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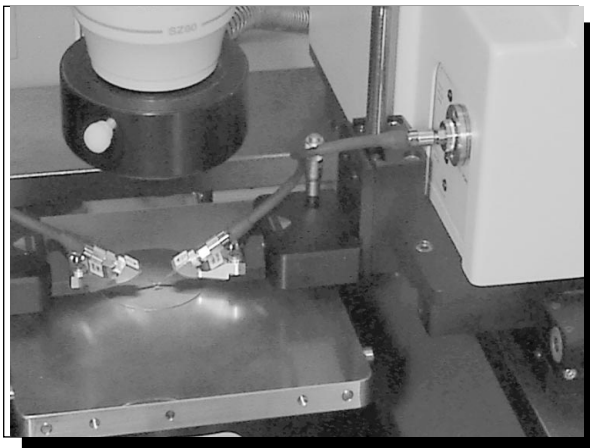
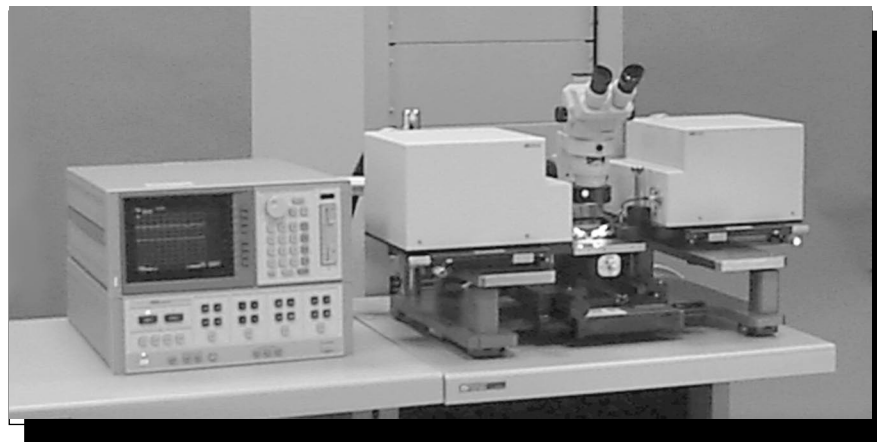
8510XF

Network Analyzer



Using Power Leveling to Control Test Port Output Power

Product Note 8510XF-1



product note

Table of Contents

Introduction3
Power leveling4
Power leveling operation6
Power control7
Measurements in the frequency domain8
Measurements in the power domain11
Appendix A. Test port cable loss compensation14
Appendix B. Wafer-probing environment considerations16

Introduction

Designers and manufacturers of active devices and components often need to control the power level at the input port¹ of their power-sensitive devices, but find it difficult to overcome insertion losses created by components in the measurement path between the (RF) synthesizer output and the test device. Accurate power control in stimulus-response measurement systems is important for several reasons. For small signal measurements, it is necessary to ensure that the device being measured is operating in its linear region. It is also desirable to maintain as high a power level as possible to increase the dynamic range of the measurement. In some cases, it may be necessary to make a measurement at a specified power level or to measure the device parameters as a function of stimulus power.

Power leveling, which uses a feedback loop to set the power incident from the test port¹, along with a power calibration of the stimulus system, are used to provide accurate control. Without power leveling, power variation over a broad frequency sweep could easily be more than 10 dB, depending on the power setting. The HP 8510XF is the first ultra-broadband vector network analyzer (VNA) system capable of implementing power leveling to set and control the power level at the test ports over the 0.045 to 110 GHz frequency range without requiring a power calibration for each measurement. This note reviews the operational considerations for power leveling with the HP 8510XF.

1. Throughout this document, “input port” refers to the point where the test device is connected; in other words, the input port of the device-under-test (DUT). “Test port” refers to either port 1 or port 2 of the HP 8510XF test head module.

To provide accurate power control, a two-level calibration process is used to characterize the frequency response and the absolute gain-step values of the system. These two levels are designed to counteract two different sources of error: (1) imprecision in the step attenuators (a programmable gain calibration), and (2) frequency-related variations in coupler and mixer performance (a frequency response calibration). Both procedures are performed on each system at Hewlett-Packard before it leaves the factory.

The first level of this calibration process is the detector gain (programmable gain) calibration, performed to collect the correction factors of the step attenuators in the programmable gain circuit. This calibration procedure can be performed anytime by the user (it takes approximately two minutes). For measurements in which absolute power levels are critical, perform this calibration before every measurement calibration. If absolute power levels are not important, perform this calibration infrequently (on a monthly basis, for example). Table 1 outlines this calibration procedure.

Table 1. Procedure for Detector Gain Calibration

HP 8510C Keystrokes ¹	Description
<p>[SYSTEM] {MORE} {RF POWER CONFIG} {MORE} {RESET DET GAIN CAL}</p>	<p>Bring up the reset detector gain calibration menu.</p>
<p>Select one of the following:</p>	<p><u>Considerations:</u> The detector gain calibration process causes some settings to change, and these are not restored to their original conditions afterward. Therefore, after the calibration, the system needs to be returned to a known state. The first two selections below are included as a convenience (and as a reminder of the need to save the present settings before running the calibration).</p>
<ul style="list-style-type: none"> • {RUN CAL + USER PRST} • {RUN CAL + FACT PRST} • {RUN CAL NO PRESET} • {CANCEL} 	<ul style="list-style-type: none"> • Runs the detector gain calibration routine, and is followed by a user preset. • Runs the detector gain calibration routine, and is followed by a factory preset. • Runs the detector gain calibration routine, and is not followed by a preset (system settings that are altered by the calibration routine will not be restored to their original conditions afterward). • Exit the menu without running the calibration routine, and return to the previous menu.

1. The front panel hardkey names are enclosed in brackets: [HARDKEYS]. The softkey names are italicized and enclosed in braces: {SOFTKEYS}.

Power leveling operation

The second level of this calibration process is the conversion loss (frequency response) calibration, performed to gather the correction factors to counteract the frequency-related variations caused by the RF-to-IF conversion loss of the coupler and mixer. This calibration procedure can be performed as part of an annual maintenance (to be conducted either on-site or at the local HP service center by HP customer service engineers with the proper power level flatness kit and equipment). This procedure takes approximately 3 to 4 hours.

The correction factors obtained during the above calibrations are valid only for the system components that are installed at the time of calibration. If any component in the system is replaced, both calibrations must be repeated. These components include the HP 8510XF millimeter-wave controller, the left and right test head modules, and the RF and LO synthesizers.

There are four different RF leveling functions available in the HP 8510XF measurement system. These functions can be found in the RF POWER CONFIG menu. This menu can be located by pressing the following keys: [SYSTEM] {MORE} {RF POWER CONFIG}¹. The four different RF leveling functions are:

- {RF LEVEL: SYSTEM}—RF power is leveled at the test ports and is entirely controlled by the HP 8510XF system. This is also the normal operating mode. The HP 8510XF system is set in this mode at the time the system leaves the factory.
- {RF LEVEL: INTERNAL}—RF power is leveled at the output port of the RF source. The RF source (HP 83651B) performs its own leveling using an internal detector. For proper operation of this mode, the connection between the ALC output of the millimeter-wave controller and the ALC input of the RF source must be removed. To return to normal operation, this connection must be restored.
- {RF LEVEL: EXTERNAL}—the RF source performs its own leveling using an external detector.
- {RF LEVEL: LEVELING OFF}—the RF source is set to the unleveled mode.

NOTE: The last three RF leveling functions are not recommended for normal operation of the HP 8510XF. They are provided as a convenience for use in applications where different methods of RF leveling are desired.

With power leveling enabled ({RF LEVEL: SYSTEM} selected), there are four functions available to detect an “unleveled” condition (for more information, refer to the HP 8510XF system manual). These functions can be found by pressing the following keys: [SYSTEM] {MORE} {RF POWER CONFIG} {MORE}. These functions are:

- {DETECT UNL: ALWAYS}—the HP 8510C polls for errors during every sweep.
- {DETECT UNL: SMART}—the HP 8510C polls for errors during the first sweep following a change in frequency, and thereafter only if an error was detected during the first sweep. This is the default mode.
- {DETECT UNL: ONCE}—the HP 8510C polls for errors only during the first sweep following a change in frequency.
- {DETECT UNL: NEVER}—the HP 8510C does not poll for errors during any sweep.

1. The front panel hardkey names are enclosed in brackets: [HARDKEYS]. The softkey names are italicized and enclosed in braces: {SOFTKEYS}.

Power control

Once power leveling is enabled (*{RF LEVEL: SYSTEM}* selected), the HP 8510XF leveling loop will control the RF source, the millimeter-wave controller and the test head modules to provide the user-requested test port power. The test port power functions described below can be found by pressing the following keys: STIMULUS [MENU] *{POWER MENU}*. (NOTE: These port power functions are valid only when the *{RF LEVEL: SYSTEM}* function is selected.)

- *{PORT1 POWER}*—followed by a number, this specifies a power level setting for Port 1 in dBm. (If the ports are coupled, this setting also applies to Port 2.)
- *{PORT1 SLOPE ON}* and *{PORT1 SLOPE OFF}*—used to enable and disable power slope for Port 1. *{PORT1 SLOPE ON}*, followed by a number, specifies the power slope setting for Port 1 in dB/GHz. The current port power level is used as the power at the first frequency of the sweep, and slope is then applied as frequency increases. Power slope has no effect on CW measurements. (If the ports are coupled, this setting also applies to Port 2.)
- *{COUPLE PORTS}* or *{UNCUPLE PORTS}*—this softkey toggles between the two labels. Pressing this softkey selects the displayed function, but changes the display to show the opposite function. If *{COUPLE PORTS}* is pressed, the Port 1 power level setting and power slope setting are applied to Port 2. If *{UNCUPLE PORTS}* is pressed, the two ports have independent power level settings and power slope settings, and the following softkeys will be displayed.
- *{PORT2 POWER}*—followed by a number, specifies a power level setting for Port 2 in dBm.
- *{PORT2 SLOPE ON}* and *{PORT2 SLOPE OFF}*—used to enable and disable power slope for Port 2. *{PORT2 SLOPE ON}*, followed by a number, specifies the power slope setting for Port 2 in dB/GHz. The current port power level is used as the power at the first frequency of the sweep, and slope is then applied as frequency increases. Power slope has no effect on CW measurements.

NOTE: Since the last two softkeys (*{PORT2 POWER}* and *{PORT2 SLOPE ON/OFF}*) control the power level from Port 2, they are displayed only if the ports are uncoupled.

While using the system in this mode (*{RF LEVEL: SYSTEM}*), the user may encounter the following error messages:

- “RF Unleveled”—displayed if test port power becomes unleveled. This indicates that the specified test port power is too high for the HP 8510XF leveling loop to maintain leveled power over the frequency span. This error message should disappear as test port power is reduced and leveling re-established.
- “No IF Found”—displayed if the IF is not found or too low. Check to make sure that the RF source has an output signal and is properly connected to the millimeter-wave controller. For more information, please refer to the HP 8510C Service Manual, under the Running Error Messages section.
- “IF Overload”—displayed if the IF is overloaded. Reducing the test port power will remove this message.

Measurements in the frequency domain

One of the benefits of the power leveling capability of the HP 8510XF measurement system is the ability to perform power measurements without doing a power calibration each time. Since the input power level to the device under test is kept constant, the HP 8510XF system can carry out power measurements such as gain, gain compression and absolute power on active devices simply, at the touch of a few keystrokes.

Table 2 provides step-by-step instructions for setting up and performing measurements on an amplifier. Included are measurements of gain, gain compression and absolute power.

Table 2. Gain, gain compression and absolute power measurements of an amplifier in the frequency domain.

HP 8510C Keystrokes	Description
(1). Set up the HP 8510C. [PRESET]	Return all instruments to a known state.
[START] F_{start} [G/n] [STOP] F_{stop} [G/n]	Set up the start and stop frequencies.
STIMULUS [MENU] {NUMBER of POINTS} {#...}	Select the number of analyzer trace points.
RESPONSE [MENU] {AVERAGING ON/RESTART} #...[x1]	Set averaging as desired.
(2). Verify that power leveling is enabled. [SYSTEM] {MORE} {RF POWER CONFIG} {RF LEVEL: SYSTEM}	Select RF "system" leveling.
{MORE} {DETECT UNL: SMART}	Select "smart" leveling detection.
(3). Set test port (port 1) power level. STIMULUS [MENU] {POWER MENU} {PORT1 POWER} P_{in} [x1]	Set test port 1 power (P_{in}) below the amplifier's (device-under-test, DUT) compression level.
(4). Perform a thru measurement calibration. [S ₂₁]	Set up the analyzer for an S ₂₁ measurement.
[CAL] {CAL #...} {CALIBRATE: RESPONSE} {THRU} {DONE RESPONSE}	Perform a thru calibration to eliminate the frequency response errors of the path in the measurement. Be sure to include any adapters that are part of the measurement in the thru calibration.
{CAL SET} {1}	Save the calibration in Cal Set 1

Considerations:

If test port cables are used to connect the amplifier, see Appendix A for test port cable loss compensation. Since leveled power is provided at the test ports, power delivered to the input port of the DUT may not be leveled due to the insertion loss of the test port cable.

HP 8510C Keystrokes	Description <i>(continued)</i>
See Appendix B for wafer-probing environments.	
(5). Connect amplifier (DUT) and measure gain.	Gain is displayed here as S_{21} versus frequency.
(6). Measure absolute power at the DUT output port. RESPONSE [MENU] {MORE} {MAGNITUDE OFFSET} P_{in} [x1]	Display absolute power at the DUT output port (versus frequency) by entering a magnitude offset equivalent to the test port 1 power level during the thru calibration (P_{in}). This value can also be calculated for any frequency measurement point by adding P_{in} to S_{21} : <ul style="list-style-type: none"> • $S_{21} = P_{out}/P_{in}$ • $P_{out} = S_{21} \times P_{in}$
(7). Set up 1 dB compression measurement. RESPONSE [MENU] {MORE} {MAGNITUDE OFFSET} 0 [x1]	Return the display to show gain, S_{21} , by removing magnitude offset.
(8). Adjust display. [REF VALUE] 0 [x1] [SCALE] 1 [x1]	Set the reference value to 0, and the scale to 1 dB per division for easy viewing.
(9). Normalize trace. [DISPLAY] {DATA AND MEMORIES} {DISPLAY → MEMORY} {MATH(/)}	By normalizing the measurement, the first frequency point to drop by 1 dB will be easy to identify.
(10). Increase power to find the 1 dB gain compression point. STIMULUS [MENU] {POWER MENU} {PORT1 POWER} use up arrow, rotate knob	Increase the test port power 1 dB at a time until one measurement point visibly drops. If needed, use the knob to adjust the test port power until a 1 dB drop has occurred, and note the test port power level ($P_{compression}$).
[MARKER] rotate knob	Measure the frequency, by using the knob to place a marker at the 1 dB point.
(11). Measure gain at the 1 dB compression point. [DISPLAY] {DATA AND MEMORIES} {DISPLAY: DATA} [AUTO]	Display gain (S_{21}) versus frequency. The marker will indicate the amplifier's gain at the 1 dB compression point for that frequency.
(12). Calculate absolute power at the 1 dB compression point.	Absolute power at the 1 dB compression point (for the specified frequency point) can be calculated by adding $P_{compression}$. $P_{compression}$ is the test port power level identified when the 1 dB gain compression point was found.

Example of the frequency-domain measurement

Figures 3 and 4 illustrate an example of the frequency-domain measurement covered in Table 2. The device-under-test was a broadband amplifier. The measurements were made using 201 trace points and 128 averaging. Figure 3 shows the measurement of absolute power at the DUT output port versus frequency (step 6 of Table 2). Figure 4 shows that the 1-dB compression point is different for each frequency (steps 7-11 of Table 2). For comparison, the measurements shown were made at two different frequency points, one at 3.89 GHz and the other at 13.24 GHz. As the frequency increases, it typically takes more power to reach the 1-dB compression point.

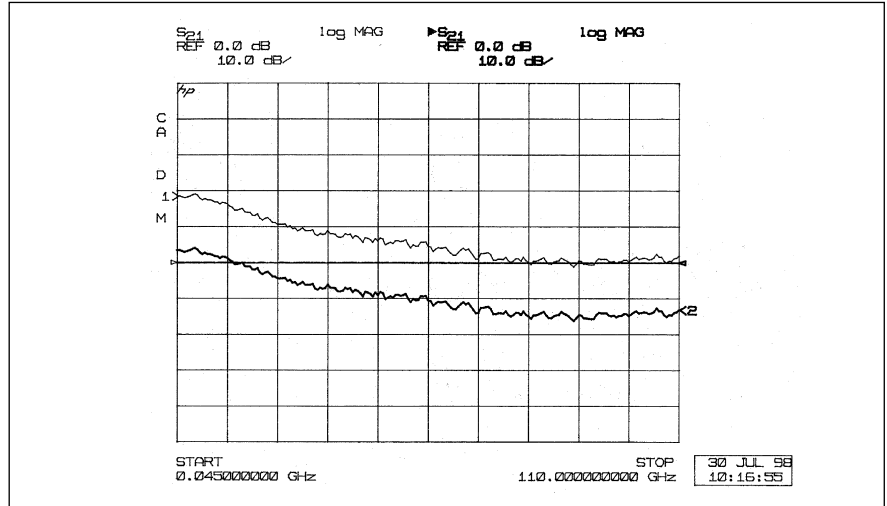


Figure 3. Measurement of absolute power at the DUT output port versus frequency. The top trace shows the S_{21} measurements of the DUT. The bottom trace shows absolute power, the equivalent of P_{in} added to S_{21} . P_{in} was set at -15 dBm

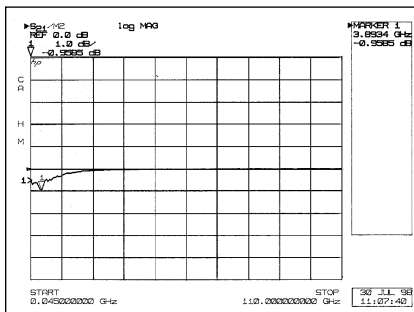


Figure 4a.

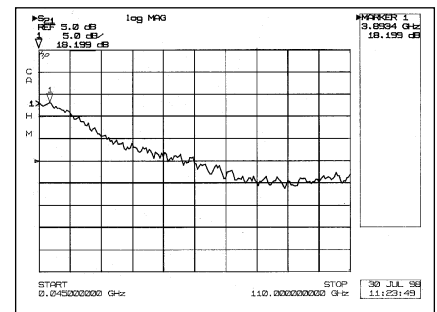


Figure 4b.

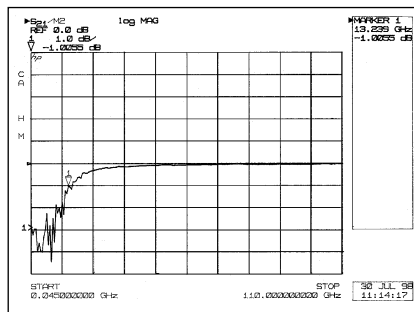


Figure 4c.

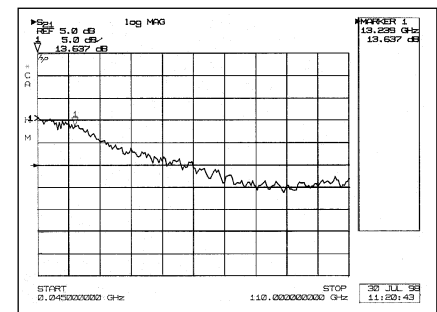


Figure 4d.

Figure 4. (a) At 3.89 GHz, the 1-dB compression point happens at $P_{in} = -11$ dBm, and (b) S_{21} measures at 18.20 dB. (c) At 13.24 GHz, the 1-dB compression point happens at $P_{in} = -6$ dBm, and (d) S_{21} measures at 13.64 dB.

Measurements in the power domain

In the frequency domain, measurements are made at one test port power level while sweeping in frequency. In the power domain, measurements are made at one frequency point while sweeping in power. Similar to frequency-domain measurements, but sweeping in power, measurements such as gain and gain compression can be easily accomplished without performing a power calibration each time.

Before beginning power-domain measurements, the system must be calibrated in the frequency range of choice. This calibration is included in Table 3, along with step-by-step instructions for setting up and performing measurements of an amplifier. It is recommended that the chosen frequency range provides frequency steps of a convenient size. This allows the measurement frequencies to be easily recalled later. For example, setting start frequency to 1 GHz and stop frequency to 101 GHz, with the number of points set to 101, gives measurement frequencies in 1 GHz increments.

Table 3. Gain and gain compression measurements of an amplifier in the power domain.

HP 8510C Keystrokes	Description
(1). Set up the HP 8510C.	
[PRESET]	Return all instruments to a known state.
[START] F_{start} [G/n] [STOP] F_{stop} [G/n]	Set up the start and stop frequencies.
STIMULUS [MENU] {NUMBER of POINTS} {#...}	Select the number of analyzer trace points.
RESPONSE [MENU] {AVERAGING ON/RESTART} #... [x1]	Set averaging as desired.
(2). Verify that power leveling is enabled.	
[SYSTEM] {MORE} {RF POWER CONFIG} {RF LEVEL: SYSTEM}	Select RF "system" leveling.
{MORE} {DETECT UNL: SMART}	Select "smart" leveling detection.
(3). Set test port (port 1) power level.	
STIMULUS [MENU] {POWER MENU} {PORT1 POWER} P_{in} [x1]	Set test port 1 power (P_{in}) below the amplifier's (device-under-test, DUT) compression level.
(4). Perform a thru measurement calibration¹.	
[S ₂₁]	Set up the analyzer for an S ₂₁ measurement.
[CAL] {CAL #...} {CALIBRATE: RESPONSE} {THRU} {DONE RESPONSE}	Perform a thru calibration to eliminate the frequency response errors of the path in the measurement. Be sure to include any adapters that are part of the measurement in the thru calibration.
{CAL SET} {1}	Save the calibration in Cal Set 1

1. If a calibration is being performed or a previously stored Cal Set is being used, the power-domain frequency of measurement must be a point in the original (frequency-domain) calibration. Otherwise, calibration will be automatically turned off.

HP 8510C Keystrokes	Description <i>(continued)</i>
(5). Connect amplifier (DUT) and measure gain.	
	Gain is displayed here as S_{21} versus frequency.
(6). Set up for a power-domain measurement.	
[MARKER] rotate knob	Place a marker at the frequency point of interest (F_{interest}) ¹ .
[DOMAIN] {POWER}	Select power domain ² .
(7). Adjust display for 1 dB compression measurement.	
[MARKER]	Place a marker on the left side of the display.
[REF VALUE] [= MARKER]	Set the marker value to become the new reference value.
[SCALE] 1 [x1]	Set the scale to 1 dB per division for easy viewing.
(8). To change start and stop test port power levels³:	
[START] P _{start} [x1]	Set up the start and stop test port power levels.
[STOP] P _{stop} [x1]	Set P _{start} below the amplifier's compression level.
(9). Increase P_{stop} to find the 1 dB gain compression point.	
[STOP] use up arrow, rotate knob	Increase the stop test port power level 1 dB at a time until the right half of the measurement trace visibly drops. Then, use the knob to adjust the power until a 1-dB drop has occurred, and note the test port power level ($P_{\text{compression}}$) for this frequency point.
(10). To measure another frequency point⁴:	
[DOMAIN] {POWER} Select {NEXT PT. HIGH.} Or {NEXT PT. LOW}	Use these keys to select the next frequency point of interest, either higher or lower, and adjust P _{stop} as necessary.

1. If multiple markers are ON, the active marker is the one that will be used for the power-domain frequency of measurement.
2. In the HP 8510XF system, the factory preset default settings for power-domain measurements are as follows:
 - Start: -35 dBm
 - Stop: -15 dBm
3. In the power domain, the stimulus keys ([START], [STOP], [CENTER], [SPAN]) refer to power and not frequency. Since the sweeps are done in power, the softkey {PORT1 POWER}, under STIMULUS [MENU] {POWER MENU}, has no effect in this mode.
4. If a calibration is being performed or a previously stored Cal Set is being used, the power-domain frequency of measurement must be a point in the original (frequency domain) calibration. Otherwise, calibration will be automatically turned off.

Example of the power-domain measurement

Figures 5 and 6 illustrate an example of the power-domain measurement covered in Table 3. The device-under-test was a broadband amplifier. The measurements were made using 201 trace points and 128 averaging. Figure 5 shows an S_{21} measurement (versus frequency) before Power Domain was enabled (step 5 of Table 3). The marker marks the frequency of interest (F_{interest}). Figure 6 shows the S_{21} measurement sweeping in power at F_{interest} and identifying the 1-dB compression point at that frequency (steps 6-9 of Table 3).

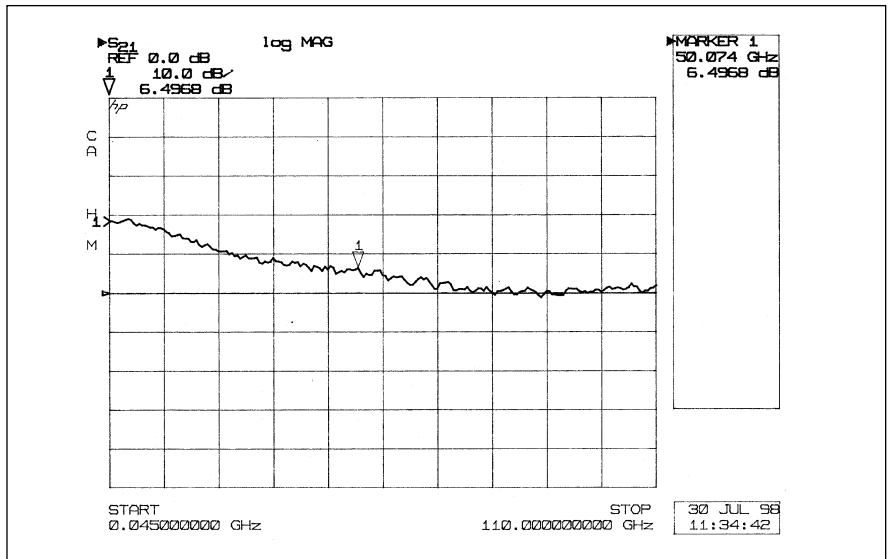


Figure 5. An S_{21} measurement (versus frequency) with the marker placed at 50.07 GHz and P_{in} set at -15 dBm (before Power Domain was enabled).

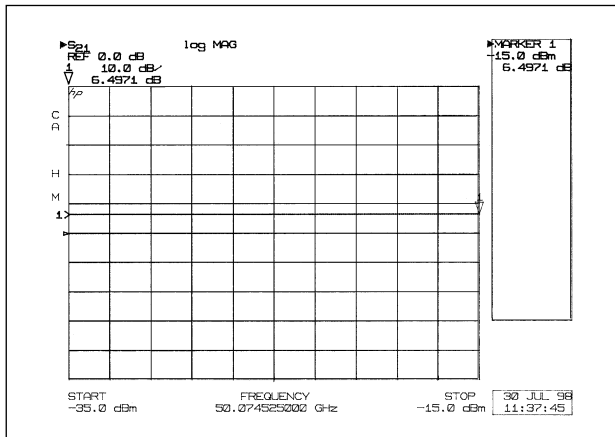


Figure 6a.

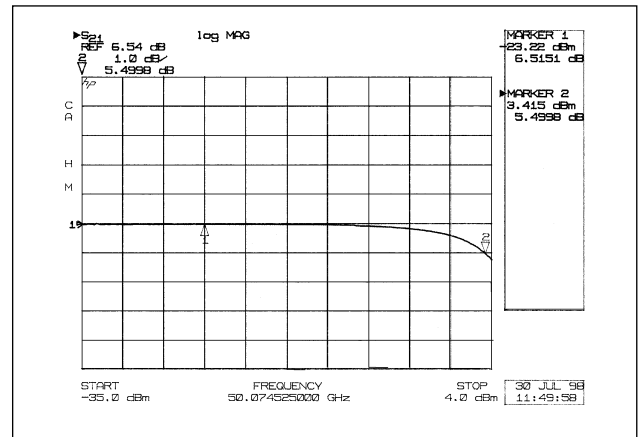


Figure 6b.

Figure 6. (a) An S_{21} measurement (versus power) at the frequency specified by the marker in Figure 5. Note the default start and stop stimulus values. (b) By increasing the stop stimulus value, the 1-dB compression point at this frequency is found to be at 3.415 dBm.

Appendix A. Test port cable loss compensation

Since leveled power is provided at the test ports of the HP 8510XF system, test port cables that are used to connect between the test port and the input port of the device-under-test (DUT) will reduce the power delivered to the input port of the DUT. This reduction in power is due to the insertion loss of the test port cable. This section describes the basic steps one can implement to compensate this loss and deliver leveled power at the end of the test port cable.

If the insertion loss of the test port cable is characterized over frequency, this data can be used in conjunction with power slope to compensate cable loss resulting in leveled power at the end of the test port cable. (Power slope of the HP 8510XF was covered above in the power control section.)

Example:

In this example, the following sequence of events took place:

1. A response (thru) calibration was performed on the HP 8510 VNA.
2. Insertion loss (S_{21}) of a test port cable was characterized (see Figure A1). In this case, the test port cable is the DUT.
3. Power (vs. frequency) at the end of the test port cable was examined (see Figure A2).
4. The power slope value was calculated and applied.

The test port cable used in this example was an HP 11500J, a 1.0 mm test port cable with male and female connectors and 16 cm in length.

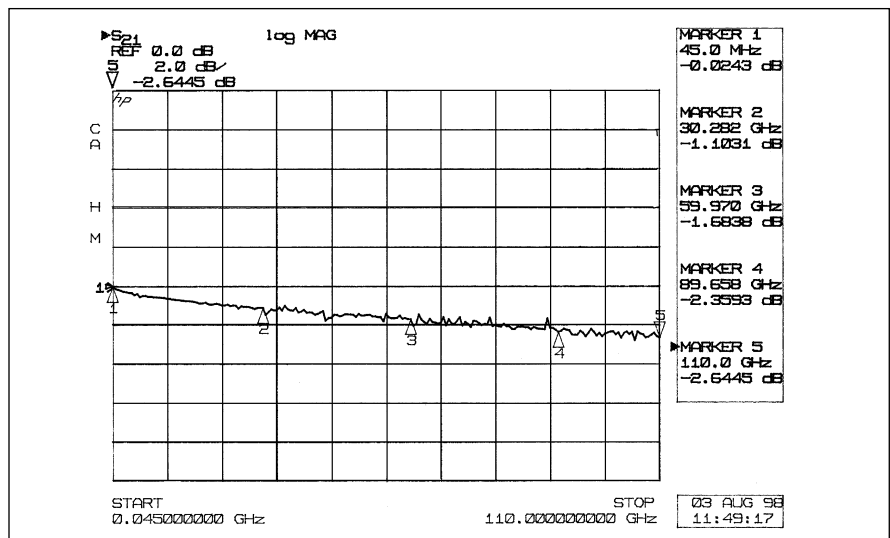


Figure A1. Insertion loss (versus frequency) of a typical HP 11500J 1.0 mm test port cable.

Figure A2 shows output power versus frequency at the end of the test port cable as connected to the test port of the HP 8510XF system. The power setting was -10 dBm. Since power at the test port is leveled, the slope shown in Figure A2 is mainly due to the insertion loss of the test port cable. Notice that the trace resembles that of Figure A1. By approximating the trace as a straight line, the insertion loss of the cable can be compensated by applying power slope¹.

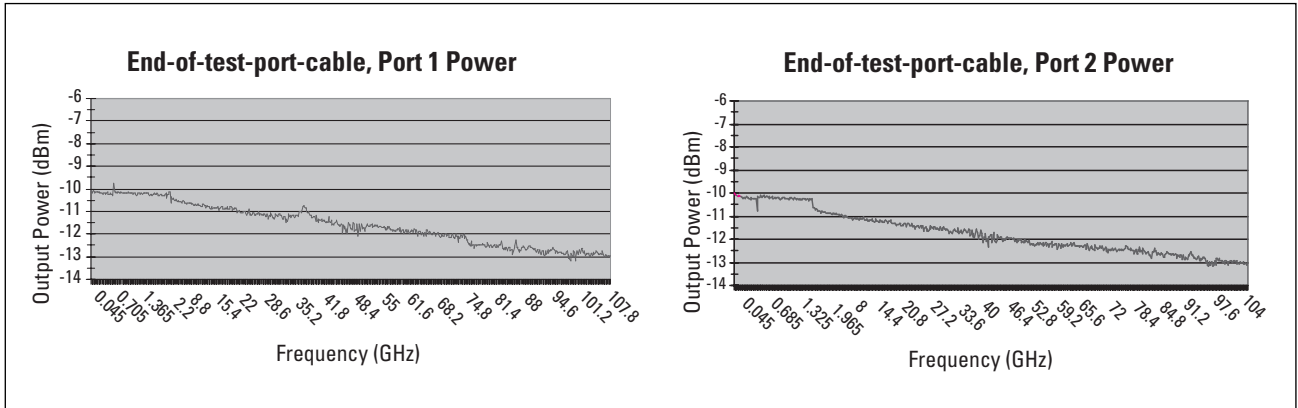


Figure A2. Output power at the end of the test port cable versus frequency. Power was set at -10 dBm. The test port cable used was an HP 11500J

Power slope calculation:

Since the insertion loss of cables is typically linear with frequency (as shown in Figure A1), a best-fit line can be used to estimate the slope of the line. The slope of the line in Figure A1 is approximately -3 dB/110 GHz (equivalent to -0.027 dB/GHz). To compensate for the insertion loss of the cable shown in Figure A1, the power slope value would be $+0.027$ dB/GHz. To enable power slope, follow this key sequence: STIMULUS [MENU] {POWER MENU} {SLOPE ON} power_slope_value [x1]. (In this case, power_slope_value would be 0.027.)

Using the technique described above, the approximated insertion loss of a test port cable can be corrected by applying power slope, resulting in “approximated” leveled power at the end of the test port cable. This way, power delivered to the input port of the DUT is approximately leveled across frequency.

1. As stated above in the power control section, power slope has no effect on CW measurements (not applicable). Thus, this is valid in frequency domain, not power domain.

Appendix B. Wafer-probing environment considerations

On-wafer S-parameter measurements at frequencies up to 110 GHz can be made using the HP 8510XF VNA system and Cascade Microtech¹ or other compatible wafer probers. Wafer probing allows immediate evaluation for device characterization and selection before dicing the wafer and packaging. The ability to calibrate on-wafer and make real-time error-corrected measurements with the HP 8510XF are the principle advantages of this system.

Since leveled power is provided at the test ports of the HP 8510XF system, test port cables and probes that are used to connect between the test port and the wafer-under-test will reduce the power delivered to the wafer. This reduction in power is mainly due to the insertion loss of the test port cable and the probe. This appendix describes the basic steps one can implement to compensate this loss and deliver leveled power at the probe tip. (For information relating to on-wafer measurements, in particular on-wafer calibration, see HP Product Note 8510-6 or contact Cascade Microtech.)

By characterizing the insertion loss of the test port cable and the probe (together) over frequency, power slope can be used in conjunction with this data to compensate the loss, resulting in leveled power at the wafer. (Since there are no power sensors for on-wafer measurements at this time, the steps described below can be used to *estimate* power at the probes, for all practical purposes, by taking advantage of the known test port reference plane.)

To characterize the combined insertion loss of a test port cable and a probe (“cable + probe”), it is necessary to follow a two-step process. Step 1 is to perform a 1-port coaxial calibration at the test port, and step 2 is to perform a “probe test” at the tip of the probe. (“Probe Test” is a feature of Cascade Microtech’s WinCal software.)

Example:

In this example, the following equipment was used:

From Hewlett-Packard:

- HP 8510XF 0.045 to 110 GHz VNA system.
- HP 11500J² 1.0 mm test port cable, male-to-female, 16 cm in length.
- HP 85059A DC to 110 GHz calibration kit.

From Cascade Microtech:

- Summit 9100, manual probe station.³
- ACP110L-GSG DC to 110 GHz low-loss probe, 150 μ m pitch, ground-signal-ground (G-S-G) configuration.
- P/N 104-783 W-band Impedance Standard Substrate (ISS), in G-S-G configuration usable through 110 GHz.
- WinCalTM automated calibration software for vector network analyzers.

1. Cascade Microtech is an HP Channel Partner and can be reached at:
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2. Different lengths of 1.0mm test port cables are also applicable. There are three lengths available: HP 11500J (16cm), HP 11500K (20cm) and HP 11500L (24cm).

3. A manual probing station was used in this example. Other probing stations are also applicable, such as semiautomatic probe stations.

The following sequence of events took place:

1. A 1-port coaxial calibration was performed at the test port of the HP 8510 VNA.
2. The test port cable and the probe were connected to the same test port that was just calibrated.
3. Using WinCal and with the test port calibration active on the VNA, the *probe test* was performed.
4. The result was an S-parameter graph of the “cable + probe” (see Figure B1).

The trace labeled S_{21} , in Figure B1, shows the insertion loss (versus frequency) of a typical HP 11500J test port cable and a typical ACP110L-GSG probe (together). S_{11} shows the reflection measurement at the test port, and S_{22} shows the reflection measurement of the ACP110L-GSG probe tip. Figure B1 was generated using Cascade’s WinCal calibration software. Table B1 outlines the steps needed to generate Figure B1.

Looking at the trace in Figure B1, the slope of the line can be estimated using straight-line approximation. The value of the slope can then be applied in power slope to compensate for the insertion loss in the path between the test port and the wafer. (Refer to Appendix A for power slope calculation.)

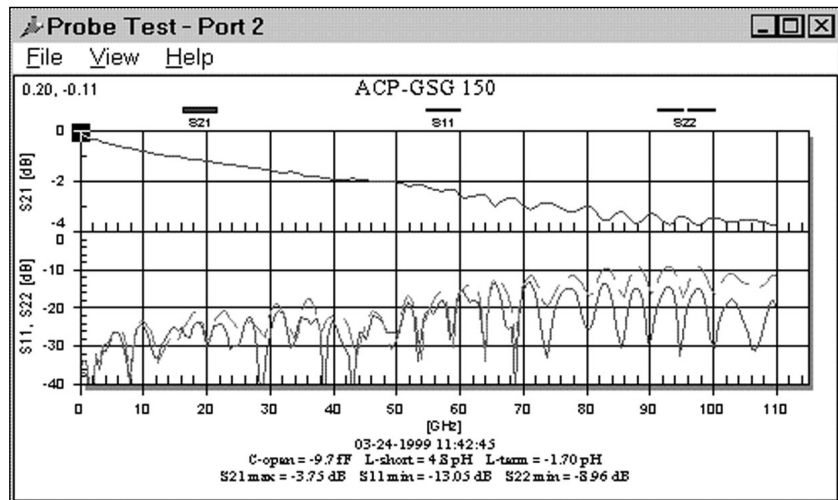


Figure B1. S_{21} shows the total insertion loss (versus frequency) of a typical HP 11500J test port cable and a typical ACP110L-GSG probe from Cascade Microtech as measured and computed using Cascade’s *Probe Test* feature in their WinCal calibration software

Table B1. Procedure to characterize a test port cable and a probe together.

Description

(1). Coaxial calibration at the test port of the VNA

Using the front panel of the HP 8510,

- Set all desired settings: start and stop frequencies, number of points, averaging, port power.
- Perform a 1-port calibration at a test port (for example, at test port 1)
- Save the calibration and turn it on.

(2). Connect the test port cable and then the probe to the test port

(that is, connect the HP 11500J test port cable to test port 1, and then connect in the probe as shown in Figure B2)

(3). Using WinCal, perform Probe Test

With WinCal running on a desktop PC¹ controlling the HP 8510XF VNA system via a GP-IB cable,

- Start WinCal. This will bring up a screen similar to the one shown in Figure B3.
- Select Probe Test from the Tools menu. This will bring up a screen similar to the one shown in Figure B4.
- For this example, select Port 1 under Method.
- Measure the Open, Short and Load standards on the ISS.
- Click Compute, and it will display results similar to Figure B1.

(4). Power slope calculation

The S_{21} trace shown in Figure B1 can be used to approximate the value for power slope.

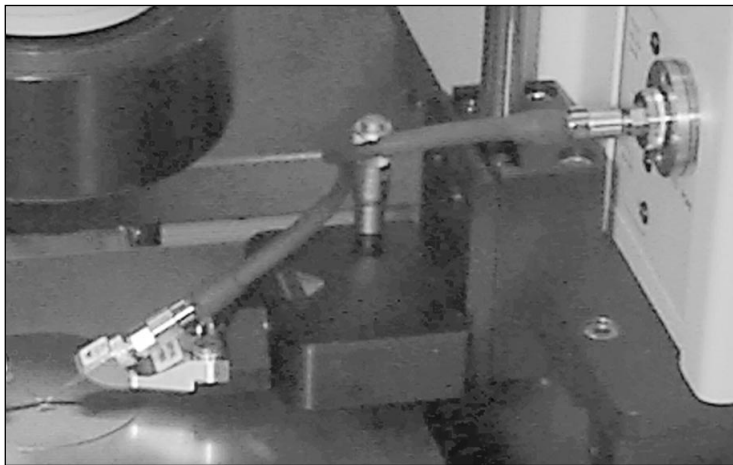


Figure B2. Test port cable and probe connection.

1. PC requirements and detailed information on WinCal can be found in Cascade Microtech's WinCal Software User Guide.

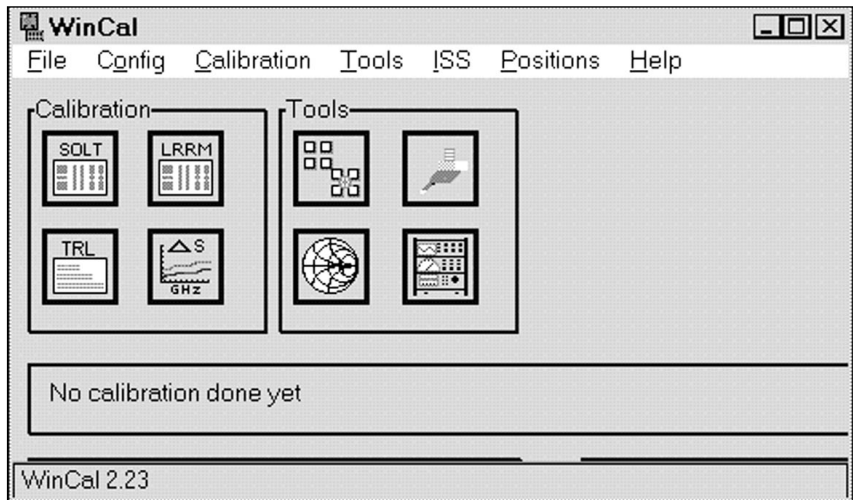


Figure B3. WinCal

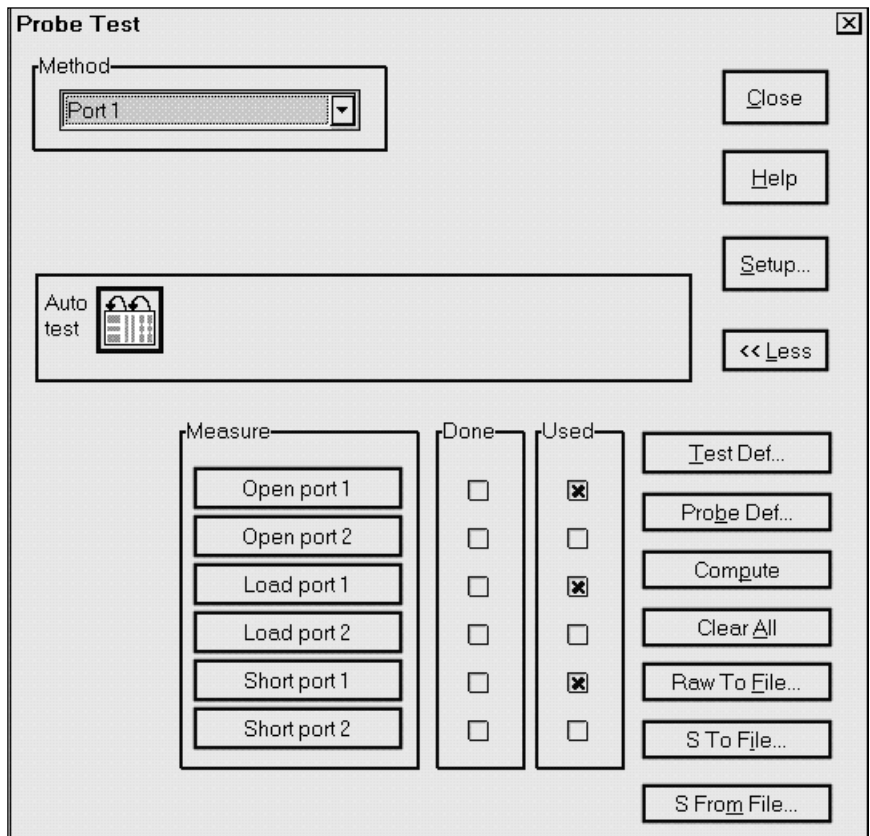


Figure B4. Probe Test dialog box

References

1. *On-Wafer Measurements Using the HP 8510 Network Analyzer and Cascade Microtech Wafer Probes*, HP Product Note 8510-6, literature number 5954-1579.
2. *Controlling Test Port Output Power, Flatness*, HP Product Note 8510-16, literature number 5091-0467E.
3. *WinCal Software User Guide*, Cascade Microtech.



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