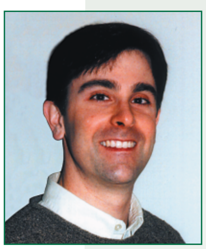
HEWLETT® PACKARD

HP 8510 8720 News

Find us on the Web
www.hp.com/go/8510-8720news

Simplify group delay measurements of frequency translation devices

Use the time domain option of the HP 8510C and HP 8720ES vector network analyzers



Mike Knox, Technical Consultant Test and Measurement —SSV

As the information bandwidth of modern digital communication systems increases, the need for networks and components with a high degree of linearity is critical to system performance. In a non-ideal network, signal distortion is created by the amplitude and phase nonlinearities present in the system components. Group delay is typically used as another measure of the phase linearity in the device.

Accurately characterizing the group delay of linear networks (which do not translate the applied frequency) is often an easy task when using modern vector network analyzers (VNAs) such as the HP 8510C and HP 8720ES. On the other hand, characterizing the group delay response of a mixer or frequency translation device (FTD) is generally difficult at best. Traditional methods for measuring the delay characteristics of FTDs tend to be slow, and often require complex equipment configurations[1,2].

A faster, simpler solution

As an alternate approach, the measurement of group delay through a mixer can be easily accomplished using the time-domain option available with the HP 8510C and HP 8720ES VNAs. This technique is fast, easy to use, and does not require the extensive hardware and filtering that other traditional methods demand.

How does it work?

You will need a single mixer and a VNA capable of time-domain transformation to measure absolute group delay and delay linearity. (This capability is available on the HP 8510C and HP 8720ES analyzers with Option 010.) The technique uses the measured reflection coefficient from a single mixer that is terminated in a 50-ohm airline and a short. The measured frequency response is transformed into the impulse response using

Continued on next page

Also in this issue

2 Test & Measurement Solutions
Simplify group delay measurements of frequency translation devices
Use time domain option of the HP 8510C and HP 8720D vector network analyzer
(continued from page 1)

6 Use HP EEsof and an HP vector network analyzer to simplify fixture de-embedding

8 Tips & Techniques
How you can benefit from the flexibility of mixer-based test sets

10 Product News
HP offers new choices for microwave component measurements

12 Need accurate testing of multiport and balanced components?

www.tmo.hp.com

the time-domain option on the VNA. Knowing the absolute delay of the airline, the absolute delay through the mixer can be calculated by examining the two-way reflection from the short in time. In addition, the delay linearity of the mixer as a function of frequency can be measured using the gating function on the VNA. The gating function filters the effects of reflections internal to the mixer and isolates only the transmitted signal through the mixer. This gated signal contains the delay distortion introduced by the frequency translation process. In this way, delay linearity through the mixer can now be directly measured in the frequency domain.

The impulse response on a VNA simulates a traditional Time Domain Reflectometry (TDR) measurement. TDR is a technique to generate an impulse or step waveform in time that is propagated down a transmission line. The reflections from discontinuities can then be detected in time on the TDR display. The measured time delay represents the two-way electrical distance to the discontinuity in the transmission line. Individual discontinuities can be examined in time if there is adequate electrical separation between them. This same TDR measurement can be simulated using a high-performance VNA capable of time-domain transformation. In this case, the measured frequency response from the VNA is mathematically transformed into the impulse response using the *Inverse Fourier Transform* algorithm present within the VNA. The measurement accuracy is improved by applying the standard one-port vector error correction to the frequency domain data of the reflection measurement.

Looking at an example

As a measurement example, the return loss of the IF port of a broadband mixer is measured on the VNA as a function of frequency. The RF port of the mixer is terminated with an airline and a short. The proper LO drive is also applied to the mixer. (Hardware configuration is shown in Figure 1.) The VNA is used to measure and transform the frequency response of the mixer under test. The limitation to time-domain measurements on the VNA is directly related to the measured frequency span. In order to examine two closely spaced discontinuities in the time, a large frequency span must be measured. Because of limitations in the operating frequency range of the device under test, it may be necessary to electrically separate the discontinuities whenever possible. Because we wish to isolate the reflected signal from the short, placing the short directly on the output of the mixer may not provide enough separation between the mixer's own internal reflections and this signal. Therefore, placing a 50-ohm airline between the mixer and the short can improve the measurement resolution by electrically separating the reflections from the mixer and the short.

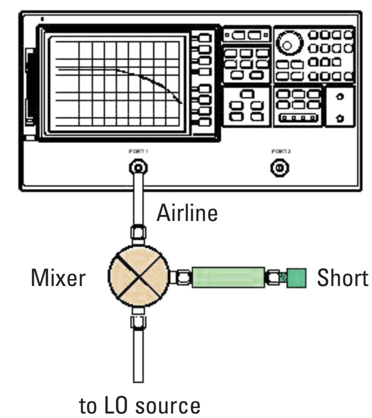


Figure 1. Hardware configuration for measuring the absolute delay and delay linearity of frequency translation devices

Continued on next page

Test & Measurement Solutions

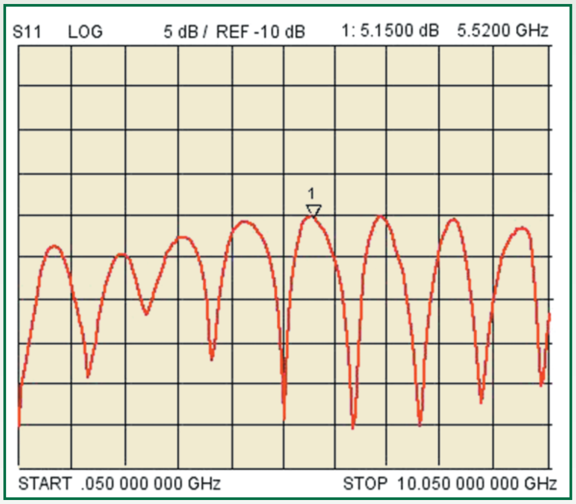


Figure 2. Measured return loss from the IF port of the mixer as a function of frequency, measurement made using a shorted airline placed on the RF port

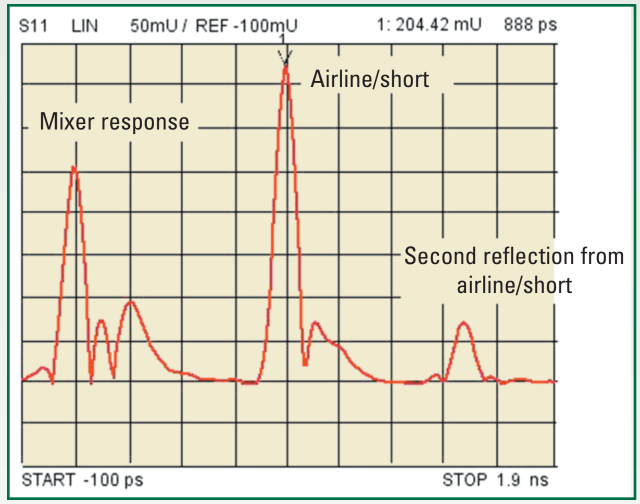


Figure 3. Low-pass impulse response of the mixer using a shorted airline placed on the RF port

For our example, the VNA is calibrated for an S11 one-port cal over the IF frequency range of 50 MHz to 10.05 GHz. The LO was set to a fixed value of 20 GHz. This IF range is chosen for two reasons; it is within the operating range of the mixer's IF port, and it allows the VNA to be used in the low-pass mode of operation. The low-pass mode yields highest resolution in the time domain. Time-domain measurements can be made when applying the stimulus to the RF port of the mixer and terminating the IF port in the airline/short. For this case, the RF port does not operate down to DC; therefore the band-pass mode will be used. This alternate time-domain mode is useful for bandlimited mixers with arbitrary start and stop frequencies.

The measured return loss of the IF port as a function of frequency is shown in Figure 2. The return loss shows the typical peaks and valleys that occur when multiple reflections are added and subtracted over the measured frequency range. This frequency response from the mixer is then transformed into the impulse response using the time-domain option on the VNA. Figure 3 shows the low-pass impulse response of the mixer terminated in the airline/short. This figure represents the TDR

Continued on next page

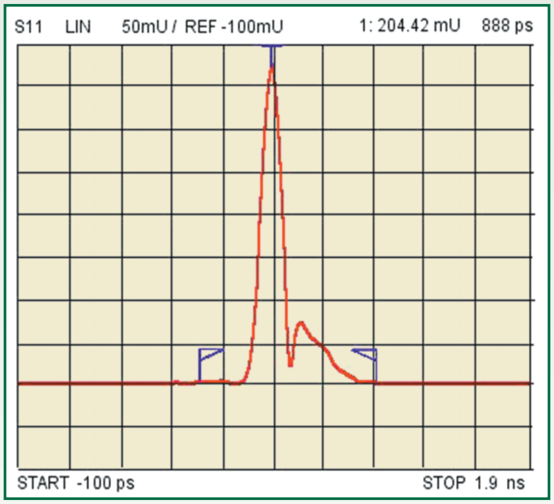


Figure 4. Low-pass impulse response using a time gate to isolate the reflection from the short

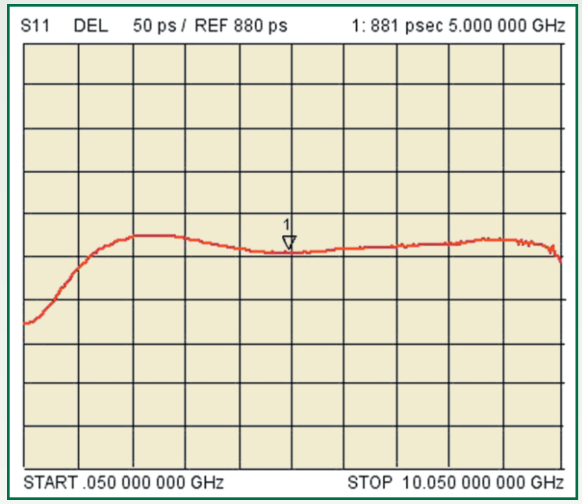


Figure 5. Measured delay linearity of the mixer as a function of frequency

response as a function of time. It shows the individual reflections from several discontinuities as the impulse waveform propagates along the transmission line. The position of each impulse shows the electrical distance in time from the calibration plane. The amplitude of each impulse shows the average amount of reflected signal from each discontinuity. The three reflections to the left of the figure are caused by discontinuities present within the mixer: for example, the input and output connectors and transformers.

The largest impulse on the figure is caused by the reflection from the short placed at the end of the airline. This is the discontinuity of interest, as it represents the signal that is transmitted through the mixer under test. A marker is used to measure the position of the short at the end of the airline in time. Because the discontinuities are electrically separated in time, each reflection can be individually examined. The measured marker value of 888 psec represents the two-way reflection from the short as the signal passes through the mixer and the airline. By knowing the electrical delay of the airline, we can subtract it from the measured delay, and then by dividing the result in half, we can obtain the mixer's absolute group delay of

Continued on next page

HEWLETT PACKARD

Test & Measurement Solutions

168 psec. Here we are assuming that the delay characteristics of the mixer are the same as the signal passes through the mixer from the IF to RF and RF to IF ports.

Measuring delay linearity

The delay linearity is also an important characteristic required by components used in broadband communication systems. In order to measure the delay linearity of the mixer using this technique, a time filter needs to be applied to the frequency domain data. The time filter is used to isolate the reflection from the shorted airline. The reflection from the short contains the delay distortion introduced by the frequency translation process as this signal is passed through the mixer. The time filter or gating function is positioned on the time-domain response around the reflection from the short. This gated measurement now represents only the response of the signal that passes through the mixer, eliminating the effects from the mixer's own internal reflections and any secondary reflections between the mixer and the short. Figure 4 shows the time-gated response of the mixer's impulse response in the time domain. As shown in this figure, only the reflection from the short is allowed to pass through the time filter, and all other reflections are essentially removed from the measurement.

Once the gate is properly centered, the time-domain function can then be turned off while leaving this gate activated. This will yield the frequency response of just the first reflection from the short. This gated measurement represents the frequency response of the signal that passes through the mixer.

The gated frequency response of the mixer's delay is shown in Figure 5. This figure shows the mixer's delay linearity as a function of frequency. In this case, the measured delay linearity is less than 50 psec peak-to-peak over a 10 GHz span. Note that the ends of the frequency range show a downturn in the measured delay response. This may be the result of the windowing function and data extrapolation that is applied to the measured frequency response data. Generally, this windowing process distorts the measurements at the very ends of the gated frequency response. The initial frequency span should be chosen larger than required to avoid possible errors in the frequency range of interest.

The measurement of group delay through the mixer can also be characterized using the reflection from the RF port of the mixer. In this case, the IF port of the mixer is terminated with the airline and short. Here, the time-domain transformation is typically operated in the band-pass mode, because the frequency range of the mixer's RF port does not typically operate down to DC. The band-pass mode allows arbitrary selection of the start and stop frequencies, which is very useful for band-limited devices. Keep in mind that the band-pass mode will reduce the time-domain resolution when compared to the low-pass mode covering the same frequency range. In this case, a larger frequency range or longer airline may be required in order to improve the time-domain resolution.

For more information, please visit
www.hp.com/go/8510
www.hp.com/go/8720

1. Hewlett-Packard Product Note 70820-10, *HP 71500A Microwave Transition Analyzer Group Delay Personality*, literature number 5091-8634E.

2. Hewlett-Packard Application Note 1287-7, *Improving Network Analyzer Measurements of Frequency Translating Devices*, literature number 5966-3318E.

Use HP EEsof and an HP vector network analyzer to simplify fixture de-embedding

Mike Knox, *Technical Consultant, Test and Measurement - SSV, Hewlett-Packard Company*

At RF and microwave frequencies, it becomes difficult to directly measure devices with nonstandard connectors (for example, devices using surface-mount packaging). Often a test fixture is required to transition the network analyzer's coaxial connectors to the non-coaxial environment of the device under test. In this case, the calibration plane is not at the device plane fixture (see Figure 6), and the uncharacterized test fixture introduces a measurement uncertainty. By modeling the test fixture, a calculation can be performed to remove the effects of this transition. The fixture *de-embedding* procedure can result in very accurate measurements for the non-coaxial device under test without the need for complex test fixtures and non-coaxial calibration standards.

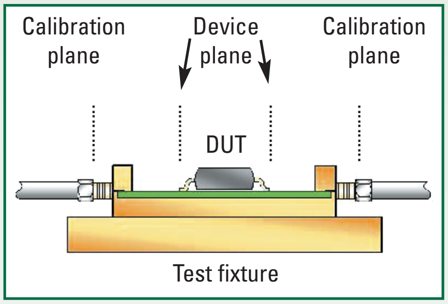


Figure 6. Measurement configuration of the non-coaxial device and test fixture

S-parameter data shared between software and hardware

Using the HP EEsof Advanced Design System (ADS) in conjunction with the HP 8510C and HP 8720ES vector network analyzers (VNAs), you can easily remove the test fixture effects from the measurement. HP EEsof ADS allows direct connection of the software environment to the network analyzer hardware over the HP-IB interface. This direct connection allows S-parameter data to be shared between the software simulation and the measurement equipment. After developing a model of the test fixture either through empirical measurements or computer modeling on ADS, the actual measurement of the device, including the test fixture, can be directly transferred into the simulation for de-embedding. Using the fixture model, ADS can mathematically remove the test fixture effects from the actual measurement, and the corrected device data can be displayed on the ADS screen or placed back into the network analyzer for viewing.

ADS implements a two-port de-embedding model that is used to negate the effects of its S-parameters from the total S-parameter simulation. For two-port devices, the test fixture will be modeled in two parts—one for each side of the coaxial-to-non-coaxial transition. In this way, the test fixture is not required to have two symmetrical sides. By placing two de-embed models on each side of the measured dataset, the fixture effects can be removed by the simulation.

Figure 7 shows the three blocks required to perform the de-embedding calculation. The first two-port Deembed2 component holds the S-parameter dataset for the left-hand side of the text fixture. Similarly, the second Deembed2 component contains the S-parameter information for the right-hand side of the fixture. The center S2P component contains the measured S-parameter dataset transferred from the network analyzer. This dataset holds the complete measurement of both the device and the test fixture. The two term components terminate the simulation in the characteristic impedance of the system, which is nominally 50 ohms. Before the measured data is transferred to ADS, the network analyzer is calibrated with a standard coaxial calibration kit, and the device and

Continued on next page

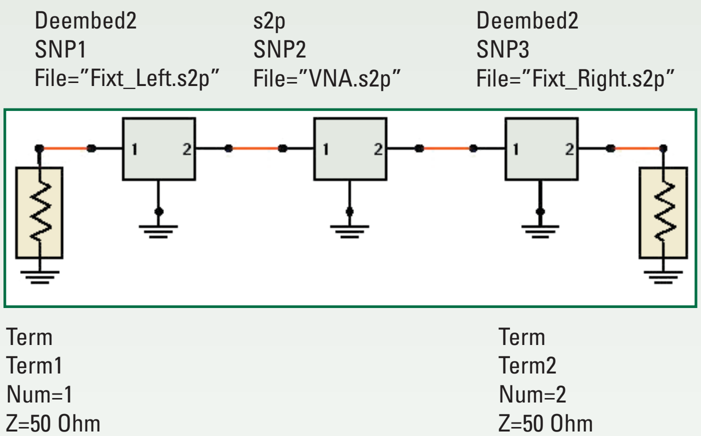


Figure 7. ADS circuit diagram for test fixture de-embedding

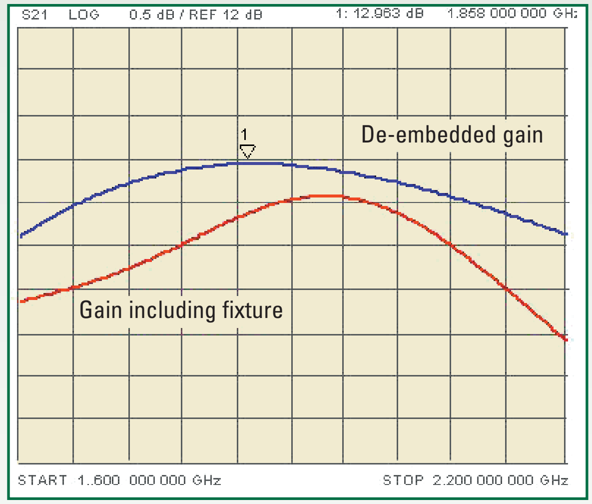


Figure 8. PCS amplifier gain showing the effects of fixture de-embedding

test fixture are measured using a full two-port calibration. The ADS software uses the instrument server function to obtain the measured dataset directly from the network analyzer, and temporarily stores this data to a file for use by the simulation. The instrument server can read and write datasets to a variety of HP test equipment and files. After the measurement is read from the network analyzer and stored as an S-parameter file, the ADS S-parameter simulation can be run over the frequency range of interest. The de-embedded measurement of the device is then available for display within ADS or can be transferred back to the network analyzer through the instrument server.

De-embedding a PCS amplifier

As an example, let's look at the de-embedded measurement of a surface-mount PCS amplifier using ADS and the HP 8720ES vector network analyzer. Figure 8 shows the data before and after the test fixture has been de-embedded. As shown in the figure, before de-embedding, the overall amplifier gain is lower due to the additional insertion loss of the coax-to-microstrip test fixture. Also, the uncorrected gain is lower at the band edges due to mismatch interaction between the test fixture and the amplifier. Once the fixture is de-embedded from the measurement, the amplifier gain shows the specified performance across the full operating bandwidth.

For more information, please visit
www.hp.com/go/8510
www.hp.com/go/8720

How you can benefit from the flexibility of mixer-based test sets

Tips & Techniques

To take full advantage of the excellent flexibility of the HP 85110 mixer-based test sets, you will first need to understand their architecture. Let's look at the differences between mixer-based test sets and sampler-based tests sets.

Johanna Larmour, Sales Development Engineer and Bill Kainu (photo not shown), Custom Engineering Specialist, both of HP's Santa Rosa Systems Division

The primary difference between the HP 85110 series test sets and other HP 851X test sets is that the HP 85110 series is mixer-based rather than sampler-based. Standard test sets, with their built-in VTO, require a CW signal to phase-lock the VTO. The fundamentally mixed HP 85110 requires two external synthesizers (offset by 20 MHz) to provide the RF and LO signals. We will see that the HP 85110 test sets are especially well-suited for making pulsed or high-power measurements, and have excellent dynamic range.

Mixer-based test sets are better for making pulsed measurements because the down converted signal is essentially sampled continuously, whereas sampler-based test sets sample individual data points and interpolate in between to generate the result. The continuous down conversion of the mixer test set offers a very exact representation of the pulsed signal, while the sampler-based down conversion results in a poor representation.

The HP 85110 series test sets are also ideal for making high-power measurements. Why? The directional couplers were chosen for their high-power handling capability of 20 W. The step attenuators can be set to protect the mixers as needed. And the user-accessible links in the RF paths allow the insertion of external amplifiers to boost input power to the DUT, or the insertion of isolators to protect the RF switch splitter from excess power.

The same links also make the HP 85110 test sets suitable as the heart of a test system, which offers more than just S-parameters with a single connection to the DUT. The links provide the access point for switching in a spectrum analyzer, noise figure meter or power meter.

Following the RF path

Figure 9 (next page) shows a block diagram of the HP 85110A test set with signal path losses and operating and damage levels of critical components.

Let's follow the RF path, starting from the RF input on the rear panel of the HP 85110A. The RF signal is first routed to a switch splitter, where it is switched to either port 1 or port 2 as stimulus for the DUT. The reference directional coupler in each of the two RF paths couples off a portion of the stimulus signal to establish reference signals for the a1 and a2 mixers. Similarly, the test directional couplers couple off a portion of the test signal from the DUT to the b1 and b2 mixers. The mixers are followed by IF amplifiers, which boost the IF signals to the level required by the HP 8510 vector network analyzer.

With the knowledge of path losses, you should estimate the power levels at each mixer's input and set attenuators appropriately. The attenuator settings in the HP 85110 test set are controlled through the HP 8510C, and are switched in pairs for each test port. Once this has been done, check all four user channels to make sure that they read below –10 dB, which is the maximum allowable IF level.

Please note that the user channel level does not represent an actual power reading. It is best to keep the user levels as close to –10 dB as possible. Much lower levels increase the uncertainty due to noise. The HP 8510 vector network analyzer usually

Continued on next page

HEWLETT® PACKARD

Tips & Techniques

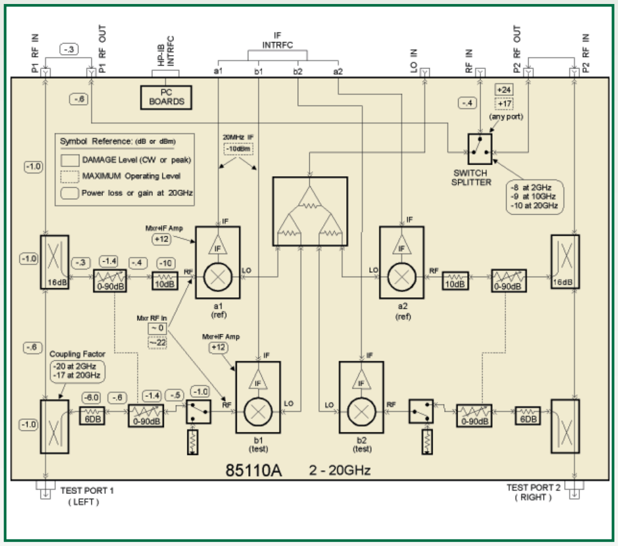


Figure 9. HP 85110A power levels and path losses

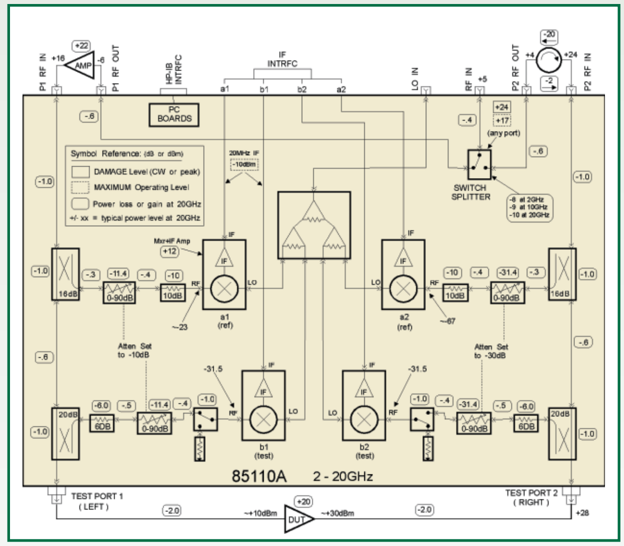


Figure 10. HP 85110A used to measure 20 dB gain amplifier

displays an *IF Overload* warning when IF power levels are too high, but these warnings are disabled when using wide IF bandwidth (pulse mode).

When considering the damage levels in the block diagram, you should be aware that the damage level applies to average power as well as for peak power values. For example, a signal with a duty cycle of 1 percent and an average power level of 10 dBm (well below PIN switch damage level) has peak power levels of 30 dBm, which exceed the damage level of the PIN switch.

Measuring an amplifier

In the example shown in Figure 10, we illustrate the setup for the measurement of a 20 dB amplifier with the HP 85110A. An amplifier has been inserted into the P1 link to supply the desired stimulus of 10 dBm to the DUT. The attenuator settings have been chosen to protect the mixers, while maximizing performance by keeping the IF levels below, but as close as possible to, –10 dB. An isolator has been placed into the P2 link to absorb the DUT power and protect the switch splitter.

For more detailed application information and additional examples, read *Making Measurements with Mixer-Based HP 85110 Series Test Sets.* Ask your HP sales representative for a copy.

For more information, please visit
www.hp.com/go/8510
www.hp.com/go/8720

HP offers new choices for microwave component measurements

With the introduction of the new HP 8720E family of microwave network analyzers, you now have more flexibility when determining the best mix of accuracy, features, and price for microwave component measurements.

Dave Ballo, Product Manager, HP's Microwave Instruments Division

Depending upon your application, choose between the convenience and accuracy of an S-parameter analyzer (ES models) or the lower price of a transmission/reflection analyzer (ET models). S-parameter analyzers let you measure the forward and reverse characteristics of your devices, with the optimum accuracy of full two-port calibration. Transmission/reflection (T/R) analyzers measure forward transmission and reflection only, and offer less sophisticated error correction. All of the models contain new features designed to make your measurements easier and faster than ever.

Model	Frequency range	T/R	S-parameter	U.S. list price
HP 8719ET	50 MHz to 13.5 GHz	•		$36,750
HP 8720ET	50 MHz to 20 GHz	•		$44,750
HP 8722ET	50 MHz to 40 GHz	•		$62,750
HP 8719ES	50 MHz to 13.5 GHz		•	$45,750
HP 8720ES	50 MHz to 20 GHz		•	$57,750
HP 8722ES	50 MHz to 40 GHz		•	$79,750
Option	**Description**			
004	Source step attenuator	•	(standard on ES models)	$2,000
007	Mechanical transfer switch	(n/a)	•	$0
010	Time-domain capability	•	•	$9,170
012	Direct-receiver access		•	$2,580
085	High-power test set		•	$10,300
089	Frequency-offset capability		•	$3,610
1D5	High-stability freq. ref.	•	•	$1,030
400	Fourth sampler/TRL cal		•	$6,180

Table 1. Network analyzer mix

Improved user interface

New front-panel keys allow easy access to commonly used features such as power, sweep, and marker-search menus. Dedicated keys provide immediate access to the four display channels, and an active two-port calibration is no longer required to use more than two display channels with ES models.

More calibration choices

The new enhanced-response calibration (available on both ET and ES models) corrects for the effects of source match during transmission measurements. Because the analyzer only sweeps in one direction with this type of calibration, measurements are twice as fast as measurements using two-port calibration. The enhanced-response calibration is as fast as a normal response calibration, but much more accurate.

Backward programming compatibility

The 8720E family is code compatible with the HP 8720D family, so existing software does not need to be modified. Also, the ET and ES models share similar command sets, reducing the time spent on writing new code to support both models.

Continued on next page

Continued from previous page

Product News

Figure 11. The HP 8720 network analyzer family

Available literature

Literature number	Description
5968-5161E	*HP 8720E family brochure*
5968-5162E	*HP 8720E family configuration guide*
5968-5163E	*HP 8720E family technical specifications*

For more information, please visit

www.hp.com/go/8720

Figure 12. New ECal module with 7-16 connectors

New ECal modules

HP has added three new modules to its line of Electronic Calibration (ECal) products. The new models include a module with 7-16 connectors (HP 85098A), one with Type-F connectors (HP 85099A) and another with 75 ohm Type-N connectors (HP 85096A).

ECal makes calibration simple, fast and less prone to operator errors. Six connector types are now available: Type-F, Type-N (50 ohm), Type-N (75 ohm), 3.5 mm, 7 mm and 7-16.

For additional information please reference the ECal product overview 5963-3743E, revised in July 1999, or please visit

www.hp.com/go/8510

New network analyzer selection guide

This attractive 20-page color selection guide gives an applications-focused overview of the various network analyzer solutions. Featured is a four-page applications matrix that lists specific component-test measurements, corresponding important features and options, and recommended third-party partners. The matrix helps you determine which network analyzer best meets your application needs. *Select the Best Network Analyzer for Your Measurement Needs*, literature number 5968-5260E.

Free Measurement Uncertainty Calculator!

This spreadsheet program quickly calculates the uncertainty of a user-defined measurement made using the HP 8720 family of network analyzers. (The program also supports measurements made using HP 871X family of analyzers and HP 8753E network analyzers.) You may use this information to set go-no go or limit lines for your measurement and to help you select which calibration type is necessary for your measurement. This program calculates and plots; magnitude and phase uncertainty for reflection and transmission measurements, magnitude and phase dynamic accuracy, and group delay accuracy. It is downloadable at:

www.tmo.hp.com/tmo/pia/component_test/PIASupp/English/comptest_na_uncertainty.html

Need accurate testing of multiport and balanced components?

Product News

ATN Microwave, an official HP Channel Partner, has added microwave measurement capability to its suite of multiport test solutions. ATN Microwave's ATN-4112 multiport test system provides differential and mixed-mode S-parameter measurements of three- or four-port, fully balanced or single-ended-to-balanced components, from 50 MHz to 20 GHz. It incorporates full four-port error correction to provide exceptional measurement accuracy. (Four-port error correction means that the test system can also be used for very accurate measurements on multiport devices like directional couplers, which are very difficult to measure using other multiport test systems.) ATN's test system includes a four-port test set, an HP 8720ES network analyzer (with special Option H32), and Windows®-based software. For more information, please order the brochure listed below or visit

www.atn-microwave.com

Figure 13. HP 8720ES and ATN-4112 multiport

Literature number	Description
5968-5480E	*ATN-4000 series multiport test systems (brochure)*

Windows is a U.S. registered trademark of Microsoft Corp.

For more information about Hewlett-Packard test and measurement products, applications, services, and for a current sales office listing, visit our web site: http://www.hp.com/go/tmdir You can also contact one of the following centers and ask for a test and measurement sales representative.

United States:
Hewlett-Packard Company
Test and Measurement Call Center
P.O. Box 4026
Englewood, CO 80155-4026
(tel) 1 800 452 4844

Canada:
Hewlett-Packard (Canada) Ltd.
5150 Spectrum Way
Mississauga, Ontario
L4W 5G1
(tel) 1 877 894 4414

Europe:
Hewlett-Packard Company
European Marketing Organisation
P.O. Box 999
1180 AZ Amstelveen
The Netherlands
(tel) (31 20) 547 9999

Japan:
Hewlett-Packard Japan Ltd.
Measurement Assistance Center
9-1, Takakura-Cho, Hachioji-Shi,
Tokyo 192-8510, Japan
(tel) (81) 426 56 7832
(fax) (81) 426 56 7840

Latin America:
Hewlett-Packard Company
Latin American Region Headquarters
5200 Blue Lagoon Drive
9th Floor
Miami, Florida 33126
U.S.A.
(tel) (305) 267 4245/4220
(fax) (305) 267 4288

Australia/New Zealand:
Hewlett-Packard Australia Ltd.
31-41 Joseph Street
Blackburn, Victoria 3130

Australia
(tel) 1 800 629 485 (Australia)
(tel) 0 800 738 378 (New Zealand)
(fax) (61 3) 9210 5489

Asia Pacific:
Hewlett-Packard Asia Pacific Ltd
19/F, Cityplaza One, 1111 King's Road,
Taikoo Shing, Hong Kong, SAR
(tel) (852) 2599 7777
(fax) (852) 2506 9285

Printed in U.S.A. 10/99
5968-5558E

HEWLETT® PACKARD
Hewlett-Packard Co.
Dept. 8510NEWS799
P.O. Box 3828
Englewood, CO 80155-3828

FIRST CLASS
US POSTAGE
PAID
PERMIT #470
SANTA ROSA, CA

www.tmo.hp.com