Agilent
Physical Layer Test Systems

Data Sheet

N1947A  80 pS (300 kHz to 9 GHz)
N1948A  80 pS (300 kHz to 9 GHz)
N1951A  36 pS (50 MHz to 20 GHz)
N1953A  36 pS (45 MHz to 20 GHz)
N1957A  14 pS (45 MHz to 50 GHz)

NOTE:
Some specifications contained herein are preliminary and subject to change.
Design Confidence Through Complete Characterization

Physical-layer structures have increasingly become the bottleneck in high-speed digital system performance. As bus speeds, clock speeds, and link speeds all push past the gigabit-per-second mark, digital data no longer looks like simple ones and zeros. In fact, digital data begins to exhibit analog behavior such as reflections from discontinuities, dispersive loss, crosstalk, and EMI radiation and susceptibility. Analog analysis can be the key to solving such digital problems as overshoot, undershoot, ringing, rise-time degradation, pulse droop, dropouts, ground bounce, and eye closure.

Of course, Time-Domain Reflectometry (TDR) and Time-Domain Transmission (TDT) measurements are also important, as are familiar time domain views such as eye diagrams. These analyses are critical for complete understanding of device performance.

Another challenge for today’s digital designers is the trend to differential topologies. The benefits of differential signaling include lower voltage swings, immunity from power supply noise, a reduced dependency on a RF ground, and improved EMI performance (reduced generation and susceptibility). The extent to which a device can take advantage of these benefits is directly related to device symmetry. Therefore, mode-conversion analysis becomes yet another requirement.

These factors make it clear that physical-layer structures – passive linear components such as interconnects, backplanes, IC packages, cables, and the like – are significant elements affecting signal propagation and have become the focal point for the emerging discipline of signal integrity.

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Frequency Range</th>
<th>Rise Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1957A</td>
<td>E8364B PNA and N4421A Test Set 4-Port / 4-Receiver</td>
<td>45 MHz to 50 GHz</td>
<td>14 pS</td>
</tr>
<tr>
<td>N1953A</td>
<td>E8362B PNA and N4419A Test Set 4-Port / 4-Receiver</td>
<td>45 MHz to 20 GHz</td>
<td>36 pS</td>
</tr>
<tr>
<td>N1951A</td>
<td>8720ES VNA and N4418A Test Set 4-Port / 3 or 4-Receiver</td>
<td>50 MHz to 20 GHz</td>
<td>36 pS</td>
</tr>
<tr>
<td>N1948A</td>
<td>E8358A PNA and N4417A Test Set 4-Port / 4-Receiver</td>
<td>300 kHz to 9 GHz</td>
<td>80 pS</td>
</tr>
<tr>
<td>N1947A</td>
<td>E8803A PNA and N4417A Test Set 4-Port / 3-Receiver</td>
<td>300 kHz to 9 GHz</td>
<td>80 pS</td>
</tr>
<tr>
<td>N1930A</td>
<td>Physical Layer Test System software that controls the system and provides advanced data analysis tools</td>
<td>-----</td>
<td>----</td>
</tr>
<tr>
<td>N4430B</td>
<td>Fast, single-connection electronic SOLT calibration</td>
<td>300 kHz to 9 GHz</td>
<td>----</td>
</tr>
</tbody>
</table>
Comprehensive analysis has become necessary

As this combination of digital and analog analysis in several modes of operation becomes more important, the need for multiple test solutions becomes difficult to manage.

A single test solution that can fully characterize differential high-speed devices while leaving domain and format of the analysis up to the designer becomes the tool of choice. The four-port network analyzer-based Physical Layer Test System (PLTS) does just that.

PLTS has been designed specifically for signal integrity analysis and provides the best of both worlds. Both frequency and time domains in single-ended, differential-mode, common-mode, and mode-conversion terms are immediately available. A digital-pattern generator feature allows a user-defined bit sequence to be applied to the measured data to convolve eye diagrams. Next, accurate RLCG transmission line parameter models can be extracted and used to enhance the accuracy of your models and simulations.

The need for mode-conversion analysis

Mode-conversion analysis is an important tool for understanding and resolving device asymmetry, which is an additional challenge in high-speed differential interconnect design.

Ideal (symmetrical) differential devices only respond to, and only generate, differential signals (two anti-phase signals of equal amplitude). These ideal devices do not respond to or generate common-mode (in-phase) signals, and they reject radiated external signals (i.e. power supply noise, harmonics of digital clocks or data, and EMI from other RF circuitry).

Non-ideal devices, however, do not exhibit these benefits. When stimulated differentially, an asymmetrical device will produce a common mode response in addition to the intended differential response, and cause EMI radiation. Conversely, with a common-mode stimulus, an asymmetrical device will produce an unintended differential response. This mode conversion is a source of EMI.

Mode-conversion analysis provides the designer with early insight so that EMI problems can be identified and resolved at the design stage.

![Figure 1. Non-ideal (asymmetrical) devices cause mode conversions, which are indicators of EMI generation and susceptibility.](image)
The Agilent Signal Integrity Portfolio

Agilent offers a wide range of signal integrity solutions. Figure 2 shows where PLTS is positioned within the signal integrity market space. On the right side of this chart, several common products are shown. These include bit-error-rate testers, logic and protocol analyzers, and the like. It is important to note that these solutions are intended for live signal analysis and validation.

TDR or VNA system?

On the left-side of the chart, PLTS and TDR-based solutions are shown. These tools are more specific to the characterization of passive linear devices, rather than the signals on the device. Within this product area, the TDR-based system has traditionally been used. With the introduction of PLTS, a common question is “Which one do I need?”

Both of these systems have advantages and, in some cases where maximum versatility is required, the use of both systems may be appropriate. However, for signal integrity (SI) engineers who need quick, first-order measurements (and appreciate the ease-of-use and familiarity), the TDR-based system is the best choice.

PLTS adds enhanced accuracy and dynamic range (signal-to-noise ratio), greater ability to remove unwanted effects (non-device-under-test structures such as test fixtures), and a much more comprehensive analysis.

Figure 2. Agilent offers a wide range of test equipment to solve your most demanding signal integrity issues throughout the design cycle.
**The Advantages of PLTS**

**Accuracy**

Accuracy is made possible with:
- low-noise RF source
- phase-locked receiver (like a tracking filter, the receiver rejects noise outside of the immediate frequency of interest)
- systematic error-correction

Systematic errors are the predictable errors associated with all test equipment. In network analyzers, these are directivity and crosstalk related to signal leakage, source and load match related to reflections, and transmission and reflection tracking related to the frequency response of the receivers.

The full four-port error model includes all six of these terms for the forward direction and the same six (with different data) in the reverse direction, equaling twelve error terms over six signal paths (port 1-2, 1-3, 1-4, 2-3, 2-4, 3-4). A total of seventy-two error terms are measured during calibration. The correction is applied to the measured data.

**Dynamic range**

High-dynamic range is important for a number of reasons. Certainly measurement of very low levels of crosstalk is possible, but today's crosstalk specifications are typically within the range of traditional tools like the TDR (approximately –40 dB). Crosstalk is only one parameter where dynamic range is important.

More importantly is the ability to overcome masking effects of multiple discontinuities, which in systems with lower dynamic range would attenuate the stimulus such that deep structures would become invisible.

Most importantly for differential devices, high-dynamic range allows for identification of very low levels of mode-conversion, which are the direct result of device asymmetry. This allows early resolution of potential EMI issues.
Removing Unwanted Effects From The Measurement

Measurement results often include unwanted effects of test fixtures, signal launches, adapters, or other non-DUT structures. PLTS offers four methods for removing these unwanted effects.

- **Time-Domain Gating** is very easy and fast. The user simply defines a start and stop point, and the software mathematically replaces the measured data in that section with an “ideal” transmission line. With the enhanced dynamic range of the network analyzer, multiple gates are possible, but accuracy diminishes in proportion to the number of gates.

- **Port Extension** (also known as Phase Rotation) mathematically extends the calibration reference plane to the DUT, and is usually implemented after a coaxial calibration has been performed at the end of the test cables. This technique is also easy to use, but assumes the fixture – (the unwanted structure) looks like a perfect transmission line: a flat magnitude response, a linear phase response, and constant impedance. If the fixture is very well designed, this technique can provide excellent results.

- **De-embedding** uses an accurate linear model of the fixture, or measured S-parameter data of the fixture. This fixture data can then be removed mathematically from the DUT measurement data in post-processing. This is a very powerful technique and accurate, but is more difficult to employ as it requires fixture characterization.

- **Calibration** at the DUT Reference Plane has the advantage that the precise characteristics of the fixture don't need to be known beforehand, as they are measured during the calibration process. This technique is commonly used in wafer probe applications.

Comprehensive analysis

The last major advantage is the comprehensive nature of the measurement and analysis. With a single setup and measurement, an incredible amount of device data is available. Forward and reverse time-domain transmission (TDT) and time-domain reflectometry (TDR), in all possible modes of operation, in both frequency and time domains.

The same data can be used to convolve eye diagrams using the Digital Pattern Generator feature, and RLCG parameters can be extracted and used to improve the accuracy of models and simulations.

PLTS provides complete confidence in your design, through complete, comprehensive, and accurate characterization. This confidence is extremely powerful, especially with today’s ever changing device requirements.
Digital Device Characterization with PLTS

Measurement flow

Device characterization with PLTS is a straightforward process. The user interface has been designed to make setup, calibration, and measurement intuitive, even for users unfamiliar with frequency domain based tools. A Startup Wizard guides the user through all of the required steps. The last prompt is to connect the device-under-test and initiate the measurement.

Setup

Upon startup, and after automatically polling the GPIB, the Startup Wizard prompts the user to accept or modify the default parameters based on hardware capabilities.

Optionally, the “Advanced” screen can be used for entering the parameters in frequency domain terms. In this interactive screen, user input will automatically change other related parameters. This provides some insight into the correlation between the time domain and the frequency domain.

Calibration

After the setup, the calibration method is selected. Depending on the network analyzer hardware configuration, one or more methods are available:

- Four-port electronic calibration (ECal)
- Short/Open/Load/Thru (SOLT)
- Thru/Reflect/Line (TRL)

The Startup Wizard simplifies the process and provides the greatest flexibility to the user.

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1. See Data Accuracy Enhancement on page 12 for more detail.
Measurement

The Startup Wizard prompts the user to connect the device-under-test, and select an initial analysis type. Then, with a single mouse-click, the system makes all of the measurements. All supported analysis types and formats are immediately available. This allows you to begin where you are most familiar.

With one setup and no additional user input, calibration measurement, and sixty-four time domain and frequency domain device parameters are available for analysis over the entire bandwidth of the instrument.

After defining just a few additional user-selected parameters, eye diagrams, and RLCG model extraction are available.

Analysis

Time domain analysis
The mixed-mode time domain is a common starting point.

![Figure 5. The Mixed-mode Time Domain Matrix](image)

Initially, sixteen parameters are displayed in thumbnail view. These thumbnails represent four modes of device operation: differential-mode, common-mode, and the two mode-conversion types (common-mode stimulus with differential response, and differential stimulus with common-mode response). A double mouse-click on any of these thumbnails will expand the selected parameter to full screen for closer analysis.

Not shown in Figure 5 are the additional sixteen single-ended time-domain parameters, which are simply a mouse-click away.

Frequency domain analysis
The mixed-mode frequency domain is another common starting point.

![Figure 6. The Mixed-mode Frequency Domain Matrix](image)

Initially, sixteen parameters are displayed in thumbnail view. These thumbnails also represent the four modes of device operation: differential-mode, common-mode, and the two mode-conversion types (common-mode stimulus with differential response, and differential stimulus with common-mode response). A double mouse-click on any of these thumbnails will expand the selected parameter to full screen for closer analysis.

Not shown in Figure 6 are the additional sixteen single-ended frequency-domain parameters, which are simply a mouse-click away.
Measurement-based eye diagrams

Using the digital pattern generator, the user is able to define a bit sequence\(^1\)\(^2\) to be applied to the acquired data. PLTS then uses the selected bit pattern to convolve an accurate measurement-based eye diagram. When the eye diagram is generated, marker functions can be used to make typical measurements like deterministic jitter, eye opening, rise and fall times, and more. The digital pattern generator eliminates the need for a hardware pulse/pattern generator, and its flexibility allows for “What if...” analysis.

RLCG model extraction

RLCG (resistance, inductance, capacitance, and dielectric loss) models describe the electrical behavior of passive transmission lines in an equivalent circuit model. From the measured frequency domain data, PLTS calculates the complex propagation constant and complex characteristic impedance for a differential transmission line. This provides an accurate, measurement-based transmission line model for export into modeling and simulation software such as Agilent Advanced Design Systems (ADS), Synopsis HSPICE\(^\text{®}\), and others.

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1. With the Arbitrary Bitstream (ABS) function, the bit stream can be as long as \(2^{32}-1\) bits.
2. User-defined patterns may be saved and re-used.
Measurement Capabilities

Parameters and formats

Time domain
Sixteen single-ended and sixteen mixed-mode time-domain parameters are available. These parameters correspond to forward and reverse TDR and TDT in single-ended, differential-mode, common-mode, and mode-conversion.

Formats for impulse or step function are volts, real part of complex parameter, log magnitude, and impedance. Each format may be displayed in time (nS) or distance (cm).

Frequency domain
Sixteen single-ended and sixteen mixed-mode frequency-domain parameters are available. These parameters correspond to forward and reverse transmission and reflection in single-ended, differential-mode, common-mode, and mode-conversion.

Formats are log or linear magnitude, phase, group delay, Smith, Polar, real part of complex parameter, and imaginary part of complex parameter.
Eye diagram

Twelve single-ended and eight mixed-mode parameters are available. These parameters correspond to forward and reverse transmission in single-ended, differential-mode, common-mode, and mode-conversion.

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Differential</th>
<th>Common</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_{12}</td>
<td>T_{13}</td>
<td>T_{14}</td>
</tr>
<tr>
<td>FWD TRANS</td>
<td>FWD TRANS</td>
<td>REV TRANS</td>
</tr>
<tr>
<td>T_{21}</td>
<td>T_{23}</td>
<td>T_{24}</td>
</tr>
<tr>
<td>FWD TRANS</td>
<td>FWD TRANS</td>
<td>REV TRANS</td>
</tr>
<tr>
<td>T_{31}</td>
<td>T_{32}</td>
<td>T_{34}</td>
</tr>
<tr>
<td>FWD TRANS</td>
<td>REV TRANS</td>
<td>REV TRANS</td>
</tr>
<tr>
<td>T_{41}</td>
<td>T_{42}</td>
<td>T_{43}</td>
</tr>
<tr>
<td>FWD TRANS</td>
<td>REV TRANS</td>
<td>FWD TRANS</td>
</tr>
</tbody>
</table>

Figure 14. Single-ended eye-diagram formats

RLCG model extraction

Thirty-two transmission line parameters are available. These correspond to resistive loss, inductance, capacitance, dielectric loss, characteristic impedance (real and imaginary), attenuation constant, and phase constant, in differential-mode, common-mode, W-element, and self and mutual terms.

<table>
<thead>
<tr>
<th>R_D</th>
<th>L_D</th>
<th>C_D</th>
<th>G_D</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIFF. RESISTANCE</td>
<td>DIFF. INDUCTANCE</td>
<td>DIFF. CAPACITANCE</td>
<td>DIFF. DIELEC. LOSS</td>
</tr>
<tr>
<td>Z_{00D}</td>
<td>Z_{00D}</td>
<td>A_D</td>
<td>B_D</td>
</tr>
<tr>
<td>CHAR. IMP. REAL</td>
<td>CHAR. IMP. IMAG.</td>
<td>ATTEN. CONSTANT</td>
<td>PHASE CONSTANT</td>
</tr>
</tbody>
</table>

Figure 16. Differential RLCG formats

<table>
<thead>
<tr>
<th>R_C</th>
<th>L_C</th>
<th>C_C</th>
<th>G_C</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMM. MODE RESISTANCE</td>
<td>COMM. MODE INDUCTANCE</td>
<td>COMM. MODE CAPACITANCE</td>
<td>COMM. MODE DIELEC. LOSS</td>
</tr>
<tr>
<td>Z_{00C}</td>
<td>Z_{00C}</td>
<td>A_C</td>
<td>B_C</td>
</tr>
<tr>
<td>CHAR. IMP. REAL</td>
<td>CHAR. IMP. IMAG.</td>
<td>ATTEN. CONSTANT</td>
<td>PHASE CONSTANT</td>
</tr>
</tbody>
</table>

Figure 17. Common-mode RLCG formats

<table>
<thead>
<tr>
<th>R_{11}</th>
<th>L_{11}</th>
<th>C_{11}</th>
<th>G_{11}</th>
</tr>
</thead>
<tbody>
<tr>
<td>REF. RESISTANCE</td>
<td>REF. INDUCTANCE</td>
<td>REF. CAPACITANCE</td>
<td>REF. DIELEC. LOSS</td>
</tr>
<tr>
<td>R_{12}</td>
<td>L_{12}</td>
<td>C_{12}</td>
<td>G_{12}</td>
</tr>
<tr>
<td>TRANS. RESISTANCE</td>
<td>TRANS. INDUCTANCE</td>
<td>TRANS. CAPACITANCE</td>
<td>TRANS. DIELEC. LOSS</td>
</tr>
<tr>
<td>R_S</td>
<td>L_S</td>
<td>C_S</td>
<td>G_S</td>
</tr>
<tr>
<td>SELF RESISTANCE</td>
<td>SELF INDUCTANCE</td>
<td>SELF CAPACITANCE</td>
<td>SELF DIELEC. LOSS</td>
</tr>
<tr>
<td>R_M</td>
<td>L_M</td>
<td>C_M</td>
<td>G_M</td>
</tr>
<tr>
<td>MUTUAL RESISTANCE</td>
<td>MUTUAL INDUCTANCE</td>
<td>MUTUAL CAPACITANCE</td>
<td>MUTUAL DIELEC. LOSS</td>
</tr>
</tbody>
</table>

Figure 18. W-element, self, and mutual RLCG formats
Data Accuracy Enhancement

**Measurement calibration**

Accuracy enhancement involves the use of several methods by which sources of error may be resolved or minimized. There are three major sources of measurement error, and the techniques for managing each are different.

- **Drift errors** - the change in system performance over time - are primarily related to environmental issues such as temperature and/or humidity change. Drift errors can be minimized through control of the test environment, or removed through re-calibration.

- **Random errors** are caused by unpredictable factors such as instrument noise. While these can not be corrected in advance, the low-noise signal source and the tuned, phase-locked receiver of the network analyzer greatly minimizes these random errors.

- **Systematic errors** are predominantly related to issues of system directivity, source and load match, tracking, and crosstalk. These errors are fully removed by measurement calibration (error-correction).

**Calibration types available**

**Four-port electronic calibration (ECal)**

For electronic calibration, the Agilent N4430B ECal Module is used. With one set of connections, this solid-state tuner simulates all of the impedance states required for full four-port, SOLT type error correction, typically in less than one minute.

The N4430B is compatible with the N1947A and N1948A configurations only.

**Four-port SOLT (Short/Open/Load/Thru) calibration**

Compensates for directivity, transmission and reflection tracking (frequency response), source match, load match, and crosstalk in both forward and reverse directions.

**Four-port TRL (Thru/Reflect/Line) calibration**

Compensates for directivity, reflection frequency response, transmission frequency response, and crosstalk.
Definitions

To specify the performance of a PLTS, this data sheet lists the dynamic range, measurement uncertainty, and measurement port characteristics for each system configuration. Two types of numbers are offered: specifications and characteristics. These terms are further defined below.

Specifications describe the instrument’s warranted performance over the temperature range of 23 °C ± 3 °C.

Characteristics are typical but non-warranted performance parameters. These are further denoted as “typical” or “nominal.”

- Typical (typ.): Expected performance of an average unit, not including guardbands.
- Nominal (nom.): A general, descriptive term that does not imply a level of performance.

Measurement port characteristics indicate the RF performance of network analyzer and test set port leakages, mismatches, and frequency response. The specification for the test set’s crosstalk does not include noise.

Dynamic range (signal-to-noise ratio) is further defined as \( P_{\text{ref}} - P_{\min} \), where \( P_{\text{ref}} \) is the nominal or reference power out of a source test port and \( P_{\min} \) is the minimum power into a receiver test port that can be measured above the peaks of the system’s noise floor (10 dB above the average noise floor). System dynamic range is the amount of attenuation that can be measured from a 0 dB reference.

Calibration is the process of measuring standards that have fully defined models (and are thus called “known” standards) in order to quantify a network analyzer’s systematic errors based on an error model. Calibration must be performed within the operating temperature specified for the calibration kit. For all calibration kits the operating temperature is 23 °C ±3 °C. For a calibration to remain fully verifiable, the temperature of the network analyzer must remain within ±1 °C around the initial measurement calibration temperature.

Error-correction is the process of mathematically removing from the measurement systematic errors determined by measurement calibration.

Measurement uncertainty curves show the worst-case uncertainty in reflection and transmission measurements using full error correction with the specified calibration kit. This includes residual systematic errors, as well as system dynamic accuracy, connector repeatability, noise, and detector errors. Cable stability and system drift are not included. Furthermore, the graphs for reflection measurement uncertainty apply to a one-port device. The graphs for transmission measurement uncertainty assume a well-matched device \( S_{11} = S_{22} = 0 \). In the phase uncertainty curves, the phase detector accuracy is better than 0.02 degrees, useful for measurements where only phase changes.
System Performance Summary

N1947A and N1948A
Physical Layer Test System
80 pS (300 kHz to 9 GHz)

The following specifications are applicable for a system in the following configuration:

Network analyzer (3-receiver): Agilent E8803A, Opt. 014
test set Agilent N4417A, Opt. 103
--or--
Network analyzer (4-receiver): Agilent E8358A, Opt. 015
Test set Agilent N4417A, Opt. 104
Calibration kit: Agilent 85052C, 3.5 mm
Calibration technique: Four-port SOLT

Dynamic range (signal-to-noise ratio)
Transmission measurements at 10 Hz IF bandwidth, with full four-port error-correction, and 10 dBm maximum output power.

<table>
<thead>
<tr>
<th>Frequency Range (MHz)</th>
<th>300 kHz to 1.3</th>
<th>1.3 to 3</th>
<th>3 to 6</th>
<th>6 to 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic range</td>
<td>120 dB</td>
<td>120 dB</td>
<td>108 dB</td>
<td>103 dB</td>
</tr>
</tbody>
</table>

Measurement port characteristics
Residual uncertainties for corrected data. These apply for 25 °C with less than 1°C variation from calibration.

<table>
<thead>
<tr>
<th>Frequency Range (MHz)</th>
<th>300 kHz to 1.3</th>
<th>1.3 to 3</th>
<th>3 to 6</th>
<th>6 to 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directivity</td>
<td>50 dB</td>
<td>47 dB</td>
<td>42 dB</td>
<td>40 dB</td>
</tr>
<tr>
<td>Source match</td>
<td>42 dB</td>
<td>42 dB</td>
<td>38 dB</td>
<td>35 dB</td>
</tr>
<tr>
<td>Load match</td>
<td>50 dB</td>
<td>47 dB</td>
<td>42 dB</td>
<td>40 dB</td>
</tr>
<tr>
<td>Refl. tracking</td>
<td>±0.006 dB</td>
<td>±0.007 dB</td>
<td>±0.009 dB</td>
<td>±0.015 dB</td>
</tr>
<tr>
<td>Trans. tracking</td>
<td>±0.012 dB</td>
<td>±0.015 dB</td>
<td>±0.040 dB</td>
<td>±0.060 dB</td>
</tr>
</tbody>
</table>

Test set typical performance

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency range</td>
<td>300 kHz to 9 GHz</td>
</tr>
<tr>
<td>Transition time (10 to 90%, TR=.72/BW)</td>
<td>80 pS</td>
</tr>
<tr>
<td>Impedance</td>
<td>50 ohms nom.</td>
</tr>
<tr>
<td>Insertion loss Source Out to Coupler In</td>
<td>4.5 dB max.</td>
</tr>
<tr>
<td>Port 2 to A In, and Port 4 to B In</td>
<td>8.5 dB max.</td>
</tr>
<tr>
<td>A In to A Out, and B In to B Out</td>
<td>8.0 dB max.</td>
</tr>
<tr>
<td>Isolation, port-to-port and A to B</td>
<td>105 dB min.</td>
</tr>
<tr>
<td>Maximum operating level</td>
<td>+20 dBm</td>
</tr>
<tr>
<td>Damage level</td>
<td>+30 dBm typ.</td>
</tr>
<tr>
<td>Test port connectors</td>
<td>50 ohm type-N</td>
</tr>
<tr>
<td>RF connectors</td>
<td>50 ohm SMA(f)</td>
</tr>
<tr>
<td>Weight (test set)</td>
<td>9 kg</td>
</tr>
</tbody>
</table>

1. May be limited to 100 dB at particular frequencies below 750 MHz due to spurious receiver residuals.
System Performance Summary

N1951A Physical Layer Test System
36 pS (50 MHz to 20 GHz)

The following specifications are applicable for a system in the following configuration:

Network analyzer (3-receiver): Agilent 8720ES, Opt. H32
Test set: Agilent N4418A
Test cables: Agilent N4418A, Option B20
Calibration kit: Agilent 85052C, 3.5 mm
Calibration technique: Four-port SOLT

Dynamic range (signal-to-noise ratio)
Transmission measurements at 10 Hz IF bandwidth, with full four-port error-correction, and +5 dBm maximum output power.

<table>
<thead>
<tr>
<th>0.05 to 0.84 GHz</th>
<th>0.84 to 20 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic range</td>
<td>77 dB</td>
</tr>
<tr>
<td></td>
<td>90 dB</td>
</tr>
</tbody>
</table>

Measurement port characteristics
Residual uncertainties for corrected data. These apply for 25 °C with less than 1 °C variation from calibration.

<table>
<thead>
<tr>
<th>0.05 to 8 GHz</th>
<th>8 to 20 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directivity</td>
<td>48 dB</td>
</tr>
<tr>
<td>Source match</td>
<td>41 dB</td>
</tr>
<tr>
<td>Load match</td>
<td>48 dB</td>
</tr>
<tr>
<td>Refl. tracking</td>
<td>± 0.005 dB</td>
</tr>
<tr>
<td>Trans. tracking</td>
<td>± 0.014 dB</td>
</tr>
</tbody>
</table>

Test set typical performance

<table>
<thead>
<tr>
<th>Frequency range</th>
<th>0.05 to 20 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition Time (10 to 90%, TR=.72/BW)</td>
<td>36 pS</td>
</tr>
<tr>
<td>Impedance</td>
<td>50 ohms nom.</td>
</tr>
<tr>
<td>Insertion loss</td>
<td>8 – 10 dB nom.</td>
</tr>
<tr>
<td>Isolation, port-to-port</td>
<td>85 dB min.</td>
</tr>
<tr>
<td>Maximum operating level</td>
<td>+20 dBm</td>
</tr>
<tr>
<td>Damage level</td>
<td>+30 dBm typ.</td>
</tr>
<tr>
<td>Test port connectors</td>
<td>3.5 mm (m)</td>
</tr>
<tr>
<td>RF connectors</td>
<td>50 ohm SMA (f)</td>
</tr>
<tr>
<td>Weight</td>
<td>9 kg</td>
</tr>
</tbody>
</table>
System Performance Summary

N1953A Physical Layer Test System
36 pS (45 MHz to 20 GHz)

The following specifications are applicable for a system in the following configuration:

Network analyzer: Agilent E8362A, Opt. 014/711
Test set: Agilent N4419A
Test cables: Agilent N4419A, Option B20
Calibration kit: Agilent 85052D 3.5 mm
Calibration technique: Four-port SOLT

Dynamic range (signal-to-noise ratio)
Transmission measurements at 10 Hz IF bandwidth, with full four-port error-correction, and -5 dBm maximum output power.

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Dynamic Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>.045 to .5 GHz</td>
<td>70 dB</td>
</tr>
<tr>
<td>.5 to 10 GHz</td>
<td>100 dB</td>
</tr>
<tr>
<td>10 to 20 GHz</td>
<td>85 dB</td>
</tr>
</tbody>
</table>

Measurement port characteristics
Residual uncertainties for corrected data. These apply for 25 °C with less than 1 °C variation from calibration.

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Directivity</th>
<th>Source Match</th>
<th>Load Match</th>
<th>Refl. tracking</th>
<th>Tran. tracking</th>
</tr>
</thead>
<tbody>
<tr>
<td>.045 to 2 GHz</td>
<td>56 dB</td>
<td>42 dB</td>
<td>56 dB</td>
<td>± 0.0015 dB</td>
<td>± 0.020 dB</td>
</tr>
<tr>
<td>2 to 10 GHz</td>
<td>42 dB</td>
<td>36 dB</td>
<td>42 dB</td>
<td>± 0.009 dB</td>
<td>± 0.032 dB</td>
</tr>
<tr>
<td>10 to 20 GHz</td>
<td>40 dB</td>
<td>33 dB</td>
<td>40 dB</td>
<td>± 0.013 dB</td>
<td>± 0.050 dB</td>
</tr>
</tbody>
</table>

Test set typical performance

Frequency range: .045 to 20.0 GHz
Transition time (10 to 90%, TR=.72/BW): 36 pS
Impedance: 50 Ohms nom.
Insertion loss
Source Out to Coupler Thru: 5.0 dB max.
Port 2 to A In, and Port 4 to B In, .045 to 1 GHz: 18-45 dB typ.
Port 2 to A In, and Port 4 to B In, 1.0 to 20.0 GHz: 18-25 dB typ.
Rcvr A In to Cplr Arm, and Rcvr B In to Cplr Arm: 8.0 dB max.
Isolation, port-to-port: .045 to 1 GHz: ≥70 dB
1.0 to 20.0 GHz: ≥90 dB
Maximum operating level: +20 dBm
Damage level: +30 dBm typ.
Test port connectors: 3.5 mm (m)
RF connectors: 50 ohm SMA(f)
Weight: 9 kg

Characteristic measurement uncertainties

Figure 23. Worst case 3.5 mm transmission magnitude and phase uncertainty
Figure 24. Worst case 3.5 mm reflection magnitude and phase uncertainty
System Performance Summary

N1957A Physical Layer Test System

14 pS (45 MHz to 50 GHz)

The following specifications are applicable for a system in the following configuration:

Network analyzer: Agilent E8364A, Opt. 014/711
Test set: Agilent N4421A
Test cables: Agilent N4421A-B20
Calibration kit: Agilent 85056A, 2.4 mm
Calibration technique: Four-port SOLT

Dynamic range
Transmission measurements at 10 Hz IF bandwidth, with four-port error correction and -17 dBm maximum output power.

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>45 MHz</th>
<th>.5 MHz</th>
<th>10 MHz</th>
<th>20 MHz</th>
<th>50 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic range</td>
<td>55 dB</td>
<td>70 dB</td>
<td>70 dB</td>
<td>55 dB</td>
<td></td>
</tr>
</tbody>
</table>

Measurement port characteristics
Residual uncertainties for corrected data. These apply for 25 °C with less than 1 °C variation from calibration.

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>45 MHz</th>
<th>.5 MHz</th>
<th>10 MHz</th>
<th>20 MHz</th>
<th>50 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directivity</td>
<td>43 dB</td>
<td>39.5 dB</td>
<td>39 dB</td>
<td>33 dB</td>
<td></td>
</tr>
<tr>
<td>Source match</td>
<td>38 dB</td>
<td>34 dB</td>
<td>34 dB</td>
<td>27 dB</td>
<td></td>
</tr>
<tr>
<td>Load match</td>
<td>43 dB</td>
<td>39.5 dB</td>
<td>39 dB</td>
<td>33 dB</td>
<td></td>
</tr>
<tr>
<td>Refl. tracking</td>
<td>±.001 dB</td>
<td>±.002 dB</td>
<td>±.008 dB</td>
<td>±.026 dB</td>
<td></td>
</tr>
<tr>
<td>Tran. tracking</td>
<td>±.015 dB</td>
<td>±.020 dB</td>
<td>±.040 dB</td>
<td>±.20 dB</td>
<td></td>
</tr>
</tbody>
</table>

Test set typical performance

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency range</td>
<td>0.045 to 50.0 GHz</td>
</tr>
<tr>
<td>Transition time (10 to 90%, TR=.72/BW)</td>
<td>14 pS</td>
</tr>
<tr>
<td>Impedance</td>
<td>50 Ohms</td>
</tr>
<tr>
<td>Insertion loss</td>
<td>Source Out to Coupler Thru: 12.0 dB max.</td>
</tr>
<tr>
<td></td>
<td>Port 2 to Rcvr A In, and Port 4 to Rcvr B In: 45 MHz to 1 GHz: 18.45 dB typ. 1.0 to 50.0 GHz: 16.26 dB typ.</td>
</tr>
<tr>
<td></td>
<td>Rcvr A In to Cplr Arm, and Rcvr B In to Cplr Arm: 15 dB max.</td>
</tr>
<tr>
<td>Isolation, port-to-port</td>
<td>45 to 200 MHz: ≥70 dB</td>
</tr>
<tr>
<td></td>
<td>200 MHz to 50.0 GHz: ≥90 dB</td>
</tr>
<tr>
<td>Maximum operating level</td>
<td>+20 dBm</td>
</tr>
<tr>
<td>Damage level</td>
<td>+30 dBm typ.</td>
</tr>
<tr>
<td>Test port connectors</td>
<td>2.4 mm (m)</td>
</tr>
<tr>
<td>Weight</td>
<td>9 kg</td>
</tr>
</tbody>
</table>

Characteristic measurement uncertainties

Figure 25. Worst case 2.4 mm transmission magnitude and phase uncertainty

Figure 26. Worst case 2.4 mm reflection magnitude and phase uncertainty
System Configurations

A Physical Layer Test System includes network analyzer hardware and application software running on an external PC.

Each PLTS system bundle includes the following:

- Four-port network analyzer system (vector network analyzer and external two-port S-parameter test set)
- CD-ROM containing the Physical Layer Test System software
- Node-locked license certificate
- Sample DUT board (balanced transmission line)
- User documentation

Test-port cables and rack mount kits with handles are available as options. Calibration kits and ECAl modules can be ordered separately, or as part of a bundled system.

Start-up assistance is available.

### Physical Layer Test System Configurations

<table>
<thead>
<tr>
<th>PLTS Bundled Systems</th>
<th>Test Set Model Number</th>
<th>System Frequency Range</th>
<th>Supported Network Analyzer</th>
<th>Network Analyzer Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A²</td>
<td>N4415A</td>
<td>30 kHz to 6.0 GHz</td>
<td>8753ES</td>
<td>006, 014</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>002, 004, 010, 1D5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>011, 075, H16</td>
</tr>
<tr>
<td>N/A²</td>
<td>N4416A</td>
<td>300 kHz to 6.0 GHz</td>
<td>E8356A⁴ /7A/8A⁶</td>
<td>015</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>010, 1D5</td>
</tr>
<tr>
<td>N1947A</td>
<td>N4417A⁶</td>
<td>300 kHz to 9.0 GHz</td>
<td>E8803A</td>
<td>014</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>010</td>
</tr>
<tr>
<td>N1948A</td>
<td>N4417A⁶</td>
<td>300 kHz to 9.0 GHz</td>
<td>E8358A</td>
<td>015</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>010, 1E1, 1E5</td>
</tr>
<tr>
<td>N1951A</td>
<td>N4418A</td>
<td>50 MHz to 20 GHz</td>
<td>8720ES</td>
<td>H32 or H42</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>010, 012, 400</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>007, 085, 089</td>
</tr>
<tr>
<td>N/A²</td>
<td>N4418A⁷</td>
<td>50 MHz to 20 GHz</td>
<td>8722ES⁷</td>
<td>H32 or H42</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>010, 012, 400</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>007, 085, 089</td>
</tr>
<tr>
<td>N1953A</td>
<td>N4419A</td>
<td>45 MHz to 20 GHz</td>
<td>E8362A/B</td>
<td>014</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>010, 022, 711, UNL</td>
</tr>
<tr>
<td>N1957A</td>
<td>N4421A</td>
<td>45 MHz to 50 GHz</td>
<td>E8364A/B</td>
<td>014</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>010, 022, 711, UNL</td>
</tr>
</tbody>
</table>

1. This table lists only the most specifically relevant options. For compatibility with options not listed here, contact the factory.
2. PLTS software, N1930A, must be ordered to create complete PLTS system.
3. Option 006 required only for operation above 3 GHz.
4. Using this network analyzer, the maximum operating frequency is limited to 3 GHz.
5. Using this network analyzer, the maximum operating frequency is limited to 6 GHz.
6. E8356A family requires N4417A Option 104; E8803A family requires N4417A Option 103.
7. When an 8722ES is used with an N4418A, the N4418A requires Option 392. The system's maximum operating frequency is limited to 20.0 GHz.
# System Ordering Guide

## N1947A Physical Layer Test System

**80 pS (300 kHz to 9 GHz)**

**Includes:**
- E8803A PNA network analyzer, 300 kHz to 9 GHz, 3-rcvr
- E8803A-014 Configurable test set
- N4417A S-parameter test set, 300 kHz to 9 GHz
- N4417A-103 E8803A compatibility
- N1930A Physical Layer Test System software

**Recommended options and accessories:**
- N4417A-B20 Test cables, 3 ft., Type-N (m) to 3.5 mm (m), qty. 4
- N4417A-1CP Rack mount kit, test set
- N4430B Four-port ECal module, 300 kHz to 9 GHz, 3.5 mm (f)

## N1948A Physical Layer Test System

**80 pS (300 kHz to 9 GHz)**

**Includes:**
- E8803A PNA network analyzer, 300 kHz to 9 GHz, 3-rcvr
- E8803A-014 Configurable test set
- N4417A S-parameter test set, 300 kHz to 9 GHz
- N4417A-103 E8803A compatibility
- N1930A Physical Layer Test System software

**Recommended options and accessories:**
- N4417A-B20 Test cables, 3 ft., Type-N (m) to 3.5 mm (m), qty. 4
- N4417A-1CP Rack mount kit, test set
- N4430B Four-port ECal module, 300 kHz to 9 GHz, 3.5 mm (f)

## N1953A Physical Layer Test System

**36 pS (45 MHz to 20 GHz)**

**Includes:**
- E8362B* PNA network analyzer, 45 MHz to 20 GHz, 4-rcvr
- E8362B-014 Configurable test set
- E8362A-711 Standard power configuration
- N4419A S-parameter test set, 45 MHz to 20 GHz
- N1930A Physical Layer Test System software

* This system is not tested or specified with network analyzer options 016/080/081/083

**Recommended options and accessories:**
- N4419A-B20 Test-port cables, 3 ft., 3.5 mm (m-f), quantity 4
- N4419A-1CP Rack mount kit, test set
- 85052D Calibration kit, 3.5 mm

## N1957A Physical Layer Test System

**14 pS (45 MHz to 50 GHz)**

**Includes:**
- E8364B* PNA network analyzer, 45 MHz to 50 GHz, 4-rcvr
- E8364B-014 Configurable test set
- E8364A-711 Standard power configuration
- N4421A S-parameter test set, 45 MHz to 50 GHz
- N1930A Physical Layer Test System software

* This system is not tested or specified with network analyzer options 016/080/081/083

**Recommended options and accessories:**
- N4421A-B20 Test-port cables, 3 ft., 2.4 mm (m-f), quantity 4
- N4421A-1CP Rack mount kit, test set
- 85056A Calibration kit, 2.4 mm

## N1951A Physical Layer Test System

**36 pS (50 MHz to 20 GHz)**

**Includes:**
- 8720ES Vector network analyzer, 50 MHz to 20 GHz, 3-rcvr
- 8720ES H32 Configurable test set
- N4418A S-parameter test set, 50 MHz to 20 GHz
- N1930A Physical Layer Test System software

**Recommended options and accessories:**
- N4418A-B20 Test-port cables, 3 ft., 3.5 mm (m-f), quantity 4
- N4418A-1CP Rack mount kit, test set
- 85052D Calibration kit, 3.5 mm
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