STIMULUS-RESPONSE MEASUREMENTS . . . Using the HP 8565A Spectrum Analyzer from 2-18 GHz

INTRODUCTION

A stimulus/response measurement technique for the 2 to 18 GHz frequency range is described in this note. This application will be of specific interest to those who have an HP 8565A Spectrum Analyzer and an HP 8620C/86290B Sweep Oscillator, and have a need to make scalar network measurements. The implementation described here includes the analyzer and sweeper mentioned along with an HP 8709A-H10 Synchronizer.

Microwave devices such as attenuators, filters, amplifiers, directional couplers, and power splitters are characterized through measurements of insertion loss, gain, frequency response, and return loss. To make these measurements with a spectrum analyzer, a swept signal source is desirable. A wide dynamic range can be achieved by forcing this swept signal to track or follow the frequency of the spectrum analyzer input tuning. If this requirement is met, the spectrum analyzer will not detect source harmonics or spurious products generated in its first mixer as it is always tuned to the fundamental. At RF frequencies up to 1300 MHz a suitable tracking signal can be obtained with an HP 8444A Tracking Generator. Further details on the operation and use of tracking generators can be found in HP Application Note 150-3, "Spectrum Analysis . . . Swept Frequency Measurements and Selective Frequency Counting with a Tracking Generator."

A tracking signal at microwave frequencies can be obtained in conjunction with the HP 8565A Spectrum Analyzer by externally phase-locking a sweep generator to the spectrum analyzer tuning. This is accomplished using an HP 8709A-H10 Synchronizer functioning as the phase comparator in a phase-lock loop. The frequency range depends upon the choice of sweep generators; here we have used an HP 8620C/86290B Sweep Oscillator which operates from 2 to 18 GHz.

PERFORMANCE

The characteristics of an actual system are summarized as follows and should be regarded as typical:

Frequency Range	Dynamic Range
2 - 4 GHz	76 dB
3.8 - 8.5 GHz	76 dB
5.8 - 12.9 GHz	66 dB
8.5 - 18 GHz	60 dB

Table 1. Typical Performance

The indicated frequency ranges correspond to available bands on the HP 8565A with the exception of the first (2 - 4 GHz). Any center frequency and frequency span may be selected on the analyzer so long as that range is available from the sweeper.

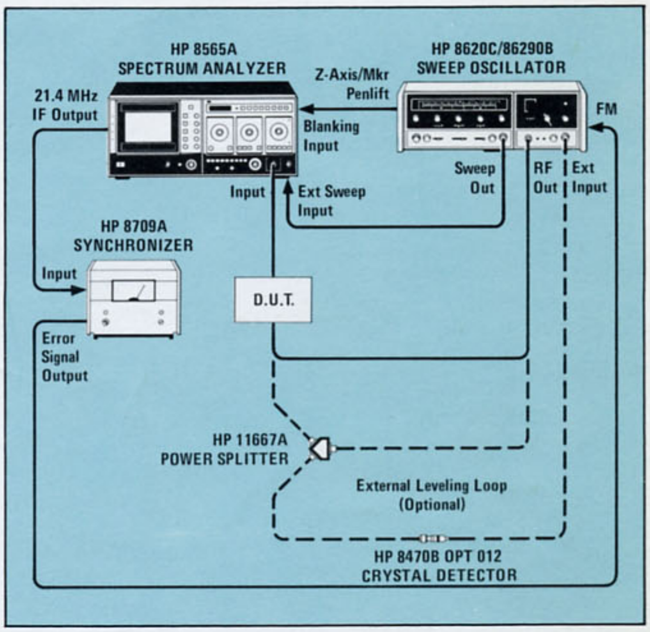


Figure 1. Test Set-Up

OPERATION

The required interconnections for the signal tracking system are shown in the figure above.

Basically, a phase-lock loop is set up so that the output of the sweeper, which is down-converted within the analyzer to an IF frequency, is compared to a fixed oscillator in the HP 8709A-H10 Synchronizer. This reference frequency is 21.4 MHz—chosen to be the same as the analyzer's final IF. The phase comparison yields an error voltage which frequency modulates the sweeper, keeping its output tuned to the center of the analyzer's passband.

Certain operating characteristics of this phase-lock loop are worth noting. The limiting loop bandwidth is the analyzer's 3 MHz IF bandwidth; using narrower bandwidths (<3 MHz) tends to decrease the loop stability to the point that oscillations can occur. For this reason, bandwidths less than 3 MHz are generally not usable.

If the DUT exhibits large out-of-band rejection, only a very low-level signal will reach the analyzer and, in turn, the synchronizer may receive insufficient signal to function. The HP 8709A-H10 in the test set-up required a minimum input level of −76 dBm (−65 dBm specified). This corresponds to a CRT display range of 6.6 divisions, measured down from the top. So long as the analyzer's noise is below this threshold level, the dynamic range lower limit is determined by the minimum IF signal required to drive the synchronizer; this is the case for the first two frequency bands listed in Table 1. For the other two ranges, the analyzer's internal noise sets the overall system sensitivity and thus determines the available dynamic range.

INITIAL SET-UP

Connect equipment as shown in Figure 1, replacing the device under test (DUT) with a "through" cable for calibration. As an illustration, the system will be set up for an analyzer full band, 5.8 to 12.9 GHz. Alternatively, any combination of center frequency and span may be used.

8565A:

Set all Normal Settings (controls marked with green)

FREQUENCY BAND GHz .... 5.8 - 12.9
INPUT ATTEN .... 10 dB
REF LEVEL .... +10 dBm
REF LEVEL FINE 0
FREQUENCY SPAN MODE .... FULL BAND
SWEEP SOURCE .... EXT
PRESELECTOR PEAK .... Centered in Green

8620C/86290B:

(Front Panel)

BAND .... Band 4 (2 - 18.6 GHz)
MARKER SWEEP pushbutton .... Depress
START MARKER pointer .... 5.8 GHz
STOP MARKER pointer .... 12.9 GHz
SWEEP TIME-SECONDS .... 1 - .01
SWEEP TIME-SECONDS vernier .... Fully Counterclockwise
RF OFF-ON .... ON
ALC SWITCH .... INT
POWER LEVEL .... Midrange

(Rear Panel)

RF BLANKING/OFF .... RF BLANKING
DISPLAY BLANKING/OFF .. DISPLAY BLANKING
FM-NORM-PL .... PL

8709A:

MOD. SENS .... 6 MHz/Volt
ERROR SIGNAL .... +
(use "+" for bands 1.7 - 4.1, 3.8 - 8.5 GHz, and "—" for 8.5 - 18 GHz)

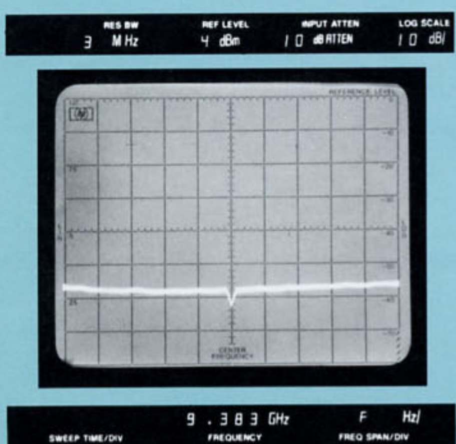
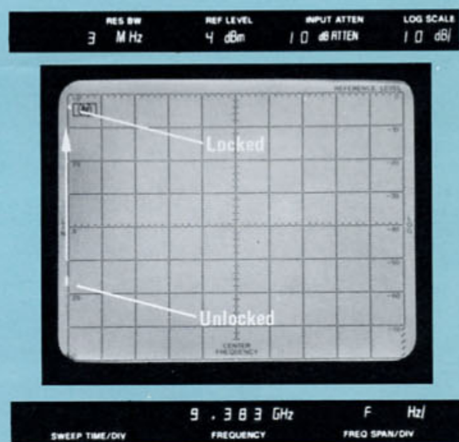


Figure 2. Sweeping Without Phase-Lock

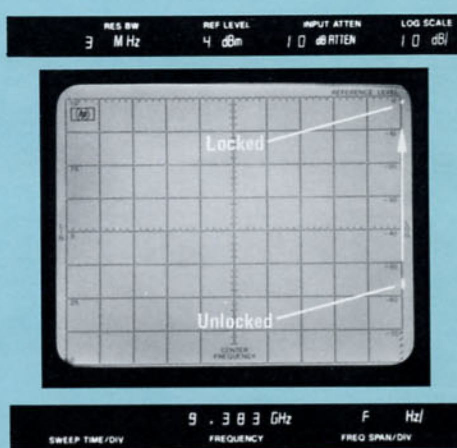
TRACKING PROCEDURE

Starting with the system out-of-lock (Figure 2), phase-lock sweep oscillator as follows:

1. Set sweep oscillator to manual sweep mode with manual sweep control fully counterclockwise.
2. Set sweep oscillator start marker to low frequency of selected spectrum analyzer FREQUENCY BAND and adjust start marker for synchronizer phase-lock (minimum phase-error). (Figure 3a.)
3. Set sweep oscillator manual sweep control fully clockwise.
4. Set stop marker to high frequency of selected spectrum analyzer FREQUENCY BAND. Adjust stop marker for synchronizer phase-lock (minimum phase-error). (Figure 3b.)
5. Set sweep oscillator to automatic sweep mode and check for phase-locked spectrum analyzer CRT display. If the system is breaking phase-lock, repeat steps 1 through 3. Phase-lock drop-outs will be minimized by using slower sweep speeds.



A. Start Frequency (Manual Sweep CCW)



B. Stop Frequency (Manual Sweep CW)

Figure 3. Adjusting for Phase-Lock At Start and Stop Frequencies

MEASUREMENT PROCEDURE

The sweeper is now generating a signal that tracks the tuning of the analyzer. For passive device testing, adjust POWER LEVEL on the sweeper to obtain the maximum leveled RF output (i.e., insure that the UNLEVELED indicator remains off during the entire sweep.) Adjust RF OUTPUT-PEAK and ALC SLOPE on the sweeper together with PRESELECTOR PEAK on the analyzer to achieve as flat a trace as possible on the CRT screen. Set REF LEVEL on the HP 8565A to position the trace at the top of the screen (Figure 4). This serves as the calibration reference level. Replace the "through" cable with the test device to measure its swept response relative to the calibration level (Figure 5).

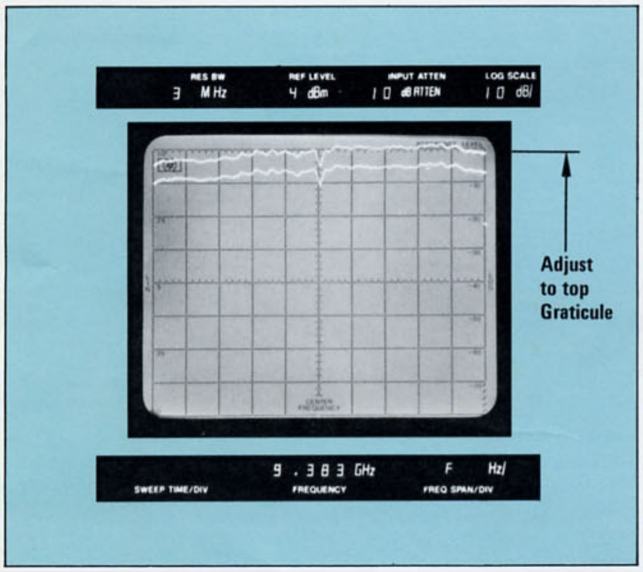


Figure 4. Phase-Locked Sweep

The display range for this analyzer band is 5.6 divisions, measured down from the top graticule line (i.e., from +10 dBm to −46 dBm). To obtain the full dynamic range listed in Table 1, shift the trace 10 dB off the top of the screen (reduce INPUT ATT to 0 dB). 5.6 divisions are again available but now the range is from 0 dBm to −56 dBm. In Figure 6, the full dynamic range of 66 dB is displayed in a composite photograph. Switching the attenuator is necessary because during "through" calibration, the reference line cannot be positioned above the 1 dB gain compression input level of 0 dBm with 0 dB attenuation. Adding 10 dB input padding raises the effective input gain compression level to +10 dBm, thereby permitting a calibration level which utilizes the maximum power available from the HP 8620C/86290B Sweeper. Thus, the usable dynamic range is as shown in Table 1 provided the operator switches the input attenuator from 10 dB to 0 dB to alter the limits of the displayed range.

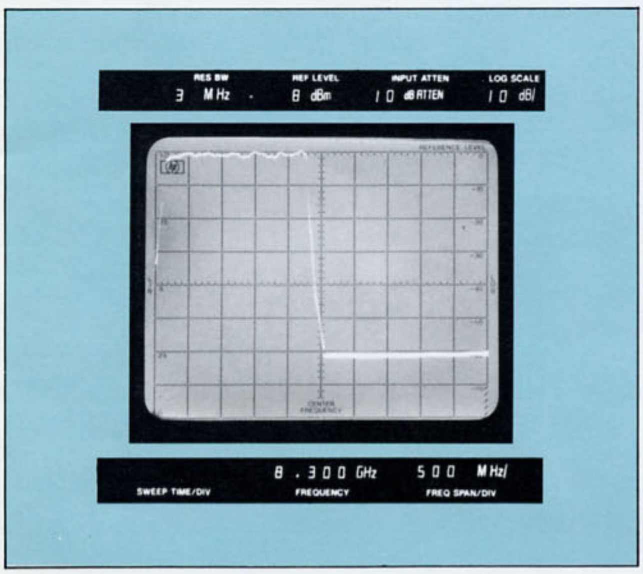


Figure 5. Frequency Response of 6 to 8 GHz Bandpass Filter

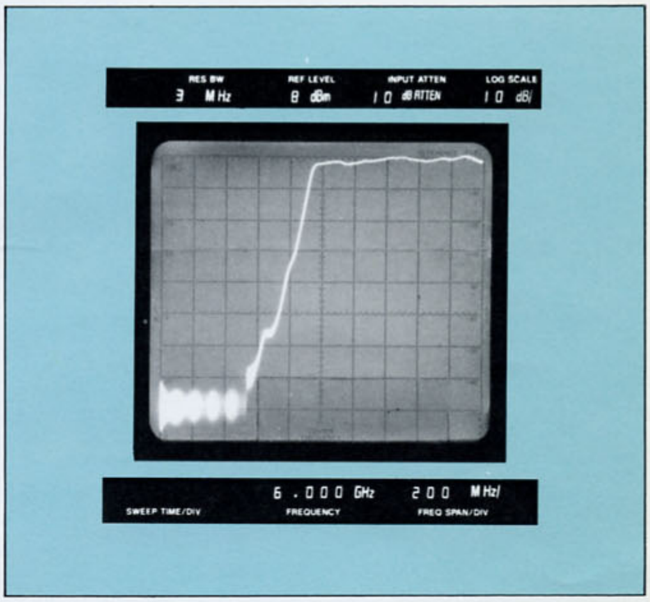


Figure 6. Composite Photo of Filter Response Showing 66 dB Dynamic Range

For test devices with gain, set the calibration level low enough on the display such that the trace remains on screen when the gain is inserted. In a log mode (such as 10 dB/div), be certain the reference line is not set below the seventh graticule so that trace calibration is retained.

To measure return loss, a directional coupler, a short and a 50 ohm termination are required, connected as shown below.

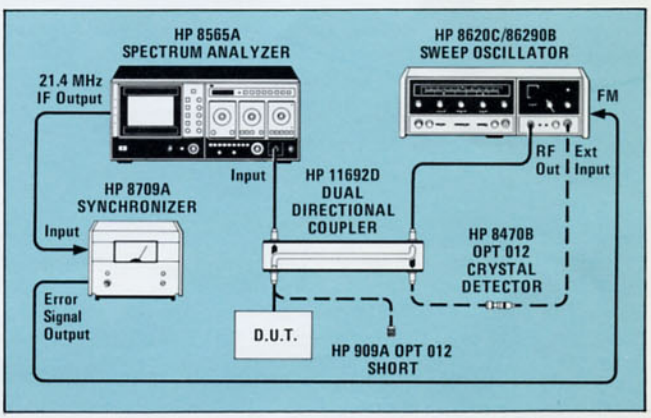


Figure 7. Return Loss Measurement Test Set-Up

First, calibrate the system with the short (total reflection, or 0 dB return loss) in place of the DUT. Then replace the short with the DUT—properly terminated in 50 ohms—and measure return loss relative to the calibration level (Figure 8).

Whichever type of stimulus/response measurement is undertaken, special care should be used when testing narrowband devices, as they may serve to limit the response time of the system and thus require the use of long sweep times. The fastest usable sweep speed should be determined by first increasing the rate of sweep until the display clearly changes (i.e., distorts), and then reducing the rate until the trace ceases to change.

IMPROVED FLATNESS

There are two ways to improve the frequency response (flatness) of this tracking system. The set-up may be configured with an external leveling loop as shown in Figure 1 with the addition of a power splitter (or coupler) and a detector. This technique reduces the effects of mismatch errors between the DUT and the loop components. An effective method to improve the spectrum analyzer's flatness uncertainty is to normalize it out of the measurement by incorporating the HP 8750A Storage Normalizer. The return loss measurement shown in Figure 8 is repeated in Figure 9 using the HP 8750A. Note the flatness achieved by normalizing during calibration.

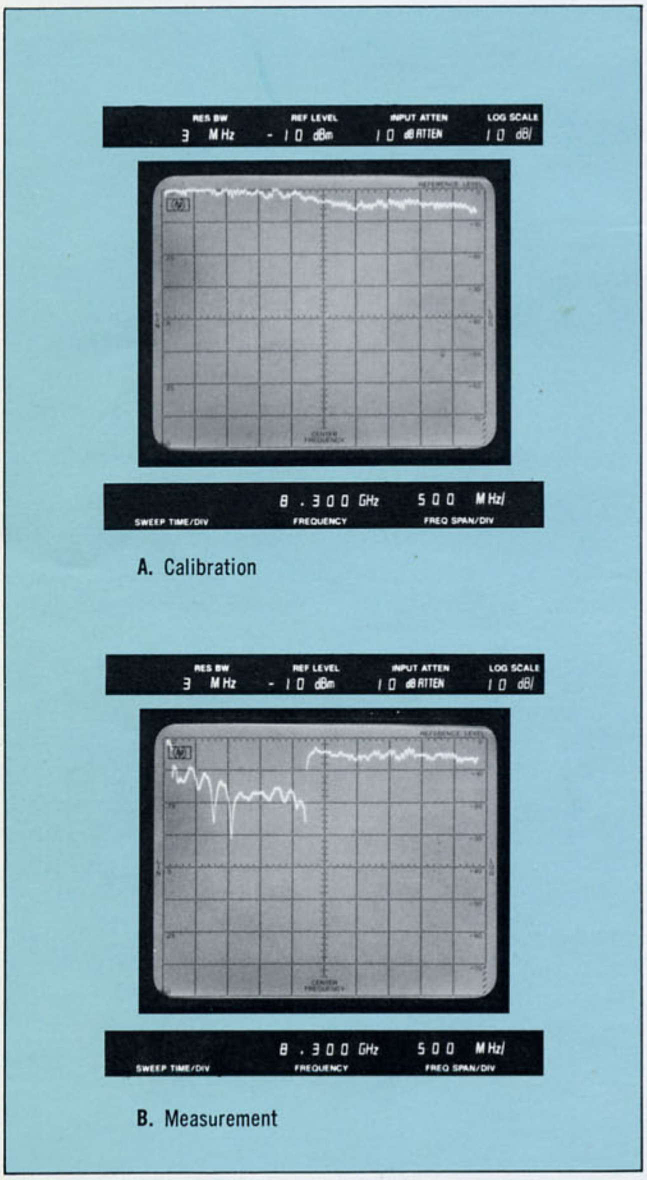


Figure 8. Return Loss of 6 to 8 GHz Bandpass Filter

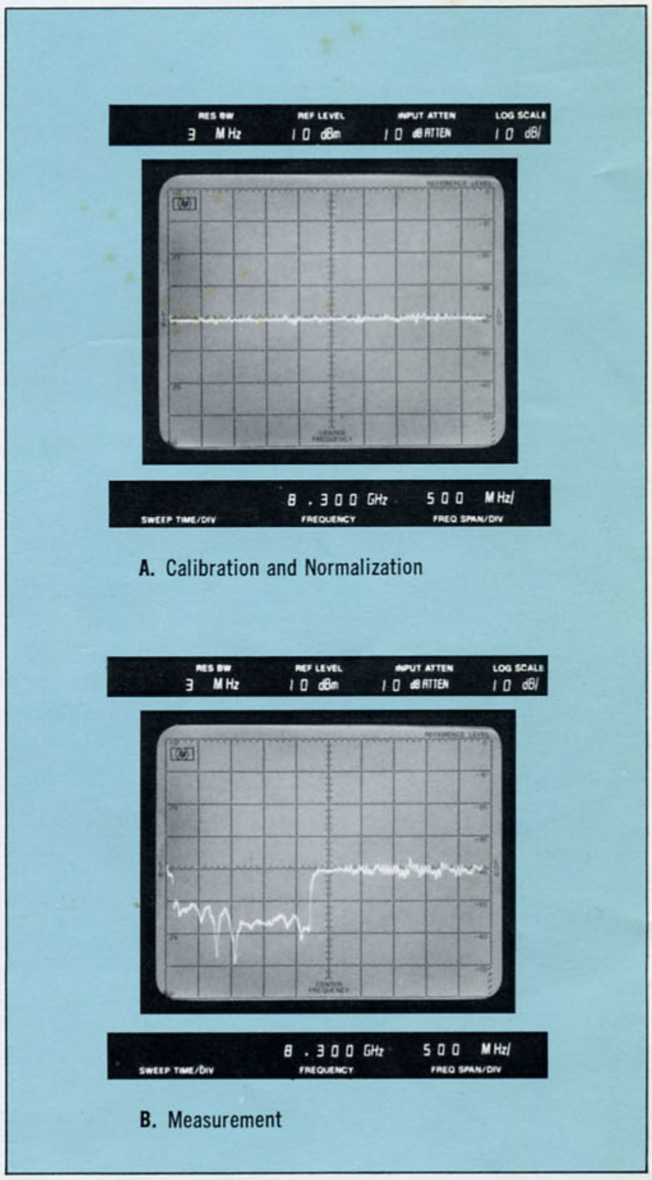


Figure 9. Return Loss of 6 to 8 GHz Bandpass Filter Using HP 8750A Storage Normalizer

HEWLETT hp PACKARD

For more information, call your local HP sales office or East (301) 948-6370 • Midwest (312) 255-9800 • South (404) 955-1500 • West (213) 877-1282; Or write, Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, California 94304. **In Europe**, Hewlett-Packard S.A., 7, rue du Bois-du-lan, P.O. Box, CH-1217 Meyrin 2-Geneva, Switzerland. **In Japan**, Yokogawa-Hewlett-Packard Ltd., 29-21, Takaido-Higashi 3-chome, Suginami-ku, Tokyo 168.

5952-9269 AUGUST 1978 PRINTED IN U.S.A.