DCD-LOCAL PRIMARY REFERENCE

DCD-LPR/C

Lesson 2: System Overview

098-44101-02 Issue 1

Contents

NOTES:

Local Primary Reference (LPR/C) System Introduction

The Local Primary Reference (LPR/C) system provides timing signals to the Digital Clock Distributor (DCD) Shelf, at a primary rate E1, from multiple Global Positioning System (GPS) satellites.

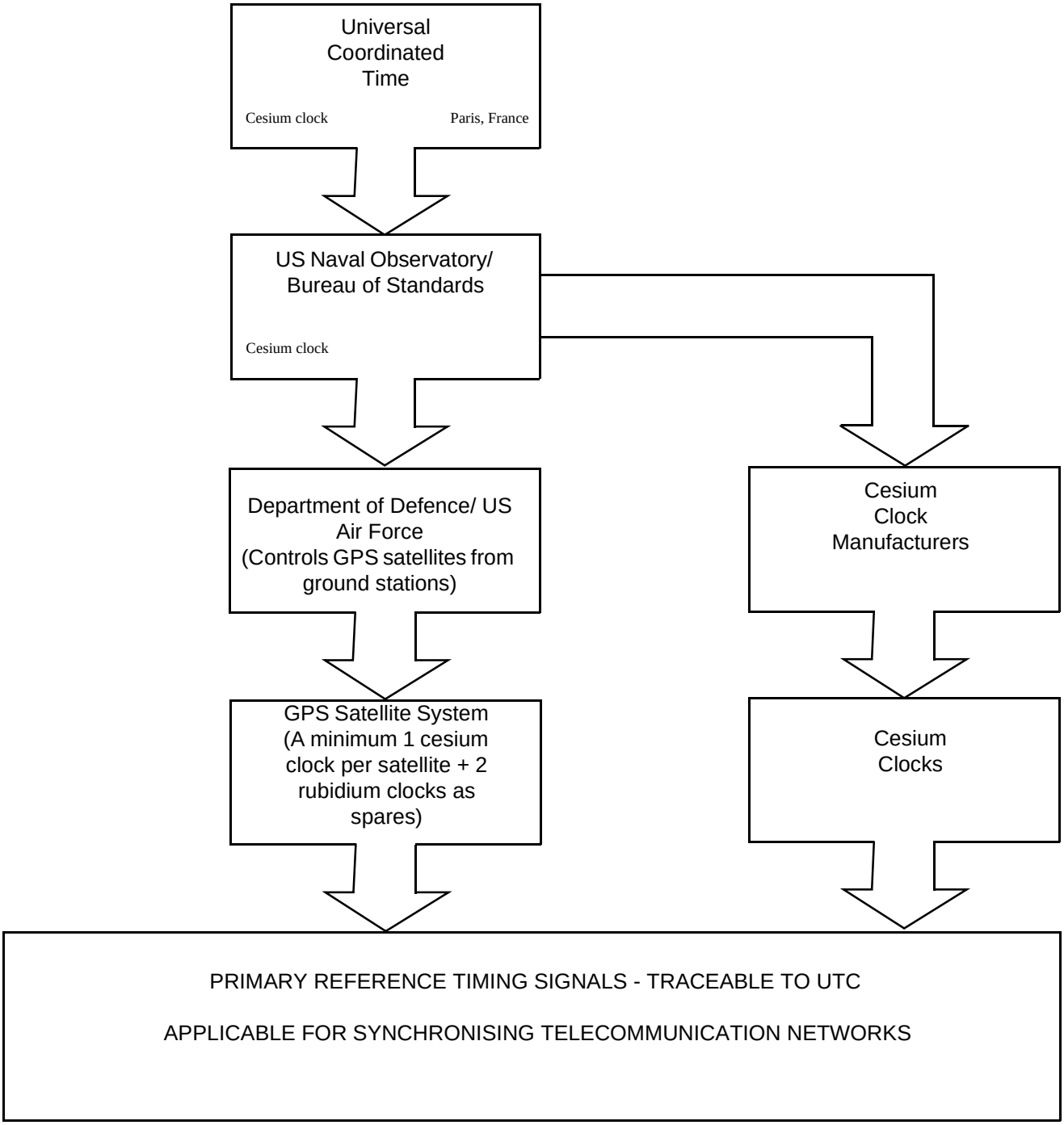
This lesson discusses the synchronization network application of the LPR/C system in conjunction with the GPS and Satellites. It provides an overview of the LPR/C system operation.

All DCD-521/C and LPR/C systems have a /C which indicates that the equipment meets CE Mark European Standards.

Lesson Objectives

Upon completion of this lesson you will be able to:

1. Describe the fundamental application of the LPR/C and GPS in providing primary reference timing signals.
2. List the functional components of the LPR/C system and identify the functions they perform.
3. Identify the meaning and conditions indicated by the lamps and display on the LPR/C.



Traceability to UTC VA 1

The Origin of Precise Time

Atomic clocks operate on the principle that all elements have a natural frequency of oscillation. That is, a particular atomic resonant frequency is produced when atoms are stimulated in a particular way. The oscillations are produced as the electrons transition between energy levels around the nucleus of the atom.

The resonant frequency of the cesium-133 atom has been chosen as a time standard. One second is defined as the time it takes for 9,192,631,770 transitions between two hyperfine levels of the cesium-133 atom (13th General Conference of Weights and Measures [CGPM 1967 Resolution 1]).

The world standard for time-of-day is **UTC** (Universal Coordinated Time).

UTC is derived by combining **TAI** and **UT1**, where:

- **TAI** (International Atomic Time) is formed from an average of nearly one hundred atomic clocks located in many countries. These clocks keep pace with each other to within two or three millionths of a second over a year's time.

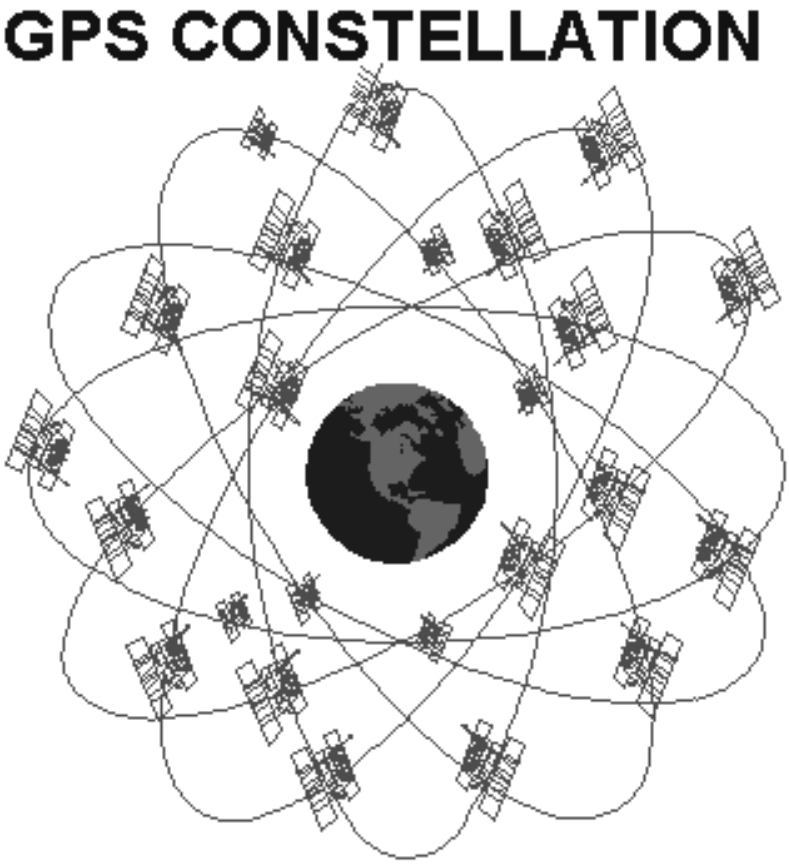
- **UT1** (Universal Time 1) provides a correction to accommodate the effects of the earth's noncircular orbit and the polar inclination on apparent solar time.

The GPS Satellites, each with at least one cesium-based clock, send digital signals in the L1 band. L1 (1575.42 Mhz) is the primary frequency; L2 (1227.6 Mhz) is the secondary frequency. The signals consist of a code sequence that is modified by pseudo-random noise (PRN).

These signals are tracked and decoded by GPS Receivers. The LPR/C System GTI card and GTR Receiver use three satellites to decode and track longitude and latitude, and a fourth satellite to track the altitude of the receiver. These four signals are averaged and become the basis of the LPR/C timing solution. If the system (receiver and GTI card) is not able to track at least four signals, it declares the GTI invalid and squelches its output to the DCD System, at the alarm integration period, until at least a four-satellite solution is achieved.

We gain access to UTC via GPS.

Each of the standards in succession is calibrated to higher-level standards. The US Naval Observatory clocks are calibrated to UTC clocks (Paris). Equipment manufacturers standards clocks, in turn, are calibrated to the US Bureau of Standards clocks. Users, in turn, must periodically return their clocks for calibration, upgrade, and/or replacement to equipment manufacturers.



Global Positioning System (GPS)

The United States government has developed a navigational system called the Global Positioning System (GPS). It is a satellite-based radio navigational aid designed to provide precise all-weather navigation and timing capability to users anywhere on the globe 24 hours a day.

The GPS Operational Constellation consists of 24 satellites: 21 navigational SVs and 3 active spares orbit the earth in 12 hour orbits.These orbits repeat the same ground track (as the earth turns beneath them) once each day. The orbit altitude is such that the satellites repeat the same track and configuration over any point approximately each 24 hours (4 minutes earlier each day). There are six orbital planes (with nominally four SVs in each), equally spaced (60 degrees apart), and inclined at about fifty-five degrees with respect to the equatorial plane. This constellation provides the user with between five and eight SVs visible from any point on the earth. The geometry of the complete installation enables direct line-of-sight timing signals from at least four satellites (and usually more) to any monitor station on or near the earth's surface at all times.

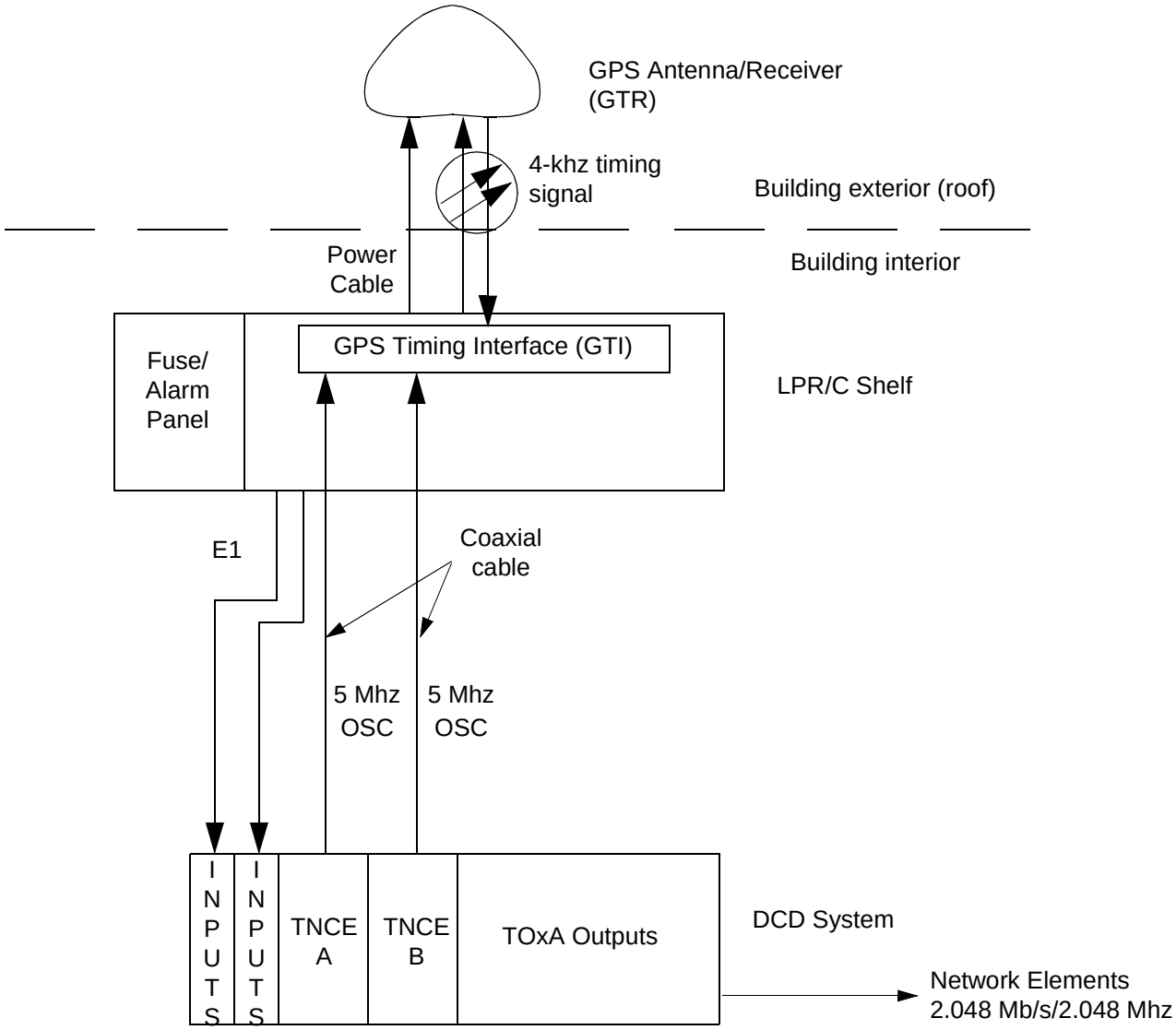
It is the UTC-traceable signal distributed within the GPS used in conjunction with the users' local rubidium oscillators that enables the DCD-LPR/C to generate a PRS compliant with ITU G.811.

The clock bias (correction to achieve G.811-quality signal) of a user's clock can be determined by using three satellites and a known height, or four satellites if the height is unknown.

The Department of Defence monitors each satellite's performance (frequency) and will perform maintenance periodically, then return them to service.

If a satellite being used for tracking/timing solution is removed from service, another satellite will be used to derive a timing solution to the DCD System. If a fourth satellite is unavailable because of the available satellite constellation, the LPR/C System (GTI and GTR) will declare a state of insufficient satellites and go into a "keep alive" mode while maintaining G.811 specs for a predetermined set time (depending on whether TNC-E or TNC clocks are used in the DCD). After this set time limit has expired, the LPR output is squelched or made AIS because its signal would be outside the G.811 requirements.

Telecom Solutions' DCD-LPR/C product tracks up to 8 satellites and uses a weighted average of up to 6 satellites to produce its output. The use of 4 satellites ensures that an invalid satellite does not corrupt the value of the output signal. The use of weighted average of multiple satellites mitigates the effects of range or out-of-limit satellites. These invalid/inaccurate signals are averaged out and ignored through filtering. The resultant signal is an average of received signals within limits.



Basic DCD-LPR/C System

VA 2

Digital Clock Distributor - Local Primary Reference System (LPR/C)

The LPR/C system is designed to provide management of the input from GPS primary reference source. The GPS Timing Antenna/Receiver (GTR) and the GPS Timing Interface (GTI) card manage the GPS primary reference source.

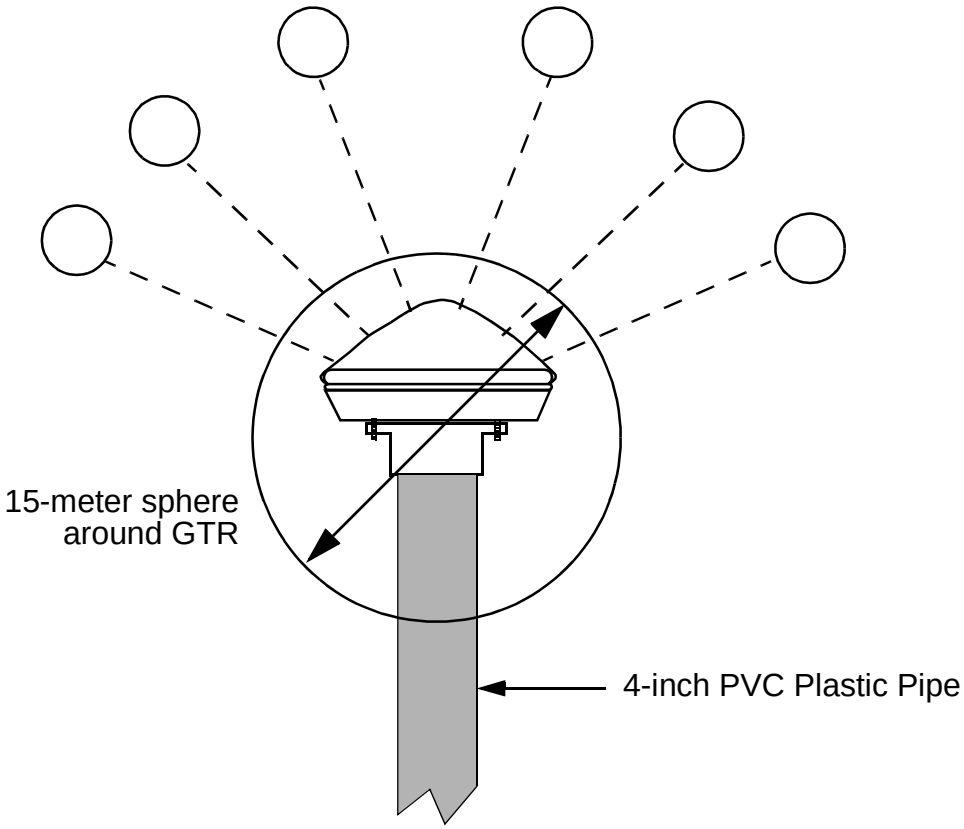
The GTR simultaneously tracks up to eight GPS satellites and provides a timing and communications channel to the GTI. The timing channel is a multiplexed 4-khz synchronization signal.

- The signal from the GTR to the GTI is a Manchester-encoded 4-khz signal which incorporates status messages, timing information, and positioning recovery information for a 1-pulse-per-second UTC signal with the 4-khz square wave signal. Communications from the GTI to the GTR is asynchronous and used to set the GTR Receiver for factory testing or reset the GTR to factory default settings.

The GTI takes the 4-khz synchronization signal from the GTR and, using the 5-Mhz inputs from the DCD system as a time base, performs an ensemble-averaged time correction to optimise the inputs. The inputs are then converted into two primary-rate E1 timing references, which are passed to the DCD system.

LPR/C System Components

- GPS Antenna/Receiver (GTR)
- LPR/C Shelf
  - Fuse and alarm
  - GPS Timing Interface (GTI)
- DCD System
  - Timing outputs to network elements
  - Clocks provide filter and HOLDOVER



- The GTR Receiver uses up to 6 satellites to develop timing solutions.
  - 3 satellites are required for longitude and latitude (triangulation).
  - 4 satellites are required for longitude, latitude, and height.
- When GTR position information from at least 4 satellites stays within the 15-meter diameter sphere, the output signal (average weighted value of 4 satellites) is suitable for G.811 output to a DCD-521/C system.

  When position information from satellites is outside the 15-meter diameter sphere, the system disqualifies the output value as suitable for G.811 qualification.

GTR Receiver VA 3

GTR Antenna/Receiver

The GTR is a eight-channel parallel receiver that:

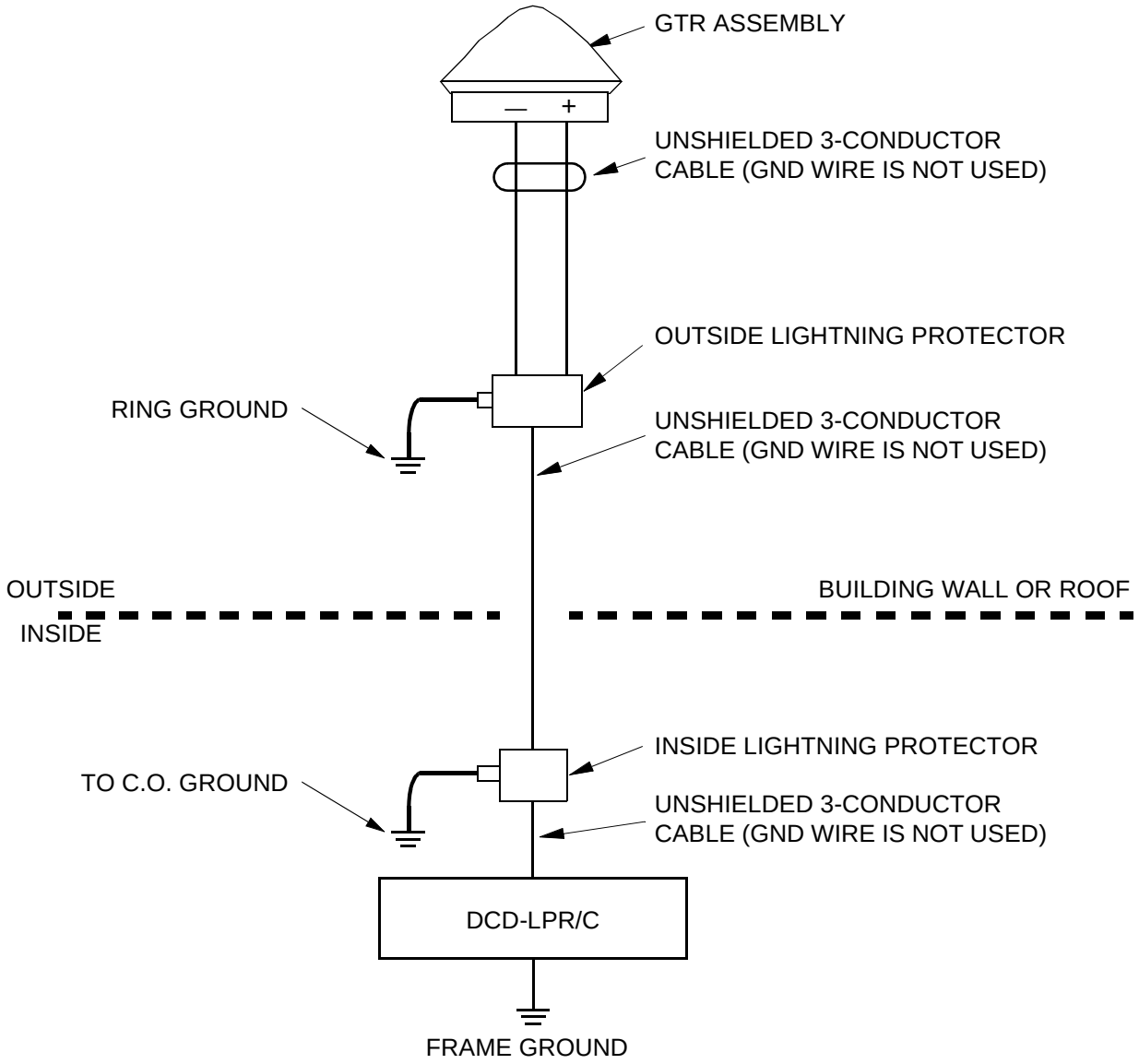
- simultaneously tracks up to eight GPS satellites
- determines the six best satellite signals in view
- derives an ensembled average timing correction input for those six satellites
- provides a multiplexed 4-khz synchronization signal incorporated into 1 pulse-per-second timing, and a data communications channel to the GTI. The fibre optic carrier is continuous between the GTR and GTI.

Status messages sent from the GTR to the GTI:

- GPS
  - Positioning and mode of operation
    - Two-dimensional: longitude and latitude
    - Three-dimensional: longitude, latitude, and height
    - Timing
  - Latitude, latitude Pole North/South
  - Longitude, longitude Pole East/West
  - UTC time
- SAL – GTR alarm information, e.g., loss of visible satellites, insufficient satellites
- SFM – current status: position or timing recovery
- SIV – satellites in view
  - Track number of satellites
  - Satellite elevation
  - Satellite azimuth
  - Satellite signal-to-noise ratio
- SSS – satellite status
  - Satellite status almanac obtained
  - Position status obtained
  - Part of timing solution

GTR to GTI communication is provided via a two-strand fibre optic cable. The maximum allowable cable length is 1300 Metres.

The GTR is attached to a pipe flange by four nuts. The pipe flange is mounted on a Class C 4 Inch PVC pipe secured to the roof or to a parapet by clamps.



GPS Antenna Grounding Scheme

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GTR-GTI Grounding Requirements

Generally, several types of central office grounds are available. Typical grounding types are:

- Ring Ground: ring ground is located around the rooftop of a structure with a low-resistance conductor (copper bar) directly to earth at multiple points. The function of this ground is to ensure that all exposed conductive surfaces are at the same potential and to provide a low reactive (inductive) resistance path to earth through which direct lightning strike currents can flow.

- Protection Ground: protection ground is used to ground lightning-protection devices to earth ground by means of a low-resistance conductor to earth.

- Frame Ground: frame ground is primarily an EMI drain at the equipment level and is not designed to dissipate high current from sources such as lightning.

- Earth Ground: this is the earth itself. All other grounds are ultimately connected to earth ground.

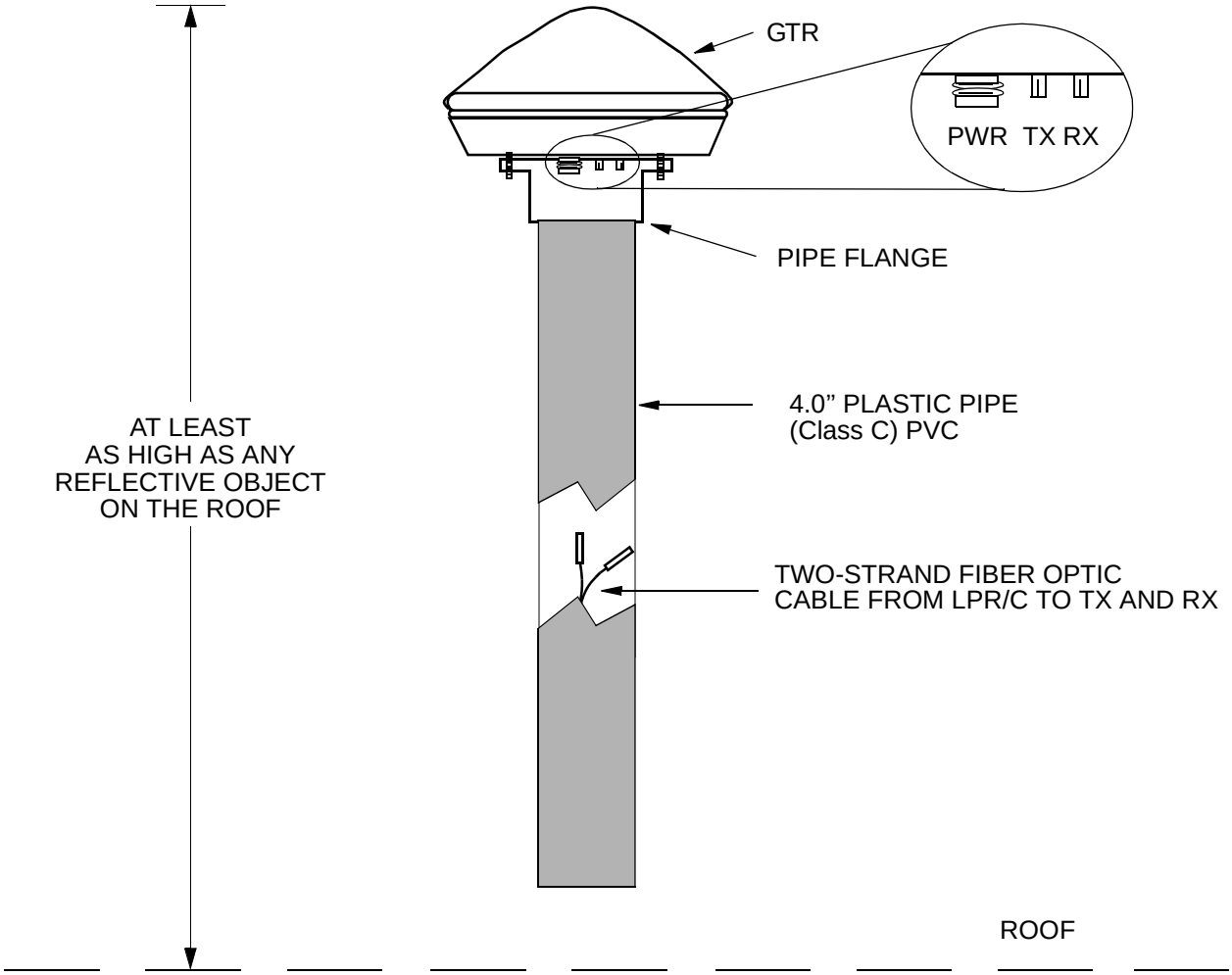
Note: Battery return is a conductor from the equipment to the office battery and should not be considered a ground.

- The Office Principle ground Point (OPGP) is a bus bar normally located near the entrance switchgear. It functions as:

    - The central connection point for all main grounding connectors and earth electrodes

    - The point of origin for the vertical equalizer

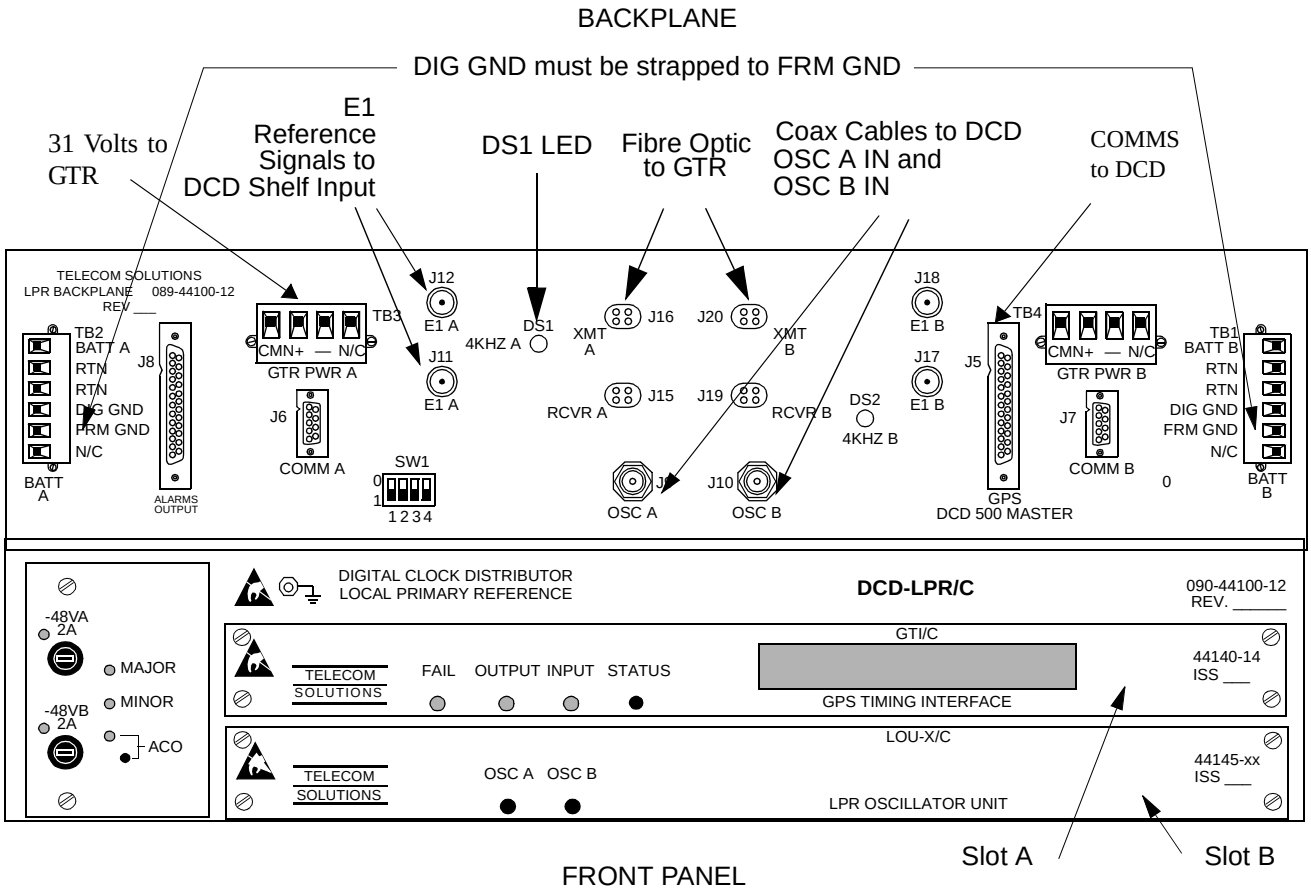
    - The C.O. ground bus bar for the floor where it is located (typically the basement)



GTR Mounting

VA 1

Notes



DCD-LPR/C Shelf (Front View)

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LPR/C Shelf

The LPR/C Shelf provides the central office rack-mounted housing, fusing, and alarms for either one or two GPS Timing Interface (GTI) cards, or one GTI card and one Local Oscillator Unit, and their associated inputs and outputs. The Local Oscillator Unit is used when there are no 5-Mhz oscillator feeds from the 521/C Shelf.

Fuse and Alarm (FA) panel provides:

- Monitoring, filtering, and fusing of two separate –48 Vdc power feeds. The –48 Vdc (A and B) connections are provided on TB1 and TB5 on the rear of the shelf. Both the A and B power should be fed from diverse loads and power frames.
- Major and minor audible and visual alarm indications. Connections to the central office alarm system are provided by a 25-way D-Type connector (ALARMS OUTPUT).

Alarm and status information can also be provided to OS Systems through the Maintenance Interface System (MIS/C) card in the DCD Shelf. This is accomplished by cabling between the LPR/C Shelf's GPS DCD 500 MASTER connector and the DCD's LPRS connector.

Inputs:

The 4-khz input signal (via the fibre optic cable) from the GTR Antenna/Receiver to the GTI card is terminated on fibre optic connectors J15, J16, position A, and J19, J20 position B.

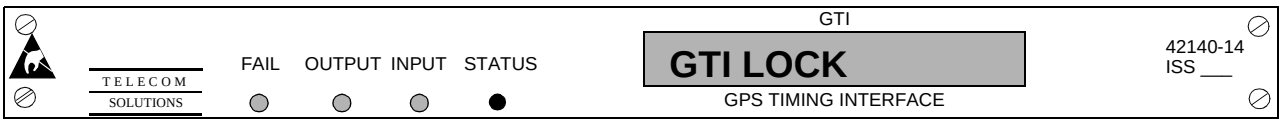
The 5-Mhz inputs from the DCD system (OSC A and OSC B connectors) are connected to J9 (OSC A) and J10 (OSC B) on the LPR/C Shelf.

Outputs:

The primary rate E1 timing reference outputs from the GTI are provided on J11 and J12 for GTI in position A, and J17 and J18 for position B.

Notes:

- GTR POWER-A (top slot) and GTR POWER-B (lower slot) normally provide the 31 Vdc Power –, Power +, constant current power to the GTR. (A separate power supply can be used)
- When the GTI is providing power, the maximum distance from the GTI to the GTR is 250 Metres.
- LED DS1 on the backplane is lit GREEN to indicate that a signal is present on the rec fibre from the GTR Receiver to GTI in position A. LED DS2 is for the GTR in position B.
- Switch 1 allows the communications settings to be changed, either to the MIS or direct into the GTI Set sections 3 and 4 up when the DCD MIS card is communicating with the GTI cards.
- When lit, the green "DS1" or "DS2" LED indicates that the 4-Mhz signal from the GTR to GTI is present.



GTI Card Front Panel Controls and Indicators

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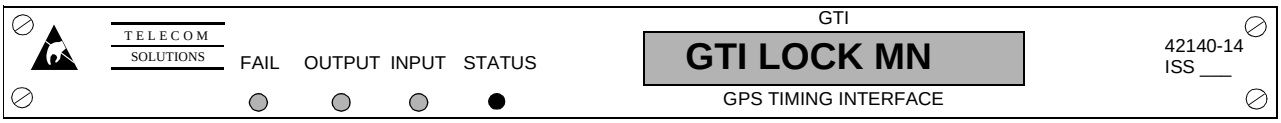
GPS Timing Interface (GTI) Card

The faceplate of the GTI contains the following controls and indicators:

FAIL	Lamp that lights red when a power supply failure, processor problem, or any LPR/C service-affecting condition exists.
OUTPUT	Lamp that lights green to indicate the GTI output is active and supplying a 2.048-Mb/s E1 signal.
	Lamp that lights red to indicate the GTI output is disabled.
INPUT	Lamp that lights green to indicate the GPS input from the GTR is present and valid.
	Lamp that lights red to indicate the GPS input from the GTR is invalid.
STATUS	Pushbutton used in conjunction with the LCD display. Press to cycle to the next GTI status display.
LCD DISPLAY	A 16-character LCD that displays the GTI status and alarm conditions.

Normal Working Condition

System in GTI lock for 20 hours



System in GTI lock, but showing minor alarm

GPS Timing Interface Display

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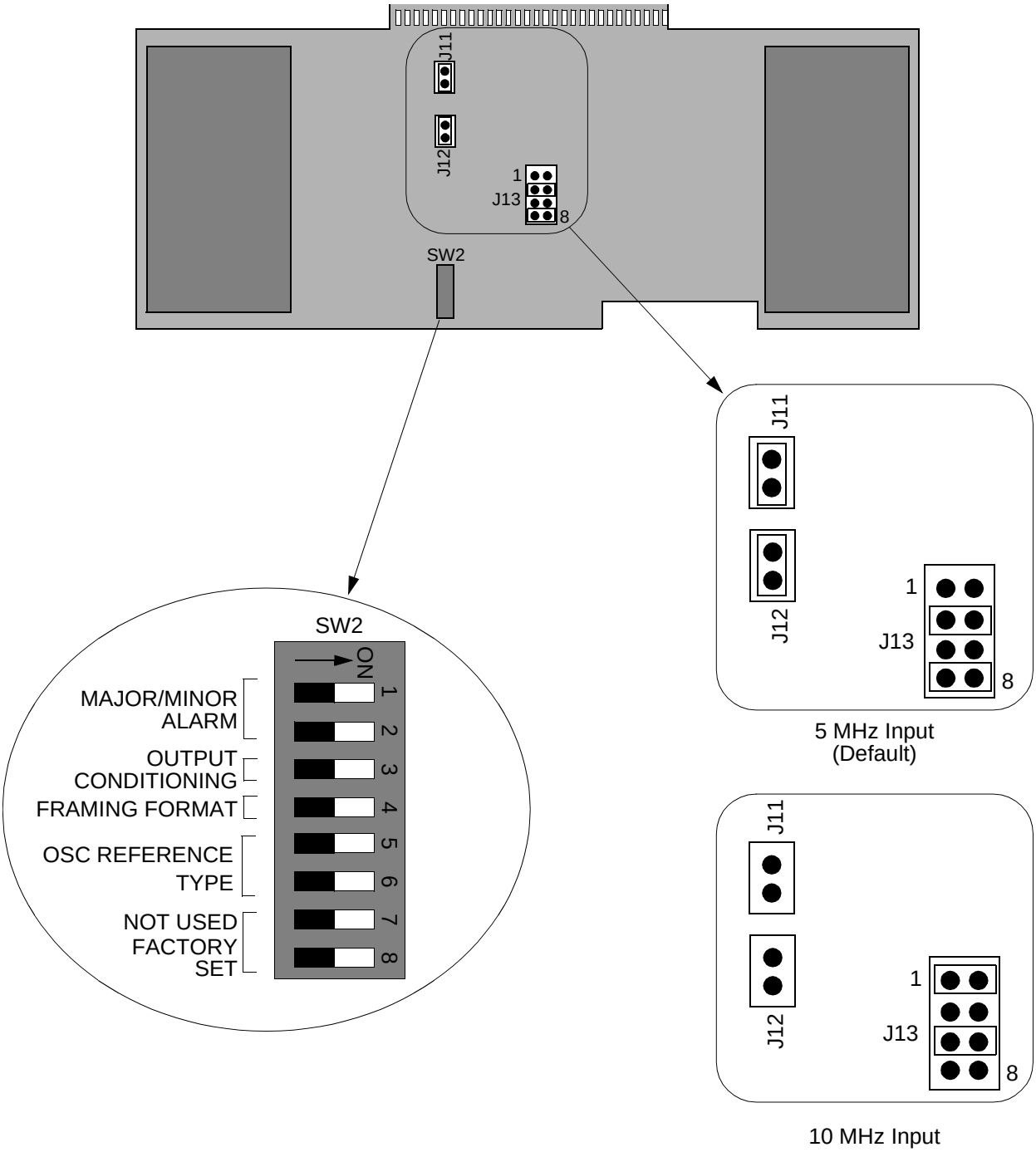
GTI Card - LCD Display

The LCD on the GTI card displays the following screen types:

- Home Display (GPS STATUS screen) — Screen default (GTI LOCK) + hours in this state + alarm (MJ or MN).
- UTC Time — Press STATUS button once to display time and date at GMT.
- Synthesizer Reference — Press STATUS button twice to display either SYNTH REF A or B. This is the reference that the GTI synthesizer is using to develop an output signal.
- Performance Metrics — Press STATUS button three times to display PERF METRICS
  GTI METRICS x E^{-12}
  – with cesium as OSC input within 3-4 days, at least 4 x 10^{-10}
  – with rubidium as OSC input within 3-4 days, at least 4 x 10^{-12}
- Software and Switch settings — Press STATUS button four times to display software revision and DIP switch settings
  – GTI SW #.##.## software
  – Config = xxxxxxxx DIP switch settings
  Switch No.87654321
  Position 4 indicates the GTI timing output framing type
  0 = FAS/CAS
  1 = FAS/CCS
  2 = FAS/CCS/CRC4
  3 = FAS/CAS/CRC4
- Current Status — Press STATUS button five times to display current non-alarm events listed
- Alarm Events — Press STATUS button five times to display current alarm conditions listed

Each screen can be reached by pressing the STATUS button the appropriate number of times to scroll through the screens.

If the STATUS button is pressed and held, the current display remains until the button is released. When the button is released, the display returns to the Home Display after a 5-second timeout.



GTI/14 Card Switch and Jumper Settings

VA 8

GTI/C Jumper Strapping

JUMPER	PIN	5-MHz (FACTORY SETTING)	10-MHz	DCD-LPR/C INPUT(S) AFFECTED
J11	1 and 2	Strapped	Not strapped (see Note)	OSC A IN
J12	1 and 2	Strapped	Not strapped (see Note)	OSC B IN
J13	1 and 2	Not strapped	Strapped	OSC A IN
	3 and 4	Strapped	Not strapped (see Note)	OSC A IN
	5 and 6	Not strapped	Strapped	OSC B IN
	7 and 8	Strapped	Not strapped (see Note)	OSC B IN
Note: Retain unused jumpers at J11 and J12 (for possible future use), by slipping the jumper over one pin only.				

GTI/C Switch Settings (Sections 1 and 2) (for GPS INVALID and GPS LOS only)

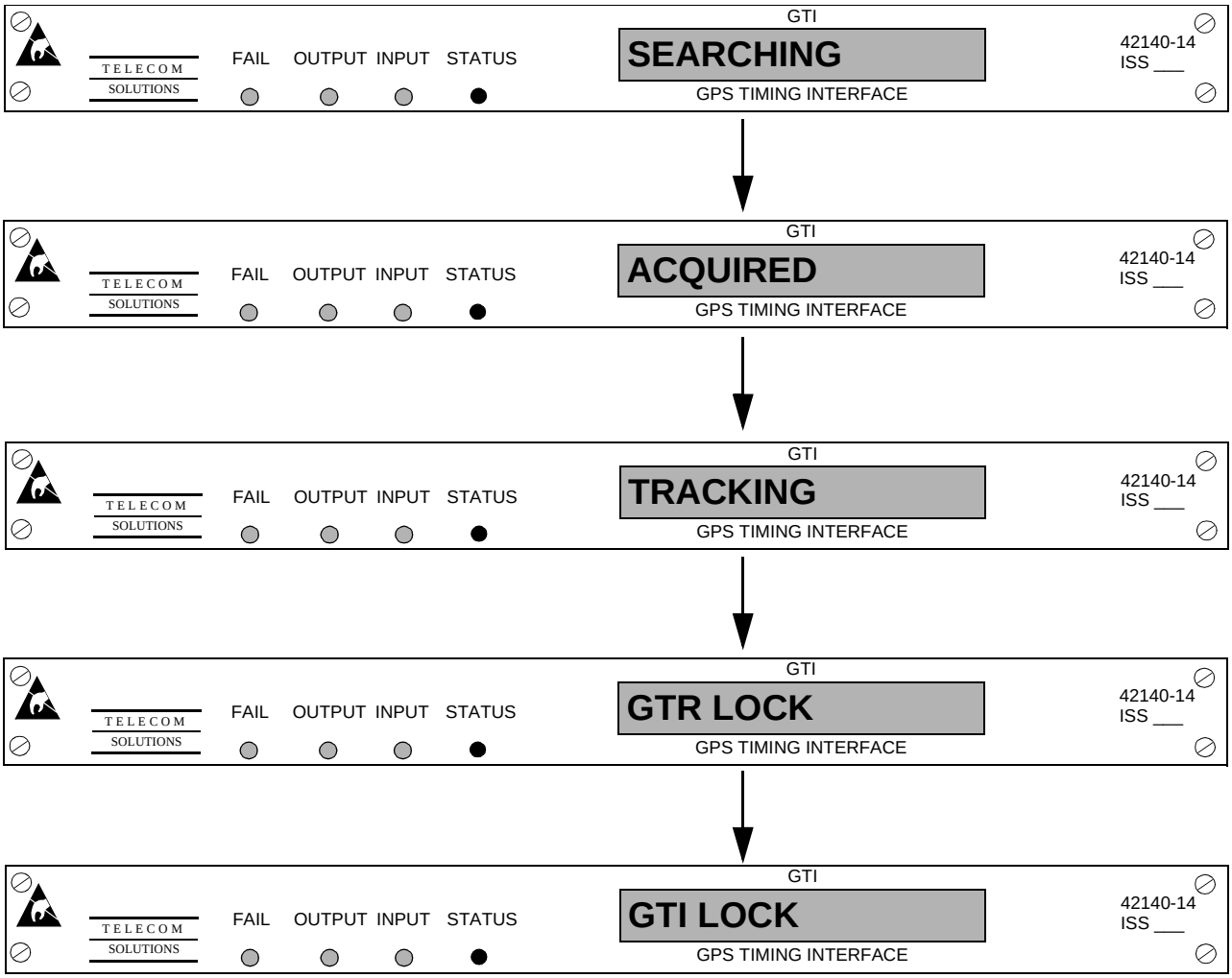
SECTION 1	SECTION 2	ALARM DELAY TIME (Note 1)		FACTORY SETTING
		MINOR ALARM	MAJOR ALARM	
OFF	OFF	4 hours	24 hours	X
ON	OFF	3 hours	18 hours	—
OFF	ON	1 hour	6 hours	—
ON	ON	10 minutes	1 hour	—

GTI/C -14 Switch Settings (Sections 3 through 8)

SECTION	POSITION	MEANING	FACTORY SETTING
3	ON	Output is squelched when the GTI/C has a Major alarm	—
	OFF	Output is AIS when the GTI/C has a Major alarm	X
4	ON	CCS output framing format	—
	OFF	CAS output framing format	X
5 and 6	OFF	TNCE Clocks supplying 5 Mhz	X
	ON	TNC Clocks supplying 5 Mhz	—
7 through 8	OFF	Reserved for factory use (must be set to OFF)	X

GTI Card Switch and Jumper Settings (Detail)

VA 9



GTI Card Front Panel VA 10

GTI LCD Display: Home Display (GPS STATUS)

The Home Display is the GPS STATUS screen, which displays the following:

state hh xx

where:

state = current state of the GTI (SEARCHING, ACQUIRED, TRACKING, GTR LOCK, GTR UNLOCK, or GTI LOCK) (explanations below)

hh = total hours in that state (after 99 hours in one state, display freezes at 99)

xx = alarm severity (MJ = major, MN = minor)

SEARCHING: The GTR is looking for satellites because it has either lost or never had the GPS constellation almanac. For example, this state exists during GTR powerup. However, during powerup, no E1 is output from the GTI card.

ACQUIRED: The GTR has found at least one valid satellite and is acquiring GPS almanac information. During acquisition, the GTR finds and locks onto as many satellites as possible. On powerup and while acquiring, the GTI outputs an E1 based on an average of the inputs from the DCD system.

TRACKING: Reception from at least four satellites is required to enter this state. The GTR is determining its position to a high degree of accuracy, based on the geometry of the four satellites being received. In this state, the GTI outputs an E1 based on an average of the inputs from the DCD system.

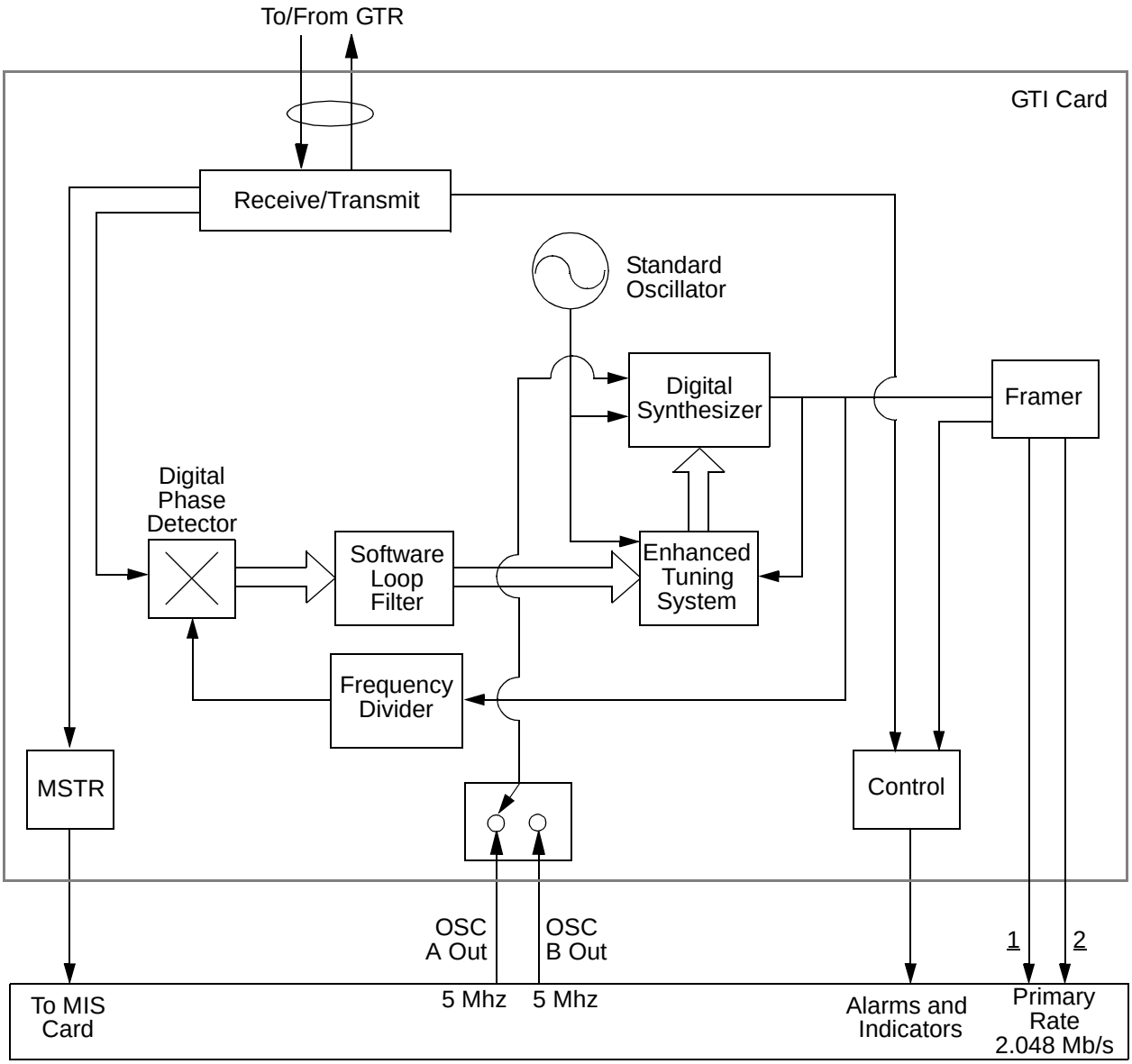
GTR LOCK: The GTR locks when its position is known. The GTR is locked when:

- it has received two position readings after two consecutive hours of averaging with less than 15 meters of difference, or
- the 4-khz clock signal from the GTR is stable.

GTI LOCK: This is the final and highest state and indicates that the 4-khz clock from the GTR is stable, as determined by the GTI, using a leaky bucket algorithm*. The output of the GTI is now being steered by the UTC-traceable GPS signals. If the 4-khz clock signal becomes unstable, the GTI card reverts to the GTR LOCK state after approximately 4 hours.

GTR UNLOCK: This state indicates that the GTR was in either the GTR LOCK or GTI LOCK state, but because for some reason, the GTR has lost its position or the 4-khz clock signal is unstable as determined by the leaky bucket algorithm*. While in this state, the GTR attempts to resume normal operation and enter GTR LOCK, then GTI LOCK.

* This leaky bucket algorithm is set such that if the clocking information from the GTR appears to be astray, the GTI filters those effects in an attempt to keep the E1 output within the MTIE performance mask.



DCD 500 Shelf

GTI Block Diagram Using PLL with Direct Digital Synthesis (DDS) Technology

VA 11

GTI E1 Output Signals

On powerup, while in searching, acquired, tracking, and GTR Lock modes, the GTI card outputs an unframed all-ones signal, an AIS signal, or the output is squelched, depending on the user-configured setting. This condition persists until the GTI has qualified all the GPS inputs, correlated its position, and is ready for PRS operation. At this point, the GTI will have entered “GTI LOCK” and now outputs a valid framed all-ones output signal.

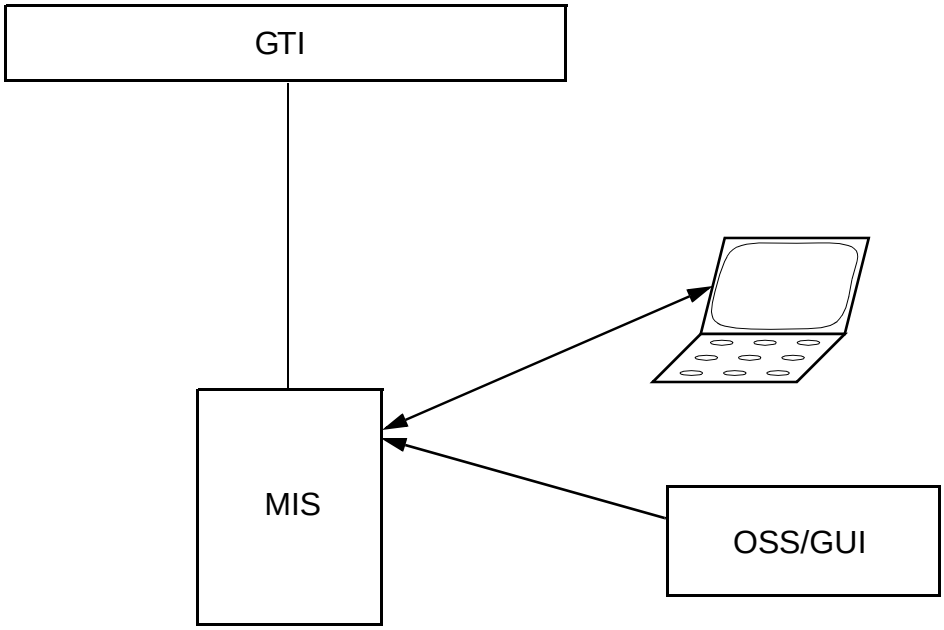
Typically, the GTI only outputs AIS or squelches its output when a major alarm is raised, e.g., loss of all inputs—both DCD oscillators, plus the GTR signal. The DCD 500 CI-EA and MRC-EA input cards will fail and will not accept an input on an AIS signal.

The GTI provides E1 output frequency (2.048 Mb/s) to the DCD-500 series Shelf. In addition, framing formats are switch-selectable. The framing formats are CAS, CRC.

The enhanced DDS software loop filter produces an offset digital word to the digital synthesizer, to maintain the G.811 value. This offset word is a weighted-average control circuit. In the event that the signal from the GTR fails or is rejected, the offset word (software loop filter and enhanced tuning system) enables the digital synthesizer to produce the required offset to the oscillator inputs and keep the output within the G.811 standards.

When the rubidium 5-Mhz input is used, the lost input degrades the digital synthesizer, but the output is maintained within the G.811 mask for a minimum of 24 hours. The GTI chooses one of the two 5-Mhz inputs to the digital synthesizer. The other input is measured, but not used as part of the solution. When a quartz 5-Mhz input is used, the lost input degrades the digital synthesizer, but the output is maintained within the G.811 mask for 6 hours.

The control circuitry passes alarm information from the GTR to the alarm inputs of the DCD. The MSTR circuitry passes GPS status information to the DCD MIS card. Commands from the MIS card to the GTR retrieve satellite status information and present it to OSS systems or graphical user interface (GUI) applications.



- Place GTI in service
- Modify GTI parameters
- Retrieve GTI Information

GTI Commands

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GTI Commands

– Place GTI in service

"ENT-EQPT: TID: GTI-1: CTAG: CAS, 1NH,RB, RB, 1;"

where CAS = Channel Assigned Sequence
1NH = All outputs are squelched when card in Maj Alarm
RB = OSC (A or B) is rubidium clock or
QTZ = OSC (A or B) is quartz clock
1 = Alarm integration time

"RST-EQPT: TID: GTI-1: CTAG;"

– Modify equipment parameters

"ED-EQPT: TID: GTI-1: CTAG:: CAS4, ALW,, QTZ, QTZ, 2;"

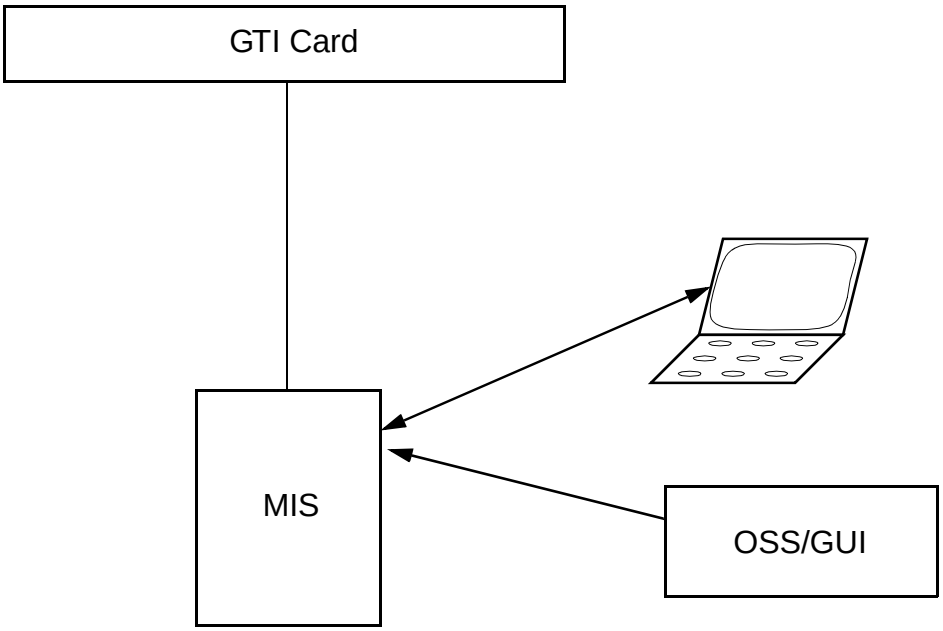
where CAS4 = Channel Associated Signalling with Cyclic Redundancy Check 4
ALW = AIS is sent when card in Maj Alarm
QTZ = OSC (A or B) is quartz
2 = Alarm integration time

– Retrieve GTI parameters

"RTRV-EQPT: TIO: GTI-1: CTAG:"

Response:

"GTI-1: CAS4, ALW,,QTZ, QTZ, 2"



- Retrieve GPS statistics

GTI Commands (Contd)

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GTI Commands (Contd)

– Retrieve GPS statistics

"RTRV-GPS-STAT: TID: GTI-1: CTAG;"

Response:

"GTI-1
UTC-TIME = 02: 04: 14
LOCATION = 3724.510-N-12156.866-W-111,
SAT-IN-VIEW = 4
SAT-2 = 343-71-47
SAT-7 = 189-51-46
SAT-15 = 76-14-41
SAT-19 = 117-23-43
GTIMDEG = 30E-12
OSCIFFREQ = 21-E9
OSC2FFREQ = 3873E-12"

where LOCATION = Latitude, longitude, and altitude (in meters)
SAT format = Satellite azimuth (degrees relative to true north), elevation, and signal-to-noise (db)

NOTES: