Agilent 85121A

Payload Test System Family

Product Overview

Figure 1.
The typical payload test system is customizable for specific measurement requirements.

Satellite-industry manufacturers have shown that automated payload testing improves measurement repeatability and reduces test time, resulting in faster satellite integration cycle time.

- Standard system configuration for 1-20 GHz testing applications
- Frequency extension options available for UHF and Ka bands
- Single setup for testing multiple transponders
- Complete suite of response and distortion measurements
- Easy-to-use system software in Windows NT® environment
- High measurement repeatability through automated system calibration
- Customization available for specific requirements

Agilent Technologies
Innovating the HP Way

Payload test system configuration

The Agilent 85121A Payload Test System (PTS) is an automated system for evaluating the radio frequency (RF) performance of communications satellite transponders, telemetry transmitters, and command receivers. The PTS presented in this document is Agilent Technologies' typical configuration (see Figure 1), which can be customized for specific measurement requirements. The typical PTS measurements and equipment are from Agilent's solution repertory developed for satellite customers.

The Agilent 85121A PTS integrates instrumentation hardware and software to provide a flexible, mobile test system that meets the needs of many test environments in satellite manufacturing and pre-launch operations. Automatic measurements in the Windows NT operating environment (see Figure 2) provide an easy-to-operate system that significantly reduces test time. Satellite manufacturers using Agilent's PTS have reduced integration and test cycle time, resulting in reduced labor costs and faster time to satellite launch.

The typical PTS instrumentation configuration is mounted in a rack assembly (see Figure 1) optimized for mobility within the factory for various testing stations: integration and test, highbay, antenna range, and thermal vacuum test facilities. Because of its compact size, the PTS can also be moved to a launch site for post-transport and pre-launch spacecraft testing.

The PTS design is based on years of Agilent experience at providing test systems to the major satellite-industry manufacturers worldwide for testing components, subsystems, antennas, and payloads. The Agilent 85121A PTS provides consistent, repeatable measurements throughout the integration and test manufacturing process. The user can, therefore, expect a high degree of correlation between measurements made during different stages of manufacturing, from panel and payload through spacecraft testing.

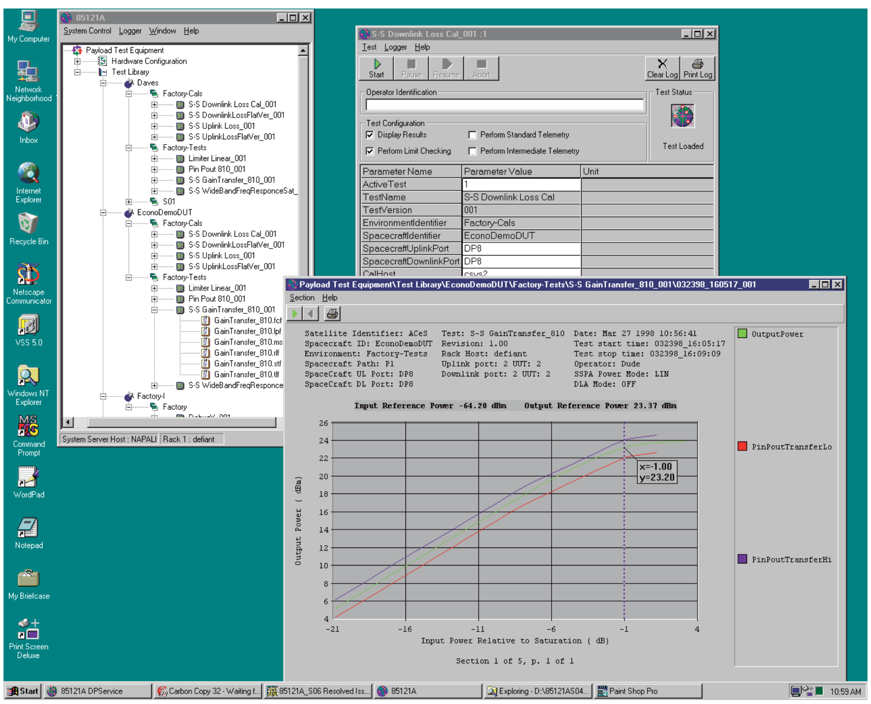
The typical PTS has the following characteristics:

- Single channel operation (A second channel can be added with another PTS rack.)
- Single- and two-tone measurements
- 1–20 GHz frequency coverage
- 18 uplink and 18 downlink ports

Enhancements are available for the typical PTS, and Agilent can evaluate customer-requested customizations for feasibility, cost, and delivery. Some PTS options currently available include the following:

- Frequency extensions
  - UHF band: 100–1000 MHz
  - Ka band: 27.5–31.0 GHz uplink, 18.0–21.2 GHz downlink
- Multiple-tone measurements
  - Noise power ratio (NPR)
  - Error vector magnitude (EVM)
- Specific number of uplink and downlink ports
- Additional channels
- Additional measurements

Figure 2.
The PTS provides an easy-to-use Windows NT measurement environment. The open windows (shown from the top left going clockwise) are the main window, test control window, and graphical data display.



Measurement equipment

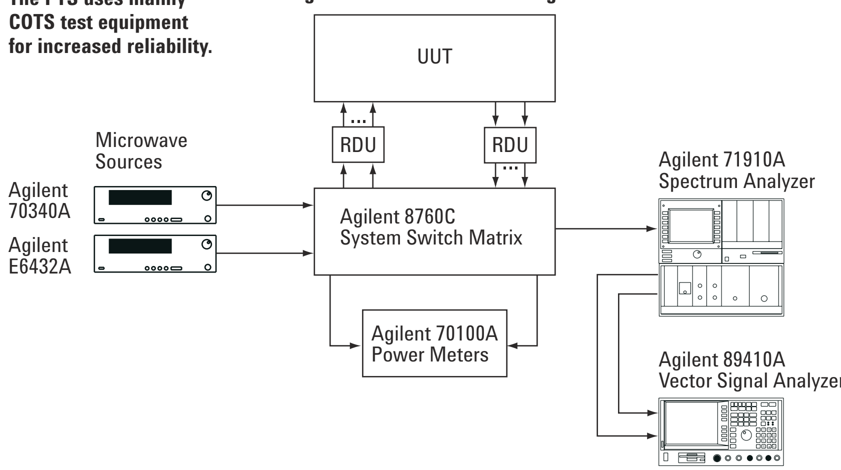
The block diagram in Figure 3 illustrates how the typical PTS instrumentation (see Figure 1) connects to a unit under test (UUT), which is a communications payload. Two microwave synthesizers (70340A and E6432A) provide the RF stimulus for the measurements. For the receiver and analysis equipment, a broadband spectrum analyzer (71910A) downcoverts the RF to an intermediate frequency (IF) or baseband signal for a vector signal analyzer (89410A). RF power meters (70100A) provide accurate signal level measurements and are used for system calibration.

The PTS switching subsystem is composed of two switching matrices (the 8760C family) that route signals within the rack and between the rack and the UUT. For rack-to-UUT signal routing, a removable distribution unit (RDU) can be placed near the UUT to minimize the number of long RF cables. That is, while 18-uplink/down- link cable pairs run between the RDU and the UUT, only one pair runs between the RDU and the PTS rack. The RDU also minimizes high-frequency cable loss for absolute power measurements because the power meter sensor heads are located in the RDU.

The PTS design minimizes the number of instruments by maximizing the use of the selected equipment and using test software to run the measurements and collect the data. The system hardware consists primarily of commercial off-the-shelf (COTS) test equipment. Use of COTS equipment provides a system with high reliability, high mean time between failures, and low mean time to repair.

Figure 3.
The PTS uses mainly COTS test equipment for increased reliability.

Agilent 85121A PTS Block Diagram



Computer equipment

The typical PTS includes two computers needed to perform UUT measurements: a measurement computer for each equipment rack, and a system computer that communicates with up to five racks (see Figure 4). The measurement computer is devoted to rack equipment control in performing UUT measurements. The system computer is devoted to system functions, such as data collection and test setup, for the different measurement racks in the system. It also communicates with the customer's host computer (not provided with the PTS) that controls test sequencing and data analysis. Both measurement and system computers are necessary to minimize test time, maximize test data collection, and optimize overall system operation.

The measurement computer can be located near to or installed in the PTS rack, and it includes an industrial grade Pentium® personal computer (PC) with a monitor and keyboard. The system control computer can be located near the PTS rack or at a remote location, and it uses a Pentium PC with a monitor, keyboard, and LaserJet printer (see Figure 5). An uninterruptable power supply (UPS) protects both computers from data loss during a power outage.

Computer software includes test algorithms for running the measurement equipment and system control for simultaneously operating multiple measurement racks and collecting test data. The system computer stores test data, and the printer provides hard copies of tabular and graphical test results. Through a graphical user interface (GUI) shown on both computer monitors, the PTS operator can setup and run tests and collect test results.

The PTS operates in either of two modes:

- Standalone: the operator conducts tests from the GUI displayed on the system control computer or the measurement computer.
- Remote: an operator executes tests from a remote host computer that communicates to the PTS system control computer through a LAN interface. This mode requires external test executive or sequencer software not supplied with the typical PTS.

Figure 4.
An operator can perform standalone testing from the system or measurement computer or remote testing from the host computer.

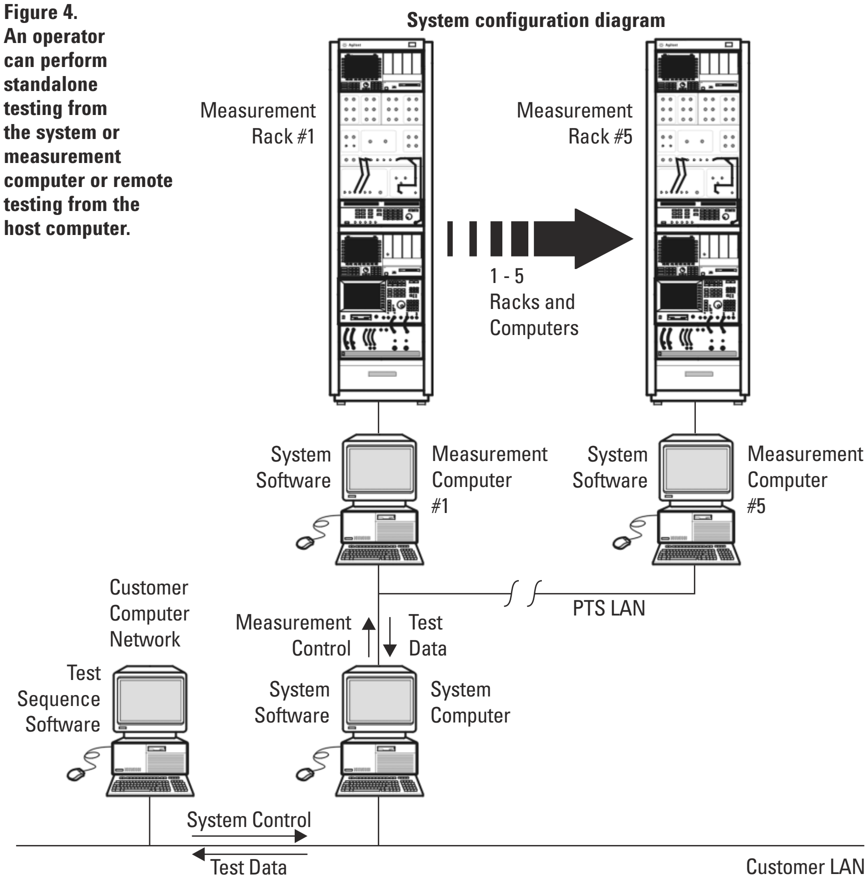


Figure 5.
The operator runs PTS measurements from the system control computer.

System software

The diagram in Figure 6 shows the major software blocks of the PTS software package. The shaded bubbles indicate software, not provided with the typical PTS, that would run on the customer's host computer. The Agilent software provided with the system includes four basic sections:

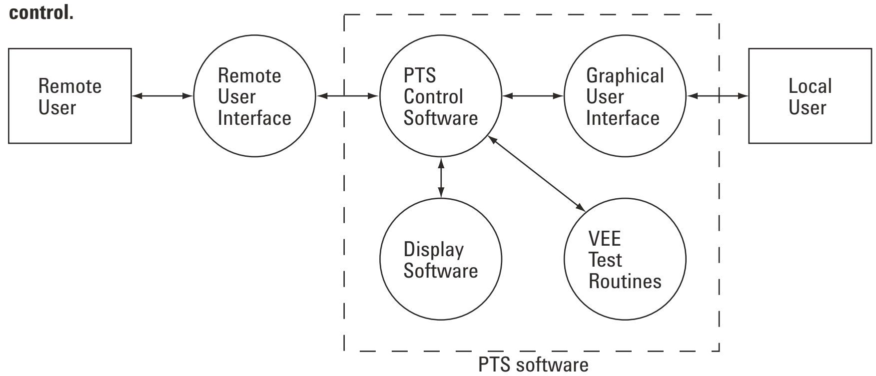
- PTS control software
- GUI software
- Agilent Visual Engineering Environment (Agilent VEE) software test routines
- Display software

The system software includes proprietary test algorithms that run in the Microsoft Windows NT operating environment. Operators run the PTS through the GUI, which has an intuitive windows-based structure. Test data gathered by the system computer can be stored or printed.

The PTS can be controlled externally with test-executive or sequencer software. This software can be provided by the customer or by Agilent as an option. External test sequencing can be performed through the use of TCP/IP socket communication.

Figure 6.
The PTS software includes four basic sections of system control.

PTS software diagram

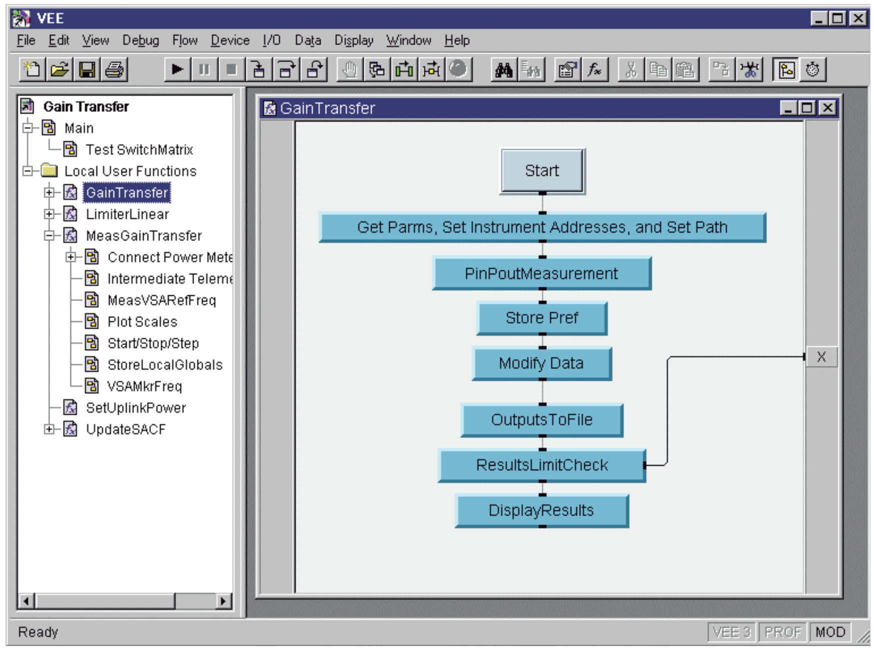


Test Software

Test algorithms were designed with Agilent VEE software, which is an easy-to-use, graphical test development tool (see the test-development window in Figure 7). VEE allows test developers to modify and add tests, while not requiring an in-depth knowledge of higher level programming languages such as C++. VEE instrument drivers provide system interfacing between the test instruments and the measurement software.

The measurements provided with the typical PTS are based on satellite industry accepted test methods for payload equipment, and they have been analyzed for accuracy and repeatability. The analysis has been verified with test equipment that has measurement accuracies traceable to industry standards. The PTS design and accuracy have been proven by multiple customers on multiple satellite programs.

Figure 7.
PTS tests can be modified using the Agilent VEE test-development window.



PTS operation

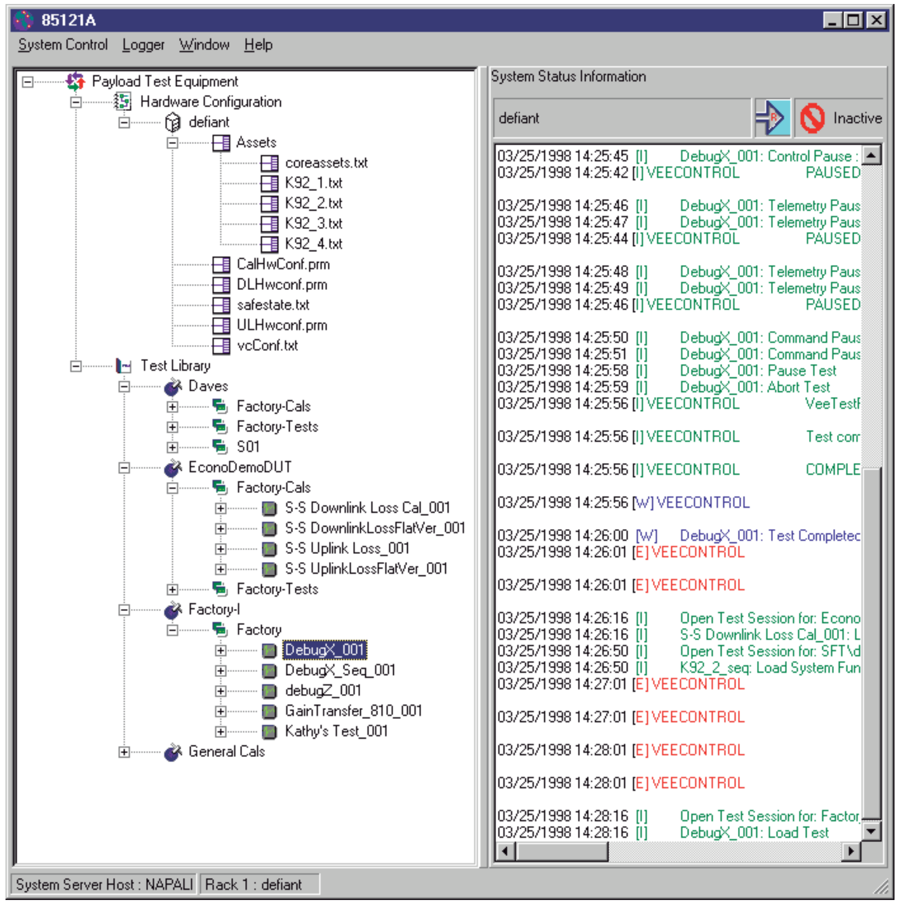
By using the computer GUI, the test operator controls the PTS, selects and runs tests, recovers test results, and verifies system functionality. The following examples demonstrate how the operator runs the PTS.

Controlling the system

An entire system of multiple PTS racks or individual racks can be operated from the GUI. From the main screen shown in Figure 8, the operator can perform the following functions.

- Define which assets are in a specific rack (e.g. the number and type of switch matrixes)
- Run tests or calibrations
- Add or remove spacecraft, environments, or tests
- Launch a text editor to modify files that define test parameters, data presentation, and other settings

Figure 8.
The operator can run tests and calibrations from the main screen.

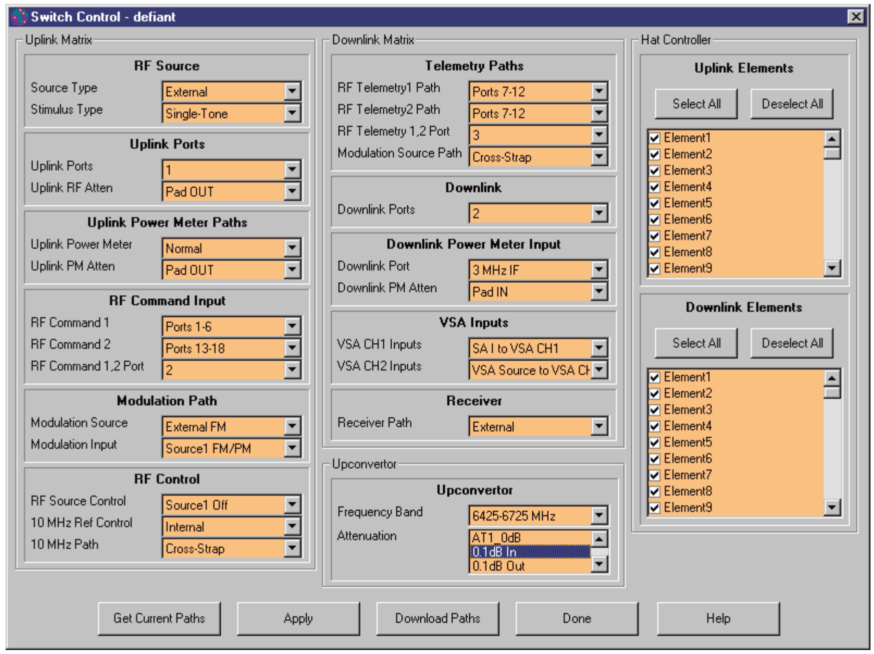


Controlling the switch matrix

Although the switch matrices are automatically set up by the system software, operators can manually control the signal routing. From the switch-control window (a typical example is shown in Figure 9), the operator can set up a switch matrix to route signals throughout the PTS and between the PTS and the UUT:

- Select the uplink and downlink
- Select whether attenuators are in or out of the signal or power meter paths
- Select modulation source
- Select modulation type (AM or FM)
- Select power meter operational mode (RF/IF measure or calibration)
- Interrogate the switch matrix to view its current settings

Figure 9.
The operator defines signal routing with the switch-control window.

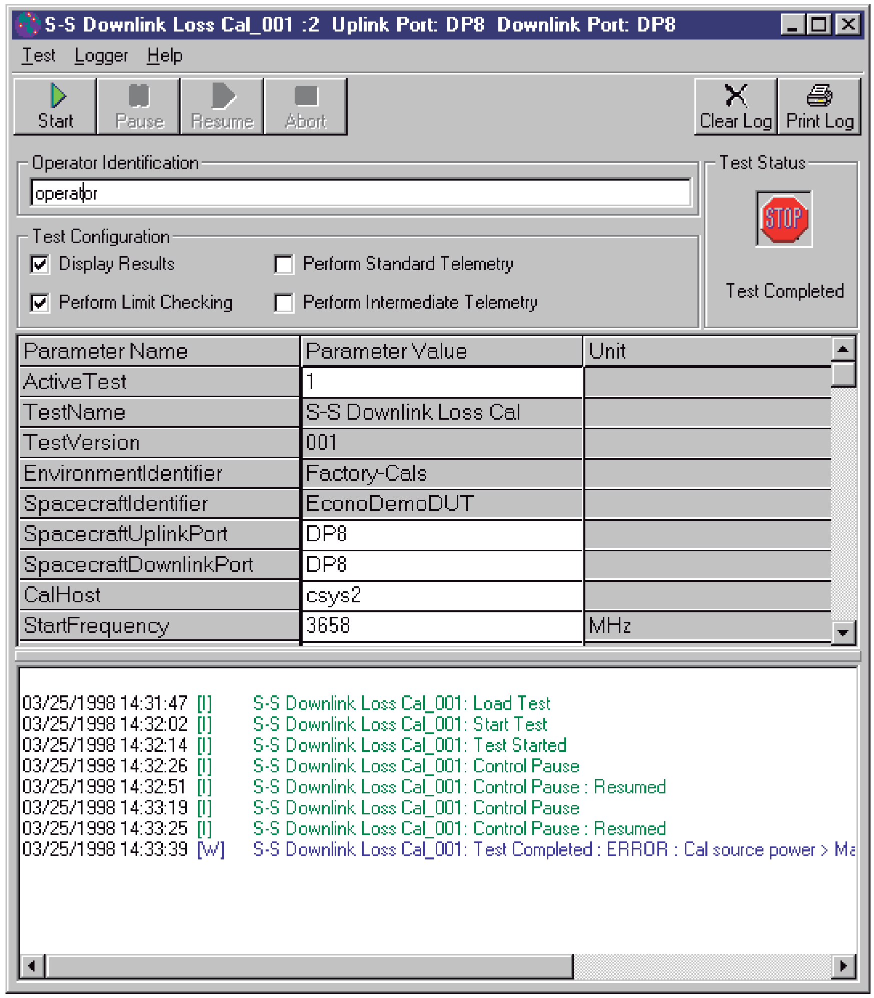


Running tests

From the test-control window shown in Figure 10, the operator can perform the following functions:

- Select and start tests
- Log test execution
- Perform limit checking
- Display and print test results

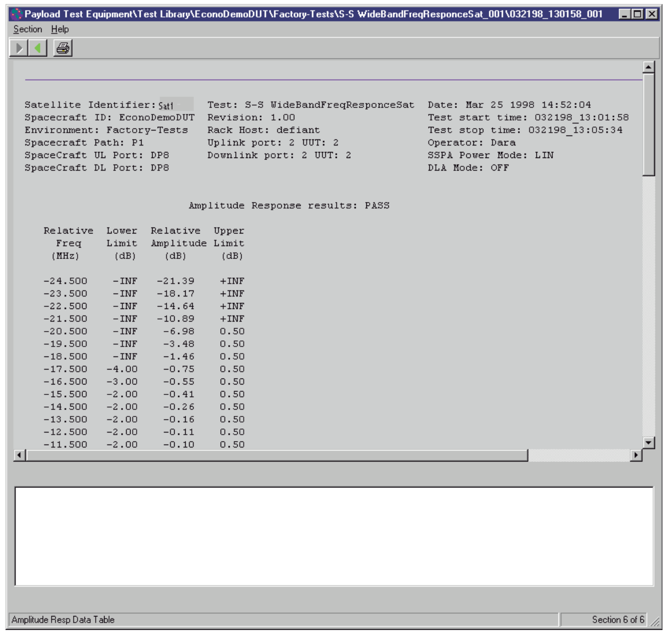
Figure 10.
Tests are started from the test-control window.



Viewing and printing results

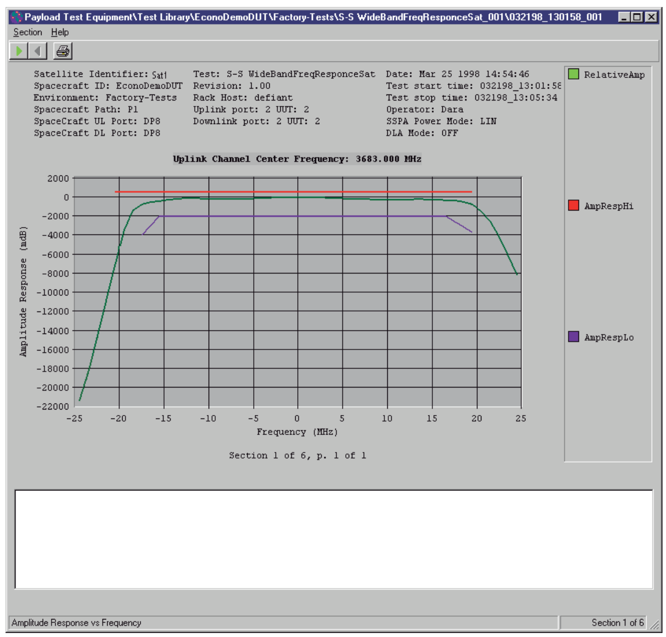
Test results can be viewed on the computer display and printed in both tabular and graphical form. The operator can select the test data file and header, which contains the test title, time the test was run, and other test information. For tabular data, the operator can select the table size, location, column width, and other formatting. For graphical data, up to eight data sets and 16 limit lines can be put on a single graph. A wide band frequency response test example is shown in Figure 11 for tabular data and Figure 12 for graphical data.

Figure 11.
Tabular results for the wide band frequency-response test



Relative Freq (MHz)	Lower Limit (dB)	Relative Amplitude (dB)	Upper Limit (dB)
-24.500	-INF	-21.39	+INF
-23.500	-INF	-18.17	+INF
-22.500	-INF	-14.64	+INF
-21.500	-INF	-10.89	+INF
-20.500	-INF	-6.98	0.50
-19.500	-INF	-3.48	0.50
-18.500	-INF	-1.46	0.50
-17.500	-4.00	-0.75	0.50
-16.500	-3.00	-0.55	0.50
-15.500	-2.00	-0.41	0.50
-14.500	-2.00	-0.26	0.50
-13.500	-2.00	-0.16	0.50
-12.500	-2.00	-0.11	0.50
-11.500	-2.00	-0.10	0.50

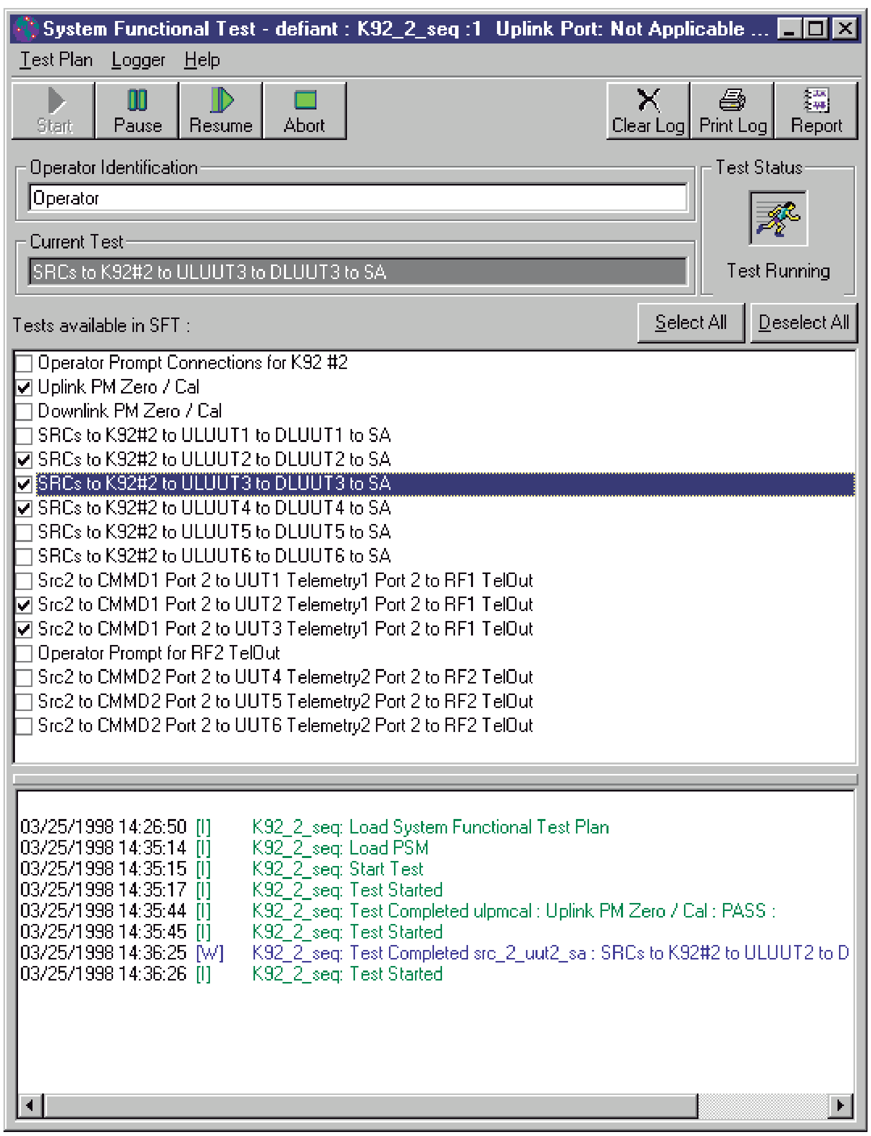
Figure 12.
Graphical results for the wide band frequency-response test



Verifying system operation

A system functional test (SFT) can be run at any time to verify that the PTS is functioning properly for instrument operation and signal path integrity. The SFT also provides a quick method of troubleshooting PTS equipment. The operator can select any or all tests from the SFT window (see Figure 13), and the PTS automatically runs the tests in sequence and reports the pass or fail results at the bottom of the window.

Figure 13. System operation can be verified by running an SFT.



Measurement description

The PTS measurement suite is described in the documentation package for the system. Detailed descriptions include the following information for each measurement.

- Test setup diagram showing test equipment and signal paths
- Detailed test description
- Input and output data descriptions
- Test input parameters with mnemonics for the program schedule message
- Test output data packages with mnemonics
- Test limits
- Test calibration file with correction file mnemonics
- Test accuracy summary
- Typical test time when available

The communications payload measurements include tests for fulltransponders and individual receivers and transmitters. Optional telemetry, tracking, and command (TT&C) measurements provide tests for the command receiver and telemetry transmitter, including the ranging path delay. The following standard and optional measurements are grouped into single- tone, radiated, and two-tone categories.

Single-tone measurements

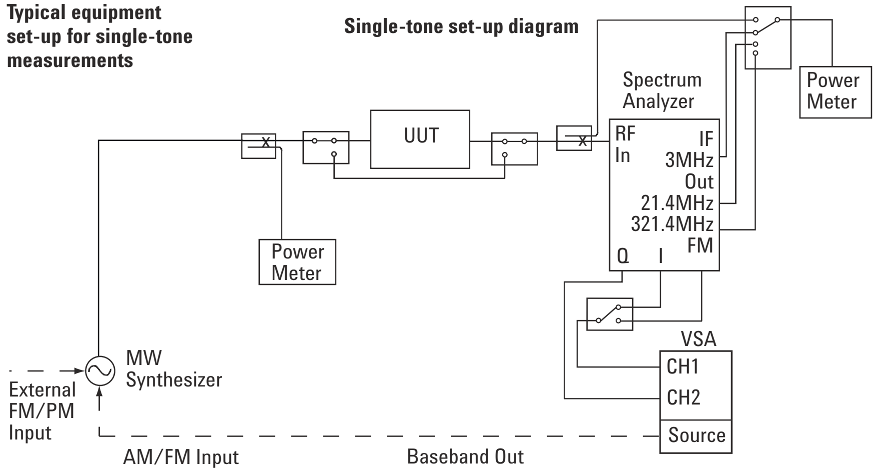
The following are summary descriptions for each single-tone measurement. The measurements are performed with uplink-source and downlink-receiver equipment: the Agilent 70340A microwave synthesizer is the source with the 70100A RF power meter; the receiver is composed of the 71910A spectrum analyzer, 89410A vector signal analyzer, and 70100A RF power meter. See Figure 14 for the typical measurement setup for single-tone measurements.

1) **Command threshold:** Determine the minimum uplink RF-power level at which the spacecraft command receiver can demodulate a spacecraft configuration request–optional TT&C measurement.

2) **Power and frequency:** Verify the amplitude and frequency of an unmodulated carrier wave (CW) tone for high- and low-level outputs and spacecraft telemetry–optional TT&C measurement.

3) **Modulation index:** Determine the frequency-modulation (FM) indexes for the beacon or telemetry carrier with any number of sub-carriers present, the individual sub-carriers, and the combined carrier with sub-carriers–optional TT&C measurement.

Figure 14.
Typical equipment set-up for single-tone measurements



4) **Ranging delay:** Measure the delay through the spacecraft for each command receiver and telemetry transmitter combination–optional TT&C measurement.

5) **Ranging threshold:** Determine the RF-uplink power level at which the spacecraft command receiver can no longer demodulate the uplink ranging tone–optional TT&C measurement.

6) **Gain transfer:** Determine the saturation point and characterize the gain-transfer curve for the transponder.

7) **Group delay:** Verify the relative group delay across a communication channel.

8) **In-band frequency response:** Verify amplitude flatness across a communication channel.

9) **Wide-band frequency response:** Measure the amplitude flatness and verify the out-of-band rejection characteristics of a communication channel.

10) **Amplitude Modulation (AM) to Phase Modulation (PM) conversion:** Measure the AM-to-PM conversion on a carrier passing through the transponder—optional measurement.

11) **Carrier-to-noise ratio:** Verify the system noise-figure performance of the transponder using the carrier-to-noise ratio technique.

12) **Noise figure:** Verify the system noise-figure performance of the spacecraft using the noise power reference technique.

13) **Frequency translation:** Verify the net frequency conversion through the transponder.

14) **Gain adjustment:** Verify the commandable gain control of the transponder.

15) **Attenuator adjustment:** Verify the commandable attenuation of the transponder.

16) **Spurious response without drive:** Examine the in-band and out-of-band spectrums of the transmit output for undesired spurious signals with no input signal applied to the spacecraft.

17) **Automatic-Level-Control (ALC) characterization:** Characterize the gain-transfer curve for the transponder in ALC mode—optional measurement.

18) **Limiter/linearizer characterization:** Characterize the gain-transfer curve for the transponder.

19) **Out-of-band attenuation:** Verify the channel-rejection characteristics at each band edge.

20) **Spurious response with drive:** Examine the in-band and out-of-band spectrums of the transmit output for undesired spurious signals with an input signal applied to the spacecraft.

21) **Repeater isolation:** Verify the isolation characteristics of the spacecraft.

Radiated Environment Tests

The following optional measurements are performed in a radiated environment using tests from the single-tone measurements (previous items 1-21). See Figure 15 for the typical equipment setup for measurements in a radiated environment.

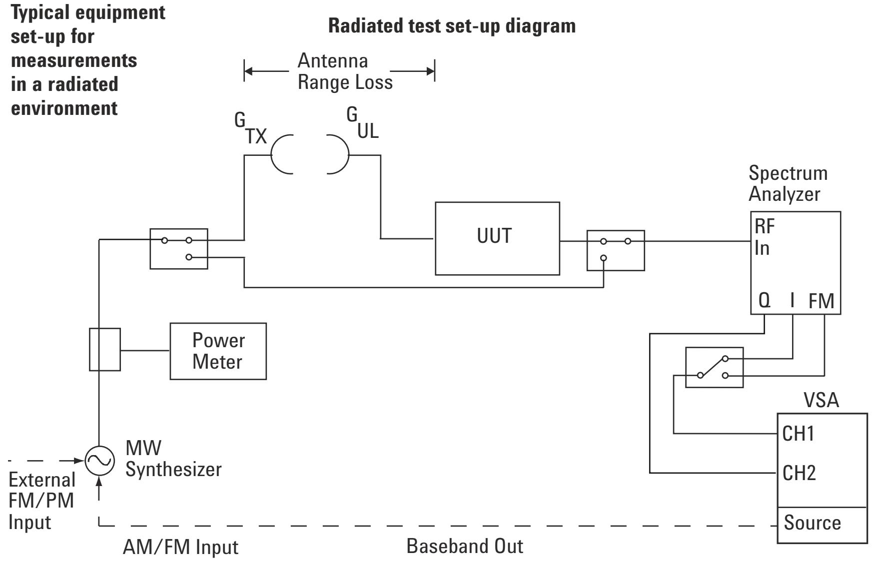
1) **Command receiver minimum flux density:** Determine the minimum uplink flux density at which the spacecraft command receiver can demodulate a spacecraft configuration request—optional measurement.

2) **Beacon or telemetry Effective Isotropic Radiated Power (EIRP):** Verify the amplitude and frequency of a CW tone (unmodulated) for high- and low-level downlink outputs and spacecraft telemetry—optional measurement. The measured amplitude is corrected to represent the EIRP.

3) **Communication payload Saturated Flux Density (SFD) and EIRP:** For the uplink and downlink, determine the saturation point and characterize the gain-transfer curve for the transponder—optional measurement. The measured amplitudes for the uplink and downlink are corrected to represent the SFD and EIRP respectively.

4) **Gain to temperature:** Verify the noise-figure performance of the transponder including the antenna gain—optional measurement.

Figure 15. Typical equipment set-up for measurements in a radiated environment



Two-tone measurements

The following are summary descriptions for each two-tone measurement. The measurements are performed with the single-tone measurement equipment and an additional source, the Agilent E6432A microwave synthesizer, for the second tone. See Figure 16 for the typical equipment setup for two-tone measurements.

1) **Passive Intermodulation (PIM):** Identify PIM related performance problems in the payload when a transponder is loaded with two carriers that cause intermodulation products to appear in the receive band of another transponder.

2) **Active intermodulation:** Measure the non-linear characteristics of the payload by applying two equal-amplitude CW signals to the uplink input, and measure the intermodulation products at the downlink port.

3) **AM-to-PM transfer:** Measure the transfer of AM from one carrier into PM on an unmodulated carrier passing through the payload—optional measurement.

Multi-Tone measurements

The following are summary descriptions for optional multi-tone measurements. The measurements are performed with the single-tone measurement equipment, and the single-tone source is replaced with a wide bandwidth (example, 80 MHz and wider), multiple tone source needed for testing digital communications equipment. The wide bandwidth source is composed of an arbitrary waveform synthesizer (AWS) and a microwave source that functions as a wide band upconverter. See Figure 17 for the typical equipment setup for multi-tone measurements.

Figure 16. Typical equipment set-up for two-tone measurements

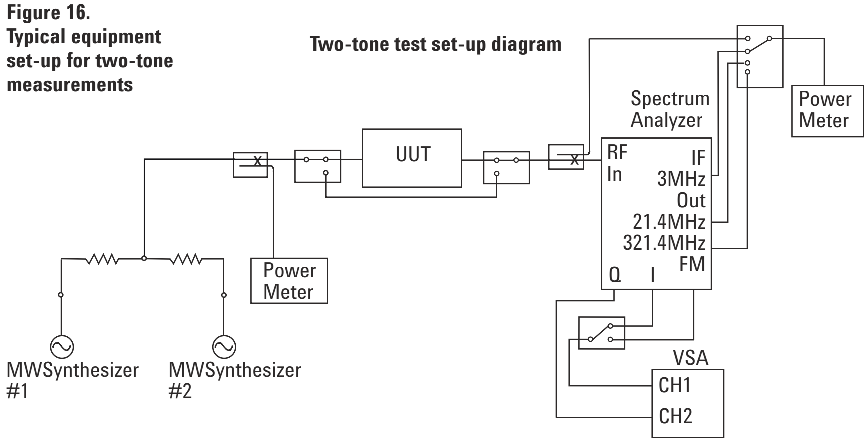
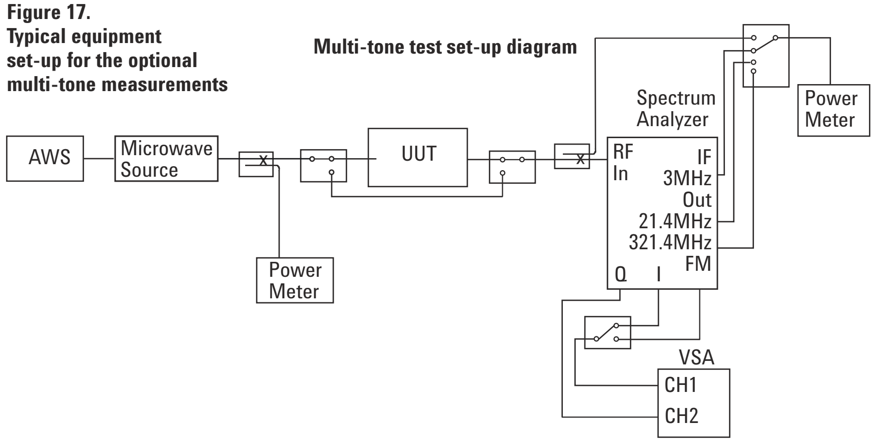


Figure 17. Typical equipment set-up for the optional multi-tone measurements



1) **Multi-carrier gain transfer:** Determine the normal operating point and the gain transfer characteristics for the transponder—optional measurement.
2) **Amplitude and phase tracking:** Verify the relative amplitude and phase relationship between all the elements of a particular beam—optional measurement.
3) **Noise Power Ratio (NPR):** Characterize the linear performance of a transponder channel including the channelizer and high power amplifier—optional measurement.
4) **Error Vector Magnitude (EVM):** Measure the quality of a demodulated signal for quadrature modulated communications systems—optional measurement.

Calibration description

PTS calibration is an automated, two-step process as follows:

- First, the PTS automatically calibrates the individual instruments in the PTS measurement rack by running built-in calibration routines. The PTS user can set the calibration interval.
- Second, the PTS performs a system calibration on the uplink and downlink UUT paths at the spacecraft interface. These calibrations are referenced to power meter sensors that have traceability to the National Institute of Standards and Technology (NIST). The PTS user initiates the calibration, which should be performed only when the test setup is changed.

Performing a system calibration is similar to running a spacecraft measurement because the calibration tests are selected and started from the test-control window. The following calibration selections are available.

- Group delay calibrations
- Uplink UUT path calibration
- Downlink UUT path calibrations

Operators can select a calibration verification function that compares the last calibration value with the current one and displays the difference. This feature can be used as a confidence check of PTS calibration when UUT test results differ from expectations or drift over time. Also, after any period of UUT testing, verifying that the PTS calibration has not drifted provides confidence in the test data.

Specifications

The following measurement uncertainties in the table apply for room temperature (20° to 30° C) conditions, and uncertainty values are typical for PTS performance.

Measurement	Uncertainty
Single-tone measurements	
Command threshold	±0.25 dB
Power and Frequency	±0.25 dB and ±55 Hz
Modulation index	±0.1 rad
Ranging delay	±1 ns
Ranging threshold	±0.25 dB
Gain transfer	±0.25 dB
Group delay	±0.5 ns
In-band frequency response	±0.25 dB
Wide-band frequency response	±0.5 dB
AM-to-PM conversion	±0.09 rad
Carrier-to-noise ratio	±0.4 dB
Noise figure	±0.3 dB
Frequency translation	±55 Hz
Gain adjustment	±0.25 dB
Attenuator adjustment	±0.25 dB
Spurious response without drive	±0.5 dB
ALC characterization	±0.25 dB
Limiter/linearizer characterization	±0.25 dB
Out-of-band attenuation	±0.5 dB
Spurious response with drive	±0.5 dB
Repeater isolation	±0.5 dB
Radiated environment measurements (single tone)	
Command receiver minimum flux density	±0.5 dB
Beacon or telemetry EIRP	±0.5 dB
Communications payload SFD and EIRP	±0.5 dB
Gain to temperature	±0.4 dB
Two-tone measurements	
Passive intermodulation	±0.5 dB
Active intermodulation	±0.8 dB
AM-to-PM transfer	±0.09 rad
Multiple-tone measurements	
Multi-carrier gain transfer	±0.2 dB
Amplitude and phase tracking–amplitude	±0.2 dB
Phase	±0.2°
NPR	±0.4 dB
EVM	<3% RMS

Documentation

The documentation provided for measurement instruments, computer equipment, and the overall system include the following items:

- Installation guide
- Test operator's guide
- Test plan developer's guide
- Measurements reference
- Measurement uncertainty analysis
- System hardware reference
- Switch matrix manuals
- Instrument manuals
- Computer manuals
- Software manuals

Training

Technical training courses are provided to train the PTS users and help integrate the PTS into a company's internal test process. The typical training is provided in two separate classes, one for a cross-section of users and another for test operators. Additional training available, but not included with the typical PTS, includes a course for test developers and standard courses in instrumentation and software.

PTS operations class

This class provides a complete coverage of PTS operation for a cross-section of users. Installers learn how to configure and verify the system, operators learn how to run the system manually and automatically, and developers learn how to configure the system. Topics include the following:

- System overview – hardware and software architectures
- PTS file system overview
- Measurement description
- Manual hardware operation
- Troubleshooting
- System functional test
- PTS operation

Test operator class

This class is designed to train test operators how to operate the PTS. The course material follows the installation guide and test operator's guide and is similar to the PTS operations class—the same topics are covered, but in-depth theory of operation is omitted.

System installations

To insure that the PTS is installed correctly and is fully functional for the customer, Agilent provides the following installation services:

- Perform an acceptance test procedure (ATP) at the Agilent factory using a transponder simulator (This equipment is not part of the PTS and is used for acceptance testing only.)
- Deliver the PTS to the customer's site
- Install the system, and setup the equipment and software
- Verify system operation after installation at the customer's site using an SFT

Warranty and support

The PTS is warranted against defects in materials, workmanship, and operability (as the system was designed), for a period of one year from the date of installation. An optional two-year extended warranty for the PTS increases the total warranty period to three years. Agilent can also provide support contracts beyond the extended warranty period.

During the warranty period, any defective hardware instrument or lowest replaceable unit for the PTS will be repaired or replaced upon return to an Agilent Technologies service center. For software defects, Agilent will either deliver an improved software version or provide instructions on how to bypass defects.

Technical phone support is an available option for customers with questions on PTS operation and troubleshooting. Although on-site repair is not provided for the typical PTS, Agilent can provide this service with a separate support contract.

Ordering information

The typical PTS is composed of COTS equipment, which may have standard instrument options that can be installed at the customer's request. Customers can also request customizations to the standard PTS:

- Different switch-matrix features and configurations
- Additional COTS equipment
- Hardware customizations
- Additional customized measurements

Contact your local Agilent Technologies sales office for price and delivery on the following equipment.

Agilent 85121A payload test system

- 1–20 GHz frequency range
- 18 uplink and downlink ports
- Single measurement channel
- Single-tone, and two-tone measurements
- AM and FM for uplink source
- System software
- A selective set of measurement software
- Rack for test equipment and measurement computer
- System computer
- Printer
- Documentation
- Training
- One-year warranty

Agilent 85121A Options

- Additional measurements
- Additional measurement channels
- Frequency extension: UHF and Ka frequency bands
- TT&C measurements
- Radiated-environment measurements
- Multi-tone measurements
- User specified number of uplink and downlink ports
- Custom configurations available
- Two-year extended warranty
- Additional support services (e.g. on-site troubleshooting and technical phone support)

Agilent Technologies' Test and Measurement Support, Services, and Assistance

Agilent Technologies aims to maximize the value you receive, while minimizing your risk and problems. We strive to ensure that you get the test and measurement capabilities you paid for and obtain the support you need. Our extensive support resources and services can help you choose the right Agilent products for your applications and apply them successfully. Every instrument and system we sell has a global warranty. Support is available for at least five years beyond the production life of the product. Two concepts underlie Agilent's overall support policy: "Our Promise" and "Your Advantage."

Our Promise

Our Promise means your Agilent test and measurement equipment will meet its advertised performance and functionality. When you are choosing new equipment, we will help you with product information, including realistic performance specifications and practical recommendations from experienced test engineers. When you use Agilent equipment, we can verify that it works properly, help with product operation, and provide basic measurement assistance for the use of specified capabilities, at no extra cost upon request. Many self-help tools are available.

Your Advantage

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