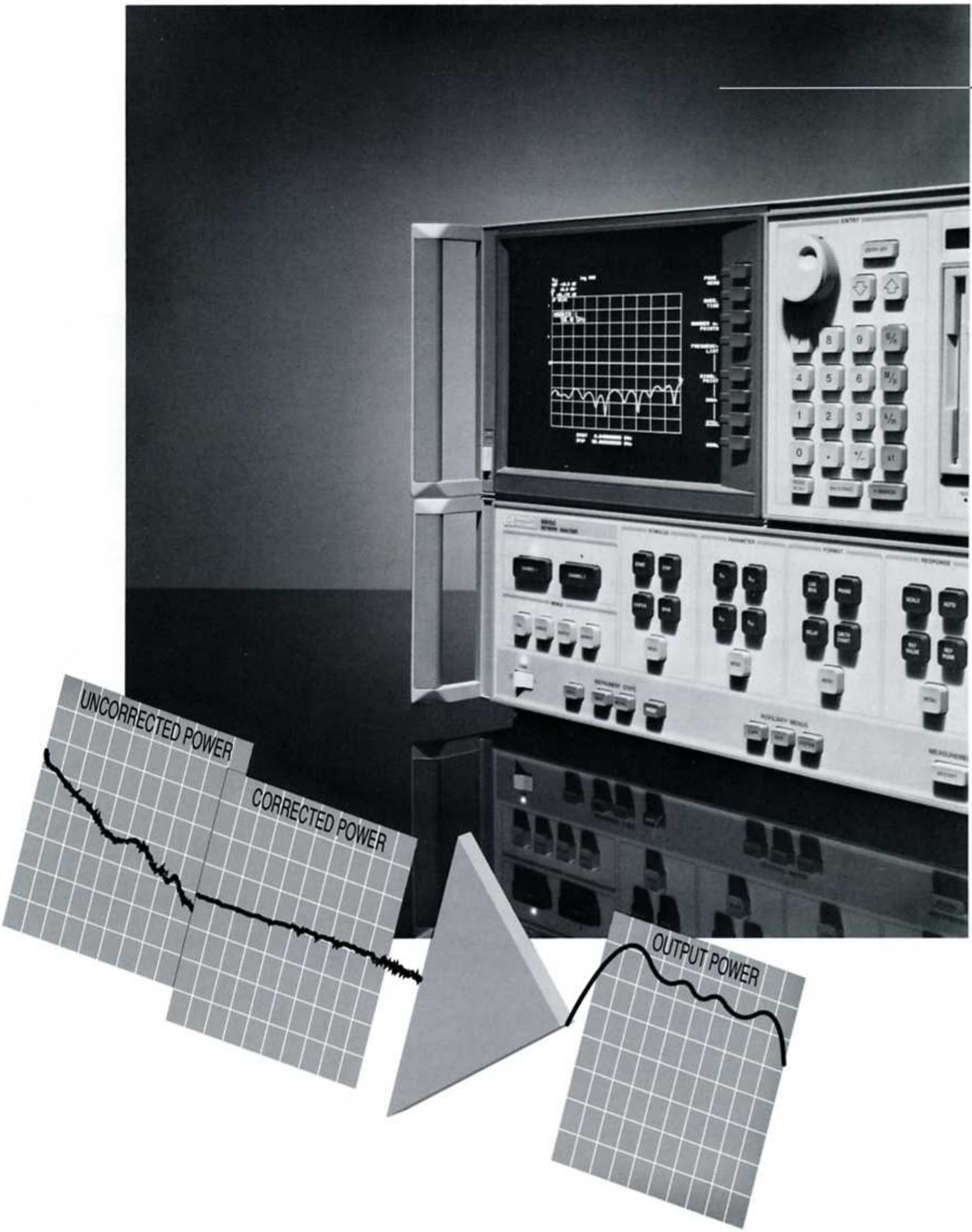
Controlling test port output power flatness

Product Note 8510-16



Introduction

Designers and manufacturers of active devices and components often need to control the power level at the input port (test port[1]) of their power-sensitive devices, but find it difficult to overcome insertion losses created by components in the measurement path between the source and the test device. The HP 8510C[2] is the first microwave network analyzer capable of setting and controlling the power level at the test port. To accomplish this, the HP 8510C performs a flatness correction calibration, by measuring the test port power level with an HP 437B Power Meter and creating a table of power corrections versus frequency which is stored in an HP 8360 Synthesized Sweeper[3]. When test port flatness correction is enabled, the source will adjust the output power to compensate for path losses at each measurement point in the frequency span. Figure 1 illustrates test port power versus frequency with and without flatness correction in an HP 8510C/83651A/8517A measurement system. This note reviews the implementation and operational considerations of the HP 8510C's test port flatness correction feature.

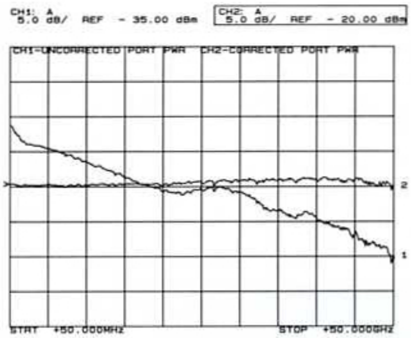


Figure 1. Uncorrected versus corrected HP 8517A test port power with the source set to –20 dBm; note the different reference levels.

Flat test port power is achieved by using the HP 8360's "user flatness correction" feature (for more information, refer to Product Note 8360-2). The flatness correction calibration does not need to be repeated unless the user wants to calibrate over a wider frequency range, unless the measurement path between the source and the test device changes, or unless the environmental conditions under which the original calibration was performed change dramatically. Once the flatness correction calibration has been completed the user may choose to reduce the measurement frequency span at any time without invalidating the flatness correction. As long as the new measurement span is a subset of the original calibration span, the source will output corrected power at the appropriate measurement points. The time it takes to accomplish a flatness correction calibration will depend on the number of measurement points, and the test port power level during the calibration.

Flatness correction calibration

Table 1 illustrates the basic setup procedure to obtain flat test port output power. To simplify the execution of the procedure, the keys to be selected are enclosed in brackets. Also, the softkeys are italicized to differentiate them from the front panel hardkeys. Connect the measurement system as shown in Figure 2.

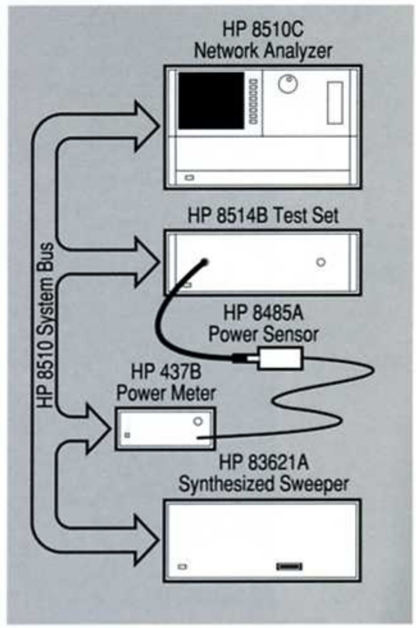


Figure 2. Basic HP 8510C measurement system block diagram for test port flatness correction capability.

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1 Throughout this document, "test port" will refer to the point in the system where the test device is connected. This may be port 1 or port 2 of any HP 8510 coaxial-based test set, or the end of a cable or adapter which is attached to the device under test.

2 HP 8510B network analyzers with revision B.06 or later may also be used to achieve constant test port power levels. To obtain the latest firmware revision, order the HP 11575F Upgrade Kit.

3 Any HP 8360 Synthesized Sweeper with a firmware revision of 25 September 1990 or earlier, must be upgraded. To upgrade your HP 8360 to the latest firmware revision, order HP part number 08360-60167.

Table 1. Flatness correction calibration procedure

HP 8510C Keystrokes	Description
Set up power meter	
	For proper operation, the HP 437B must be set up before initiating the flatness correction calibration routine. See the Appendix for specific instructions.
Verify that the HP 437B is connected to the HP 8510C system bus.	
Verify the power meter's address	
[LOCAL] *[POWERMETER]*	When shipped from the factory, the address of the power meter is 13. If this conflicts with another instrument on the system bus, make the appropriate adjustment.
Set up analyzer and measurement	
	Set up the start/stop frequencies and the measurement type, (S11, S21....).
If needed, adjust the number of analyzer trace points	
STIMULUS [MENU] *[NUMBER of POINTS] [PTS.]*	When the flatness calibration is initiated, the analyzer sends the source a list of flatness correction frequencies equal to the number of trace points set on the analyzer.
Set source to maximum leveled power	
STIMULUS [MENU] *[POWER MENU]* *[POWER SOURCE 1]* P_1 [x1]	Set the HP 8360 for maximum specified power (P_1) at the highest frequency in the measurement span; see Table 7 in the Appendix. The power meter will take less time to settle between measurement points during the calibration process at higher power levels.
Connect the power sensor to the active test port, or change the measurement parameter being measured.	
Initiate flatness calibration	
[MORE] *[CALIBRATE FLATNESS]*	Do not cycle the power on the analyzer or the source during the calibration process. The calibration may be aborted at any time by pressing any key on the analyzer's front panel. Once initiated, the analyzer retrieves the power meter measurement data and transfers it to the HP 8360 where it is processed and stored with the appropriate correction frequency. During the flatness correction calibration the analyzer will display "MEASURING DATA, xx% DONE, PRESS ANY KEY TO ABORT." The "xx% DONE" indicates the percent of the total number of correction points that have been measured; it is not an indication of elapsed measurement time. When the flatness correction calibration is complete, the analyzer will automatically store the correction table into register 1 of the source.
Upon completion of the calibration, activate flatness correction	
[MORE] *[FLATNESS ON]*	The source output power will now be unleveled, as it attempts to output the test port power level (Power Source 1) plus the flatness correction for each measurement point in the frequency span. "IF Overload" may be displayed on the analyzer until the test port power level is reduced.
Set test port power level	
[PRIOR MENU] *[POWER SOURCE 1]* P_2 [x1]	Set the test port power level (P_2) equal to or below the maximum settable test port power (see Table 2) for the highest frequency in the measurement span. A constant power level equivalent to P_2 will now be available at the test port. The flatness correction calibration can be verified by using the HP 437B to measure the test port power at CW frequencies. As the power is manually measured, the user must enter each test frequency on the HP 437B so that the correct cal factor will be used.
Perform measurement calibration	
	Compensate for systematic errors by performing a measurement calibration (if desired). The measurement calibration can be performed before or after the flatness correction calibration, with or without flatness correction enabled.
Connect the device under test to the test port.	

Flatness correction operation

When flatness correction is enabled in an HP 8510C measurement system, the analyzer's [Power Source 1] softkey actually controls the test port power level, not the RF input power into the test set. The source and test set used will determine the available test port power range. The settable test port power range is limited by the maximum leveled power the source can output minus the maximum loss incurred during the flatness correction calibration, and the minimum power the test set can receive to achieve system phaselock at any frequency in the measurement span. The test port power level must be set within the power range presented in Table 2 for common source/test set combinations.

The user may encounter the following error messages while attempting to enable the flatness correction and reduce the test port power level:

- If flatness correction is enabled before reducing the test port power level, "IF Overload" may be displayed on the analyzer as the source becomes unleveled while attempting to output its maximum specified power plus the flatness corrections.
- If the output power is reduced to the correct test port power level before turning flatness correction on, "No IF Found" may be displayed. There may not be sufficient input power at the test set RF Input port for the HP 8510C to phaselock to the signal.

These error messages should disappear when flatness correction is enabled with the appropriate test port power level setting. If the test port power level is not correctly reduced, the source will become unleveled and try to output maximum power. Although flatness correction will still be applied to the unleveled signal, the measurement for the unleveled portion of the frequency span will not be valid since the flatness correction feature cannot compensate for the inconsistent power variations that will occur.

Power control with flatness correction

Table 2 provides the typical maximum and minimum settable test port power levels necessary to achieve a constant power across the measurement span with the flatness correction feature. To determine settable test port power levels for a particular frequency span, pick a power level between P_{max} of the highest frequency in the measurement span and P_{min} of the lowest frequency in the span.

Table 2. Settable test port power ranges[4,5]

RF Source HP 8510 Test Set	HP 83620A/83621A w/HP 8514B	 w/HP 8515A	HP 83631A w/HP 8515A	HP 83651A w/HP 8517A
Frequency	Test Port Power Levels [Pmax/Pmin] (dBm)			
0.05 GHz	+2.5/–20.5	–3.5/–26	–3.5/–26	+1.5/–21.5
2 GHz	+1/–22	–6/–29	–6/–29	+0.5/–23.5
20 GHz	–7.5/–27	–13.5/–30	–13.5/–30	–7.5/–30
26.5 GHz			–25/–30	–13.5/–30
40 GHz				–20/–30
50 GHz				–27/–30

4 Assumes no test set step attenuation.
5 The HP 8516A Test Set has not been characterized, since the test port flatness correction feature cannot compensate for losses above 20 GHz.

The ability to compensate for power variations across the entire measurement span of the source will depend on the highest leveled output power the source can produce and the amount of power compensation required.

The test port power may be adjusted over the entire P_{max} to P_{min} range without degrading the flatness correction calibration. For example, the settable power range for a 50 MHz to 20 GHz span with an HP 83621A/8515A system is from –13.5 to –27 dBm. A high-power HP 83623A Synthesized Sweeper adds 7 dBm to the P_{max} of the HP 83620A/83621A values. If a user sets up a 50 MHz to 20 GHz measurement with an HP 83623A and an HP 8515A, the settable test port power range is from –6.5 to –27 dBm.

The HP 8511A Frequency Converter test set may also be used with the test port power flatness correction feature. The settable test port power range is determined by the available power of the HP 8360, and the insertion loss of the components the user adds to the measurement system.

Using test set step attenuators with flatness correction

If lower test port power levels are desired, the test set step attenuators[6] may be used as shown in Figure 3. As can be seen, there is only a slight degradation in flatness.

The frequency response of the step attenuators can be eliminated from the measurement by performing the flatness correction calibration with the appropriate attenuation enabled. High-sensitivity power sensors (HP 8485D to 26.5 GHz and HP 8487D to 50 GHz) are available for power measurements from –20 to –70 dBm.

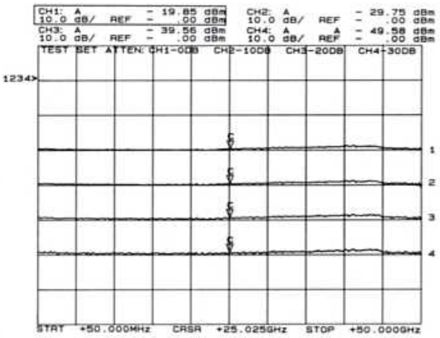

Figure 3. Step attenuator performance with flatness correction enabled from 50 MHz to 50 GHz.

The limitation of making power meter measurements at these low power levels is that the actual calibration process takes considerably more time since the power meter takes much longer to settle at each correction frequency.

Table 3. Absolute power measurements with flatness correction

HP 8510C Keystrokes	Description
Set up the source and power meter as shown in Table 1.	
Set up the measurement PARAMETER [MENU] *[USER 2 b2]*	Set up the analyzer for a b2 measurement.
Activate test port power flatness correction	Perform the flatness correction calibration; set the test port power level and enable the flatness correction as shown in Table 1.
Connect a thru.	
Perform a thru calibration with flatness correction enabled [CAL] *[CAL #.....]* *[CALIBRATE: RESPONSE]* *[THRU]* *[DONE RESPONSE]* *[CAL SET] [1]*	Perform a thru calibration to eliminate the frequency response errors of the port 2 path in the measurement. Be sure to include any attenuators or adapters which are part of the measurement in the thru calibration. It may be necessary to swap adapters for the thru connection. Any cal set may be selected to access the response calibration in the calibration menu structure.
Reconnect the test device.	
Measure absolute power RESPONSE [MENU] *[MORE]* *[MAGNITUDE OFFSET]* P_2 [x1]	When the device is reconnected, gain will be displayed. Enter a magnitude offset equivalent to the test port power level (P_2) set in Table 1. Measure the absolute power at any point in the measurement span.

Absolute power measurements with flatness correction

One of the benefits of the flatness correction capability of the HP 8510C/8360 measurement system, is the ability to measure the absolute power of active devices before and after gain compression. Since the input power level to the device under test is kept constant, the magnitude offset feature of the HP 8510 can be used to display absolute power across the entire frequency span of the device. Table 3 provides the procedure for absolute power versus frequency measurements with test port flatness correction.

Amplifier measurement example

Table 4 provides step-by-step instructions for setting up and applying flatness corrections for the measurement of an amplifier. Some of the topics covered include the measurement of: gain, absolute power and gain compression. This measurement utilizes an HP 83621A Synthesized Sweeper and an HP 8514B Test Set.

[6] Step attenuators are not available on S-parameter test sets with Option 002, or for controlling test port power flatness in the HP 85110A Pulse Test Set.

Table 4. Absolute power and 1 dB compression measurements of an amplifier

HP 8510C Keystrokes	Description
Set up the power meter; see the Appendix for specific information.	
Verify that the HP 437B is connected to the HP 8510C system bus.	
Verify the power meter's address as shown in Table 1.	
[PRESET]	Return all instruments to a known state.
[START] Fstart [G/n] [STOP] Fstop [G/n]	Set up the start and stop frequencies.
PARAMETER [MENU] *[USER 1 a1]*	Activate port 1 of the test set.
Connect the power sensor to the end of the cable at test port 1.	
Adjust the number of analyzer trace points STIMULUS [MENU] *[NUMBER of POINTS] [401]*	Send the source a list of 401 points for the flatness correction calibration.
Set source to maximum leveled power STIMULUS [MENU] *[POWER MENU]* *[POWER SOURCE 1]* 10 [x1]	Set the source power level to +10 dBm which is the maximum specified power at 20 GHz with an HP 83621A synthesizer; see Table 7 in the Appendix.
Initiate flatness calibration[7] *[MORE]* *[CALIBRATE FLATNESS]*	Initiate the flatness correction calibration.
Upon completion of the calibration, activate flatness correction *[MORE]* *[FLATNESS ON]*	The source will now output unleveled power, attempting to provide +10 dBm (source's maximum specified power) at the test port cable attached to port 1 of the HP 8514B Test Set, until the test port power level is appropriately reduced.
Set test port power level [PRIOR MENU] *[POWER SOURCE 1]* P_A [x1]	Set the test port power below the amplifier's compression level (P_A) and within the settable power range presented in Table 2.
Set up a b2 measurement, then connect a thru. PARAMETER [MENU] *[USER 2 b2]*	Set up the analyzer for a b2 measurement.
Perform a thru calibration [CAL] *[CAL #.....]* *[CALIBRATE: RESPONSE]* *[THRU]* *[DONE RESPONSE]* *[CAL SET] [1]*	Perform a thru calibration to eliminate the frequency response errors of the port 2 path in the measurement. Be sure to include any attenuators or adapters which are part of the measurement in the thru calibration. It may be necessary to swap adapters for the thru connection. Any cal set may be selected to access the response calibration in the calibration menu structure.
Connect amplifier and measure absolute power [RESPONSE MENU] *[MORE]* *[MAGNITUDE OFFSET]* P_A [x1] [AUTO]	Display the absolute power by entering a magnitude offset equivalent to the test port power level during the thru calibration (P_A). Gain can be calculated for any measurement point by subtracting P_{in} from P_{out} ($P_{measured}/P_A$), or gain may be measured by performing an S_{21} thru calibration.
Set up 1 dB compression measurement; normalize trace [DISPLAY] *[DISPLAY -> MEMORY 1]* *[MATH(/)]*	By normalizing the measurement, the first frequency point to drop by one dB will be easy to identify.
Adjust display [REF VALUE] 0 [x1] [REF POSN] use down arrow [SCALE] 1 [x1]	Move the reference line to the bottom of the graticule to allow full use of the display.
Increase power to find the 1 dB gain compression point STIMULUS [MENU] *[POWER MENU]* *[POWER SOURCE 1]* use up arrow [MARKER] rotate knob	Increase the test port power 1 dB at a time until one measurement point visibly drops. Then, use the knob to adjust the power until a 1 dB drop has occurred, note the test port power level, and use a marker to measure the frequency.
Measure absolute power at the 1 dB compression point [REF POSN] up arrow 5 times [DISPLAY] *[DISPLAY: DATA]* [AUTO]	Move the reference level back to the center of the screen and display absolute power versus frequency. The marker will indicate the amplifier's absolute power for the 1 dB compression point.

[7] Do not cycle power during the flatness correction calibration.

Operational considerations

Calibration time

The time it takes for a flatness correction calibration is dependent on the number of measurement points selected and the test port power level during the calibration. Once a flatness correction calibration has been completed, the user may adjust the number of trace points on the analyzer or change the measurement frequency span to a subset of the original calibration span without invalidating the calibration. The source will output corrected power at the appropriate measurement points. This capability is particularly useful for users who are testing a number of devices with different frequency spans at the same test station. In this case the user may choose to perform the flatness correction calibration with the maximum amount of calibration points (801) across the full frequency span covered by the test devices. Then, subsets of the original calibration frequency span can be used to meet the specific testing requirements of the individual devices.

The user may also choose to reduce the number of calibration points to speed up the calibration process by reducing the number of trace points on the analyzer. Table 5 provides some typical calibration times for flatness correction calibration over the full frequency span of the source for different source/test set combinations.

Table 5. Typical calibration times (minutes) versus number of calibration points.

Number of Points	HP 83620A/83621A w/HP 8514B	HP 83620A/83621A w/HP 8515A	HP 83631A w/HP 8515A	HP 83651A w/HP 8517A
801	30	32	60	60
401	15	16	30	30
201	8	8	15	15
101	4	4	8	8
51	2	2	4	4

Using test port 1 calibrations on test port 2

In most cases, port 1 would be the input port of the device under test. When port 2 must be used as the input port to the device, the user may choose to use a port 1 flatness correction calibration on port 2, since the port 1 and port 2 signal paths within the test sets are symmetrical (not including test sets with Option 003). As can be seen in Figure 4, the port 2 measurement with the port 1 flatness correction calibration tracks the port 1 corrected performance extremely well below 30 GHz.

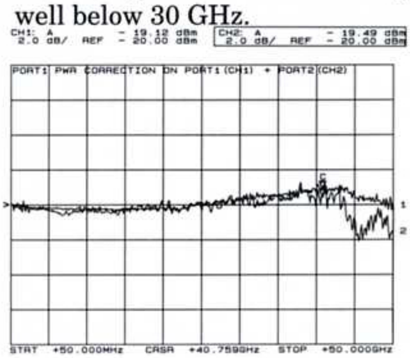

Figure 4. Corrected test port power using port 1 flatness correction calibration on ports 1 and 2.

Verifying flatness corrections

If a user would like to verify the flatness correction calibration, the power sensor should be reconnected to the test port to measure the test port power at individual frequencies. Make sure to enter each test frequency on the power meter, otherwise the wrong calibration factor will be used for the measurement. Since the measurement system is calibrated in 50 ohms, inaccuracies will occur when a device is attached that is not 50 ohms. Since the flatness correction calibration is not a real-time power leveling feature, it cannot correct for mismatches that occur between the test port and the device under test. Mismatches can be reduced by using attenuators at the input or output of the device under test.

Flatness corrections in fixture or wafer-probing environments

Test port flatness correction may be applied with any other power function, such as power slope. Power slope may be used to compensate for the path loss in non-coaxial environments, such as microstrip and coplanar-waveguide measurement systems. When power slope is used with flatness correction enabled, the user must be sure that there is sufficient test port power available for the additional power compensation. The maximum settable test port power for any particular frequency span cannot exceed the maximum test port power level for the highest frequency in the span (Table 2) minus the maximum power slope compensation required.

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Table 6. HP 437B Power Meter setup

HP 437B Keystrokes	Description
[PRESET] [ENTER]	Return the power meter to a known state.
[ZERO]	Adjust the power meter's internal circuitry for a zero power indication when there is no power applied.
Connect power sensor to POWER REF output on power meter [SHIFT] [PWR REF]	Activate power reference measurement to calibrate the power meter and the power sensor to a known reference.
If 0.0 dBm or 1mW is not displayed, calibrate [SHIFT] [CAL] use arrow keys	Initiate the calibration process. If the reference calibration factor for the sensor in use is not displayed, adjust the display with the arrow keys.
[ENTER]	Enter the power sensor's reference calibration factor. "CAL *****" will be displayed until the gain of the meter has been adjusted to read 0.0 dBm or 1mW when the sensor is connected.
Select or create the calibration factor table that applies to the power sensor in use. See the HP 437B manual (page 3-90 "Sensor Data") for specific cal factor entry information.	
Select a calibration factor table [SHIFT] [SENSOR]	Access the sensor data tables. Use the arrow keys to view the available sensor data tables. The factory enters nine tables of typical calibration factors for nine different sensors in the HP 437B. If tables 2-9 are cleared, the data previously stored in those tables cannot be restored.
[ENTER]	Use the calibration factors for the displayed power sensor.

Table 7. HP 8360 Series Synthesized Sweepers maximum leveled power (dBm)

Frequency	HP 83620A/83621A	HP 83623A	HP 83631A	HP 83651A
20 GHz	+10	+17	+10	+10
26.5 GHz	—	—	+4	+4
40 GHz	—	—	—	+3
50 GHz	—	—	—	0

For more information, call your local HP sales office listed in your telephone directory.

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