HEWLETT PACKARD

**Product Note 8566A-1**

# USING THE HP 8566A SPECTRUM ANALYZER FOR SIGNAL ANALYSIS ABOVE 22 GHz WITH EXTERNAL MIXERS

## INTRODUCTION

External mixers which cover frequency ranges up to 220 GHz are now compatible with the HP 8566A Spectrum Analyzer. This has been made possible by several spectrum analyzer modifications, all of which have been incorporated into the 8566A's shipped after March 15, 1980. For information on retrofitting older models of the 8566A to make them compatible with external mixers, see the "Retrofit" section of this note.

Most of the measuring capability of the 8566A in the 0 to 22 GHz frequency range is transferred directly to the 22 to 300 GHz frequency range. (The 8566A is frequency calibrated to 300 GHz, although commercially available mixers go only to 220 GHz at this time.) For example, at 100 GHz, in zero span, the frequency accuracy is approximately:

100 Hz, if measured within one day of calibration
10 kHz, if measured within six months of calibration

The 8566A also has a unique microprocessor-based signal identification routine which greatly simplifies the procedure for identifying the frequency of unpreselected responses. This is explained in more detail in the "Operation-Signal Identification" section of this note.

## SETUP

### PHYSICAL ARRANGEMENT OF COMPONENTS

Figure 1 shows the physical arrangement of components that will allow the 8566A to operate in the 22 to 40 GHz frequency range. Figure 2 shows the arrangement of components for operation of the 8566A from 40 to 220 GHz. Also recommended with all external mixers, but not shown in Figures 1 or 2, is a protection circuit to prevent excessive DC current or reverse voltage from being applied to the external mixer. An example of such a circuit is shown in Figure 3. Other mixer precautions should be taken as per mixer manufacturers' instructions.

### SUGGESTED COMPONENTS

**22 to 40 GHz**

External Mixer Kit HP 11517A-Opt. E20

**Includes HP 11517A Opt. C02 External Mixer** (same as HP 11517A External Mixer except that the BNC connector on the LO/IF/DC port has been replaced by an SMA connector).

**HP 11519A, HP 11520A Waveguide Adapters** for the HP 11517A External Mixer. Adapters cover 18 to 26.5 GHz and 26.5 to 40 GHz frequency ranges.

**HP 5086-7721 LO/IF Diplexer** with SMA female connectors on ports 1 and 2 and an SMA male connector on port 3. Port connection diagram is shown in Figure 1.

**HP 33150A Bias Tee**

**HP 08566-60003 Bias Protection Circuit**

This circuit, similar to the one shown in Figure 3, will limit the DC current and reverse voltage applied to the external mixer:

$I_{FORWARD} \leq 10$ mA
$V_{REVERSE} \leq 3.3$ V

**2 – HP 5061 – 1086 Cables with SMA male connectors**

**HP 11592-60001 BNC male to SMC female cable**

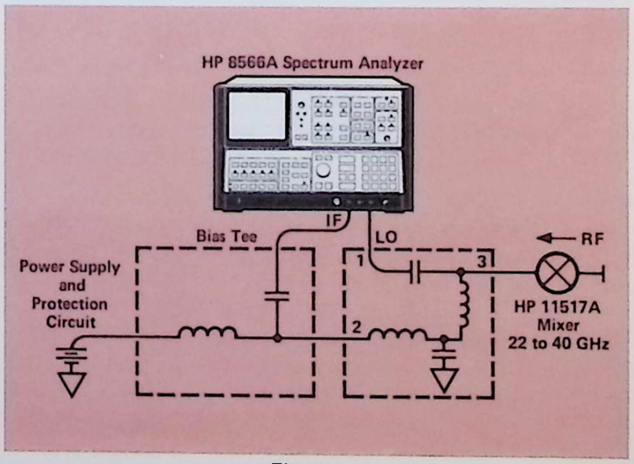



Figure 1.

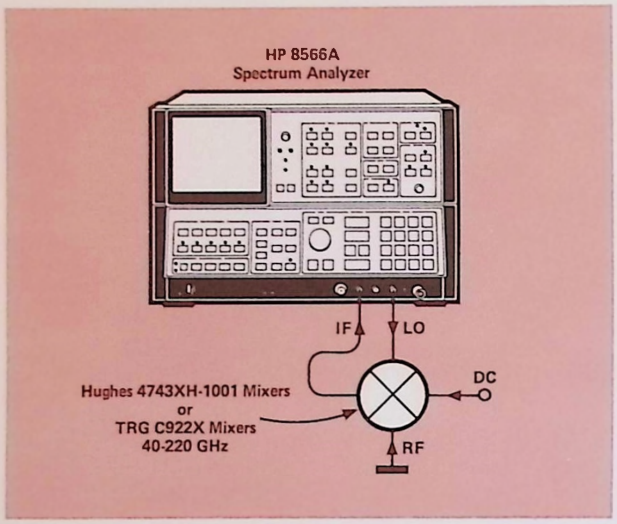



Figure 2.

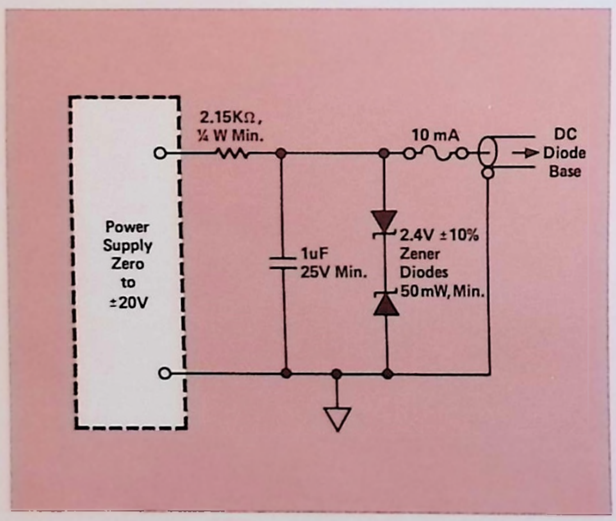



**Figure 3.** Protection circuit.

### 40 to 220 GHz

**Mixers—**Mixers manufactured by both Hughes[1] and TRG[2] have been verified as working satisfactorily with the 8566A in the 40-220 GHz frequency range. Other mixers may also work satisfactorily with the 8566A, but they were not available for testing at the time this note was written.

**Hughes 4743XH-1001 Harmonic Mixer**

The X is replaced by a number from 1 to 9 depending on the waveguide band selected:

| | |
|---|---|
| 1 = 26.5–40 GHz | 6 = 75 –110 GHz |
| 2 = 33 –50 GHz | 7 = 90 –140 GHz |
| 3 = 40 –60GHz | 8 = 100–170 GHz |
| 4 = 50 –75 GHz | 9 = 140–220 GHz |
| 5 = 60 –90 GHz | |

The Hughes 4743XH-1001 Harmonic Mixer ordinarily comes with a tunable backshort. To obtain a flat termination, which will give reduced sensitivity by about 5 dB, but which may improve flatness, ask for the "Flat Termination Option."

**TRG C922X Millimeter Wave Broadband Harmonic Mixer**

The X is replaced by a letter representing the waveguide band:

| | |
|---|---|
| A = 26.5–40 GHz | E = 60– 90 GHz |
| B = 33 –50 GHz | W = 75–110 GHz |
| U = 40 --60 GHz | F = 90–140 GHz |
| V = 50 –75 GHz | G = 140–220 GHz |

**Cables—**Cables with SMA connectors, to connect the LO and IF ports of the 8566A to the LO and IF ports of the external mixers, can be purchased from Hewlett-Packard —HP Part Number 5061-1086.

**Protection Circuit—**A packaged Bias Protection Circuit, similar to the circuit shown in Figure 3, can be purchased from Hewlett-Packard—HP Part Number 08566-60003. For a voltage supply of 0 to ±20 volts, the current and voltage to the diode will be limited to:

$$I_{FORWARD} \leq 10\text{ mA}$$
$$V_{REVERSE} \leq 3.3\text{ V}$$

Hewlett-Packard cannot guarantee that these current and voltage limits will protect every mixer, but, in our experience, these limits have provided adequate protection.

## RETROFIT

All 8566A's whose RF sections have serial numbers prefixed 2007A and above (units shipped after March 15, 1980) are fully compatible with the external mixers described in this note. Older models will require two changes in order to be used with external mixers:

### CHANGE NUMBER ONE

The existing A14 Memory Board must be replaced by Memory Board 85660-60173.

### CHANGE NUMBER TWO

External Mixer Modification Kit, HP P/N 85660-60143.

Routes the 321.4, MHz IF to the front panel and replaces the A6A10 Miscellaneous Bias/Driver and the A6A11 Slope Generator Assemblies.

[1]Hughes Aircraft Co., Electron Dynamics Div., 3100 W. Lomita Blvd., Torrance, CA 90505 (213) 534-2121

[2]Alpha Industries, Inc., TRG Div., 20 Sylvan Rd., Woburn, MA 01801 (617) 935-5150

The operation of the 8566A is here considered in two parts—the operation of the signal identification routine and the operation of the other functions.

## SIGNAL IDENTIFICATION

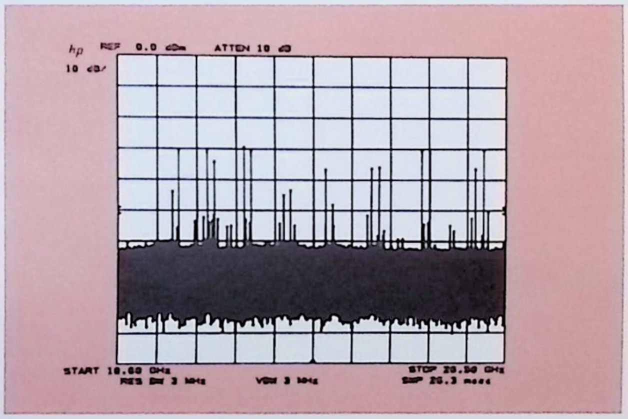
Above 22 GHz, spectrum analyzers are unpreselected, which means that many multiple responses will appear, making some type of signal identification procedure necessary. The signal identification scheme used in the 8566A differs from the scheme used in some other spectrum analyzers in that for each input frequency, the 8566A allows the display to be frequency calibrated for only one response from among the many multiple responses. This means that, for the 8566A, we must have some type of signal identification procedure which locates the *correct* responses. This is easily done, because the 8566A has a unique, time-saving, microprocessor-based signal identification routine.

## HOW TO USE THE 8566A TO IDENTIFY SIGNALS

### A. Place the 8566A in an External Mixing Frequency Range

Before a signal can be identified, the 8566A must be shifted into an unpreselected, external mixing frequency range.

To do this, press (SHIFT)(⇧).




This sets the START FREQUENCY[3] at 18.6 GHz and the STOP FREQUENCY at 26.5 GHz. However, as discussed previously, most of the responses on the display do not indicate the correct frequency.

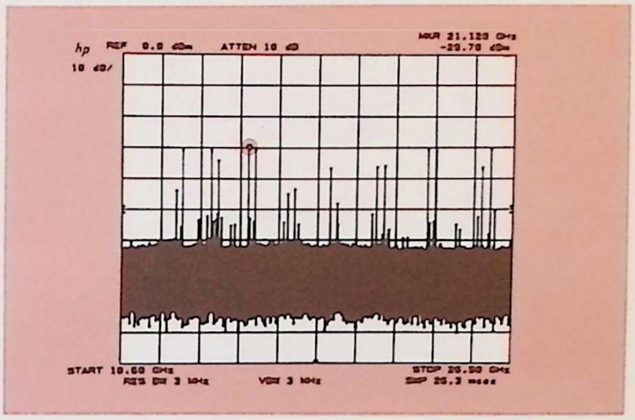
If desired, after (SHIFT)(⇧) has been pressed, a new frequency range can be selected. For example, if a 94 GHz response is being identified, the operator may elect to set the START FREQUENCY at 90 GHz and the STOP FREQUENCY at 100 GHz. (The operator wouldn't *have* to change the frequency range, however. The 94 GHz signal would be identified, even in the 18.6 to 26.5 GHz span.)

### B. Place a Marker on a Response

Next the operator places a marker on a response:

Press (NORMAL)(◯).

Turn the knob to place the marker on the desired response.



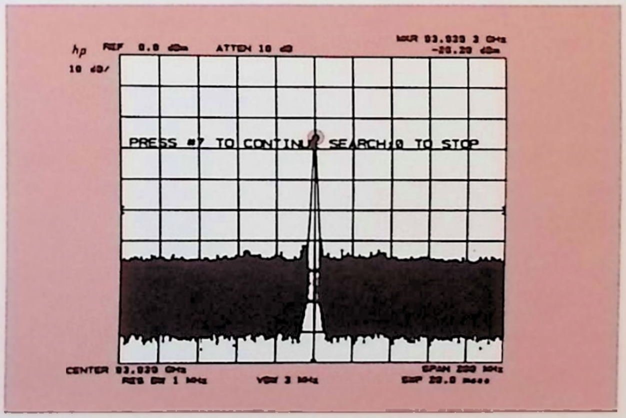

For frequencies greater than *120 GHz*, place the marker on a response that is near the right hand side of the display. In addition, for frequencies greater that *170 GHz*, set the Stop Frequency to at least 60 GHz before activating the signal ID routine. For frequencies greater than *240 GHz*, follow the procedure described in Footnote 5 of Appendix II.

### C. Activate the Signal Identification Routine

Signal identification is a two-step procedure.

**Step One**

Press (SHIFT)(FREQ).




This activates the 8566A's microprocessor based signal identification routine. (Appendix II describes how this routine works.)

If no positive identification is made by the signal identification routine, then the 8566A will return the display that was present before (SHIFT)(FREQ) was pressed. Should this occur, adjust the DC bias into the mixer or adjust the mixer's tunable backshort (if the mixer has one). This may improve the conversion loss or flatness in the frequency range of interest and thus make identification possible. Another way to make identification easier is to select a window of 15 dB or more in the signal identification routine. This is described in Footnote 6 of Appendix II.

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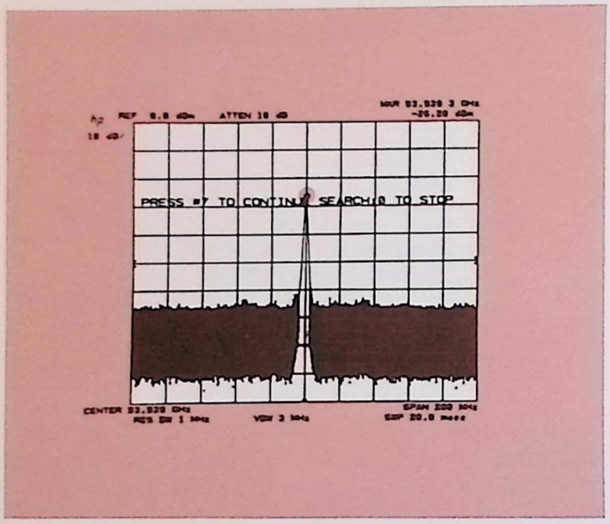
[3] Because the 8566A employs harmonic mixing, the references here to START and STOP FREQUENCIES actually apply to the harmonic number selected for calibration. The local oscillator fundamental in this case tunes from 3.05 to 4.36 GHz, which with the 6+ mixing mode, yields the range 18.6 to 26.5 GHz.

**Step Two**

Press [7].




This causes the microprocessor based signal identification routine to continue its search for other frequencies that might be positively identified (for the same selected response). If the same frequency that was found in Step 1 is again found in Step 2, then it is fairly certain that the correct frequency has been located. To be completely certain that the correct frequency has been found, follow the procedure described in Appendix III.

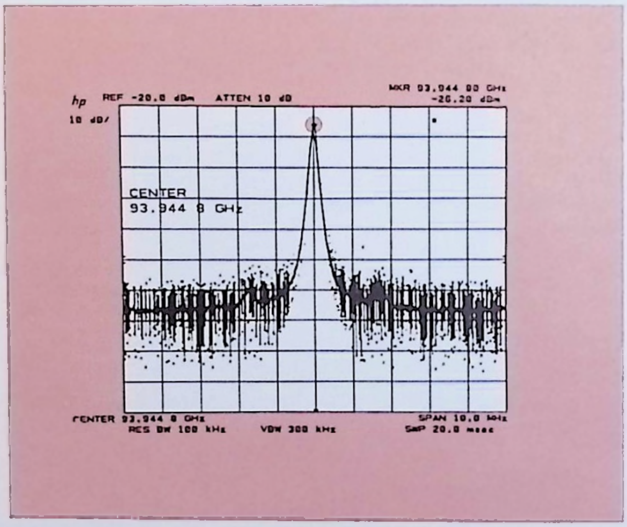
## OTHER FUNCTIONS

Except for the [REFERENCE LEVEL] and [ATTEN] functions, all frequency related functions (e.g., Center Frequency and Frequency Span), all marker functions (e.g., Signal Track, Δ), all memory and display capabilities (e.g., [RECALL] [7], [A↔B]), and all other special functions are used exactly the same from 22–220 GHz as from 0–22 GHz, as described in the 8566A Operation Manual.

For the [REFERENCE LEVEL] control to be used correctly, the [ATTEN] control should be set to 10 dB. This is automatically accomplished when [SHIFT] [⇧] is pressed.

A method that can be used to obtain an amplitude-corrected display is described in Appendix IV.

The 8566A has many special features which can greatly increase measurement capability. For example, here is photograph of a 94 GHz signal, digitally averaged from 100 previous traces and stored in Display Memory A, and a current trace stored in Display Memory B. For more information on the many special functions of the 8566A, see the 8566A Operation Manual.




# Appendix I

## 8566A EXTERNAL MIXER SIGNAL FREQUENCY/HARMONIC NUMBER DESIGNATIONS

$f_S = nf_{LO} + f_{IF}$ $\qquad$ $f_{IF} = 0.3214$ GHz

| INPUT SIGNAL FREQUENCY | MIXING PRODUCT | LO TUNING RANGE | INPUT SIGNAL FREQUENCY | MIXING PRODUCT | LO TUNING RANGE |
|---|---|---|---|---|---|
| 18.6 - 26.5 | 6+ | 3.05 - 4.36 | 170.9 - 183.3 | 30+ | 5.69 - 6.10 |
| 26.3 - 40.2 | 8+ | 3.25 - 4.98 | 183.1 - 195.5 | 32+ | 5.71 - 6.10 |
| 40.0 - 60.3 | 10+ | 3.97 - 6.00 | 195.3 - 207.7 | 34+ | 5.73 - 6.10 |
| 60.1 - 72.3 | 12+ | 4.98 - 6.00 | 207.5 - 219.9 | 36+ | 5.75 - 6.10 |
| 72.1 - 84.3 | 14+ | 5.13 - 6.00 | 219.7 - 232.1 | 38+ | 5.77 - 6.10 |
| 84.1 - 97.9 | 16+ | 5.24 - 6.10 | 231.9 - 244.3 | 40+ | 5.79 - 6.10 |
| 97.7 - 110.1 | 18+ | 5.41 - 6.10 | 244.1 - 256.5 | 42+ | 5.80 - 6.10 |
| 109.9 - 122.3 | 20+ | 5.48 - 6.10 | 256.3 - 268.7 | 44+ | 5.81 - 6.10 |
| 122.1 - 134.5 | 22+ | 5.54 - 6.10 | 268.5 - 280.9 | 46+ | 5.83 - 6.10 |
| 134.3 - 146.7 | 24+ | 5.58 - 6.10 | 280.7 - 293.1 | 48+ | 5.84 - 6.10 |
| 146.5 - 158.9 | 26+ | 5.62 - 6.10 | 292.9 - 300.0 | 50+ | 5.85 - 5.99 |
| 148.7 - 171.1 | 28+ | 5.66 - 6.10 | | | |

# Appendix II
# HOW THE SIGNAL IDENTIFICATION ROUTINE WORKS

After the operator of the 8566A places a marker on a response and presses [SHIFT] [FREE RUN], the 8566A goes through these steps:

1. If the span is greater than 200 MHz, the 8566A auto zooms down to a 200 MHz span.
2. The 8566A determines the LO frequency, $f_{LO}$, for the response marked by the operator.
3. The 8566A determines the possible input frequencies, $f_s$, that could have produced the "marked" response.

$$f_s = nf_{LO} \pm f_{IF}$$

Possible input frequencies → $f_s$; Possible harmonic numbers which could have produced the response (Integers 5—40 are ordinarily tried; see Footnote 4.) → $n$; LO frequency of the "marked" response (known by the 8566A) → $f_{LO}$; 321.4 MHz → $f_{IF}$

4. The 8566A tunes to each of the possible input frequencies, $f_s$, and checks to see at which of these frequencies responses exist.
5. If any $f_s$ is found, the 8566A looks for the image response of $f_s$.

$$f_{\bar{s}} = f_s + 2f_{IF}$$

6. If a response at $f_s$ and its image are both found, and if the amplitudes of these two responses are approximately equal (normally within 10 dB of one another; see Footnote 5), then the analyzer tunes to $f_s$ and identifies $f_s$ as the correct signal.

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[4]The n used in step 3 is ordinarily incremented between 5 and 40. However, other start and stop values for n (between 5 and 50) can be selected. This may be useful for two reasons—to obtain greater speed by reducing the range of the n values, or to allow signals beyond the range of the 40th harmonic (about 240 GHz) to be identified.

The following procedure may be used to change the start and stop values of n:

PRESS:

1. [INSTR PRESET]
2. [SAVE] [5]
3. [SHIFT] [⇧]

(This is done to save the original PRESELECTOR VALUES, which are replaced, via this routine, by the START and STOP VALUES.)

4. [FREQUENCY SPAN] [1] [GHz/-dBm/dB]
5. [CENTER FREQUENCY] [4] [GHz/-dBm/dB]
6. [SHIFT] [GHz/-dBm/dB] [ ] [ ] [Hz/μV/μs]
   START VALUE of n
   Select number between 5 and 49.
7. [CENTER FREQUENCY] [8] [GHz/-dBm/dB]
8. [SHIFT] [GHz/-dBm/dB] [ ] [ ] [Hz/μV/μs]
   STOP VALUE of n
   Select number between 6 and 50
   (For frequencies greater than 240 GHz, select 50 as the STOP VALUE of n.)
9. [START FREQ] [1] [8] [.] [6] [GHz/-dBm/dB]
10. [STOP FREQ] [2] [6] [.] [5] [GHz/-dBm/dB]
    (Frequencies other than 18.6 GHz and 26.5 GHz can be selected.)
11. [SAVE] [6]
    Now, instead of pressing [SHIFT] [⇧] to get into the external mixing bands, press [RECALL] [6]. To get back into the 0 to 22 GHz frequency range, press [RECALL] [5]. (This recalls the original PRESELECTOR VALUES.)

[5]The *10 dB* allowed amplitude difference between responses can be replaced by a difference of 5, 15, 20, 25, 30, or 35 dB. To do this, press the following:

[SHIFT] [illegible] $\underbrace{[\ ]\,[\ ]}_{X}$ [GHz/-dBm/dB]

where X is *twice* the numerical value desired (e.g., 30 for 15 dB).

# Appendix III
# UNDERSTANDING AND USING THE 8566A DISPLAY

It is important to understand the origin of responses on the 8566A display when an external mixer is used, both because it makes immediate interpretation of the input signals easier and also because knowing how to recognize "image pairs" is necessary for verifying the accuracy of the signal ID routine.

## THE APPEARANCE OF RESPONSES ABOVE 22 GHz

Figure 4 shows what the 8566A display looks like when a 34.2 GHz signal is input to the external mixer. The four pairs of large responses are produced by the mixing of the 34.2 GHz signal with the seventh, eight, ninth and tenth harmonics of the LO of the spectrum analyzer to produce the required 321.4 MHz IF.

The harmonic mixing numbers corresponding to each of these four pairs of large responses are shown in Figure 5. (Look for a pair of markers in each photograph.)

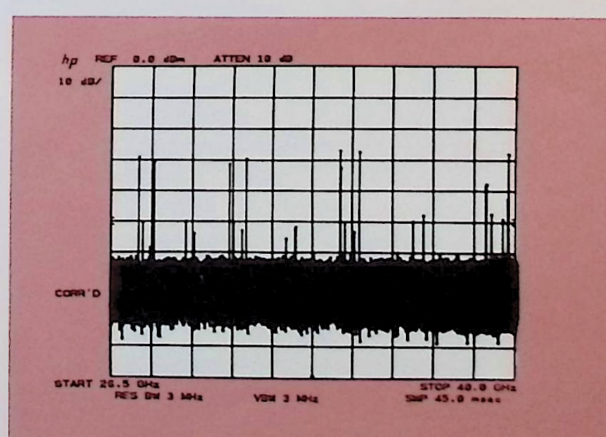


Figure 4.

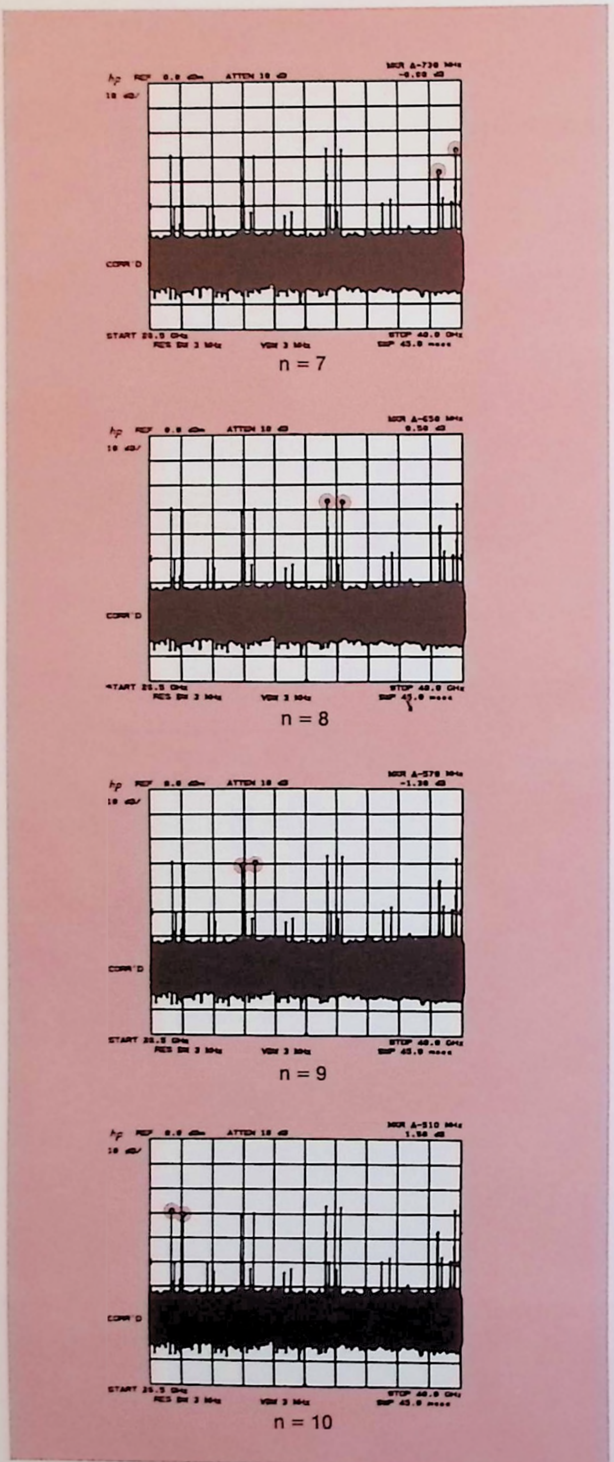


**Figure 5.**

For the frequency range of 26.5 to 40 GHz, the 8666A is calibrated for the n = 8+ response. This is demonstrated by the photograph in Figure 6, where a marker placed on the 8+ response reads out the correct frequency of 34.2 GHz.

The seven smaller responses on the display correspond to the second harmonic of the 34.2 GHz signal. This 68.4 GHz signal may be a "true" signal, that is, a signal that is applied to the external mixer, or it may be a "spurious" signal, generated *within* the external mixer.

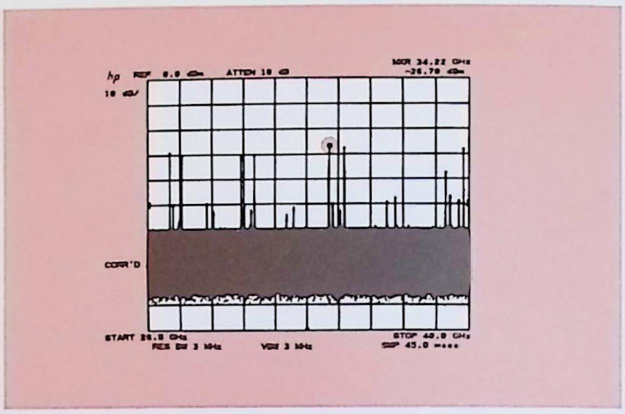

**Figure 6.**

A test which will distinguish between true and spurious responses is to apply 10 dB of external attenuation in front of the external mixer. If the response corresponds to a true signal, its amplitude will drop by 10 dB. If it is a false response, its amplitude will drop by 20 dB if it is a second harmonic or 30 dB if it is a third harmonic.

Figure 7 shows three 68.4 GHz responses. The harmonics of the LO's corresponding to these are n = 14, n = 15 and n = 16. The other four small pairs correspond to n = 17, 18, 19 and 20.

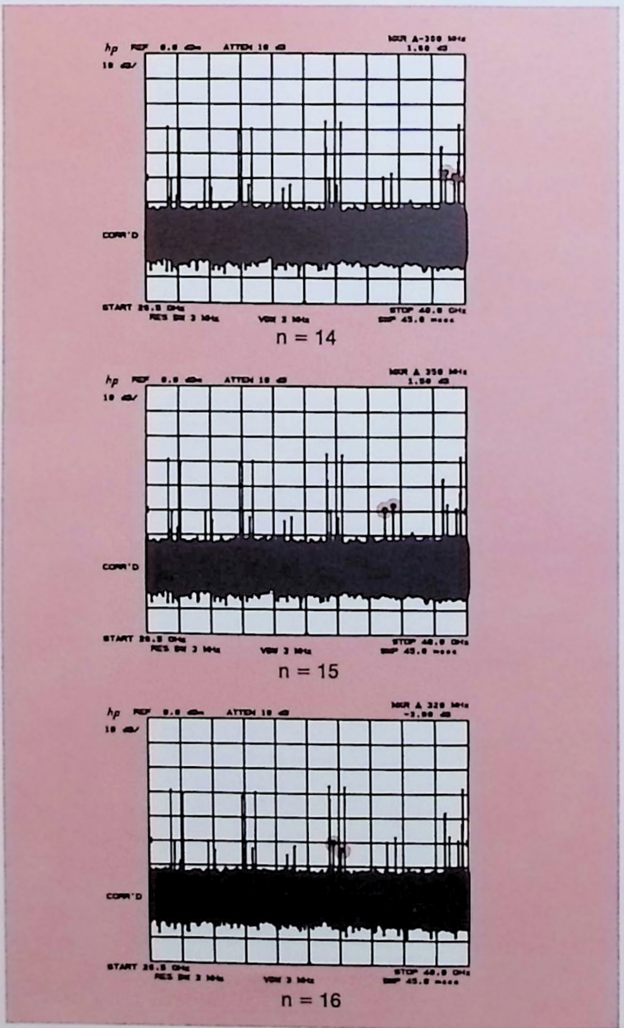


**Figure 7.**

## HOW TO VERIFY THE ACCURACY OF THE SIGNAL IDENTIFICATION ROUTINE

Although the signal identification routine can, on occasion, identify a signal incorrectly, such an error can be checked for by measuring the displayed frequency separation between the identified response and its image. Since the IF frequency is 321.4 MHz, the frequency separation between the identified response and its image should be 642.8 MHz. Look at the frequency separations between the image responses shown in Figure 8. As indicated in Appendix I, the frequency calibration for this 26.5 to 40 GHz frequency range is based on a harmonic number of n = 8+.

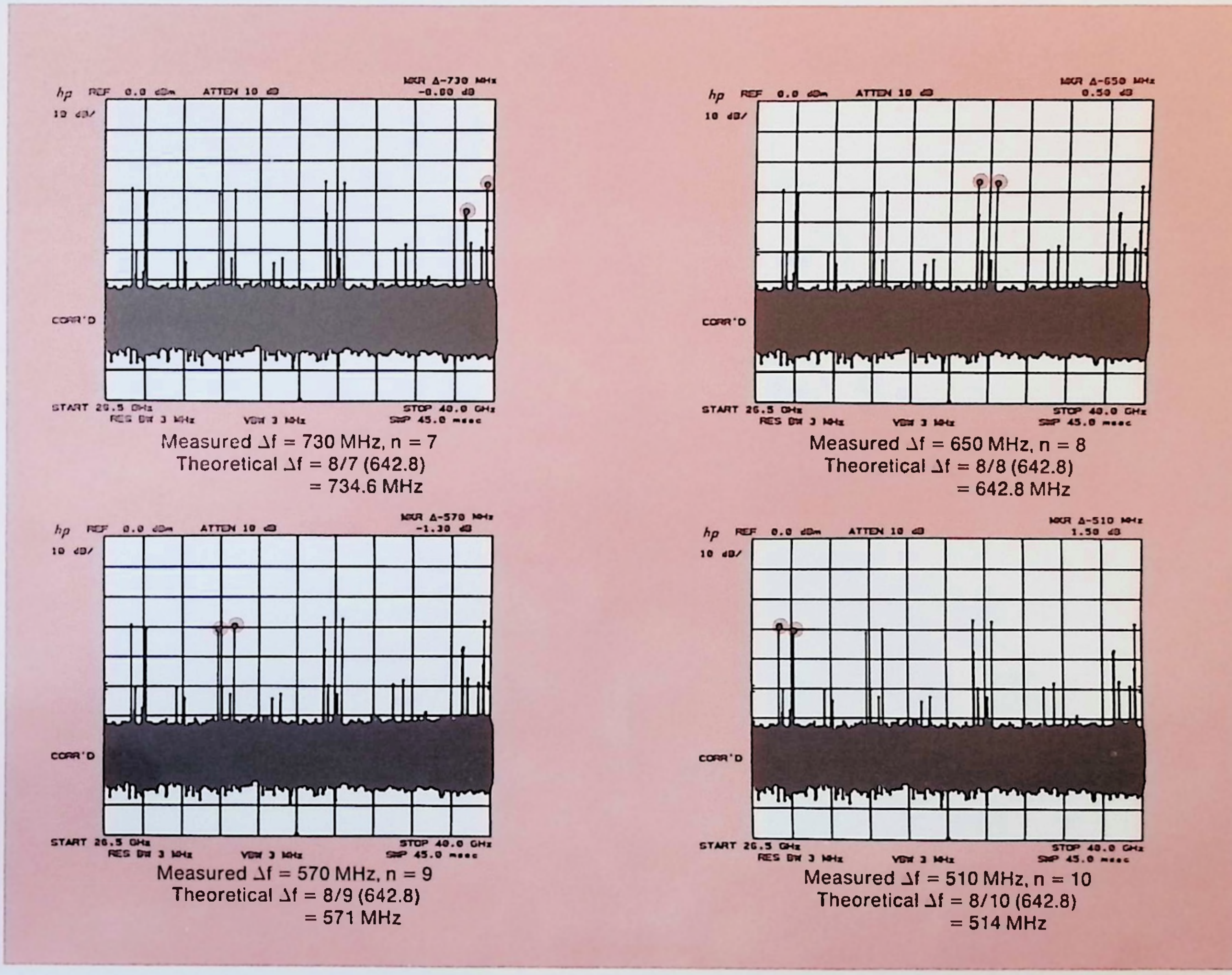


**Figure 8.**

Only for n = 8 is the frequency separation close to 642.8 MHz. Figure 9 shows that when the frequency span is reduced, the displayed frequency separation is only 0.6 MHz from the expected separation (643.4 MHz compared to the expected 642.8 MHz).

Recalling that the correct frequency was given for n = 8+, we can now outline the steps for verifying the accuracy of the signal identification routine:

1. After the signal has been identified with (SHIFT) [illegible], increase the span until the image for the identified response can be seen.
2. The image response should be to the right of the identified response. If it is not, a false identification has occurred.
3. The separation of frequencies between the two responses should be 642.8 MHz (±2% of the frequency span). If it is, the true signal has been identified. Otherwise, a false identification has occurred.

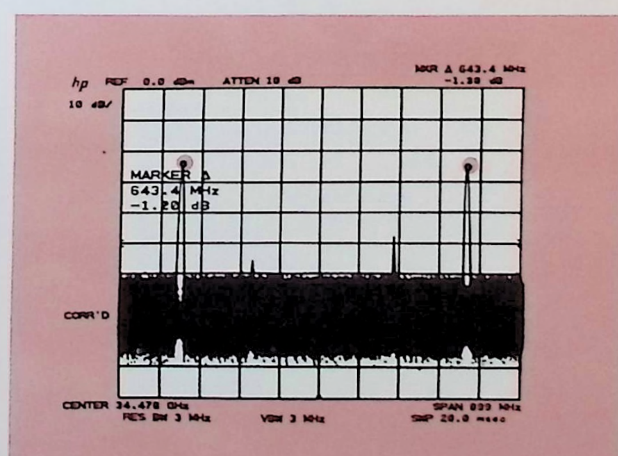


**Figure 9.**

# Appendix IV

# TECHNIQUES FOR MAKING AMPLITUDE CORRECTED MEASUREMENTS

The 8566A is not amplitude calibrated above 22 GHz, but it is amplitude correctable, either with a simple correction for an entire band, or point-by-point. These two correction techniques are described below.

## AMPLITUDE CORRECTION ACROSS ENTIRE BAND

This amplitude correction technique applies a *single* amplitude correction value to any amplitude measured in a given band. The amplitude accuracy that is achieved with this technique is approximately ±5.5 dB plus the mixer's frequency response.

As an example of how such a measurement might be made, consider the setup in Figure 10 which can be used up to 40 GHz. Similar circuits can be used at higher frequencies.

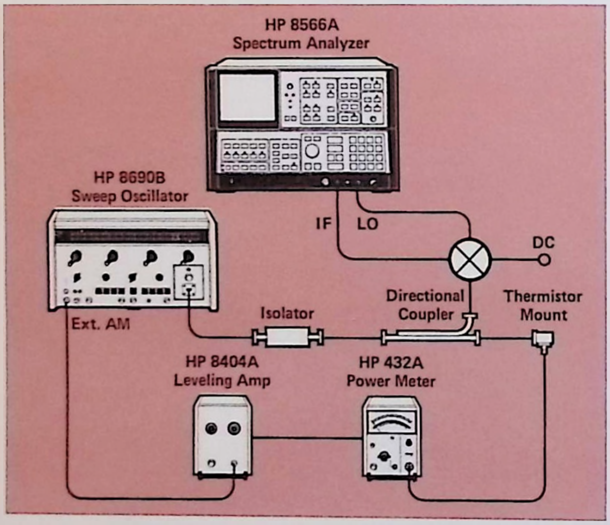


**Figure 10.** Circuit used to determine the amplitude correction value.

The power displayed on the power meter will not vary, so the difference between the average displayed amplitude on the 8566A (as a function of frequency) and the displayed amplitude on the power meter can be easily calculated. This can be made particularly simple by using the Signal Track feature of the 8566A to track the varying frequency of the applied signal.

The amplitude accuracy which is achievable with this scheme is calculated as follows:

| | |
|---|---|
| Coupling variation | ±0.7 dB |
| Mismatch uncertainty, thermistor/coupler interface | ±0.3 dB |
| Mismatch uncertainty, mixer/coupler interface | ±0.4 dB |
| Thermistor drift (assuming that the thermistor is zeroed every minute or two) | ±1.0 dB |
| Thermistor error (Cal. Factor) | ±1.5 dB |
| Error correction uncertainty (to make measurement) | ±0.4 dB |
| Display (log amp) uncertainty on the 8566A | ±1.0 dB |
| Error correction uncertainty (to get correction factor) | ±0.4 dB |

TOTAL: ±5.7 dB plus mixer flatness and DUT/mixer mismatch

While typical mixer frequency response is ±5 dB, it can vary a great deal from unit to unit. The DUT/mixer mismatch error arises, not from the process of generating the amplitude correction factors, but from the mismatch that occurs in actual measurements

## AMPLITUDE CORRECTION — POINT-BY-POINT

If a narrow frequency range is of interest, the point-by-point amplitude correction technique, which provides amplitude accuracies of approximately ±2.2 dB, may be useful. This technique is the same as the technique described for making an "across the band" correction, except that more care is taken to remove inaccuracies. In particular, uncertainties are removed in the following ways:

### Coupling variation

Coupling variation is reduced by using two couplers of the same type to remove common amplitude variations or by using test data on the coupling characteristics provided by the coupler manufacturer or by using any of several other possible techniques.

### Thermistor error

Thermistor variation is reduced by adding the manufacturer's stated correction factor (for the particular frequency being used) to the power reading on the power meter.

### Thermistor drift

Thermistor drift is reduced by zeroing the power meter before each point is measured and by using power levels that are high enough to place the power meter near the upper end of its range.

### Display (log amp) uncertainty

Display uncertainty is removed by using IF substitution (placing the response three divisions below the reference level before reading the amplitude). The amplitude accuracy which is achievable with this scheme is calculated as follows:

| | |
|---|---|
| Coupling variation | ±0.2 dB |
| Mismatch uncertainty, mixer/coupler interface | ±0.4 dB |
| Mismatch uncertainty, thermistor/coupler interface | ±0.3 dB |
| Thermistor error | ±0.5 dB |
| Error correction uncertainty (to get correction factor) | ±0.4 dB |
| Error correction uncertainty (to make a measurement) | ±0.4 dB |

TOTAL: ±2.2 dB plus mismatch DUT/mixer

Because power calibration is made for each frequency, response errors which occur as a function of frequency are removed.

For more information, call your local HP Sales Office or nearest Regional Office: Eastern (201) 265-5000; Midwestern (312) 255-9800; Southern (404) 955-1500; Western (213) 970-7500; Canadian (416) 678-9430. Ask the operator for instrument sales. Or write Hewlett-Packard, 1501 Page Mill Road, Palo Alto, CA 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.

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