mode is not selected, the following operations are available:

*   The coverage display can be copied to the clipboard.

*   The coverage display can be zoomed. Hold down the Ctrl key and move the cursor to one corner of the area to be zoomed. Hold down the left mouse button and drag the mouse to the diagonal corner. To reset the display, hold down the Ctrl key and click the right mouse button.

*   A marker can be applied to the display.

Marker

Select the Marker menu item to bring up the marker. The location of cross hair marker is shown as a distance and bearing from the base sta-tion and as its geographic coordinates.
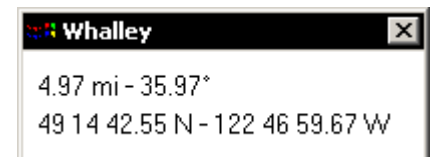
Click the left mouse button to move the marker or hold the left mouse button down and drag the marker to the desired location.

Coverage Parameters

The coverage parameter menu selection reviews the parameters set in steps 1 to 3. The parameters cannot be edited. If any changes are required, you must load the last valid step (Ter4 or Cvg4 file) and repeat the calculation from the chosen starting point. If a change is required in the step 1 dialog box, then a new project must be created.

Title Block

The title block can be viewed in the page display mode by double clicking the left mouse button on the title block outline.

In all modes, you can select Display - Title Block in the menu bar.

The title block is formatted for the selected display (line of sight or signal level ranges). The title block only includes the parameters which have been specified. For example, if the mechanical downtilt field is zero or blank, then mechanical downtilt will not be shown on the title block.

LINES

The line attributes and color coding for each signal level range is set in the Line Attributes dialog box. The line attributes (line width and style) are used for radial displays.

To edit a line attributes, click on its line display box. This selects the line into the Edit Line group box. The line color, width and style for that line are then set using the standard color, line width and style controls.

If a signal level range has not been specified, the corresponding line selection will be disabled.

Any line may be excluded from the display. In some cases, the overall presentation can be improved by excluding the highest signal level range. In other cases, excluding the line which represents signals below the lowest range, produces the best overall display. Lines are included or excluded with the check box, opposite the line.

Note that the Windows graphics device interface cannot display a thick dotted or dashed line. If a pen plotter will be used, all line widths should be set to zero. This will ensure a single pass on all lines. The Windows plotter driver does not handle thick lines efficiently. Print manager may require in excess of ten minutes to format the drawing for the plotter. The plotting times are too long to be practical.
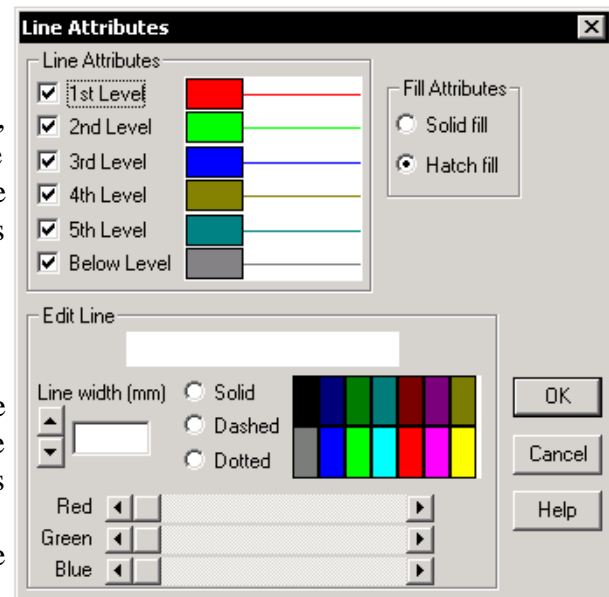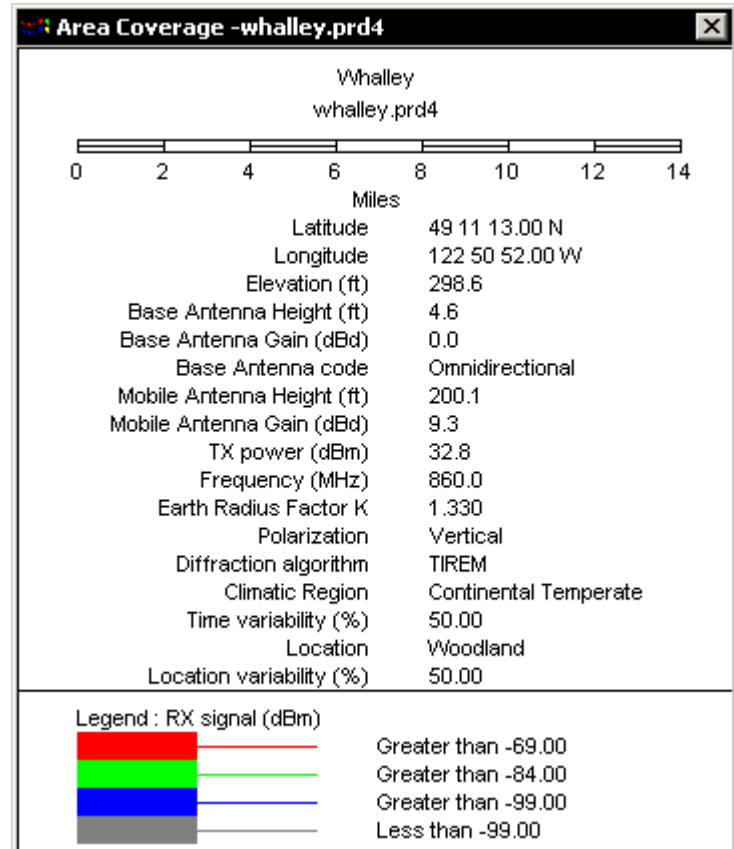
PAGE SETUP

Select Print - Page Setup to access the Page Set-up dialog box. All options in this dialog box apply only to the page display mode.

Scale

Coverage drawings are usually overlaid on topographic maps to assess the overall effectiveness of the design. The size of the coverage drawing is set in this module by specifying the map scale. The size of the page is determined by the currently selected printer. Three scaling options are provided.

- The drawing can be fit to the page using an arbitrary scale. The program will determine the required scale.

- The drawing can be printed to a specified map scale. In this case, one or more pages may be required.

- The drawing can be printed to a specified map scale using a single page. In this case, the edges of the coverage drawing may not be printed.
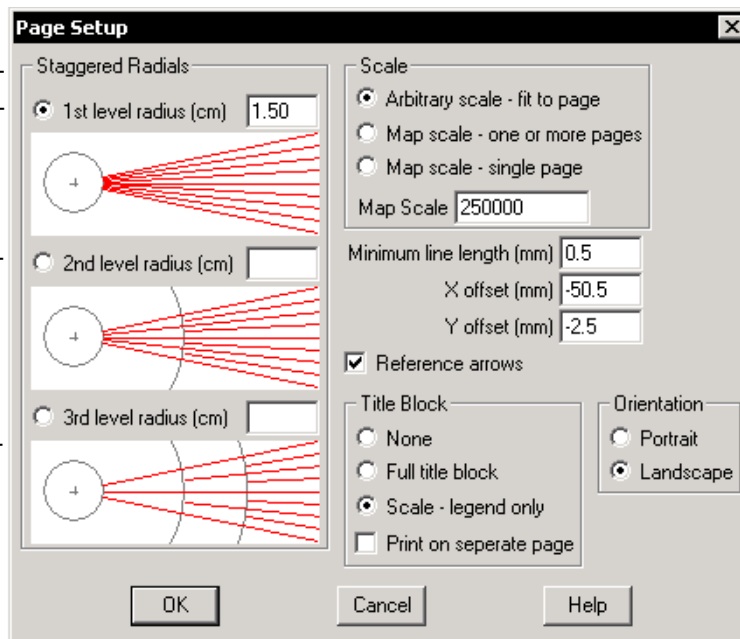
Minimum Line Length

A signal may go through several ranges in a relatively short distance. Depending on the map scale, it may not be practical to show the different ranges over this distance interval. On a pen plotter, the drawing quality may degrade, if several ranges are printed in a short distance. The minimum line length setting is used to ignore small line increments. Any line which is less than the minimum line length setting will not be printed.

X-Y Offsets

The coverage display can be positioned on the page by directly specifying the X and Y offset in millimeters with respect to the center of the page. In the page display mode, to set the X and Y offsets directly, hold down the Shift key and then press the left mouse button on the coverage display. Drag the coverage display to the desired location on the page.

Reference Arrows

Reference arrows can be drawn at the ends of the 0 and 180 degree radials. These are useful when overlaying the coverage drawing on a topographic map.
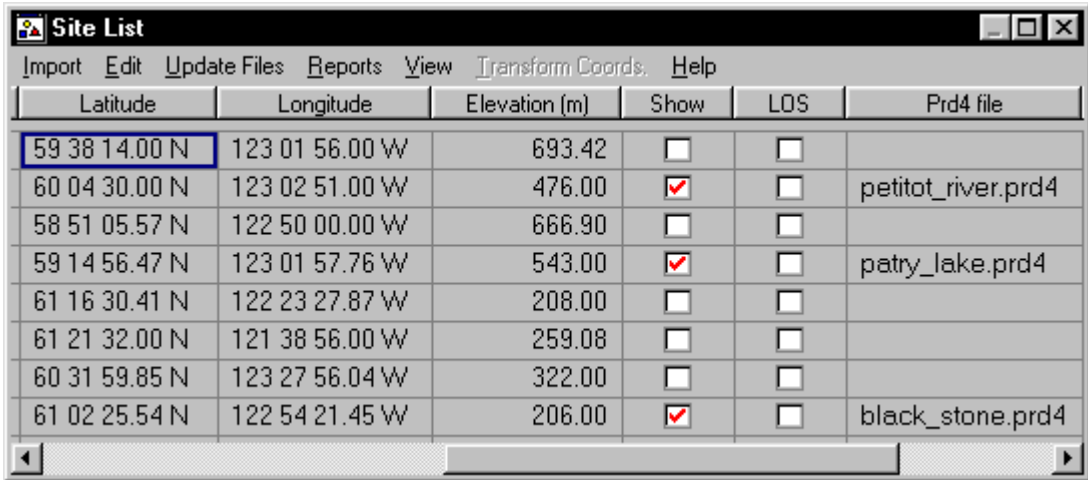
Title Block Options

The title block can be shown as a scale and legend only or as a complete title block. It can be printed in the lower right hand corner of the page or on a separate page. The title block is formatted for either line of sight or signal coverage and contains only the specified parameters.

Staggered Radials

The staggered radials options apply to radial displays only. The radial presentation inherently produces a display with a high density of lines near the center and a decreasing density towards the edges. A more uniform presentation can be obtained by staggering the radials.

Select one of the staggered radial formats and enter the corresponding radius to start the radial line drawing in centimeters. Some experimentation will be required.
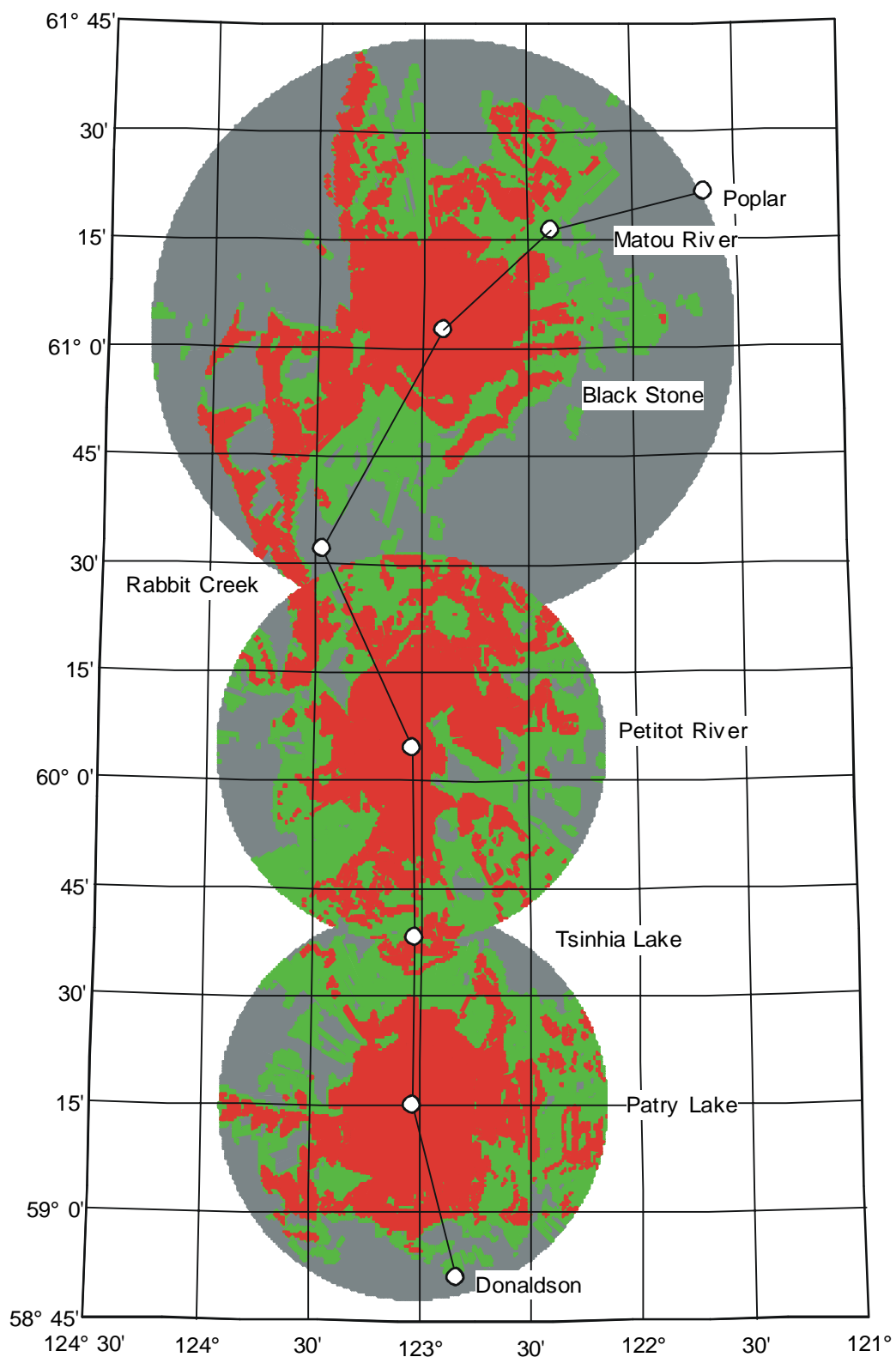
MULTISITE COVERAGE

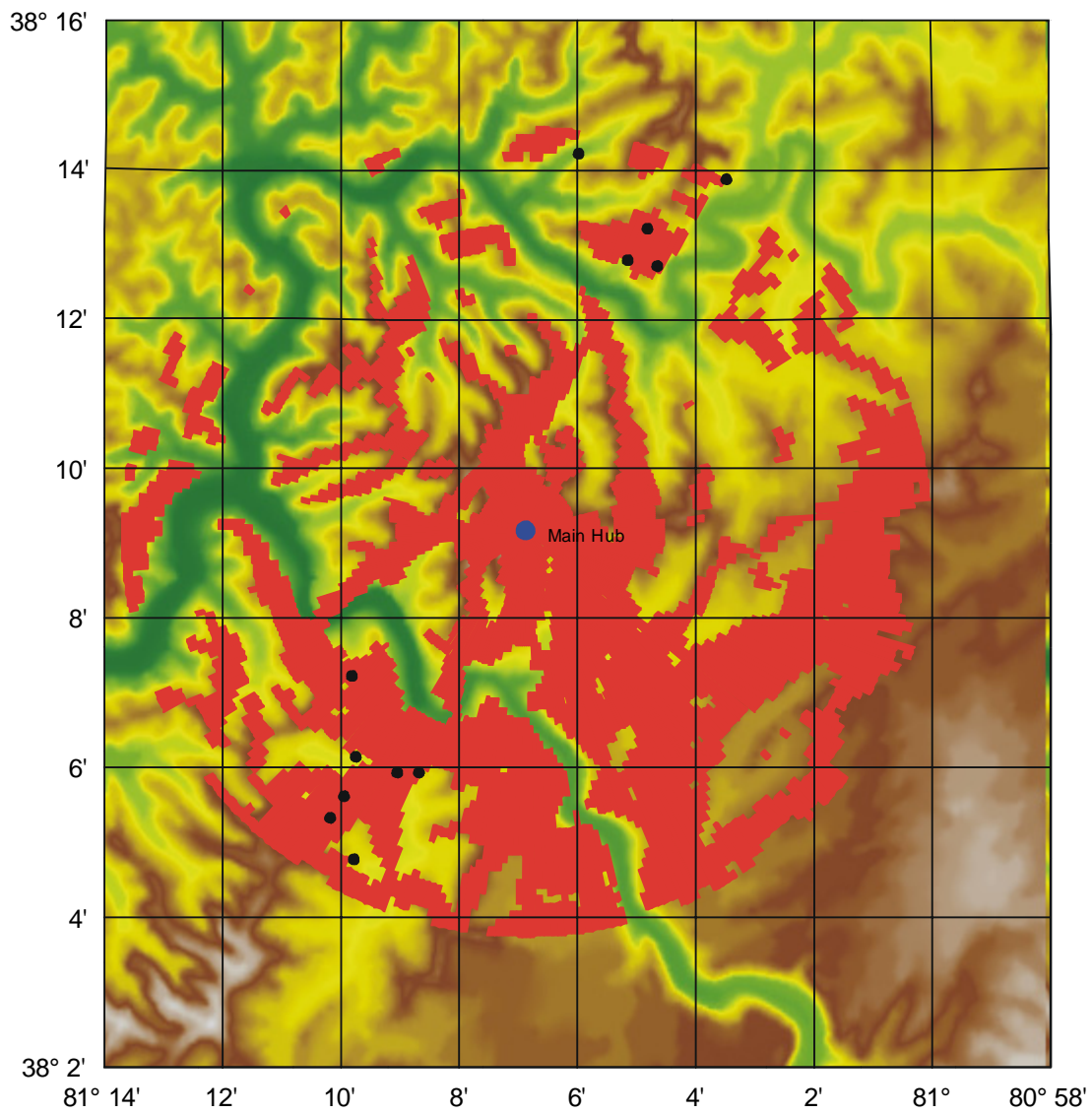| Latitude	Longitude	Elevation (m)	Show	LOS	Prd4 file
59 38 14.00 N	123 01 56.00 W	693.42	☐	☐	
60 04 30.00 N	123 02 51.00 W	476.00	☑	☐	petitot_river.prd4
58 51 05.57 N	122 50 00.00 W	666.90	☐	☐	
59 14 56.47 N	123 01 57.76 W	543.00	☑	☐	patry_lake.prd4
61 16 30.41 N	122 23 27.87 W	208.00	☐	☐	
61 21 32.00 N	121 38 56.00 W	259.08	☐	☐	
60 31 59.85 N	123 27 56.04 W	322.00	☐	☐	
61 02 25.54 N	122 54 21.45 W	206.00	☑	☐	black_stone.prd4

Multisite coverage displays are created in the Network Module. Either a signal or line of sight coverage can be selected. The colors currently specified in the line attributes dialog are used on all coverage displays. On overlapping displays, the drawing sequence assures that the highest signals are always on top.

In the Network module, select Site Data - Site List from the Network menu bar to access the Site List grid entry form. Select Import - Prd4 file and load the required files. The Prd4 file name is displayed in the last column of the display. The two check boxes - Show and LOS, determine if the coverage is visible and whether the display is link of sight or signal ranges.

Several examples of coverage displays are given on the following pages.

Page 13 show a multisite coverage analysis. Page 14 shows a line of sight coverage display which has been carried out to analyze the feasibility of a point to multipoint application.

RADIO AND ANTENNA DATA FILES

OVERVIEW

The Pathloss program uses antenna and radio data files for interference and area coverage calculations, general reference purposes and for direct data entry. When combined with lookup tables, a very flexible data entry operation results. Data files contain the basic specifications for the model and the following types of curves:

microwave antennas   radiation pattern envelopes for the four polarization combinations; HH, HV, VV, and VH. Curves are always available for the horizontal plane. Vertical plane data is provided where available; however, the range is limited to ±5° and is not used.

VHF-UHF antennas   typical radiation patterns for the HH and VV polarization combinations in both vertical and horizontal planes. In most cases, the data does not include the HH polarization combination.

microwave radios   threshold to interference curves, transmitter spectrum, receive selectivity, TX - RX filters and default masks.

A data file starts out as an ASCII file which can be created and edited by the user. This ASCII file must be converted to a binary format in the program before it can be used. Data files are identified by their file name suffixes as shown below:

	Type	ASCII	Binary
Microwave antennas			MAS
VHF-UHF antennas		VAF	VAS
Microwave radio		RAF	MRS

The ASCII file name suffix is arbitrary; however, the binary file name suffix is fixed. The file name less the suffix is referred to as a code (antenna code, radio code).

Microwave antenna data files are required for an interference calculation and to determine the orientation loss in point to mulitpoint applications. Microwave radio data files are optional in an interference calculation. If the file is not available, only cochannel cases with like modulation will be calculated down to the threshold degradation. All others will terminate at the interfering signal level.

VHF-UHF antenna data files are optional in area coverage calculations. If the antenna code is not specified, an omnidirectional pattern is assumed and there will be no corrections for the vertical angles. A data file is also required to calculate the orientation loss in point to multipoint applications.

A large number of antenna and radio data files are supplied with the Pathloss program in both the ASCII and binary formats. These are <u>not</u> installed during program installation. The Pathloss CD-ROM contains these files under the directory structure shown on the right. Each data file directory (MAS, VAS and MRS) is organized by manufacturer. Sub directories under each manufacturer are organized by frequency band or model.
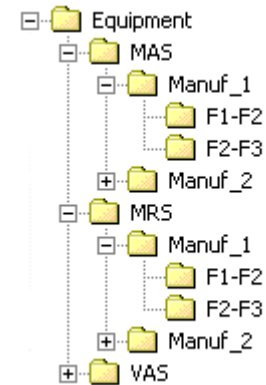
Code Index

One file is used for each antenna - radio model. The only reference available to the user is the code name which may not relate to the model number. The CD-ROM contains thousands of data files. Some means of selecting a specific data file is required. This is accomplished by the code index feature. The code index can be accessed in the applicable data entry forms, in lookup tables, in the Summary Module menu bar and in the equipment parameters section of area coverage calculations.

Code	Manuf.	Model	SY	Gain	BW	D(m)	F Lo	F Hi
a1081	Andrew	HP4-65A		36.0	2.7	1.2	6425	7125
a1093	Andrew	P8-6812		42.4	1.3	2.4	6875	7125
a1095	Andrew	P10-6812		43.0	1.2	3.0	6875	7125
a1700	Andrew	HP6-65F		39.8	1.7	1.8	6425	7125
a1709	Andrew	UHX15-65E	L	46.9	0.7	4.6	6425	7125
a1710	Andrew	UHX15-65E	R	46.9	0.7	4.6	6425	7125
a1715	Andrew	UHX12-65J	R	45.7	0.9	3.7	6425	7125
a1716	Andrew	UHX12-65J	L	45.7	0.9	3.7	6425	7125
a1717	Andrew	UHX6-65E	R	39.5	1.7	1.8	6425	7125
a1718	Andrew	UHX6-65E	L	39.5	1.7	1.8	6425	7125

New Index   View   Add   Cancel

When Code Index is first selected on a menu bar, a blank form stating "No Data Available" will appear. Click the New Index button and point to the directory containing the data files. The program will read each data file in the directory and create an index including the major specifications. The specific format of the Code Index will vary depending on its usage. If a lookup table was used to access the Code Index, you can select multiple items. In a data entry form, a single selection is available for either or both sites.

Location of Data Files

When a radio or antenna code is loaded into an antenna or radio data entry form, only the required specifications and the code name are transferred. The code name is used as a reference to the curve data. Since only this reference is available in a Pathloss data file, the location of the data files on your computer is an important consideration. Remember, that a Code Index displays the data for a single directory. To view the data files in another directory, you would click the New Index button and point to the new directory. There-

fore Pathloss data files can contain code references to data files located in multiple directories. In order to find the data files, one rule must be followed:

> Data file directories must be located under a common root directory
> The user must identify the root directory (Configure - Directories -)

Microwave antennas, VHF-UHF antennas and microwave radios can have different root directories; however, all data files of one type must share a common root directory. The user must identify the root directory for each type. Select Configure - Directories and then select the type of data file and point to the root directory. An example of a typical directory structure is given below to illustrate the procedure for setting the microwave antenna data files root directory.

All microwave antenna data files are located in EQUIPMNT\MAS. Under this directory the antenna data files are organized by manufacturer and frequency bands. The number of subdirectories is a trade off between performance and convenience. The choice of several antenna directory settings is shown below:
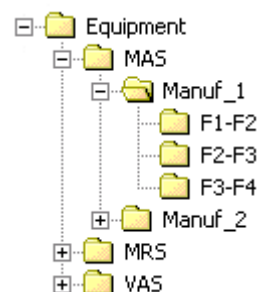
D:\EQUIPMNT\MAS

All antenna data files can be located.

D:\EQUIPMNT\MAS\MANUF_1

Only antenna files for the subdirectories for MANUF_1 can be located.

D:\EQUIPMNT\MAS\MANUF_1\F1-F2

Only antenna files for the frequency band F1-F2 for MANUF_1 can be located.

D:\EQUIPMNT

All antenna files will be located; however, the search will be very inefficient as the microwave radio and VHF-UHF antenna directories (MRS and VAS) and all of their subdirectories will be searched.

When the program starts, the message "Working .. Setting Directories" appears on the screen. The program is scanning the directory structure for the microwave and VHF-UHF antenna and radio codes and creating an internal lookup table. The scan will start at the specified topmost directory.

Transferring Antenna and Radio Data Files
The antenna and radio data files can be used directly from the CD-ROM; however, there will be a performance penalty due to increased disk access time. Most projects only use a few different antenna and radio models. These can be transferred to the hard disk. The only requirement is that all antenna files must have a common root directory and all radio files must also have a common root directory. Once the required files have been copied to your hard disk, select Configure - Directories and select the type of data file to set the topmost directory containing these files.

Data Files and Lookup Tables

Lookup tables are provided for microwave and VHF-UHF antennas, transmission lines and for microwave and VHF-UHF radios. Only the microwave and VHF-UHF antenna and microwave radio lookup tables can access their data files through the code index. The diagram below shows the relationship between radio data files, code index, lookup tables and a data entry form using microwave antennas as an example.
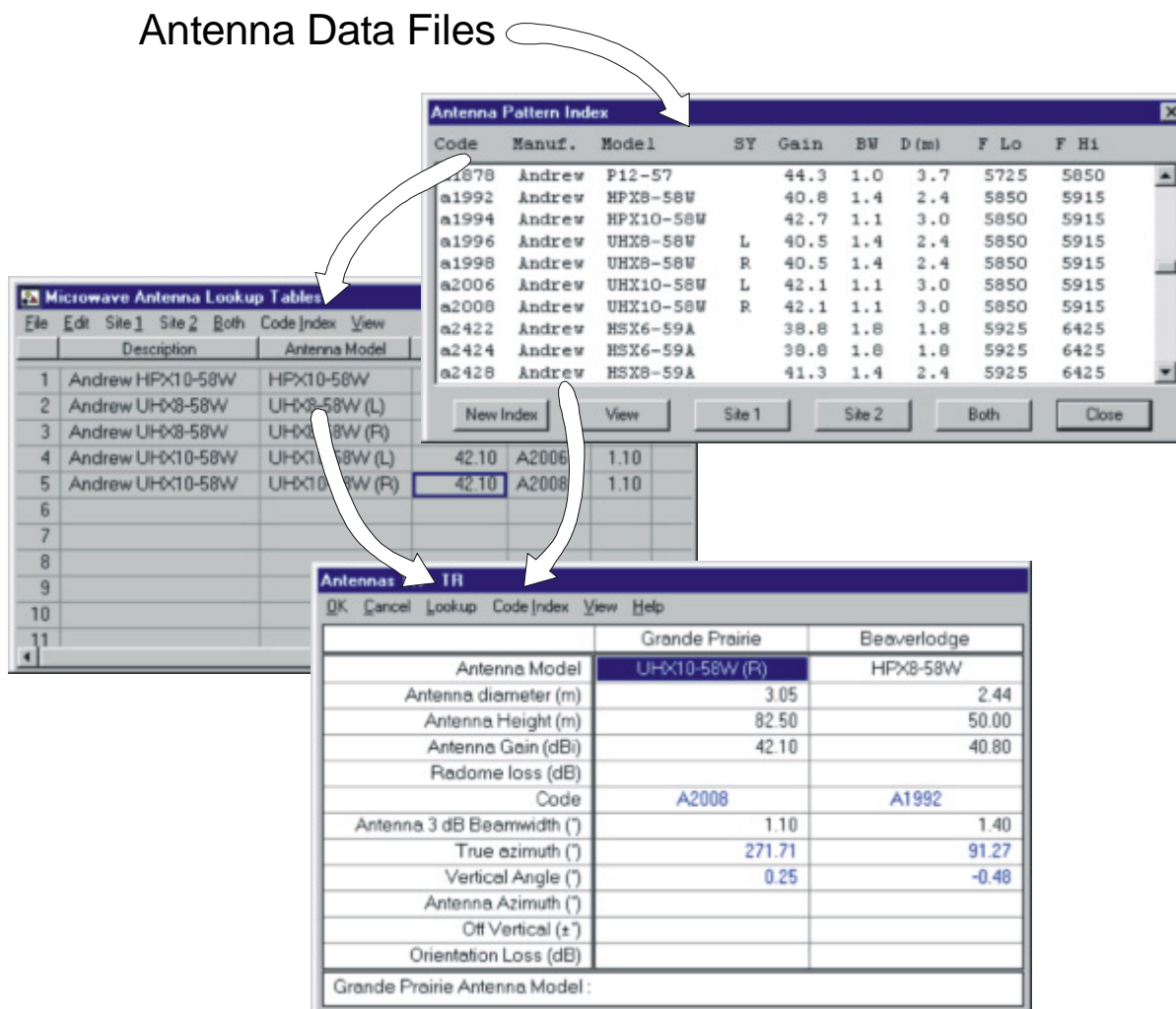
Most projects use a small number of antenna and radio models. Rather than search through thousands of data files in multiple directories, it makes sense to create a project lookup table. In the Microwave Worksheet, click the left mouse button on any of the antenna icons to bring up an Antenna data entry form.

Select Lookup from the radio data entry form menu bar. The last lookup tables used will be automatically loaded. If there is an existing lookup table, Select Files - New from the lookup table menu bar to clear the table.

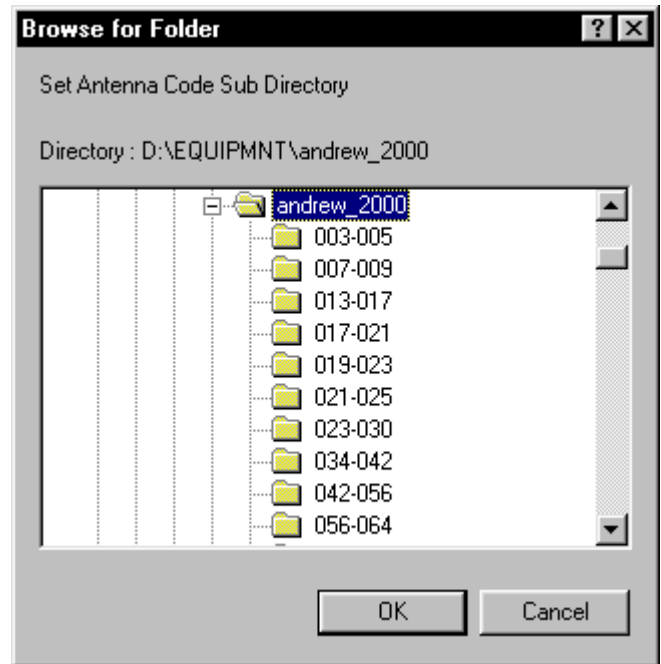Select Code Index from the lookup table menu bar.

The Antenna Pattern Index dialog shows the antennas in a single directory. If there is no data available, click the New Index button to display the Select Antenna Pattern Subdirectory. Select a directory containing antenna data files (*.mas).

Click OK to select the directory displayed. The program will read all mas files in the directory and create an index. The width of the Antenna Pattern Index dialog is determined from the available index data.

Select Code Index from the lookup table menu bar to display the Antenna Patterns Index dialog. Note that this is a multiselect list box. Hold down the Shift or Ctrl key while selecting the antennas.

Note that the width of Code Index dialog boxes is determined by the width of the data on entry. If a new index is selected, the width may be too narrow to display all of the fields. Just close the dialog and reopen it.

Lookup tables use the standard grid data entry display. Refer to the General Program Operation section for details of this display.

Browse for Folder ? ✕

Set Antenna Code Sub Directory

Directory : D:\EQUIPMNT\andrew_2000

- andrew_2000
  - 003-005
  - 007-009
  - 013-017
  - 017-021
  - 019-023
  - 021-025
  - 023-030
  - 034-042
  - 042-056
  - 056-064

OK   Cancel

Transmission Line Lookup Tables (TXL)

The directory EQUIPMNT\TXL contains the currently available transmission line lookup tables.

MICROWAVE ANTENNA DATA FILES

ASCII antenna data files use the current standard of the National Spectrum Managers Association (NSMA) "Standard Format for Electronic Transfer of Terrestrial Antenna Pattern Data". This format has been adopted by most antenna manufacturers. There are several limitations in this file format:

- High performance antennas have asymmetrical antenna patterns in the horizontal plane. The resultant pattern depends on the feed horn installation and is usually designated as left or right. Two separate data files are provided for left and right feed horn installation on the same antenna model; however, the data file does not contain any information on the feed horn installation (left or right). Furthermore, it is not always possible to determine the left - right orientation from an inspection of the pattern.

- The diameter of the antenna is usually coded into the name of the antenna model and is not specified in the data file. The antenna diameter is required for near field calculations on passive repeater applications. It is not possible to rely on the model name for the information as the diameter can be expressed in feet, meters or in some case inches.

- A three dimensional interference study cannot be carried out using this file format.

The ASCII to binary file conversion utility in the program prompts the user for the antenna diameter and the pattern symmetry (left, right or symmetrical). The binary antenna data file contains separate fields for the diameter and left-right feed horn installation for antennas with asymmetrical patterns. A large number of binary antenna data files are supplied with the program. The pattern symmetry was determined from the manufacturer's printed data sheets.

Antenna data files are used in interference calculations, as a standalone lookup table and in conjunction with the standard lookup tables.

Standard Antenna Data ASCII File Format

The format of standard antenna data ASCII files is given below. The file consists of ten header lines followed by the data for the various polarization combinations. There must be exactly ten lines as a blank line is interpreted as "no entry" for that field.

Line	Description	Size
1	Antenna manufacturer	[30]
2	Model number	[30]
3	Comment	[30]
4	FCC ID number	[16]
5	Reverse pattern m number	[16]
6	Date of data	[16]
7	Manufacturer ID number	[16]
8	Frequency range	[16]
9	Mid-band gain	[16]
10	Half-power beam width	[16]

The header information is followed by the polarization combination and the number of data points. This is followed by the data expressed as the angle and response. All antenna files include data for the horizontal plane. Some antennas particularly angle diversity antennas may contain data for the vertical plane although the pathloss program only uses the horizontal plane data. The following are the commonly accepted polarization designators for linear polarization:

HH   Horizontal polarized port response to a horizontally polarized signal in the horizontal plane

HV   Horizontal polarized port response to a vertically polarized signal in the horizontal plane

VV   Vertical polarized port response to a vertically polarized signal in the horizontal plane

VH   Vertical polarized port response to a horizontally polarized signal in the horizontal plane

ELHH   Horizontal polarized port response to a horizontally polarized signal in the vertical plane

ELHV   Horizontal polarized port response to a vertically polarized signal in the vertical plane

ELVV   Vertical polarized port response to a vertically polarized signal in the vertical plane

ELVH   Vertical polarized port response to a horizontally polarized signal in the vertical plane

The data is presented in two columns : angle followed by the antenna response.

In the horizontal plane, the angle starts from -180º (defined as the left side of the antenna) and increases to 0º on the antenna boresight. The angle then increases to +180º, thereby covering the full 360º of the antenna pattern.

In the vertical plane, the angle starts at -5º (defined as the antenna response below the antenna boresight) and increases to 0º on the antenna boresight. The angle then increases to +5º which is above the antenna boresight. The full data will cover 10º centered about the main beam.

The antenna response is listed as dB below the main lobe response and is shown as negative. A partial example of an ASCII antenna pattern file is shown below:

```
MARK ANTENNA PRODUCTS Inc.
MHP-100A120D
(none)
M15028
M15027
11-25-85
NONE
10700-11700 MHZ
48.4 dB
0.6 Deg
     HH      39
     -180  -88
     -160  -88
      ↓       ↓
      0       0
```

```
↓              ↓
160      -88
180      -88
HV        33
-180     -89
-170     -89
↓              ↓
0        -36
↓              ↓
170      -89
180      -89
VV        39
-180     -88
-160     -88
↓              ↓
0          0
↓              ↓
160      -88

180      -88
VH        33
-180     -89
-170     -89
↓              ↓
0        -36
↓              ↓
170      -89
180      -89
ELHH       7
-4       -36
↓              ↓
0          0
↓              ↓
4        -36
ELHV      11
-4.5    -63.4
↓              ↓
0        -36
↓              ↓
4.5     -63.4
ELVV       7
-4       -36
↓              ↓
```
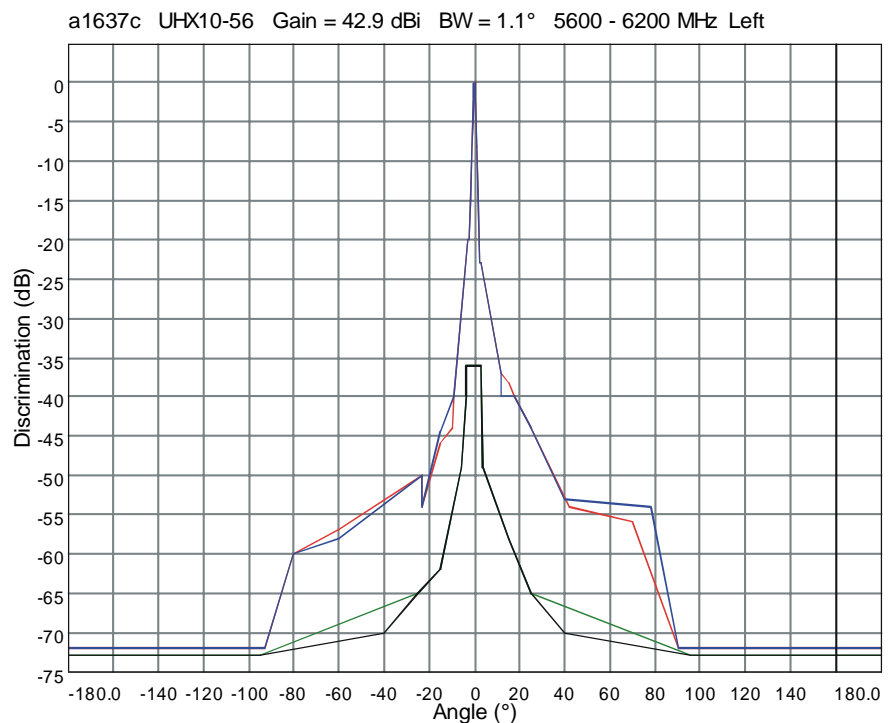
Microwave Antenna Data File - 65a10.mar

```
1   MARK ANTENNAS DIV. RSInc.
2   P-65A120
3   (NO COMMENTS)
4   (NO ID NUMBER)
5   (NO REVERSE PATTERN)
6   07-20-88
7   (none)
8   6425-7125 MHz
9   44 dBi
10  1 Deg
```

Pattern
- ● Symmetrical
- ○ Left
- ○ Right

Antenna diameter [10]

Units
- ● feet
- ○ meters

OK   Cancel   Help

a1637c   UHX10-56   Gain = 42.9 dBi   BW = 1.1°   5600 - 6200 MHz   Left

Binary File Conversion

To convert an ASCII antenna data file to the binary format, select Configure - Convert - Microwave Radio ASCII files from the Pathloss menu bar. This is a multi selection open file dialog box. If a single file is

selected, a standard save dialog box will appear to prompt the user for the full path name of the binary file. The suffix MAS will always be added. If the file exists, a prompt is issued to overwrite the existing file.

If multiple files are selected, the converted files will be automatically saved in the same directory as the ASCII file and will overwrite any existing binary files without warning.

To resolve the ambiguities described above, the user must specifically enter the diameter and the pattern symmetry. The file will be converted and renamed with the suffix "mas". This is the only suffix that can be used with binary antenna patterns. Verify the conversion using the viewer in the antenna lookup tables.

In addition to the above standard, the program supports antenna files in the current NSMA format described in the following paragraph.

NSMA ANTENNA PATTERN STANDARD

The NSMA standard accomodates omnidirectional, sectorized and generic antenna types. It will accommodate worst case patterns (radiation pattern envelopes) as well as typical patterns and will be able to handle three dimensional patterns and general polarization schemes. This format will be implemented in the base station antenna segment of the industry, where each manufacturer currently uses a proprietary format and will replace the microwave antenna format. The format is given in the NSMA document NSMA WG16_99_050 which is available on the NSMA web site, the Pathloss web site and is supplied on the Pathloss program CD-ROM in the equipment directory

The file format provides for one antenna pattern per file. Each file contains the following information in the order listed. Each data field will be ended with a CR/LF.

FIELD	LENGTH	MNEMONIC	
Revision Number	42	REVNUM	*
Revision Date	16	REVDAT	*
Comment1	80	COMNT1	
Comment2	80	COMNT2	
Antenna Man.	42	ANTMAN	*
Model Number	42	MODNUM	*
Pattern ID Num	42	PATNUM	
Pattern File Number	13	FILNUM	
Feed Orientation	13	FEDORN	
Description1	80	DESCR1	
Description2	80	DESCR2	
Description3	80	DESCR3	
Description4	80	DESCR4	
Description5	80	DESCR5	
Date of data	16	DTDATA	
Low Frequency (MHz)	21	LOWFRQ	*
High Frequency (MHz)	21	HGHFRQ	*

Gain Units	15	GUNITS	*
Low-band gain	12	LWGAIN	
Mid-band gain	16	MDGAIN	*
High-band gain	12	HGGAIN	
Mid-band Azimuth Beamwidth	16	AZWIDT	
Mid-band Elevation Beamwidth	16	ELWIDT	
Connector Type	80	CONTYP	
VSWR	13	ATVSWR	
Front-to-back Ratio(dB)	10	FRTOBA	
Electical Downtilt(deg)	16	ELTILT	*
Radiation Center(m)	13	RADCTR	
Port-to-Port Isolation (dB)	12	POTOPO	
Maximum Input Power (W)	17	MAXPOW	
Antenna Length (m)	14	ANTLEN	
Antenna Width (m)	14	ANTWID	
Antenna Depth (m)	14	ANTDEP	
Antenna Weight (kg)	16	ANTWGT	
Future Field	80	FIELD1	
Future Field	80	FIELD2	
Future Field	80	FIELD3	
Future Field	80	FIELD4	
Future Field	80	FIELD5	
Pattern Type	16	PATTYP	*
Number of frequencies in this file	10	NOFREQ	*
Pattern Frequency (Mhz)	21	PATFRE	*
Number of Pattern cuts	11	NUMCUT	*
Pattern Cut	11	PATCUT	*
Polarization	15	POLARI	*
Number of Data Points	13	NUPOIN	*
First and Last Angle	25	FSTLST	*
X-axis Orientation	53	XORIEN	
Y-axis Orientation	53	YORIEN	
Z-axis Orientation	53	ZORIEN	
Pattern cut data	28 max for each point		
Additional pattern cut data	28		
*End of file	11	ENDFIL	*

Each pattern cut data set is preceded by the fields "pattern cut", "polarization", and "number of data points".

VHF-UHF ANTENNA DATA FILES

The ASCII file format for VHF-UHF antennas uses the proposed new NSMA standard for the electronic transfer of antenna pattern data. This is a general format for antennas patterns in all frequency bands; however, at this time manufacturers have not produced antenna data in this format. VHF-UHF antenna data files are used in the area coverage module and in the VHF-UHF worksheet.

The Pathloss program uses binary antenna data files. A large number of antenna pattern files are supplied with the program in both ASCII and binary format. As a first step, it was necessary to convert the manufacturer's antenna data files to this new format. Then these were converted to the binary format in the Pathloss program.

ASCII VHF-UHF antenna data files use the file suffix "vaf". The binary files use the same file name with the suffix "vas".

In most cases, only an elevation patter and an azimuth pattern is available. There are no cross polarized data available. A typical example of an VHF-UHF antenna data file in the NSMA format is given below:

REVNUM:,NSMA WG16.99.050
REVDAT:,19980706
COMNT1:,
COMNT2:,
ANTMAN:,Sinclair
MODNUM:,SRL410-C5 R60
DESCR1:,
DTDATA:,01-18-1990
LOWFRQ:,824.00
HGHFRQ:,894.00
GUNITS:, DBI/DBR
LWGAIN:,
MDGAIN:,15.15,
HGGAIN:,
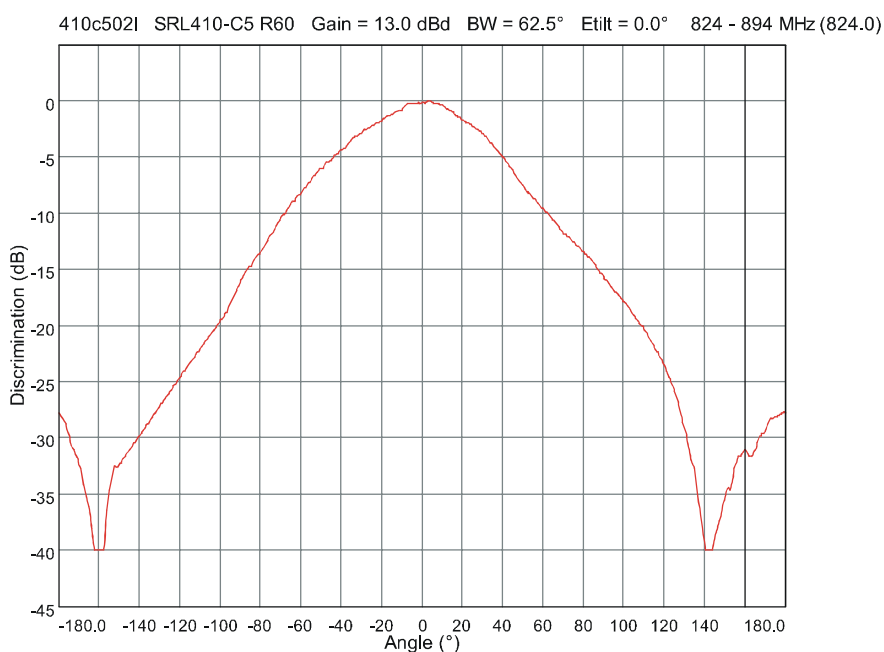AZWIDT:,62.50,
ELWIDT:,17.00,
CONTYP:,
ATVSWR:,
FRTOBA:,
ELTILT:,0.00,
RADCTR:,
POTOPO:,
MAXPOW:,
ANTLEN:,

410c502I SRL410-C5 R60   Gain = 13.0 dBd   BW = 62.5°   Etilt = 0.0°   824 - 894 MHz (824.0)

ANTWID:,

ANTDEP:,

ANTWGT:,

FIELD1:,

FIELD2:,

FIELD3:,

FIELD4:,

FIELD5:,

PATTYP:,typical

NOFREQ:,1

PATFRE:,824.00

NUMCUT:,2

PATCUT:,H

POLARI:,V/V

NUPOIN:,721

FSTLST:,-179.5,180.0

-179.5,27.8

-179.0,28.0

-178.5,28.1

....

-1.5,0.1

-1.0,0.2

-0.5,0.2

0.0,0.1

0.5,0.1

1.0,0.1

1.5,0.2

178.5,27.8

179.0,27.8

179.5,27.7

180.0,27.8

PATCUT:,V

POLARI:,V/V

NUPOIN:,721

FSTLST:,-180.0,179.5

-180.0,27.2

-179.5,27.8

-179.0,28.5

410c502I   SRL410-C5 R60   Gain = 13.0 dBd   BW = 62.5°   Etilt = 0.0°   824 - 894 MHz (824.0)
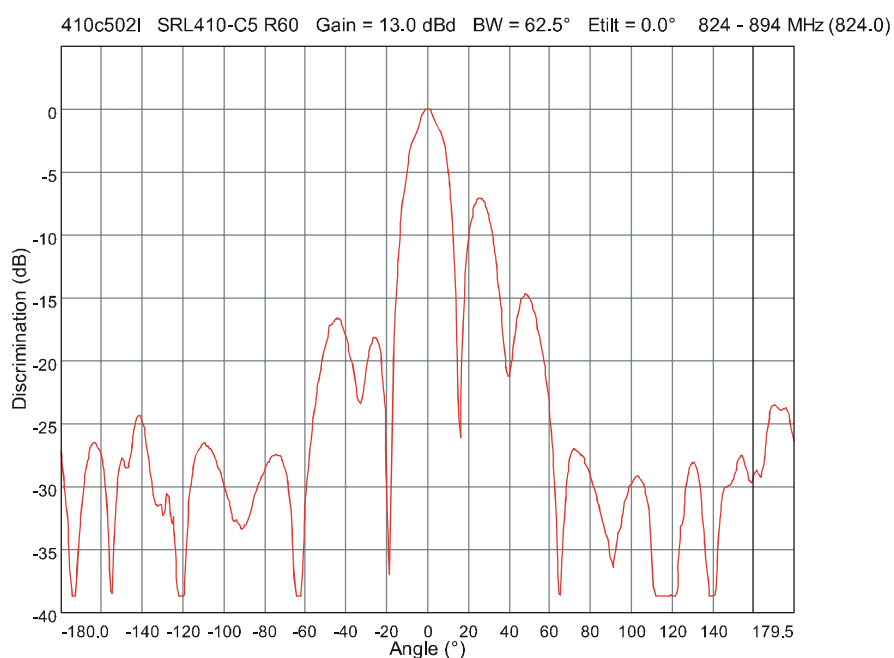
-178.5,29.3

....

-1.5,0.2

-1.0,0.1

-0.5,0.0

0.0,0.1

0.0,0.1

0.5,0.1

1.0,0.0

1.5,0.1

....

178.5,25.4

179.0,25.9

179.5,26.5

ENDFIL:,EOF

RADIO DATA FILES

The Pathloss program uses a generalized radio data file for all digital radio specifications and data curves. Generating a radio data file is a two step process. First, you must create an ASCII file as described in this section and then convert this file to a binary format. The binary conversion is carried out in the Pathloss program. The binary file name (less the extension) is referred to as a radio code.

Radio data files are used in interference calculations, as a standalone lookup table and in conjunction with the standard lookup tables.

The file "template.raf", located in the directory EQUIPMNT\MRS, contains a list of mnemonics used in an ASCII file and can be used as a template to generate the radio data files. These are listed below along with a description and the number of characters allowed for non numeric entries.

Table 1: Radio Data File Format

Mnemonic	Size	Description	Example
PLW40_RADIOSPECS	*	raf file identifier	
MANUFACT	* char[35]	radio manufacturer	Acme Radio
MODEL	* char[23]	radio model	ASDH-64
COMMENT_1	char[35]	optional comment	
COMMENT_2	char[35]	optional comment	
COMMENT_3	char[35]	optional comment	
COMMENT_4	char[35]	optional comment	

Table 1: Radio Data File Format

Mnemonic	Size	Description	Example
COMMENT_5	char[35]	optional comment	
EMDESIG	char[23]	emission designator	2M50D7W
RADIO_ID	char[23]	optional radio identifier	ACM-64-01
MODULATION	* char[23]	modulation - see below	64TCM
CAPACITY	* char[23]	channel capacity	STM1
DATA_RATE	numeric	data rate	155.52
STABILITY_PRC	numeric	frequency stability in percent	
STABILITY_PPM	numeric	frequency stability in parts per million	5
SPECTRMBW_MHZ	* numeric	spectrum 3db bandwidth in MHz used to create default TX emission and RX sensitivity masks	18
CHANNELBW_MHZ	numeric	channel bandwidth in MHz	20
MAXRXSIG_10-3	numeric	maximum receive signal at BER 10^{-3}	-12
MAXRXSIG_10-6	numeric	maximum receive signal at BER 10^{-6}	-10
TtoI_COCHAN_LIKE	** numeric	threshold to interference ratio like modulation (dB)	26.8
TtoI_COCHAN_CW	numeric	threshold to interference ratio CW modulation (dB)	25.0
TXPOWER_DBM	* numeric	transmit power (dBm)	30.0
FREQ_LO_MHZ	* numeric	lower frequency limit (MHz)	5900
FREQ_HI_MHZ	* numeric	upper frequency limit (MHz)	6400
ATPC_RANGE	numeric	automatic TX power control range (dB)	10
NUM_ATPCSTEPS	numeric	number of steps in the ATPC range	5
DIGRADIO_TYPE	PDH, SDH or NB_DIGITAL	digital radio type -PDH, SDH or narrow band digital default is PDH	SDH
SD_OPERATION	BBS or IFC	space diversity type baseband switching or IF combining default is BBS	IFC

Table 1: Radio Data File Format

Mnemonic	Size	Description	Example
COCHANNEL_OPERATION	YES or NO	calculate using cochannel operation - default is NO	YES
USE_SIGNATURE	YES or NO	use signature (YES) or dispersive fade margin (NO) to calculate the selective outage default is NO	YES
XPIF	numeric	the XPD improvement factor of the XPIC device in cochannel operation	17.0
XPD_XPI	numeric	the residual XPD of the XPIC device in cochannel operation	42.0
IF_COMB_GAIN	numeric	the thermal fade margin improvement in dB produced by IF combining in space diversity	3.0
LCOMB_FACTOR	numeric	the selective outage improvement factor produced by IF combining in space diversity	10.0
BITS_BLOCK	*** numeric	bits per block (SDH)	19940
BLOCKS_SEC	*** numeric	blocks per second (SDH)	8000
ALPHA1	*** numeric	errors per burst in the BER range from 10^{-3} to BER_{SES} (SDH)	10 to 30 20 typical
ALPHA2	*** numeric	errors per burst in the BER range from BER_{SES} to the residual bit error rate (SDH)	1 to 10 5 typical
ALPHA3	*** numeric	errors per burst below the residual bit error rate (SDH)	1
SIGNATURE_DELAY_10-3	numeric	signature echo delay in nanoseconds for a 10^{-3} BER	6.3
SIGNATURE_WIDTH_10-3	numeric	signature bandwidth width in MHz for a 10^{-3} BER	28.0
SIGNATURE_MINPH_10-3	numeric	signature null depth for a minimum phase echo at 10^{-3} BER	23.4
SIGNATURE_NONMINPH_10-3	numeric	signature null depth for a non-minimum phase echo at 10^{-3} BER	23.4

Table 1: Radio Data File Format

Mnemonic	Size	Description	Example
SIGNATURE_DELAY_10-6	numeric	signature echo delay in nano-seconds for a 10^{-6} BER	6.3
SIGNATURE_WIDTH_10-6	numeric	signature bandwidth width in MHz for a 10^{-6} BER	28.3
SIGNATURE_MINPH_10-6	numeric	signature null depth for a mini-mum phase echo at 10^{-6} BER	21.7
SIGNATURE_NONMINPH_10-6	numeric	signature null depth for a non-minimum phase echo at 10^{-6} BER	21.7
SIGNATURE_DELAY_RBER	numeric	signature echo delay in nano-seconds for the residual BER	6.3
SIGNATURE_WIDTH_RBER	numeric	signature bandwidth width in MHz for the residual BER	28.7
SIGNATURE_MINPH_RBER	numeric	signature null depth for a mini-mum phase echo at the residual BER	19.5
SIGNATURE_NONMINPH_RBER	numeric	signature null depth for a non-minimum phase echo at the residual BER	19.5
SIGNATURE_DELAY_SES	numeric	signature echo delay in nano-seconds for the SES BER	6.3
SIGNATURE_WIDTH_SES	numeric	signature bandwidth width in MHz for the SES BER	28.0
SIGNATURE_MINPH_SES	numeric	signature null depth for a mini-mum phase echo at the SES BER	23.4
SIGNATURE_NONMINPH_SES	numeric	signature null depth for a non-minimum phase echo at the SES BER	23.4
DISPFM_10-3	numeric	dispersive fade margin for the 10^{-3} BER	48
DISPFM_10-6	numeric	dispersive fade margin for the 10^{-6} BER	45
DISPFM_SES	numeric	dispersive fade margin for the SES BER	46.2
DISPFM_RBER	numeric	dispersive fade margin for the residual BER	43

Table 1: Radio Data File Format

Mnemonic	Size	Description	Example
RXTHRESH_10-3	* numeric	receive threshold level (dBm) at the 10^{-3} BER	-73.5
RXTHRESH_10-6	* numeric	receive threshold level (dBm) at the 10^{-6} BER	-70.0
RESIDUAL_BER	*** numeric	residual bit error rate	1.0E-10
RXTHRESH_RBER	*** numeric	receive threshold level (dBm) at the residual BER	-66.0
SES_BER	*** numeric	SES bit error rate	4.6E-4
RXTHRESH_SES_BER	*** numeric	receive threshold level (dBm) at the SES BER	-73.1
TtoI_	data	threshold to interference curve	
TX_EMISSION	data	transmit emission curve	
RX_SELECTIVITY	data	receive selectivity curve	
RX_FILTER	data	receive filter curve information only	
TX_FILTER	data	transmit filter curve informtion only	
IRF_	data	interference reduction factor curve. Use either T to I or IRF	

Several equipment / calculation options are included in the radio data file:

DIGRADIO_TYPE SDH - Permissible values are PDH, SDH or NB_DIGITAL(narrow band digital). These options only affect the formatting of the data entry forms in the microwave worksheet. For example, signature data or the dispersive fade margin cannot be accessed with the NB_DIGITAL radio type set.

SD_OPERATION - Permissible values are IFC for IF combining and BBS for baseband switching. This option automatically set the space diversity improvement calculation to IF combining or baseband switching. The default value is baseband switching.

COCHANNEL_OPERATION - Permissible values are YES or NO. This sets the Cochannel operation option in the Reliability Options dialog box. The default value is NO.

USE_SIGNATURE - Permissible options are YES for selective fading calculations using the equipment signature or NO to use the dispersive fade margin and dispersive fade occurrence factor. Note that this options has the effect of calculating diversity improvement is strict accordance with P.530-8.

The ASCII file is created by adding the entry or value after the mnemonic. Leave at least one space between the mnemonic and the entry.

- The mnemonic lines can be in any order and blank lines are allowed in the file; however the file identifier "PLW40_RADIOSPECS" must be the first entry in the file.

- If there is no entry after the mnemonic, the line is ignored. Therefore, it is not necessary to erase any unused entries.

- If a duplicate mnemonic line exists, the value of the last one in the file will be used. Frequency stability can be expressed as either a percent or in parts per million. The value used will be the last one in the file.

Transmitter Power

Transmitter power has been included in the radio data file to allow these files to be used as lookup tables. A transmitter may contain several power level options. Do not create a separate file for each power option. Use the default power option and then use the standard lookup tables to handle the other power options.

Modulation

The modulation is used to determine default threshold to interference curves. The format must be as follows:

[number of levels][modulation type] e.g. 64QAM

No spaces or dashes are allowed. The modulation type must be one of the following:

FSK   frequency shift keying

CPSK   coherent demodulation phase shift keying

DPSK   differential demodulation phase shift keying

QAM   quadrature amplitude modulation

QPR   quadrature partial response

TCM   trellis code modulation - this is interpreted as QAM

QPSK   quadrature phase shift keying - this is interpreted as 4DPSK

MSK   minimum shift keying - this is interpreted as 2FSK

The table below lists the modulation types and allowable levels.

Receiver Type	Number	S/N for 10⁻⁶ BER	CW T/I for 10⁻⁶ BER (T Value)	F Factor		
				CW or FDM-FM	Similar Modulation	Other
FSK	2	14.2	16.8	0.0	3.4	6.4
	4	20.2	22.8	0.0	3.4	6.4
	8	26.2	28.8	0.0	3.4	6.4
	16	32.2	34.8	0.0	3.4	6.4
CPSK	2	10.4	16.2	0.0	0.0	3.0
	4	13.6	18.7	0.0	0.0	3.0
	8	18.8	23.8	0.0	0.0	3.0
	16	24.6	29.5	0.0	0.0	3.0
DPSK	2	11.0	16.4	0.0	0.0	3.0
	4	15.9	22.0	0.0	0.0	3.0
	8	21.6	28.0	0.0	0.0	3.0
	16	27.7	33.5	0.0	0.0	3.0
QAM	4	13.8	18.1	0.0	-1.5	1.5
	16	20.8	25.1	0.0	1.0	4.0
	32	23.9	28.2	0.0	1.8	4.8
	64	27.0	31.3	0.0	2.2	5.2
	128	30.1	34.4	0.0	2.5	5.5
	256	33.1	37.4	0.0	2.7	5.7
	512	36.1	40.4	0.0	2.9	5.9
	1024	39.1	43.4	0.0	3.0	6.0
QPR	9	16.5	20.8	0.0	0.0	3.0
	25	20.8	25.1	0.0	1.6	4.6
	49	23.5	27.8	0.0	2.1	5.1
	81	25.5	29.8	0.0	2.3	5.3

Channel Capacity

Channel capacity is expressed in terms of the digital hierarchy, (e.g. 1DS3, 8E1).

Traffic Code

The channel capacity and modulation are combined to form a unique radio descriptor using the following format:

[channel capacity]-[modulation] e.g. 1DS3-64QAM

This identifier is used to compare the characteristics of an interfering transmitter with the receiver.

The traffic code does not appear in the radio data file as a unique entry. It is derived from the channel capacity and modulation.

In the case of analog radios, the traffic code must be specified using the format below:

[CAPACITY]-ANALOG e.g. 600CH-ANALOG

The capacity prefix (600CH) is not used.

Threshold to Interference Curves

The mnemonic ToI_ indicates that T to I data follows. There can be any number of T to I curves in a radio data file. Each curve can represent the interfering effects of different transmitter modulations and channel capacities. In order to differentiate between these curves, the TtoI_ mnemonic is followed by the traffic code of the interfering transmitter.

For the special case of a T to I curve for a carrier wave interfering transmitter, the traffic code must be CW.

The number of points of data follows the mnemonic - traffic code combination. The data must be in ascending order of frequency and there must not be any duplicate frequencies or blank lines. Each line contains a frequency followed by the T to I value. The frequency must be relative to the operating frequency. The data can be symmetrical or asymmetrical. The following is an example of the data entry format of an 8DS1 receiver using 128TCM modulation interfered with by a similar radio.

```
TtoI_8DS1-128TCM 171
 -125.000   -143.6
 -123.000   -142.8
 -121.000   -141.0
    ....
   -1.000     30.0
   -.800      34.0
   -.600      35.0
   -.400      34.3
   -.200      32.4
   0.000      34.0
    .200      33.0
    .400      35.5
    .600      35.5
    .800      33.0
   1.000      33.0
    ....
  121.000    -142.9
  123.000    -143.8
  125.000    -145.1
```
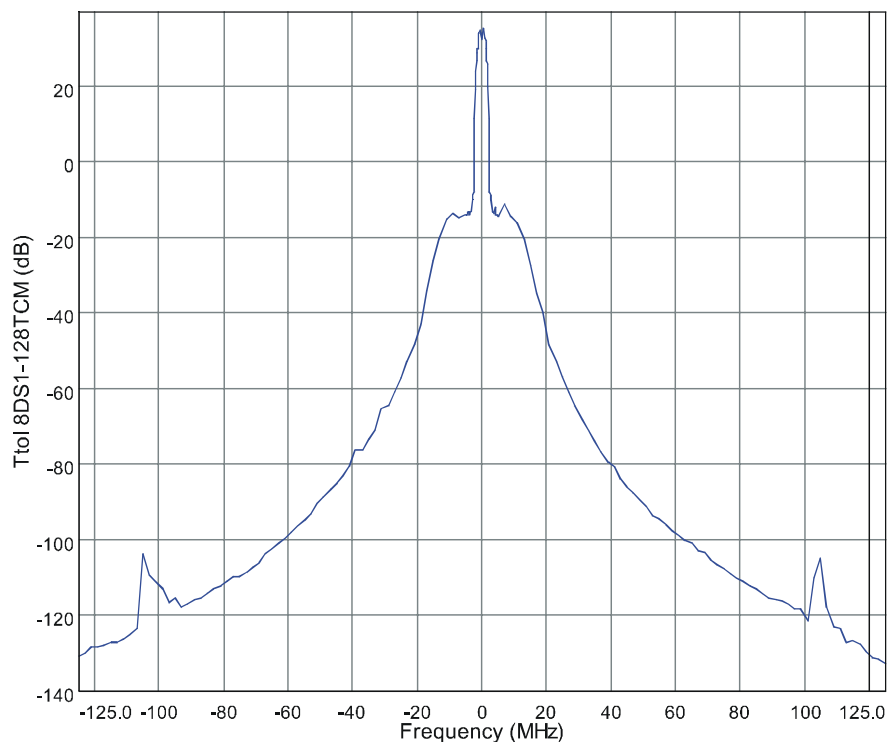

The first line "TtoI_8DS1-128TCM 171" indicates that this is a T to I curve of 171 points. The interfering transmitter has the same modulation and channel capacity as the receiver.

Interference Reduction Factor Curves

The mnemonic IRF_ indicates that interference reduction factor (IRF) data follows. There can be any number of IRF curves in a radio data file. Each curve can represent the interfering effects of different trans-

mitter modulations and channel capacities. In order to differentiate between these curves, the IRF mnemonic is followed by the traffic code of the interfering transmitter.

The number of points of data follows the mnemonic - traffic code combination. The data must be in ascending order of frequency and there must not be any duplicate frequencies or blank lines. Each line contains a frequency followed by the IFR value. The frequency must be relative to the operating frequency. The data can be symmetrical or asymmetrical. The following is an example of the data entry format for a 8E1 4PSK receiver (8E1-4PSK) interferred with similar modulation:

```
IRF_8E1-4PSK           61
     0.0          0.00
     1.0         -0.11
     2.0         -0.42
     .....
    58.0        -78.55
    59.0        -79.70
    60.0        -80.90
```

The first line "IRF_8E1-4PSK 61" indicates that this is an IRF curve of 33 points. The interfering transmitter has the same modulation and channel capacity as the receiver.

Transmitter Emission Data

The mnemonic TX_EMISSION indicates that the data for the transmitter emission spectrum follows. The absolute values of the power density or the measurement bandwidth are not important. The file conversion process will normalize the data such that the total power over the frequency band is equal to unity. The chart display of the spectrum is based on a total power of one watt and a measurement bandwidth of 4 KHz. This means that the data values in the ASCII file may not be the same as the displayed values.
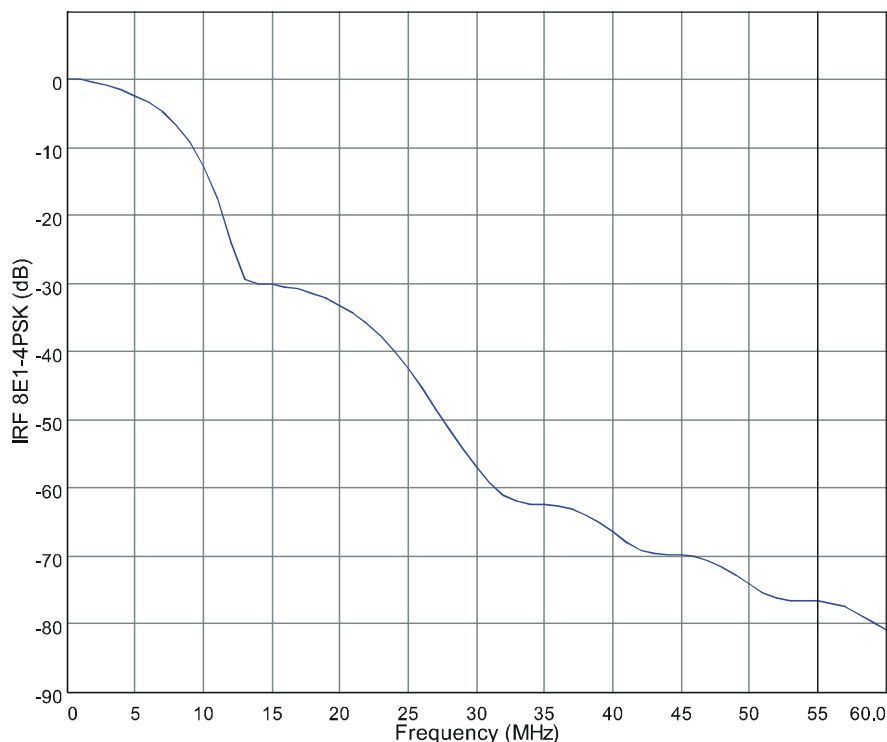
The number of points follows the mnemonic TX_EMISSION on the same line. The data must be in ascending order of frequency and there must not be any duplicate frequencies or blank lines. Each line contains a frequency followed by the emission level. The frequency must be relative to the operating frequency. The data can be symmetrical or asymmetrical.

Receiver Selectivity

The mnemonic RX_SELECTIVITY indicates that the receiver selectivity data follows. This is the composite receiver selectivity including RF, IF and Nyquist filtering. Do not use RF or IF filtering alone.

The number of points follows the mnemonic RX_SELECTIVITY on the same line. The data must be in ascending order of frequency and there must not be any duplicate frequencies or blank lines. Each line contains a frequency followed by the selectivity expressed in dB. The frequency must be relative to the operating frequency. The data can be symmetrical or asymmetrical.

Binary File Generation

The default suffix for ASCII radio data files is "raf". To convert the file to the binary format, select Configure - Convert - Microwave Radio ASCII files from the pathloss menu bar. This is a multi selection open file dialog box. If a single file is selected, a standard save dialog box will appear to prompt the user for the file name and the directory to save the converted file in. If the file exists, a prompt is issued to overwrite the file.

If multiple files are selected, the converted files will be automatically saved in the same directory as the ASCII file and will overwrite an existing file without warning.

The file will be converted and renamed with the suffix "mrs". This is the only suffix that can be used. The location of the files is an important performance consideration. Refer to the General Operation section for details.

Default Interference Parameters

In many cases, the required T to I and TX emission curves will not be available. This section describes the techniques used to handle these situations. The analysis uses the 3 dB bandwidth of the transmit spectrum and the type of modulation. Both of these must be specified in the radio data file.

When a radio data file is generated from the user's ASCII text file, a default transmit emission mask and a default receiver selectivity mask is always created in accordance with Annex B of TIA /EIA Telecommunications Systems Bulletin TSB-10G (Interference Criteria for Microwave Systems). These masks are based on the FCC Rules and Regulations, § 101.111 - emission limitations for digital fixed point to point operation below 15 GHz as stated below:

> For operating frequencies below 15 GHz, in any 4 KHz band, the center frequency of which is removed from the assigned frequency by more than 50 percent up to and including 250 percent of the authorized bandwidth: As specified by the following equation but in no event less than 50 decibels: (Attenuation greater than 80 decibels is not required.)

$$A \ = \ 35 + 0.8 \cdot (P - 50) + 10 \cdot log_{10}(B) \tag{1}$$

where:

A = Attenuation (in~ decibels) below the mean output power level

P = Percent removed from the carrier frequency

B = Authorized bandwidth in MHz

Default TX Emission Mask

In place of the authorized bandwidth (channel bandwidth), the 3 dB bandwidth of the transmit spectrum is used. For frequencies from 50 percent to 250 percent removed from the carrier frequency, the power spectral density of the interference follows the FCC Mask. In other words, each 4 KHz of spectrum contains -A dBW of power. To complete the definition of the default TX emission mask, the following assumptions are made:

- emission is -80 dBW/4kHz for frequencies from 250 percent to 500 percent removed from the carrier frequency

- the emission is zero for frequencies more than 500 percent removed from the carrier frequency,

- for frequencies from 0 to 50 percent removed from the carrier frequency, each 4 kHz of spectrum contains an equal amount of power such that the total power in the signal (from 0 to 500 percent removed from the carrier frequency) is 1 Watt.
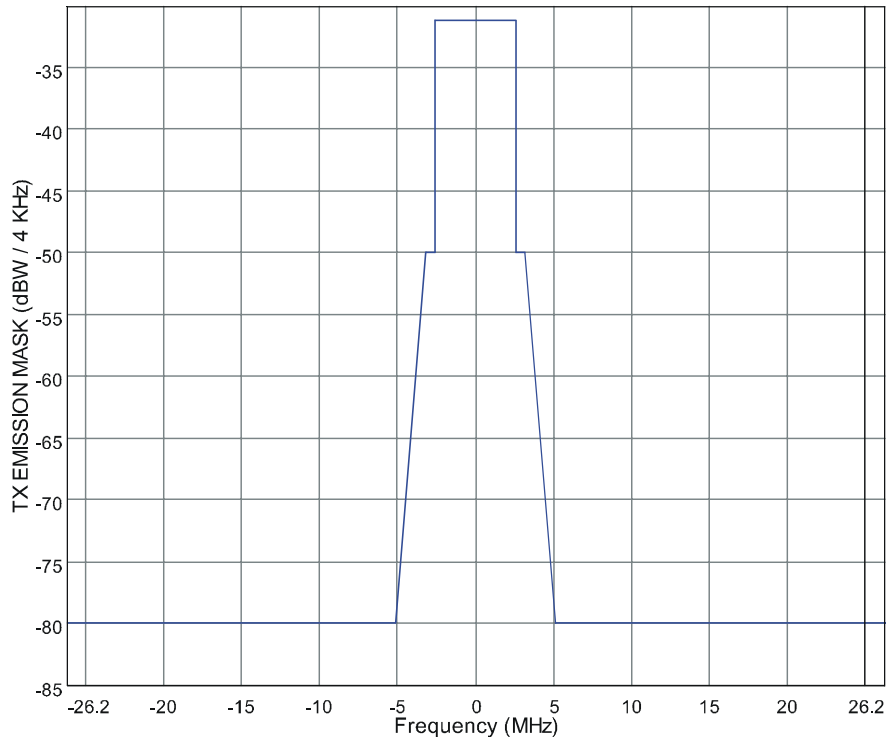
The mask is generated from the following break points:

$$
\begin{aligned}
bp_1 &= 50 \\
bp_2 &= 68.75 - 12.5 \cdot \log_{10}(bw) \\
bp_3 &= 106.25 - 12.5 \cdot \log_{10}(bw) \\
bp4 &= 500 \\
&where \\
bw &= transmit\ spectrum\ 3\ dB\ bandwidth\ in\ MHz
\end{aligned}
\tag{2}
$$

and the equations below:

$$if(P \leq bp_1)$$

$$A = 10 \cdot log_{10}\left(\frac{0.004}{bw}\right)$$

$$if(P > bp_1) and (P \leq bp_2)$$

$$A = -50$$

(3)

$$if(P > bp_2) and (P \leq bp_3)$$

$$A = -35 - 0.8 \cdot (P - 50) - 10 \cdot log_{10}(bw)$$

$$if(P > bp_3) and (P \leq bp_4)$$

$$A = -80$$

Default Receiver Selectivity Mask

The default receiver selectivity mask has the identical shape as the default TX emission mask. However, it is shifted so that for frequencies from 0 to 50 percent removed from the carrier frequency, the filter attenuation is zero.

Default T to I Curves

Default T to I curves are created as required using the default RX selectivity mask and the parameters T and F from the above table. The T to I curve is given by:

$$\frac{T}{I}(F) = A(f) + T + F \quad \textbf{(4)}$$

EXAMPLES

MICROWAVE PROJECT

The project example provides an overview of the network operation and intra system interference calculations. The Pathloss CD-ROM is required and the description assumes that the CD-ROM is located in drive D.
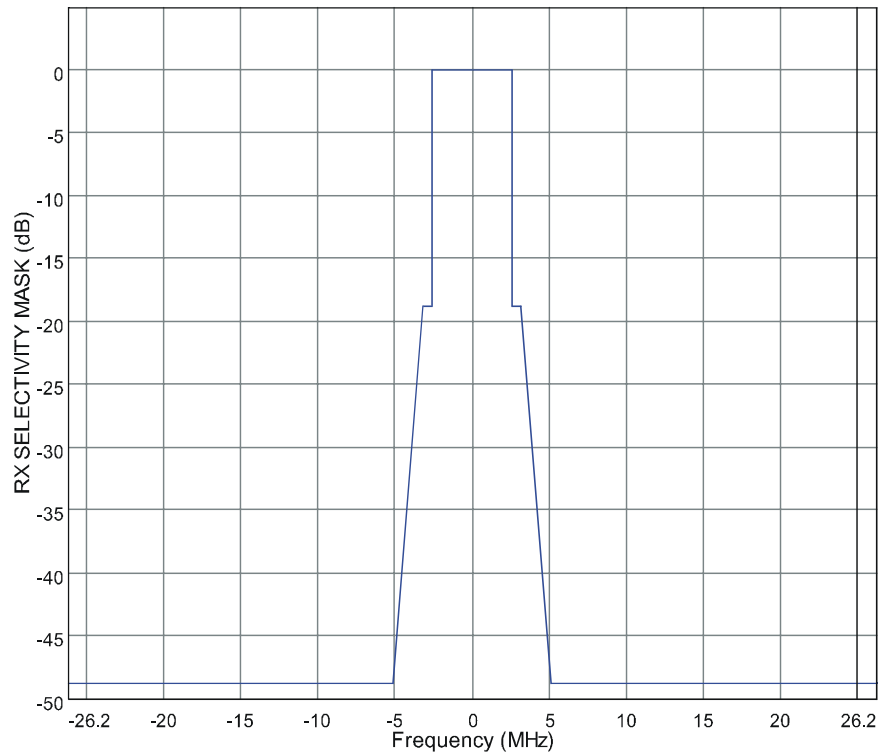
Create a Project from Pathloss data files

Normally, one would start a project in the Network module. In this example, a reverse procedure is used by creating a project from existing Pathloss data files.

- Select Module - Network to access the Network module. If a drawing exists, select File - New from the Network menu bar to clear the display.

- Select Site Data - Site List from the Network menu to access the Site List grid data display.

- Import the Pathloss data files. Select Import - Pathloss File. The files are located on the CD-ROM in the directory Examples\Project. This is a multi-select open file dialog box. Select all of the Pathloss files. Close the Site List and the network is displayed.

- Rearrange the site names as required. Place the mouse cursor on the site name, hold down the left mouse button and drag the name to the desired location.
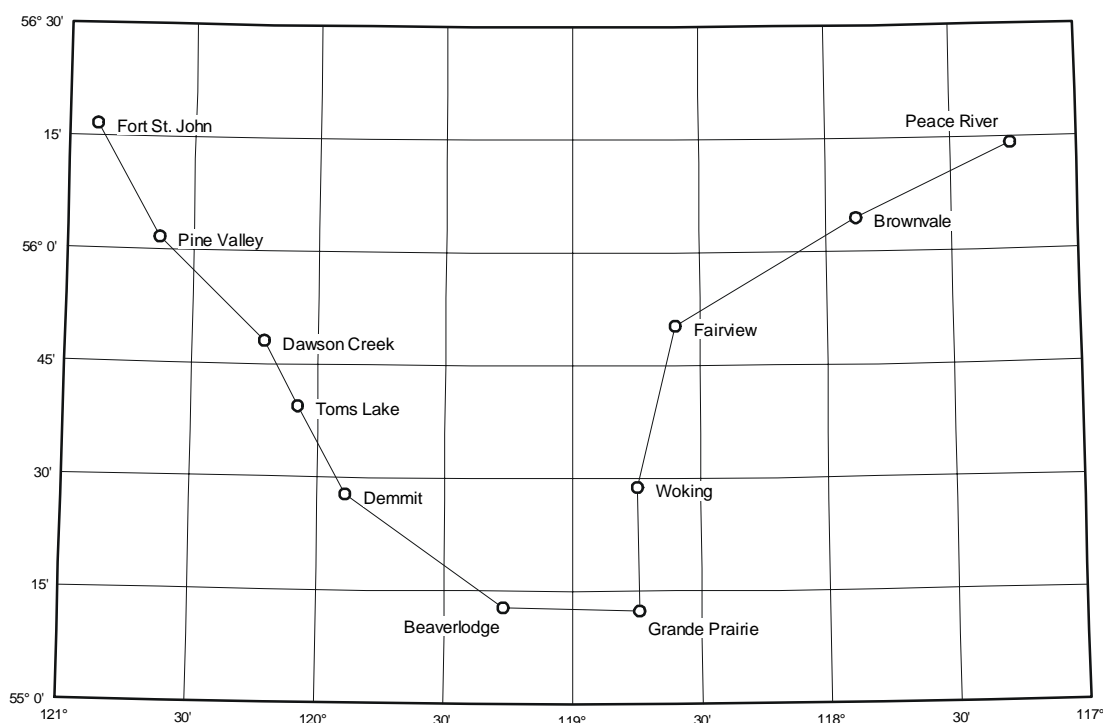
Access the Pathloss Design Modules from the Network Display

Click the left mouse button on one of the paths to bring up the design module menu. Select one of the modules and the file will be loaded and the display will switch to that module. The right mouse button brings up the map crossing and several display attributes. Return to the Network module.

Intra System Interference Calculation

One objective of this example is to demonstrate the requirements for intra system interference calculations. This calculation uses radio and antenna data files (codes) and a terrain database. The location of these files must be identified and the program must be configured for the terrain database.

Microwave Antenna Data Files Directory Setup

Select Configure - Directories - Microwave Antenna Codes. Select D:\Equipment\Mas as the directory containing all of the antenna data files. This project actually only uses antennas in the directory D:\Equipment\Mas\Andrew\056-064, and if this directory is selected, there will be a slight performance improvement.

Microwave Radio Data Files Directory Setup

Select Configure - Directories - Microwave Radio Codes. Select D:\Equipment\Mrs as the directory containing all of the radio data files. This project uses a single radio model located in the directory D:\Equipment\Mrs\Alcatel\6000, and this directory could be selected for improved performance.

Verification of Directories

To verify the directory selections click on one of the paths and select the Worksheet module. Click on one of the antenna icons to bring up the antenna data entry form and the select View from its menu bar. The antenna data file should be displayed. If the file cannot be found, re-verify the above directory selection. Repeat this step for one of the radio icons to verify the radio directory selection.

Terrain Database Setup

The intra system interference calculation requires a terrain data base to analyze over the horizon interference paths. The example GTOPO30 30 second terrain database will be used for this purpose. Select Configure - Terrain Database. Set the primary data base to GTOPO30 and click the Setup Primary button.

The setup procedure loads a header file and identifies the DEM file.

Click Header File and open the file D:\Examples\Dems\GTOPO30\W140n90.hdr.

Close the Setup dialog box and click the OK button in the Configure Terrain Database dialog box to register this database.

Calculation Directory

The interference calculation uses database tables. These are saved in the same directory as the network data file. At this point, you must save the network file in some directory on your hard drive to identify the directory for the database tables. The name and location of this directory is unimportant.

Running the Interference Calculation

Select Interference - Calculate Intra to bring up the Interference Dialog box and then click the Calculate button. The calculation is carried out in two steps. The first step loads the Pathloss data files and creates the transmit and receive tables. The second step performs the interference calculation and stores the results in a third table.

When the calculation is complete select Interference - View Error Log. As the calculation proceeds, a log file is generated for any errors encountered. The view error log uses the Windows Notepad.
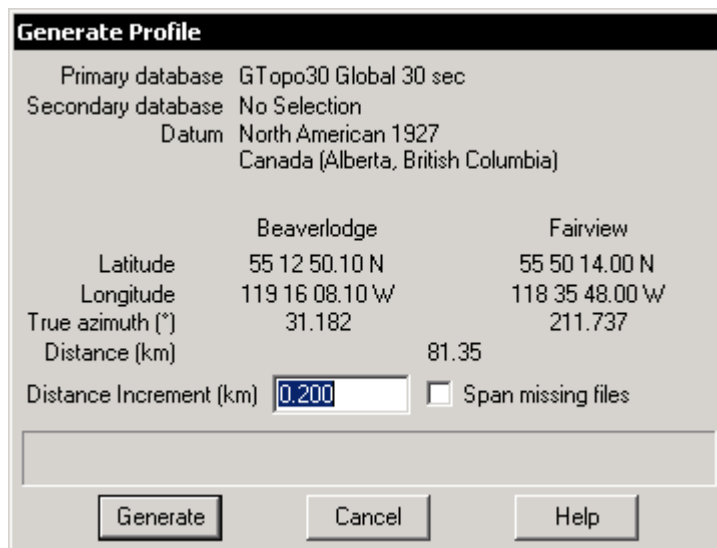
Interference Results

Select Interference - Reports - Case Detail to display the results of the calculation. The report is organized into interference cases and sub-cases. A case is a victim receiver. A sub-case is a transmitter interfering with that receiver. The green arrows on the control bar change the interference case number. The red arrows change the sub-case number. The case and sub-cases are shown on the status bar. If there is more than one sub-case, the last sub-case provides the composite interference of all sub-cases.

Over the Horizon Loss Calculation

To illustrate an over the horizon loss calcula-
tion, move through the cases / sub-cases until
the OHLOSS menu and button become active.
This state indicates that the current interference
case is a candidate for an OHLOSS calculation.
Click the OHLOSS button. The Generate Pro-
file dialog box first appears. Click the Generate
button to create the profile and run the
OHLOSS calculation.

The results for this two hop overshoot interfer-
ence path are displayed. Click OK to accept the
OHLOSS and enter the results into the report.
Note that the report is reformatted to handle the
long and short term situation.

Generate Profile
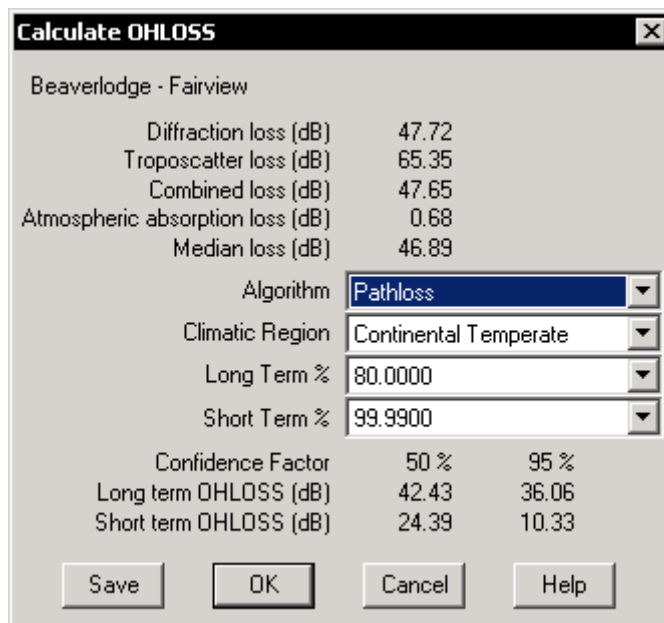
	Beaverlodge	Fairview
Primary database	GTopo30 Global 30 sec	
Secondary database	No Selection	
Datum	North American 1927	
	Canada (Alberta, British Columbia)	
Latitude	55 12 50.10 N	55 50 14.00 N
Longitude	119 16 08.10 W	118 35 48.00 W
True azimuth (°)	31.182	211.737
Distance (km)	81.35	

Distance Increment (km) [0.200]　　☐ Span missing files

[Generate]　　[Cancel]　　[Help]

Performance Degradation

Objective (dBm)	113.00	
RX Signal (dBm)	-36.26	
Noise Threshold (dBm)	-107.00	
Interfering Signal (dBm)	-121.98	
Frequency Separation (MHZ)	0.00	
Filter Improvement (dB)	0.00	
Other loss (dB)		
Long Term - Short Term (%)	80.00	99.99
OHLOSS (dB)	36.06	10.33
Adj. Interfering Level (dBm)	-158.04	-132.32
C to I (dB)	121.79	96.06
Threshold Degradation (dB)	0.00	0.01

Calculate OHLOSS

Beaverlodge - Fairview

Diffraction loss (dB)	47.72
Troposcatter loss (dB)	65.35
Combined loss (dB)	47.65
Atmospheric absorption loss (dB)	0.68
Median loss (dB)	46.89

Algorithm	Pathloss
Climatic Region	Continental Temperate
Long Term %	80.0000
Short Term %	99.9900

	50 %	95 %
Confidence Factor		
Long term OHLOSS (dB)	42.43	36.06
Short term OHLOSS (dB)	24.39	10.33

[Save]　[OK]　[Cancel]　[Help]

Threshold Degradation to Outage Times

The basic procedure is to examine each case - sub-
case. The results are saved in database tables and
you can always return to review them. The only requirement is that the corresponding network data file must first be loaded. Once the results have been reviewed, the next step is to enter the threshold degradation into the microwave worksheet and determine if the increased outage times can be tolerated. Note the next program build will include a provision to automatically transfer the composite threshold degradation to the microwave worksheet.

MICROWAVE ANTENNA HEIGHTS

The file ant_calc.pl4 located on the CD-ROM under examples\ant_calc is used to illustrate an antenna height calculation and shows several problems which can occur by using stringent clearance criteria.
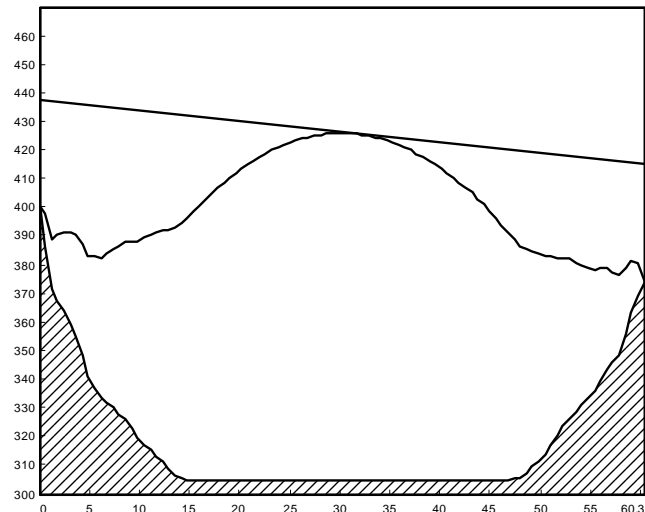
Select Module - Antenna Heights to access the Antenna Heights module and then select Operations - Set Clearance Criteria . Enter the 1st and 2nd clearance criteria as shown. The 100%F1 @ K=4/3 and 30%F1 @ K=2/3 is the classic heavy route clearance criteria. On long paths, the 30%F1 @ K=2/3 criteria is the controlling factor in the central portion of the path. The diversity clearance criteria are not used.

Set Clearance Criteria

OK   Cancel   Help

	Main	Diversity
1st Criteria - K	1.330	1.330
1st Criteria - %F1	100.00	60.00
1st Criteria - Fixed Height (ft)		
2nd Criteria - K	0.670	
2nd Criteria - %F1	30.00	
2nd Criteria - Fixed Height (ft)		
Frequency (MHz)	1925.00	

Main 2nd Criteria - %F1 :

Click OK on the menu bar to accept the criteria and then click the calculate button or press the F9 key to optimize the antenna heights for the clearance criteria.

At this point, a potential performance problem exists on this hop due to excess clearance at normal values of the earth radius factor (K = 4/3). The severity of the problem will depend upon the characteristics of the terrain and vegetation in the central area. There are two checks for excessive clearance.

- Use the Diffraction module to plot even Fresnel zone number references.

- Use the Reflection Analysis module to determine the locations of receive signal nulls due to a specular reflection.

Click the wrench button to register the antenna heights shown on the control bar or press the F1 key.

Select Module - Diffraction from the menu bar and if required set the earth radius factor to 1.33 on the diffraction control bar. Draw a Fresnel zone reference using a Fresnel number of 2. The main and reflected signals will be out of phase on a path with 2nd Fresnel zone clearance and therefore, signal cancellation will occur.

Select Diffraction Loss and draw a second Fresnel zone reference. Select Operations - Fresnel Zones or press the F2 key and set the parameters as shown. The second Fresnel zone is tangent to the earth at mid path. This means that if the terrain is capable of supporting a specular reflection in this area, then destructive interference will result. Furthermore since this conditions exists at K = 4/3, the condition will be present for most of the time.
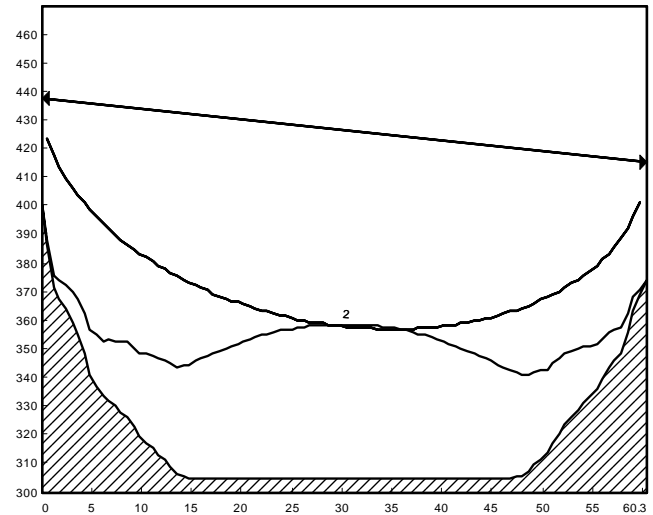
Refection Analysis
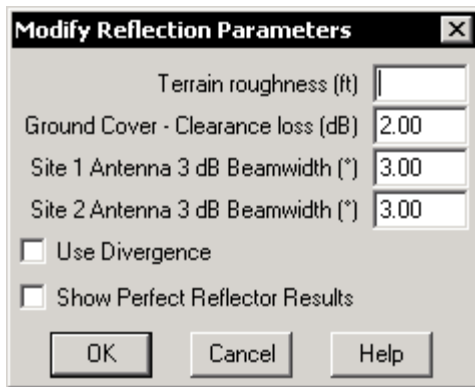
Select Module - Reflections then select Define Plane. This is always the first step in any reflection analysis. The reflective plane is defined over the mid path flat section of the profile. Place the arrow at 14.78 km and press the F1 key or click the right mouse button. Move the arrow to 47.41 km and press the F1 key again.
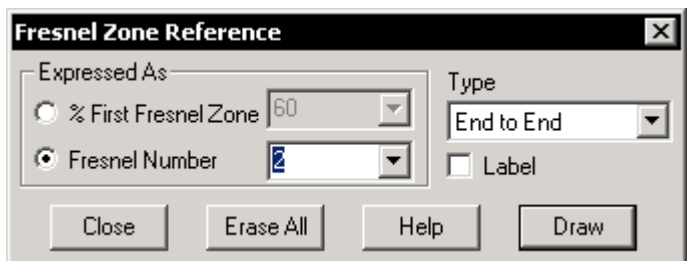
Select Variable - Earth Radius Factor and use the default values as shown. Click the OK button to carry out the calculation.

The display shows a signal null at the median value of K = 4/3; a very undesirable situation.
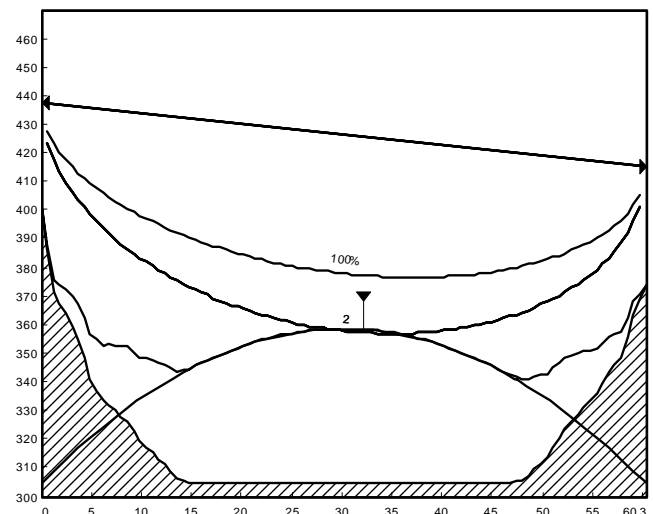
Modify Reflection Parameters

Terrain roughness (ft)	
Ground Cover - Clearance loss (dB)	2.00
Site 1 Antenna 3 dB Beamwidth (°)	3.00
Site 2 Antenna 3 dB Beamwidth (°)	3.00
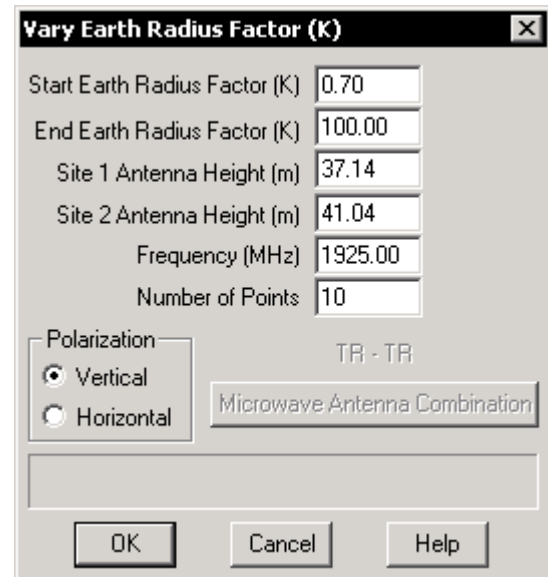
☐ Use Divergence

☐ Show Perfect Reflector Results

[OK]   [Cancel]   [Help]

Vary Earth Radius Factor (K)

Start Earth Radius Factor (K)	0.70
End Earth Radius Factor (K)	100.00
Site 1 Antenna Height (m)	37.14
Site 2 Antenna Height (m)	41.04
Frequency (MHz)	1925.00
Number of Points	10

Polarization

TR - TR

◉ Vertical

○ Horizontal

Microwave Antenna Combination

[OK]   [Cancel]   [Help]

Detailed knowledge of the terrain characteristics is required at this point. In this example, the central terrain is grassland with virtually no relief. Sparse shrubs are scattered throughout the area. Under these conditions, the terrain roughness can be assumed to be zero. It remains then, to estimate the attenuation of the reflected signal due to the vegetation. A value of 2 dB is used for this estimate. Select Modify - Parameters and enter 2 dB for the ground cover loss. The null depth with this loss is approximately 12 dB. Although this is not sufficient to produce an outage, the null will produce a notch in the digital passband. This will limit the effectiveness of equalizer in handling dispersive fading due to atmospheric multipath.

In view of this situation, a single clearance criteria of 100%F1 @ K=4/3 will be used. This is the constructive interference case, and the receive signal will be located on the broad peak during average propagation conditions.

H1=37.1 m, H2=41.0 m, F=1925.0 MHz, V
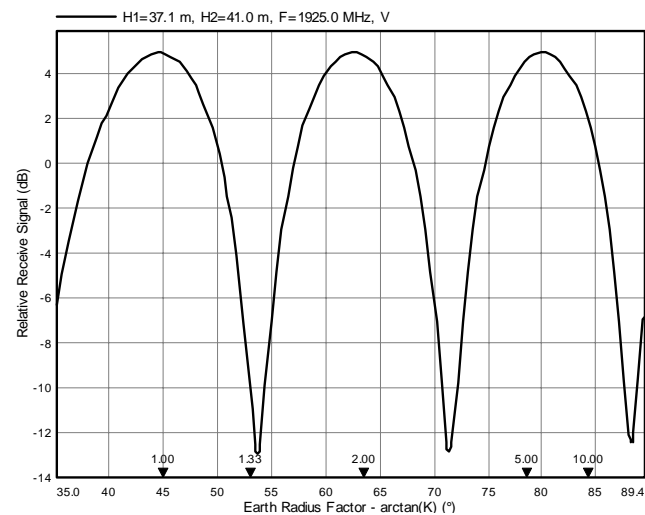
Select Module - Antenna Heights and reset the clearance criteria as shown. Use the F3 key to erase the 2nd clearance criteria entries.

Click the calculate button or press the F9 to determine the new antenna heights for this re-duced clearance criteria. Click the wrench button to register the new antenna heights.

Note that a significant reduction in antenna heights has resulted.

• 37.3 m to 18.8 m at Site #1

• 40.9 m to 21.7 m at Site #2

The heavy route clearance criteria virtually guaranteed that diffraction fading due to low values of K would not result in an outage. This remains to be verified.

Set Clearance Criteria

OK   Cancel   Help

	Main	Diversity
1st Criteria - K	1.330	1.330
1st Criteria - %F1	100.00	60.00
1st Criteria - Fixed Height (ft)		
2nd Criteria - K		
2nd Criteria - %F1		
2nd Criteria - Fixed Height (ft)		
Frequency (MHz)	1925.00	

Main 1st Criteria - K :

Diffraction Analysis

Select Module - Diffraction to access the diffraction module and the select Variable - Earth Radius Factor (K). Diffraction loss will be calculated as a function of K. Set the start value of K to the lowest expected value (0.5) and the end value to 2. Any end value greater than 4/3 is adequate. Beyond this the diffraction loss is guaranteed to be zero. Click the OK button to complete the calculation.

Diffraction over a smooth earth produces the most severe losses.

Vary Earth Radius Factor (K)

Start Earth Radius Factor (K)	.5
End Earth Radius Factor (K)	2
Site 1 Antenna Height (m)	18.85
Site 2 Antenna Height (m)	21.69
Frequency (MHz)	1925.00
Number of Points	10

Polarization
○ Vertical
● Horizontal

TR - TR

Microwave Antenna Combination

OK   Cancel   Help

Free space loss conditions are in effect down to K = 0.9. Below this value, the diffraction loss increases rapidly and is greater than 12 dB at K = 2/3.

The feasibility of these antenna heights will depend on the probability distribution of K. From the graph given in the Antenna Heights section of the manual, K will be less than 0.8 for 0.1% of the worst month on a 56 kilometer path. Low values of K generally occur at night. Increasing the height of both antennas by 5 meters results in a diffraction loss of 10 dB at K = 2/3. A reflection analysis shows that the receive signal is still well on the peak with these antenna heights.

H1=18.9 m, H2=21.7 m, F=1925.0 MHz, H

REFLECTION ANALYSIS

The pathloss data file for this example is located on the CD-ROM under examples\reflect\reflect.pl4.
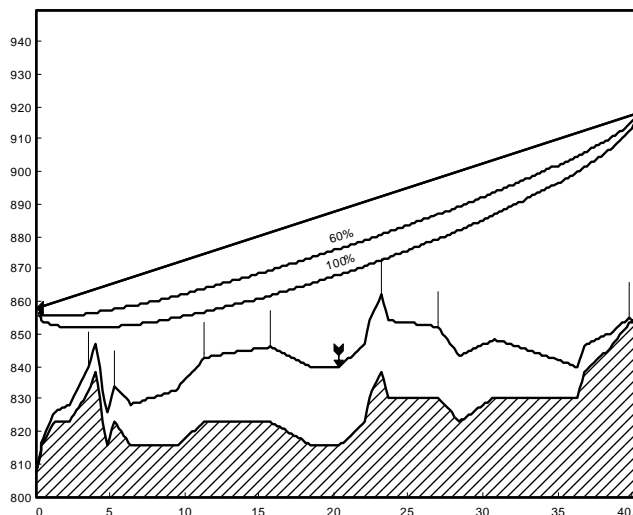
The designer has established that space diversity is required to meet the reliability objectives and now needs to analyze the reflective characteristics of the path. If the path is reflective, the antenna spacing criteria can be summarized as follows:

- Simultaneous nulls on the main and diversity antennas do not occur at any value of K.

- At the median value of K (4/3), a signal null does not occur on either the main or diversity antenna.

It is necessary to define a reflective plane to analyze reflections. This requires some judgement, and on this path, it is not obvious where the plane should be defined. The first step of any reflection analysis should be carried out in the multipath module.

Multipath Analysis

Select the Multipath module. The ray trace is automatically generated on entry to this module. Two ray tracing methods are available: constant gradient and variable gradient. The current method is displayed on the status bar. To determine the reflective characteristics of a path, the constant gradient method is used.

The profile is drawn for a specified earth radius factor and all rays are drawn as straight lines. If required, select Method - Constant Gradient on the Multipath menu bar and use the settings shown above.

The ray trace shows that reflections into the site 2 antenna can only occur in the area from 11.3 to 15.6 kilometers. This is the critical area over which the reflective plane will be defined in the Reflection module.
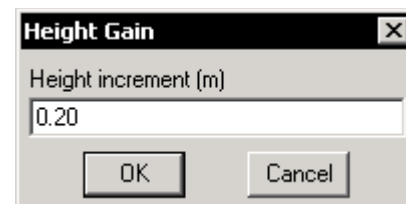
Click the height gain button to display the relationship between the relative receive signal and the site 2 antenna height. Use the default 0.2 meter height increment. The display shows that there are no reflected signals in the site 2 antenna height range from 10 to 47 meters. Above 47 meters, the classic pattern of a single reflected signal is evident with the peak at 1.2 dB and the nulls at -2.4 dB.
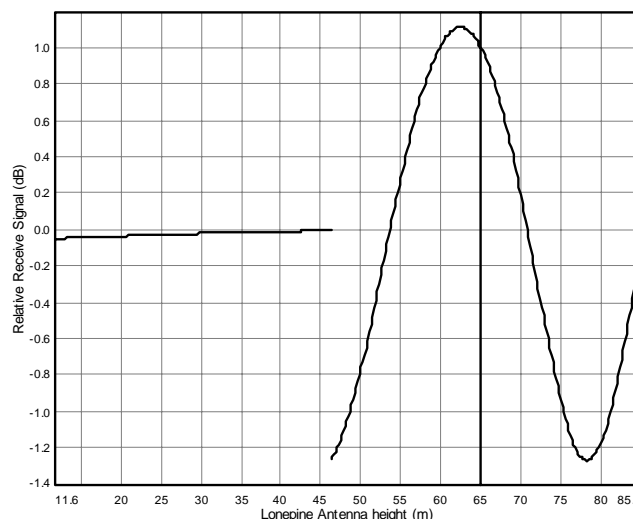
Note that option "Include ray densities" has been checked in the constant gradient dialog box. It is apparent that the density of the reflected rays arriving at site 2 is less than that of the direct rays. This factor has been taken into account in deriving the height gain display.

Reflection Analysis

Select the Reflection module and then select Define Plane on its menu bar. If required, set the parameters as follows:
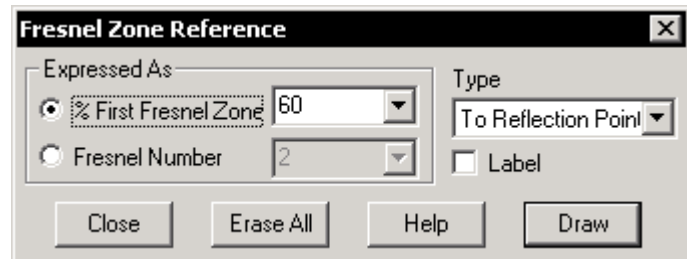
- Set the antenna combination to TR-TR. Click the antenna combination box in the status bar.

- Select K = 1.33 on the control bar.

- Set the reflective plane method to least squares. Click the plane method box on the status bar.

The reflective plane will be defined over the range 11.3 to 15.6 kilometers, as determined in the Multipath module. Place the arrow at 11.3 km and press the F1 key or click the right mouse button. Move the arrow to the opposite end of the plane at 15.6 km and press the F1 key or click the right mouse button again. The plane is calculated as a least squares fit over the defined range and is drawn as a solid line. The plane is extended as a dotted line to the ends of the profile. Effective antenna heights are defined as the antenna heights above this plane. In effect, the profile has been replaced by the reflective plane and the effective antenna heights. All calculations are based on this reflective plane definition.
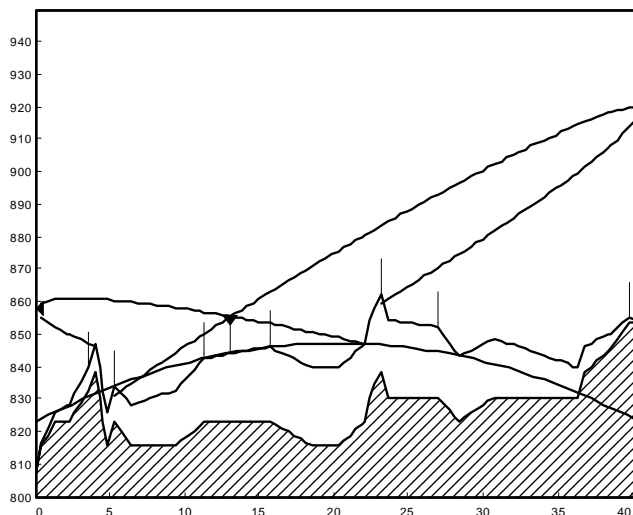
The control bar displays the location of the reflection point (12.4 km) and the time delay of the reflected signal relative to the main signal (0.4 nanoseconds). Change the value of K on the control bar and select different antenna combinations from the status bar to see the effects on the reflection point and time delay.

A reflection does not occur at a single point. Depending on the path geometry, a significant area along and transverse to the profile is required to support a specular reflection. An approximate indication of this area is given by the intersections of the 60% first Fresnel zone radius with the ground, with the antennas pointed directly at the reflection point. Select Fresnel zones from the menu bar or press the F2 key. Use a 60% first Fresnel zone, select "To Reflection Point" type and then click the Draw button. The Fresnel zones show that the required area extends beyond the points over which the reflective plane was defined.

The reflection analysis is carried out using the earth radius factor K as the variable parameter. Select Variable - Earth Radius Factor (K) from the menu bar. Click the OK button to carry out the calculation. Repeat the calculation using different main and diversity antenna combinations. Up to 4 calculations can be superimposed on the screen. The composite picture shows the effectiveness of the selected antenna heights to avoid simultaneous signal nulls.
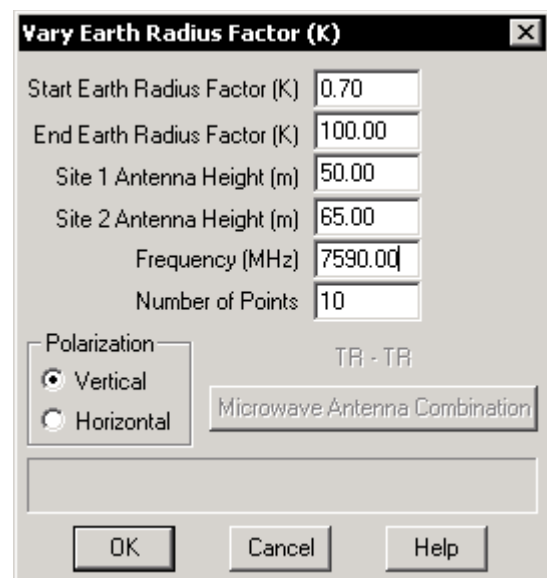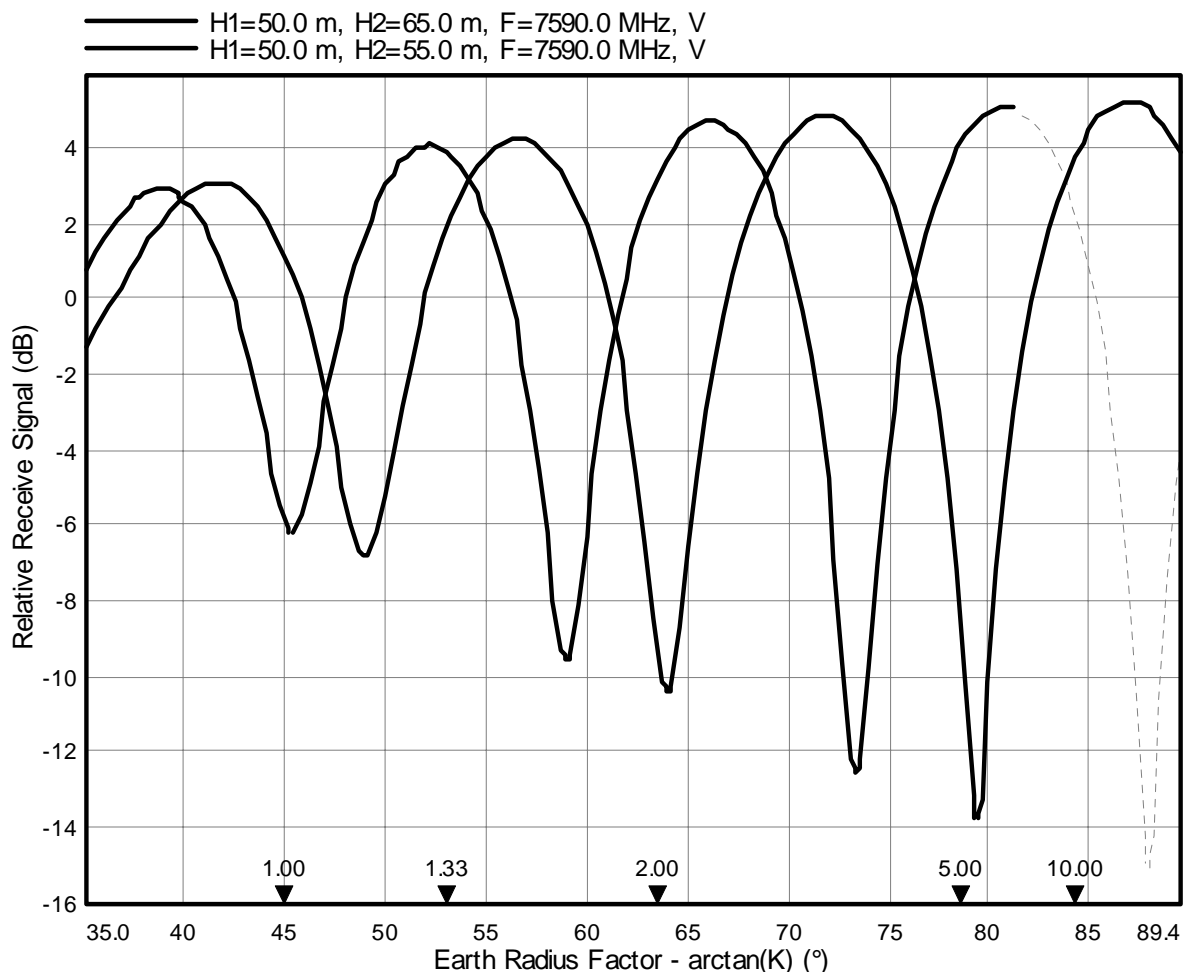
Dispersion

The final check on any reflection analysis is made on the relative time delay and amplitude of the reflected signal. Click Dispersion on menu bar to access the Dispersion data entry form.

Any of the parameters in black print can be varied without affecting the file data. The reflection loss and delay are critical performance parameters. The dispersive fade margin measurement is made with a time delay of 6.3 nanoseconds. If the reflection delay is significantly greater than this, then serious performance impairments will occur unless the reflection loss is correspondingly high.

In practice, the reflection delay is completely determined from the path geometry. The reflection loss is affected by the antenna discrimination, terrain roughness and ground cover - clearance loss.

Dispersion Analysis

OK Cancel Help

	TAU Nevis	Lonepine
Antenna height (ft)	50.00	65.00
Discrimination Angle (°)		
Antenna 3 dB beamwidth (°)	1.10	1.10
Discrimination (dB)		
Earth Radius Factor K	1.33	
Frequency (MHz)	7590.00	
Polarization	Vertical	
Reflection Point Location (mi)		
Reflection loss (dB)		
Reflection Delay (ns)		
TAU Nevis Antenna height (ft) :		

H1=50.0 m, H2=65.0 m, F=7590.0 MHz, V
H1=50.0 m, H2=55.0 m, F=7590.0 MHz, V

Relative Receive Signal (dB) vs Earth Radius Factor - arctan(K) (°)

DIFFRACTION LOSS CALCULATIONS

This example illustrates manual diffraction procedures using the file Diffract.pl4 on the CD-ROM under examples\diffract. The following description uses metric units. If necessary, change the program to the metric system. All calculations will use an earth radius factor (K) of 1.333. If required, select this value for K in the drop down list on the control bar. The analysis will be carried out using five different methods.

Note the values of diffraction and scatter loss on the status bar. A question mark for diffraction loss means that it has not been calculated yet. If scatter loss is shown as N/A (not applicable), one of the following situations exist:

- the path is line of sight

- the value of K is outside the valid range of 1.2 to 1.5

- the path is close to grazing and the scatter loss calculation is not valid

Analyzing the Profile

Always start the analysis by drawing a Fresnel zone reference. Select Operations - Fresnel Zones on the menu bar or press the F2 key. Use the following settings:

Expressed as	% first Fresnel zone
Value	60 %
Type	between horizons
Label	check

These are the most meaningful on an obstructed path. Click Draw, and then Close.

The path consists of two obstacles and can be characterized as a double knife edge.
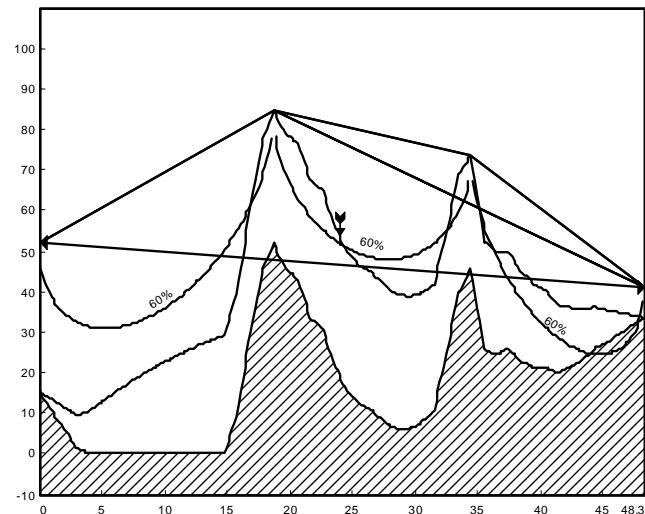
The minimum clearance to first Fresnel zone ratio (C /F1) required for free space loss is 60%. The actual theoretical value used in the program is 56.57%; however, in practice this is rounded off to 60%.

First examine the profile segment from the site 1 antenna to its horizon (the peak at 18.72 km). Except for the section between 16.75 and 18.72 km, the terrain is below the 60% first Fresnel zone reference. In other words, C /F1 is greater than 60% and hence, there will be no significant loss to the radio wave as it propagates from the site 1 antenna to its horizon.

Between the site 2 antenna and its horizon at 34.49 km, the terrain is above the 60% first Fresnel zone reference; and therefore, additional loss will occur in this segment.

In this manual, the loss between an antenna and its horizon is referred to as foreground loss. This is usually calculated by the Height - Gain algorithm, which is somewhat of a misnomer, as the result is always a loss.

Between the two horizons (the region from 18.72 to 34.49 km), the path has approximately 60% first Fresnel zone clearance. Of all the automatic diffraction algorithms, only the TIREM algorithm imposes a check on the clearance between horizons.
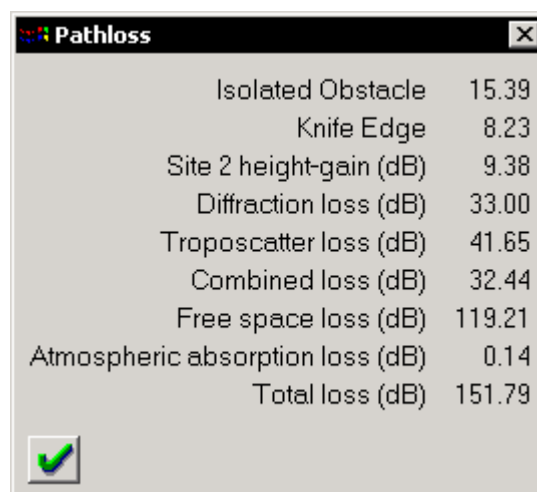
Double Knife Edge - Deygout

The Pathloss automatic algorithm, with the default settings will calculate the diffraction loss using this method. First, the automatic calculation will be made and then the results will be simulated using the manual diffraction algorithms.
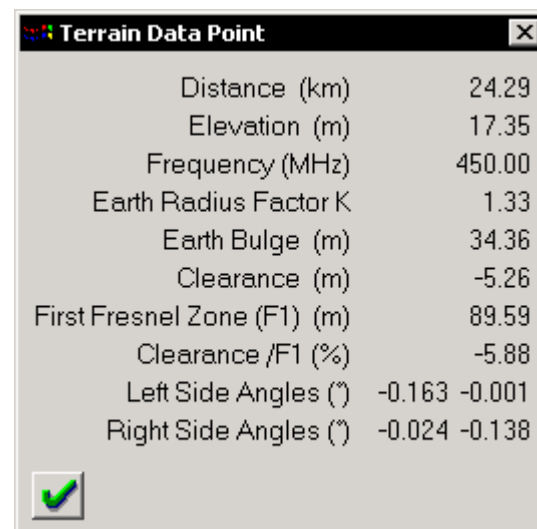
The Deygout method is limited to a double knife edge. The diffraction loss of the major obstacle is calculated as an isolated obstacle (a knife edge modified by the radius of the obstacle) over the entire profile. The diffraction loss of the minor obstacle is then calculated as a knife edge from the peak of the major obstacle to the other site. The height gain algorithm is used to calculate the foreground loss.

1)   Reset the cursor type to an arrow. Press the letter 'A'. Reset the cursor movement to all points on the profile. Press the letter 'P'.

2)   Set the Pathloss automatic algorithm to the default settings. Select Options - Pathloss Algorithm on the menu bar and click the Defaults button. Close the dialog box with the OK button.

3)   Select the Pathloss algorithm on the control bar and calculate the diffraction loss. Click the Calculate button or press F9. Any automatic diffraction loss algorithm will always erase existing calculations. The total diffraction loss is displayed.

4)   Now the calculation will be simulated using the manual algorithms. Erase the existing calculations. Click the Erase button or press F3.

5)   Determine which of the two obstacles is the major obstacle. This is the obstacle with the minimum value of C /F1. Place the arrow on the first peak at 18.72 km and click on the cursor location box on the status bar or press the Ins key. Note the value of the C /F1 (-42.11). Repeat for the second peak at 34.49 km. The C /F1 at this point is -36.54 and therefore, the first obstacle is identified as the major obstacle

When using the terrain point display, the reference for clearance and C/F1 are the end points of the display which in this case is the complete profile.

Pathloss

Isolated Obstacle	15.39
Knife Edge	8.23
Site 2 height-gain (dB)	9.38
Diffraction loss (dB)	33.00
Troposcatter loss (dB)	41.65
Combined loss (dB)	32.44
Free space loss (dB)	119.21
Atmospheric absorption loss (dB)	0.14
Total loss (dB)	151.79

Terrain Data Point

Distance (km)	24.29
Elevation (m)	17.35
Frequency (MHz)	450.00
Earth Radius Factor K	1.33
Earth Bulge (m)	34.36
Clearance (m)	-5.26
First Fresnel Zone (F1) (m)	89.59
Clearance /F1 (%)	-5.88
Left Side Angles (°)	-0.163 -0.001
Right Side Angles (°)	-0.024 -0.138

The next step is to calculate the diffraction loss of the major obstacle as an isolated obstacle referenced to the complete profile. The radius of the obstacle is required for this calculation.

6)   Select the Isolated Obstacle algorithm on the control bar.

7)   Calculate the radius of the obstacle. Place the cursor on the peak of the major obstacle at 18.72 km. Select Operations - Radius on the menu bar or press the F7 key. The initial value of the radius depends on whether the cursor is on a peak when the radius is activated. If this is the case, then the radius is calculated using three points. The first is the peak. The other two are determined by examining the slope of the terrain on either side of the peak. Otherwise, a default radius of 250 km is used.
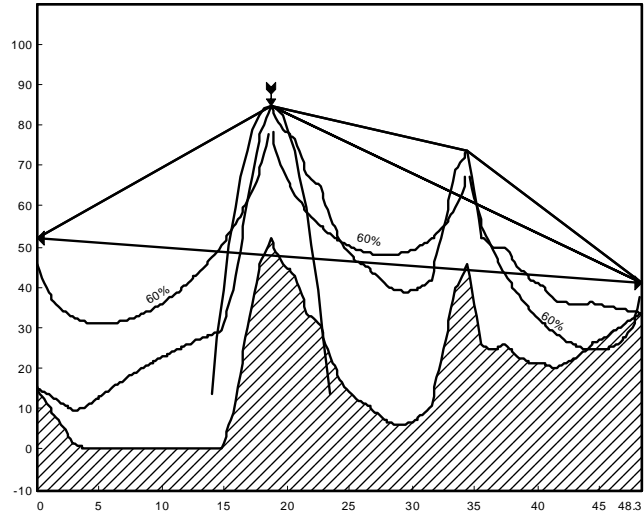
If a radius which is greater than the path length seems odd, remember that on a perfectly flat path, the radius would be the earth radius times K (6378 * 1.33 = 8483 km). Note that the segment of a circle drawn to represent the radius appears as a parabolic arc due to the extreme differences between the horizontal and vertical scales.

To change the radius, place the windows cursor on one of the boxes at the end of the arc, hold down the left mouse button and move the mouse to set a new radius. With the keyboard, hold down the Ctrl key and use the up, down, left and right cursor keys to set the radius. As in the continuous cursor movement, the radius increment is changed with the '+' and '-' keys. There is no visible indication of the increment.

On complex terrain, it will usually be necessary to set the cursor movement to continuous. This will allow you to move the radius to determine the best fit to the obstacle.

In this example, the default radius will be used as this is the value used in the automatic calculation. If you have changed the radius, press the F7 key twice to turn off the radius and then reactivate it. Calculate the isolated obstacle diffraction loss. Click the Calculate button or press the F9 key. Click the OK button to accept the results.
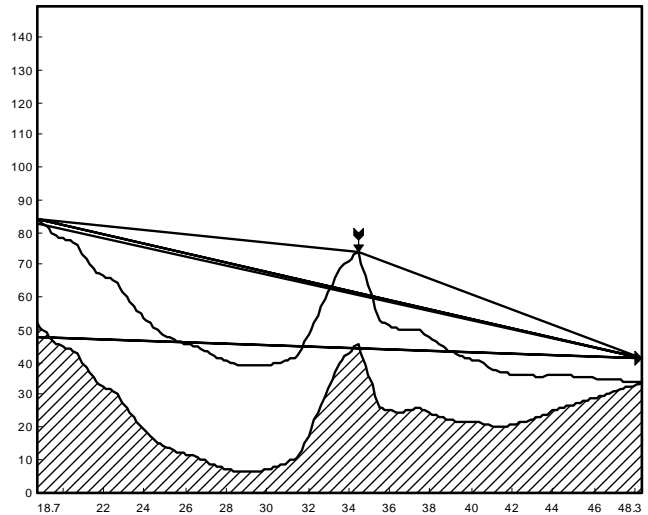
The diffraction loss of the minor obstacle will now be calculated as a single knife edge from the peak of the major obstacle at 18.72 km to site 2. To do this, you must select that segment of the profile. The clearance and C /F1 will be referenced to the end points of the selected segment.

Isolated Obstacle	
Location (km)	18.83
Left side (km)	0.00
Right side (km)	48.28
Radius (km)	87.37
Clearance (m)	-36.74
Clearance /F1 (%)	-42.03
v	0.59
Diffraction loss (dB)	15.37

8) Select the segment from the peak of the major obstruction at 18.72 km to site 2. Move the arrow to an end point of the segment, either site 2 or the peak at 18.72 km. You are at site 2 if the arrow is above the antenna marker. Click the right mouse button or press F1. The arrow changes color and is a fixed marker indicator. Move the arrow to the other end of the segment and click the right mouse button again or press F1. The selected segment is now displayed.

Note the following when selecting a segment:

- The F8 key corresponds to the Reset button.

- You can only select a segment if one of the C /F1 algorithms have been selected (knife edge, average or isolated obstacle).

- There must be three points between the end points of a profile segment.

- When the first end point is selected, the Reset button is enabled. To cancel the first point selection, click the reset button.

- When the segment has been selected, the Reset button is still enabled. To change back to the complete profile, click the Reset button.

9) Calculate the diffraction loss of the obstacle at 34.49 km as a knife edge. Select the Knife Edge diffraction algorithm on the control bar. Move the arrow to the peak at 34.49 km and click the Calculate button or press F9. Click OK on the diffraction loss calculation display to accept the results.

The choice of a knife edge for the secondary obstacle is based on experience which indicates the loss predictions are consistently higher than the measured values, when an isolated obstacle is used throughout a multiple knife edge calculation.

Knife Edge

Location (km)	34.49
Left side (km)	18.72
Right side (km)	48.22
Clearance (m)	-16.51
Clearance /F1 (%)	-23.63
v	0.33
Diffraction loss (dB)	8.92

10) Reset the display to show the complete profile. Click the reset button.

11) Calculate the foreground loss using the Height Gain algorithm. Select this algorithm on the control bar and click the Calculate button or press F9. Click the OK button to accept the results. The calculation is now complete. Press the letter 'D' to display the overall results.

Height Gain

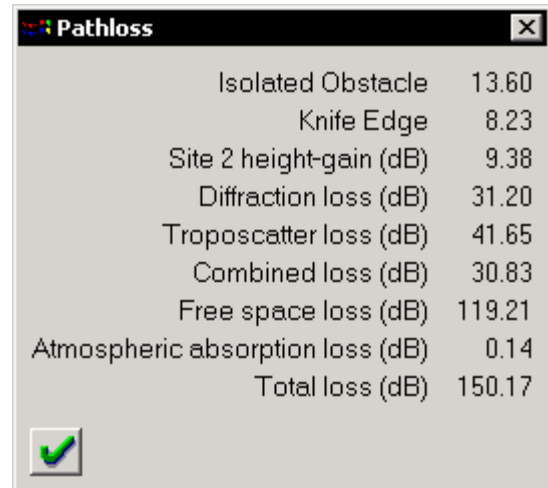|	
Site 1 height-gain (dB)	0.00
Site 2 height-gain (dB)	9.38

Double Knife Edge - Epstein & Peterson

The Epstein & Peterson model treats the terrain as a succession of knife edges starting at site 1. Each knife edge calculation is referenced to the two horizons of the knife edge.

The Pathloss automatic algorithm will be reconfigured for this model and then used to calculate the loss. Then the results will be simulated using the manual algorithms.

1) Configure the Pathloss automatic algorithm for the Epstein & Peterson model. Select Options - Pathloss Algorithm on the menu bar. Set the multiple knife edge method to Epstein & Peterson. In this model, there is no theoretical limit to the number of knife edges; however, the program has an internal limit of 10. The user can set aa upper limit in the range 2 to 10.
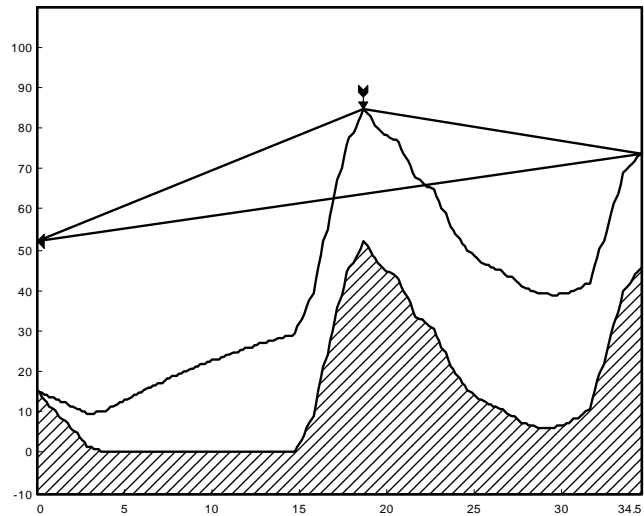
   Note that the definition of the major obstacle is different between the Deygout and Epstein & Peterson models. In the Deygout model, the C /F1 of both obstacles is referenced to the end points of the entire profile. In the Epstein & Peterson method, the reference is between the horizons of the obstacle under test. The automatic calculation scans the profile twice, the first time to determine the major obstacle and the second time to calculate the diffraction loss. This complication will be avoided in this example. Set the radius method to No Radius.

   Click the OK button to close the dialog box.

2) Select the Pathloss algorithm on the Diffraction control bar and click the Calculate button or press the F9 key.

3) Now repeat the calculation using the manual diffraction algorithms. Erase the existing calculations. Click the Erase button or press F3. Select the Knife Edge algorithm on the control bar.

4) Select the segment from site 1 to the peak at 34.49 km. Place the arrow at site 1 and click the right mouse button or press F1. Move the arrow to the peak at 34.49 km and click the right mouse button again or press F1.

5) Calculate the diffraction loss of the peak at 18.72 km referenced to site 1 and the horizon at 34.49 km. Place the arrow on the peak at 18.72 km and click the Calculate button or press F9.

   Click the OK button to accept the results displayed.

Pathloss	
Isolated Obstacle	13.60
Knife Edge	8.23
Site 2 height-gain (dB)	9.38
Diffraction loss (dB)	31.20
Troposcatter loss (dB)	41.65
Combined loss (dB)	30.83
Free space loss (dB)	119.21
Atmospheric absorption loss (dB)	0.14
Total loss (dB)	150.17

6)   In order to select the second segment, you need to reset the display to the entire profile. Click the Reset button or press F8.

7)   Select the segment from the peak at 18.72 km to site 2. Place the arrow on the peak at 18.72 km. and click the right mouse button or press F1. Move the arrow to site 2 and click the right mouse button again or press F1.

Knife Edge

Location (km)	18.72
Left side (km)	0.00
Right side (km)	34.49
Clearance (m)	-20.71
Clearance /F1 (%)	-27.45
v	0.39
Diffraction loss (dB)	9.37

8)   Calculate the diffraction loss of the peak at 34.79 km referenced to its horizon at 18.72 km and site 2. Place the arrow on the peak at 34.79 km and click the Calculate button or press F9.

Click the OK button to accept the results displayed.

9)   Reset the display to the complete profile. Click the reset button or press F8. As in the case of all C /F1 diffraction algorithms, it is necessary to calculate the foreground loss. Select the Height - Gain algorithm on the control bar and click the Calculate button or press F9. The calculation is now complete. Press the letter 'D' to display the results.

Pathloss

Knife Edge	6.30
Knife Edge	7.11
Diffraction loss (dB)	13.41
Troposcatter loss (dB)	37.54
Combined loss (dB)	13.39
Free space loss (dB)	119.21
Atmospheric absorption loss (dB)	0.14
Total loss (dB)	132.74

Effective Knife Edge

In this example, the diffraction loss will be calculated as an effective knife edge. This is sometimes referred to as the Bullington method. Lines are drawn between the antennas and their respective horizons. The diffraction loss is calculated as a single knife edge at the intersection of the horizon rays.

1)   Select the knife edge diffraction algorithm on the control bar.

2)   Set the cursor to continuous movement. Click the cursor movement box on the status bar to display the letter 'C' or press the letter 'C'.

3)   Change the cursor style from a default arrow to lines to the antennas. Click the cursor style box on the status bar or press the letter 'A'.

4)   Move the cursor so as to encompass the profile, as shown above. The lines should just touch the peaks at 18.72 and 34.49 kilometers.
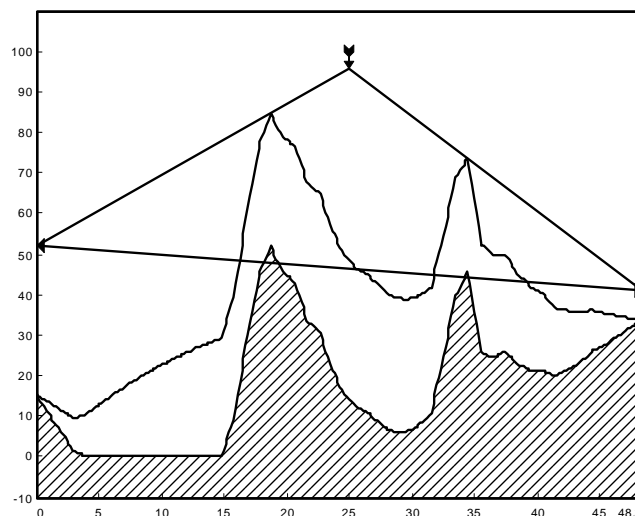
Note that if you move the cursor above the screen, the profile display scale will be reduced by 20%. To restore the scale to the default value, move the cursor below the display. This is only possible in the continuous cursor mode.

If you are using the keyboard cursor keys, the cursor movement increment can be changed with the '+' and '-' keys. There is no visible indication of the sensitivity.

5)   Calculate the diffraction loss. Click the Calculate button on the control bar or press F9. <u>You must click the OK button to accept the calculation</u>; otherwise, the results are discarded.

6)   Calculate the foreground loss using the Height Gain algorithm. Select this algorithm on the control bar and click the Calculate button or press F9. Note that only the site 2 foreground loss has been calculated as expected. Again, click the OK button to accept the results.

7)   The calculation is now complete. To display the total loss, click on either the diffraction loss box on the status bar or press the letter 'D'.

Effective Obstacle

The effective obstacle method replaces the two peaks with a single rounded obstacle. This type of analysis is useful when rationalizing the results produced by different algorithms.
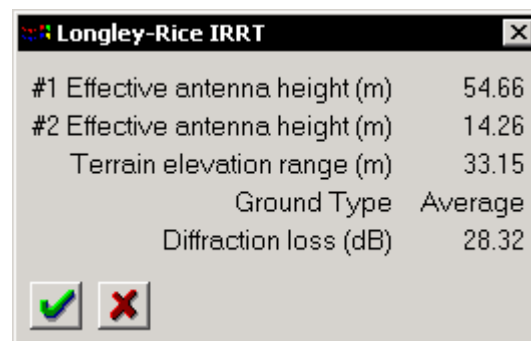
1)   Erase the existing calculations. Click the Erase button or press F3.

2)   Set cursor movement to continuous. Press the letter 'C' or click the cursor movement box on the status bar until the letter C appears.

3)   Select the Isolated Obstacle algorithm on the control bar.

4)   Create an effective obstacle which encompasses the two peaks on the display. Move the arrow between the two peaks and press F7 to initiate the radius calculation. Change the radius and the location of the effective obstacle to achieve this. To move the obstacle, hold down the left mouse button and move the obstacle to the desired position. To change the radius, place the mouse cursor on either box at the ends of the arc, hold down the left mouse button and move the mouse.

5)   Calculate the diffraction loss of the effective obstacle. Click the Calculate button or press F9.

6)   Calculate the foreground loss. Select the Height - Gain algorithm on the control bar and click the Calculate button or press F9. This completes the calculation. Press the letter 'D' to display the results.
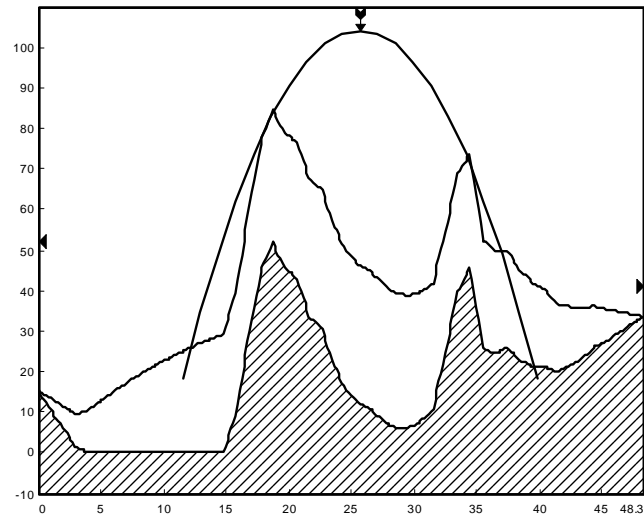
Longley & Rice Irregular Terrain

The final diffraction loss calculation uses the Longley & Rice irregular terrain algorithm. This is the default in the Pathloss automatic algorithm when the terrain cannot be characterized as some combination of knife edges or isolated obstacles.

1)   Select the Longley and Rice IRRT algorithm on the control bar.

2)   Calculate the diffraction loss. On an obstructed path, the calculation is automatic. On a line of sight path, you would be prompted to define a reflective plane, if one did not exist. Click the Calculate button or press F9. Click OK to accept the results. With this algorithm, any existing calculations are erased when you accept the results. Press the letter 'D' to display the total results.

Longley-Rice IRRT	
#1 Effective antenna height (m)	54.66
#2 Effective antenna height (m)	14.26
Terrain elevation range (m)	33.15
Ground Type	Average
Diffraction loss (dB)	28.32

Summary of Results

The diffraction loss results of the above five methods are summarized below:

Double knife edge - Deygout	32.3 dB
Double knife edge - Epstein & Peterson	30.6
Effective knife edge	12.3
Effective obstacle	28.0
Longley & Rice irregular terrain	28.4

PASSIVE REPEATERS

Microflect Example Calculations

The Microflect Passive Repeater Engineering publication "Catalog 161A" contains a number of examples of rectangular passive repeaters. These examples have been incorporated into Pathloss data files using make up profiles with the same path lengths and included angles. The elevations of the end sites and the passive sites are all the same, in order to minimize the effects of the vertical angles on the calculated results. In these examples, the Microflect analysis does not consider the vertical angles. The table below shows the individual link files and the complete passive file. These files are located in the directory EXAMPLES\PASSIVE on the CD-ROM.

Table 1:

Passive File	Link Files	Description	Passive Size	Microflect Reference
PASS_100.PL4	LINK_101.PL4 LINK_102.PL4	Single passive repeater, far field of both antennas	30 x 40 ft	Page 27
PASS_200.PL4	LINK_201.PL4 LINK_202.PL4	Single passive repeater, near field of one antenna	24 x 30 ft	Page 28
PASS_300 PL4	LINK_301.PL4 LINK_302.PL4	Close coupled double passive repeater, far field of both antennas	30 x 32 ft 30 x 32 ft	Page 29
PASS_400 PL4	LINK_401.PL4 LINK_402.PL4	Close coupled double passive repeater, near field of one antenna	24 x 30 ft 24 x 30 ft	Page 30

Table 1:

Passive File	Link Files	Description	Passive Size	Microflect Reference
PASS_500 PL4	LINK_501.PL4 LINK_502.PL4 LINK_503.PL4	Double passive repeater, near field of both antennas	16 x 20 ft 24 x 30 ft	Page 31

PASSIVE DESIGN EXAMPLE

In the following description, distances and elevations are expressed in miles and feet. If necessary, switch the program to these units. The first step in a passive design is to create Pathloss data files for each link in the passive repeater chain. This example uses two files to illustrate the basic design procedure and typical problems for a single rectangular passive repeater. The directory Examples\Passive on the CD-ROM contains the following files used in this example.

S1-PR.PL4   Pathloss data file for the Site 1 to Passive link

S2-PR.PL4   Pathloss data file for the Site 2 to Passive link

Both files must have the exactly same coordinates and elevation at the passive site to be successfully merged together as a passive link. Each of these files must be analyzed for clearance and reflections. This analysis must be carried out on the individual files. Once the files have been merged, only the Worksheet, Terrain Data and Print Profile design modules can be accessed. The passive antenna height has been set to 24 feet which is the height of the passive center above ground. The Site 1 and 2 antenna heights are both 50 feet. Equipment parameters have been entered in both files for convenience. The diagrams below show the results basic link designs.
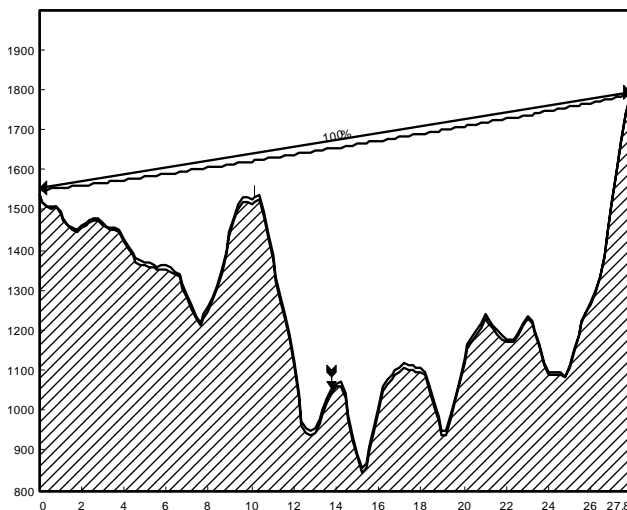

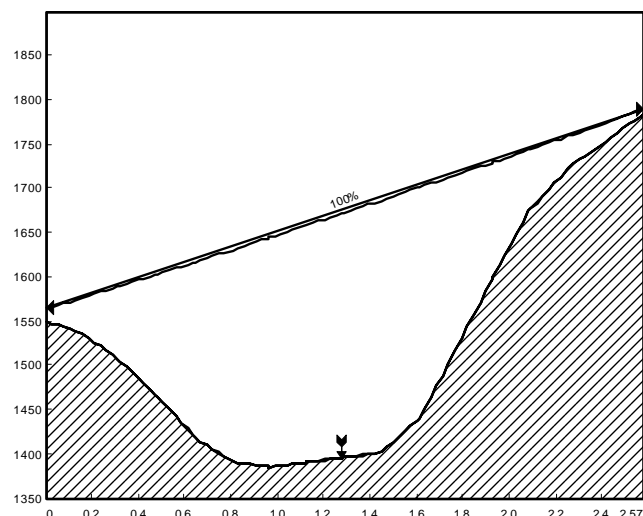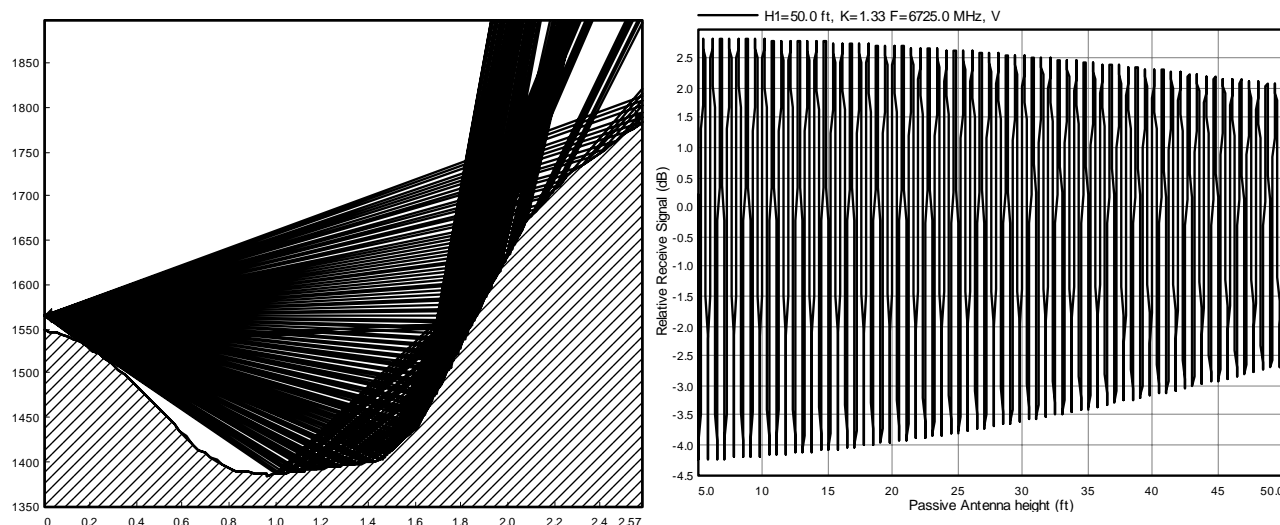Figure 1: Site 1 to Passive Clearance


Figure 2: Site 2 to Passive Clearance

Both links have excess clearance which may be unavoidable considering the nature of the terrain; however, the site 2 to passive link may be subject to reflections in the passive foreground. This is analyzed in the Multipath module and the results are shown below:

The results show that a 5 db ripple would occur across the passive face. The dispersion worksheet in the Reflection module shows that the time delay is 5 nanoseconds. The situation here is marginal and further investigations on the ability of the equipment to handle this signal distortion would be required. Two common failures of passive repeaters are the foreground reflections and reflections from the surrounding terrain; particularly, if the passive is located on the side of a hill and the surface of the hill acts as a second reflector.
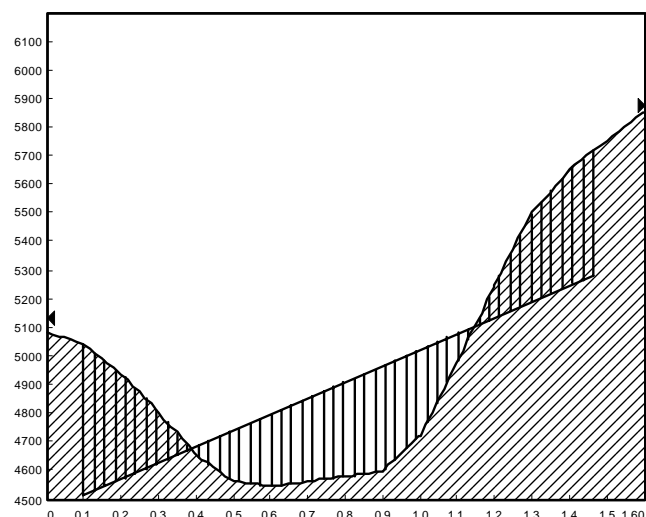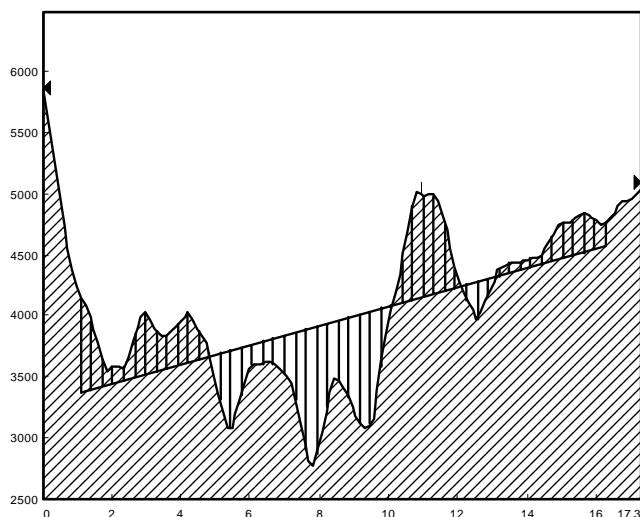
Creating the Passive Repeater
Load the file S1-PR.PL4 and select the Microwave Worksheet. Select Operations - Create Passive Repeater. Select the single passive repeater type and click the OK button. An open file dialog box appears in which the second file S2-PR.PL4 is loaded. The two files are merged together and the complete passive repeater link is displayed on the screen. Click on the passive repeater icon. The data entry form is formatted for the single passive repeater. Enter the
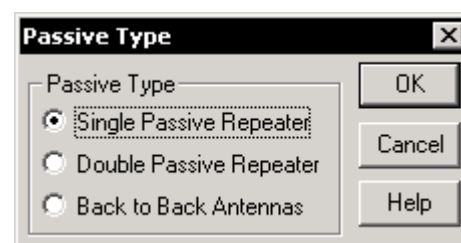
height and width as 24 feet and 30 feet respectively. A loss factor of 1.5 dB is used to account for surface imperfections at the 6 GHz operating frequency.

Single Passive Repeater		
OK Cancel Help		
	Azimuth 58.46°	Azimuth 15.00°
Passive height (ft)	24.00	
Passive width (ft)	30.00	
Passive center height (ft)	24.00	
Loss Factor (dB)	1.50	
Vertical angle (°)	-5.020	-0.586
Included Angle (°)	43.460	
Face angle (°)	-3.017	
Effective area (ft²)	668.46	
Far field gain (dB)	111.88	
Inverse K	1.45	15.67
L value	0.27	
Alpha (dB)	-5.50	
Near field effect (dB)	-0.14	
Passive Gain (dB)	110.24	
Passive height (ft) :		

The passive is marginally in the near field of the site 2 antenna. At this point, the worksheet calculation is complete down to the fade margin level. The next step depends on the selected reliability method. If the Vigants Barnett or ITU-R P.530-6 are selected, then it will be necessary to calculate terrain roughness or grazing angle for both sides of the passive. In all other methods the required reliability parameters can be entered on either side of the passive. An example of the terrain roughness calculations is given below:

This step completes the basic transmission design for the passive repeater link.

Site 1 to Site 2 Direct Path Evaluation

The direct path between site 1 and site 2 must always be evaluated to ensure that the direct signal is sufficiently below the main signal. This will depend on the diffraction loss of the direct path and the antenna discriminations. Make a note of the antenna azimuths and elevation angles (H = 195.09º, E = 0.4º at site 1 and H = 238.49º, E = 5.0º at site 2). A terrain data base and antenna data files will be used to carry out this analysis. The following setup is required:

Microwave Data Files Directory Setup

Select Configure - Directories - Microwave Antenna Codes. Select Equipment\Mas on the CD-ROM as the directory containing the microwave antenna data files.

Terrain Database Setup

The example creates a direct profile from Site 1 to Site 2 using the USGS 30 second terrain database. Select Configure - Terrain Database. Set the primary data base to USGS 30 sec World and click the Setup Primary button.

The setup procedure loads a header file and identifies the DEM file.

Click Header File and open the file D:\Examples\Dems\Gtopo30\W140N90.hdr.

Close the Setup dialog box and click the OK button in the Configure Terrain Database dialog box to register this database.

Generate Profile

Switch to the Network module. The passive link is displayed. Create a direct link between site 1 and site 2. First place the cursor on the site 1 legend and then hold down the left mouse button and drag the cursor to site 2. Now click the left mouse button on the link and select the Terrain Data module. Ignore the prompt to save the new passive file. This is available on the CD-ROM as S1-PR-S2.PL4. A default profile using the site 1 and site 2 elevations is displayed in the Terrain Data module.

Select Operations - Generate Profile to create the path profile. Set the antenna heights to 50 feet at both sites. Select Configure - Antenna Heights from the menu bar.
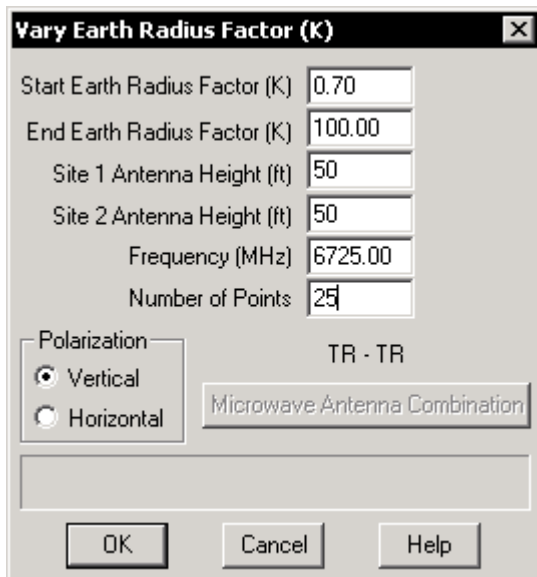

Generate Profile

Primary database	GTopo30 Global 30 sec	
Secondary database	No Selection	
Datum	North American 1927	
	Canada (Alberta, British Columbia)	

	Site 2	Site 1
Latitude	55 02 27.02 N	55 16 11.63 N
Longitude	121 57 56.43 W	121 53 12.51 W
True azimuth (°)	238.488	195.093
Distance (mi)	18.87	

Distance Increment (mi) [0.100]   ☐ Span missing files

[Generate]   [Cancel]   [Help]

Diffraction Loss

Select Module - Diffraction to carry out the diffraction loss calculation. If required select the Pathloss algorithm and set K to 1.33 on the diffraction tool bar. Click the calculate button or press the F9 key to calculate the diffraction loss. The result is 28.5 dB.

The diffraction loss must be evaluated over the full range of the earth radius factor (K). Select Variable - Earth Radius Factor and enter the values shown below:
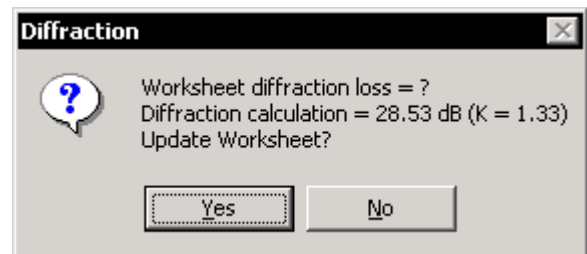
The diffraction loss will be greater than 26 dB for any value of K. It remains to calculate the receive signal using this diffraction loss and adding the antenna discriminations.
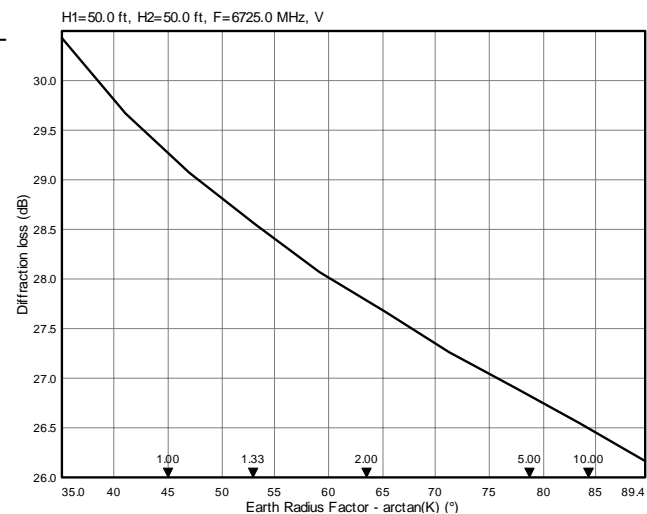
Site 1 to Site 2 Receive Signal

Select Module - Worksheet. You will be prompted to add the diffraction loss calculation into the worksheet. In this case, click Yes to update the worksheet.

The template feature will be used to transfer the Site 1 and Site 2 equipment parameters into the worksheet. Select Template and load the complete passive file S1-PR-S2.PL4 on the CD-ROM. The recalculated worksheet shows a fade margin of 30 dB. One would ask if the passive is justified and consider operating the direct path from Site 1 to Site 2 on a diffracted basis.

To complete the analysis click on an antenna icon and add the actual antenna azimuths and downtilt. Note that the opposite signs have been used to express downtilt.

Antennas TR - TR

OK   Cancel   Lookup   Code Index   View   Help

	Site 1	Site 2
Antenna model	P8-65D	P8-65D
Antenna diameter (ft)	8.00	8.00
Antenna height (ft)	50.00	50.00
Antenna gain (dBi)	42.30	42.30
Radome loss (dB)		
Code	A2626	A2626
Antenna 3 dB beamwidth (°)	1.30	1.30
True azimuth (°)	191.19	11.12
Vertical angle (°)	-0.06	-0.12
Antenna Azimuth (°)	195.09	238.49
Antenna Downtilt (±°)	-0.40	-5.00
Orientation Loss (dB)	27.08	74.86

Site 1 Antenna model : |

The total antenna discrimination is 102 dB. This results in receive signal of -154 dBm which is sufficiently below the passive receive signal to avoid any degradation.