Measurement Guide

Agilent Technologies ESA Spectrum Analyzers

This manual provides documentation for the following instruments:

Agilent ESA-E Series

E4401B (9 kHz – 1.5 GHz)
E4402B (9 kHz – 3.0 GHz)
E4404B (9 kHz – 6.7 GHz)
E4405B (9 kHz – 13.2 GHz)
E4407B (9 kHz – 26.5 GHz)

and

Agilent ESA-L Series

E4411B (9 kHz – 1.5GHz)
E4403B (9 kHz – 6.7 GHz)
E4408B (9 kHz – 26.5 GHz)

Agilent Technologies

Manufacturing Part Number: E4401-90175
Supersedes E4401-90111

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CAUTION *Caution* denotes a hazard. It calls attention to a procedure that, if not correctly performed or adhered to, could result in damage to or destruction of the instrument. Do not proceed beyond a caution sign until the indicated conditions are fully understood and met.

NOTE *Note* calls out special information for the user's attention. It provides operational information or additional instructions of which the user should be aware.

⚠ The instruction documentation symbol. The product is marked with this symbol when it is necessary for the user to refer to the instructions in the documentation.

| This symbol is used to mark the on position of the power line switch.

⏻ This symbol is used to mark the standby position of the power line switch.

~ This symbol indicates that the input power required is AC.

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http://www.agilent.com/find/esa

Contents

1 Making Basic Measurements

What is in This Chapter

This chapter demonstrates basic analyzer measurements with examples of typical measurements; each measurement focuses on different functions. The measurement procedures covered in this chapter are listed below.

To find descriptions of specific analyzer functions, refer to the user's guide.

Comparing Signals

Using the analyzer, you can easily compare frequency and amplitude differences between signals, such as radio or television signal spectra. The analyzer delta marker function lets you compare two signals when both appear on the screen at one time or when only one appears on the screen.

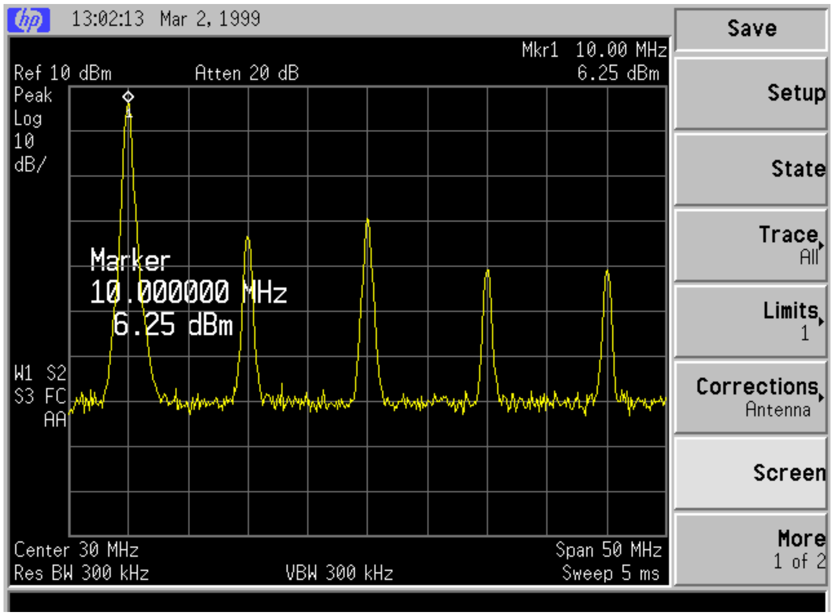
Example 1:

Measure the differences between two signals on the same display screen.

1. Connect the 10 MHz REF OUT from the rear panel to the front-panel INPUT.
2. Set the center frequency to 30 MHz and the span to 50 MHz by pressing **FREQUENCY**, **30 MHz**, **SPAN**, **50 MHz**.
3. Set the reference level to 10 dBm by pressing **AMPLITUDE**, **10 dBm**.

   The 10 MHz reference signal and its harmonics appear on the display.
4. Press **Peak Search** to place a marker at the highest peak on the display. (The **Next Peak, Next Pk Right** and **Next Pk Left** keys are available to move the marker from peak to peak.) The marker should be on the 10 MHz reference signal. See Figure 1-1.

Figure 1-1 Placing a Marker on the 10 MHz Signal

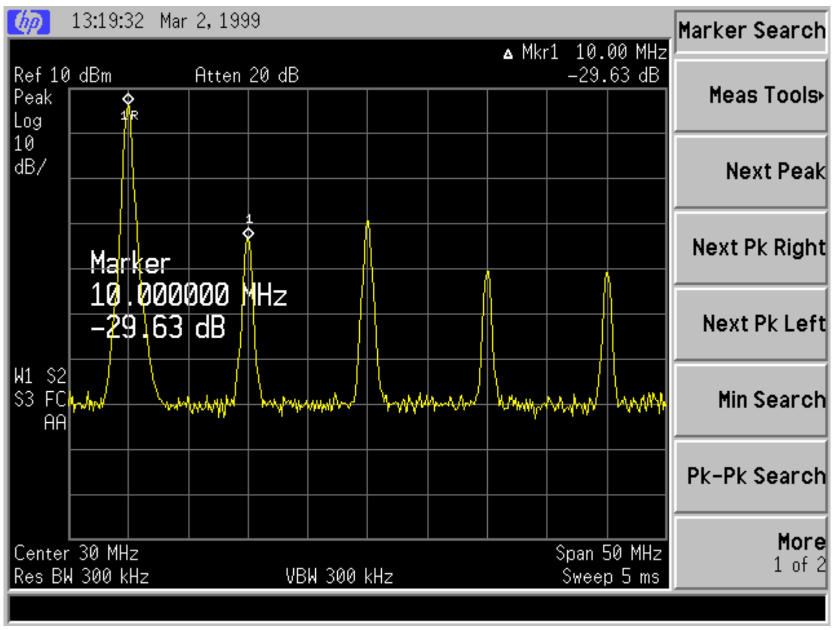


5. Press **Marker**, **Delta**, to activate a second marker at the position of the first marker. Move the second marker to another signal peak using the knob, or by pressing **Peak Search** and **Next Peak**, **Next Pk Right** or **Next Pk Left**.

6. The amplitude and frequency difference between the markers is displayed in the active function block and in the upper right corner of the screen. See Figure 1-2. The resolution of the marker readings can be increased by turning on the frequency count function. Press **Freq Count**. Both signals are counted.

   Press **Marker**, **Off** to turn the markers off.

Figure 1-2 Using the Marker Delta Function



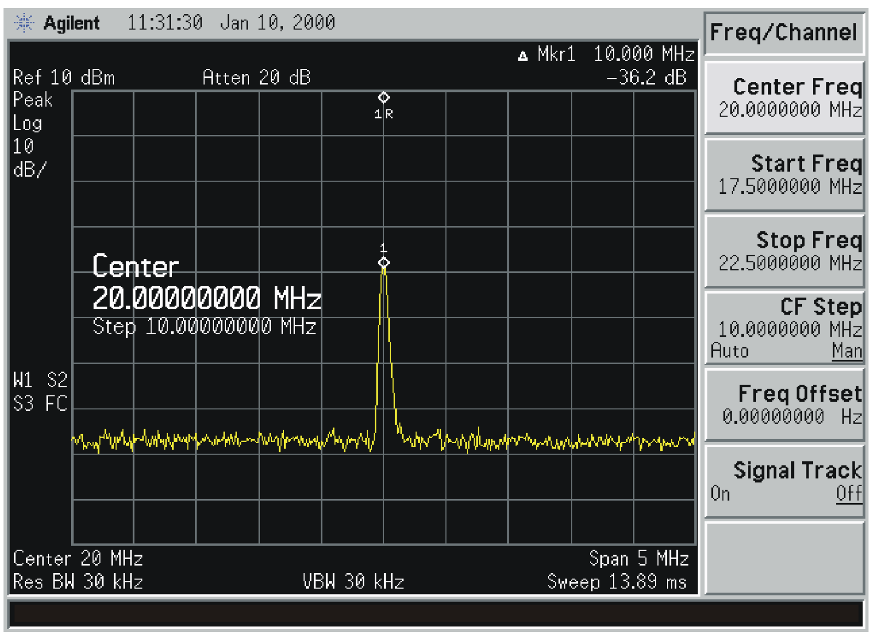
Example 2:

Measure the frequency and amplitude difference between two signals that do not appear on the screen at one time. (This technique is useful for harmonic distortion tests when narrow span and narrow bandwidth are necessary to measure the low level harmonics.)

1. Connect the 10 MHz REF OUT from the rear panel to the front-panel INPUT.
2. Set the center frequency to 10 MHz and the span to 5 MHz by pressing **FREQUENCY**, **10 MHz**, **SPAN**, **5 MHz**.
3. Set the reference level to 10 dBm by pressing **AMPLITUDE**, **10 dBm**.
4. Press **Peak Search** to place a marker on the peak.
5. Press **Marker→**, **Mkr→CF Step** to set the center frequency step size equal to the frequency of the fundamental signal.
6. Press **Marker**, **Delta** to anchor the position of the first marker and activate a second marker.
7. Press **FREQUENCY**, **Center Freq** and the (↑) key to increase the center frequency by 10 MHz. The first marker remains on the screen at the amplitude of the first signal peak.

   The annotation in the upper right corner of the screen indicates the amplitude and frequency difference between the two markers. See Figure 1-3.
8. To turn the markers off, press **Marker**, **Off**.

Figure 1-3 Frequency and Amplitude Difference Between Signals



Resolving Signals of Equal Amplitude

Two equal-amplitude input signals that are close in frequency can appear as one on the analyzer display. Responding to a single-frequency signal, a swept-tuned analyzer traces out the shape of the selected internal IF (intermediate frequency) filter. As you change the filter bandwidth, you change the width of the displayed response. If a wide filter is used and two equal-amplitude input signals are close enough in frequency, then the two signals appear as one. Thus, signal resolution is determined by the IF filters inside the analyzer.

The bandwidth of the IF filter tells us how close together equal amplitude signals can be and still be distinguished from each other. The resolution bandwidth function selects an IF filter setting for a measurement. Resolution bandwidth is defined as the 3 dB bandwidth of the filter.

Generally, to resolve two signals of equal amplitude, the resolution bandwidth must be less than or equal to the frequency separation of the two signals. If the bandwidth is equal to the separation and the video bandwidth is less than the resolution bandwidth, a dip of approximately 3 dB is seen between the peaks of the two equal signals, and it is clear that more than one signal is present. See Figure 1-5.

In order to keep the analyzer measurement calibrated, sweep time is automatically set to a value that is inversely proportional to the square of the resolution bandwidth (for resolution bandwidths ≥ 1kHz). So, if the resolution bandwidth is reduced by a factor of 10, the sweep time is increased by a factor of 100 when sweep time and bandwidth settings are coupled. (Sweep time is proportional to $1/BW^2$.) For shortest measurement times, use the widest resolution bandwidth that still permits discrimination of all desired signals. The analyzer allows you to select from 1 kHz to 3 MHz resolution bandwidths in a 1, 3, 10 sequence and 5 MHz for maximum measurement flexibility.

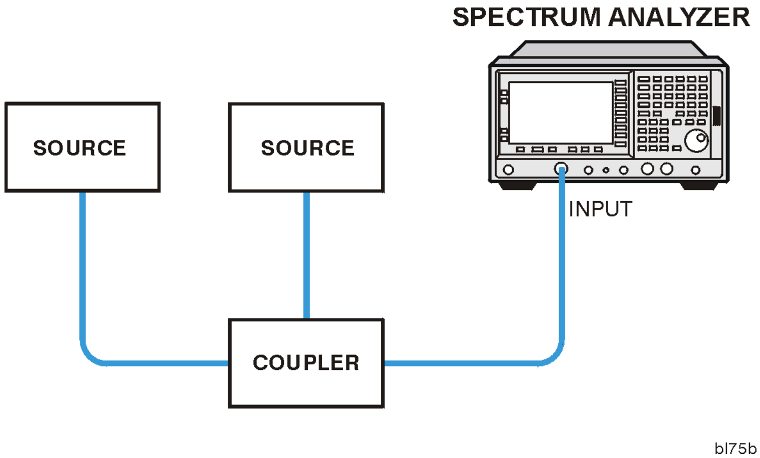
Option 1DR adds narrower resolution bandwidths, from 10 Hz to 300 Hz, in a 1-3-10 sequence. These bandwidths are digitally implemented and have a much narrower shape factor than the wider, analog resolution bandwidths. Also, the autocoupled sweeptimes when using the digital resolution bandwidths are much faster than analog bandwidths of the same width.

Example:

Resolve two signals of equal amplitude with a frequency separation of 100 kHz.

1. Connect two sources to the analyzer input as shown in Figure 1-4.

Figure 1-4 Setup for Obtaining Two Signals



2. Set one source to 300 MHz. Set the frequency of the other source to 300.1 MHz. The amplitude of both signals should be approximately –20 dBm.

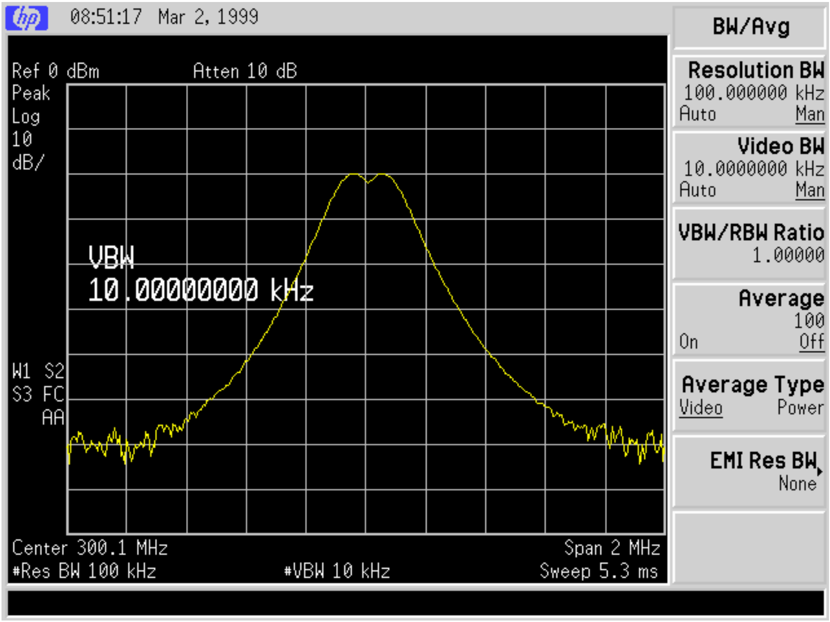
3. On the analyzer, press **Preset**, **Factory Preset** (softkey), if present. Set the center frequency to 300 MHz, the span to 2 MHz, and the resolution bandwidth to 300 kHz by pressing **FREQUENCY, 300 MHz**, **SPAN, 2 MHz**, then **BW/Avg**, **Resolution BW**, **300 kHz**. A single signal peak is visible.

NOTE If the signal peak cannot be found, increase the span to 20 MHz by pressing **SPAN, 20 MHz**. The signal should be visible. Press **Search**, **FREQUENCY**, **Signal Track (On)**, then **SPAN**, **2 MHz** to bring the signal to center screen. Then press **Signal Track (Off)** to turn the signal track function off.

4. Since the resolution bandwidth must be less than or equal to the frequency separation of the two signals, a resolution bandwidth of 100 kHz must be used. Change the resolution bandwidth to 100 kHz by pressing **BW/Avg, 100 kHz**. Two signals are now visible as shown in Figure 1-5. Use the knob or step keys to further reduce the resolution bandwidth and better resolve the signals.

5. Decrease the video bandwidth to 10 kHz, by pressing **Video BW (Man)**, **10 kHz**.

Figure 1-5 Resolving Signals of Equal Amplitude



As the resolution bandwidth is decreased, resolution of the individual signals is improved and the sweep time is increased. For fastest measurement times, use the widest possible resolution bandwidth. Under factory preset conditions, the resolution bandwidth is “coupled” (or linked) to the span.

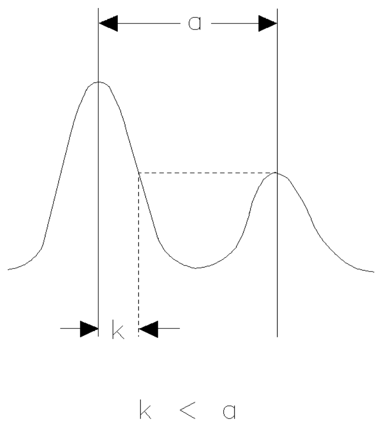
Since the resolution bandwidth has been changed from the coupled value, a # mark appears next to `Res BW` in the lower-left corner of the screen, indicating that the resolution bandwidth is uncoupled. (Also see the **Auto Couple** key description in the user’s guide.)

NOTE To resolve two signals of equal amplitude with a frequency separation of 200 kHz, the resolution bandwidth must be less than the signal separation, and resolution of 100 kHz must be used. The next larger filter, 300 kHz, would exceed the 200 kHz separation and would not resolve the signals.

Resolving Small Signals Hidden by Large Signals

When dealing with the resolution of signals that are close together and not equal in amplitude, you must consider the shape of the IF filter of the analyzer, as well as its 3 dB bandwidth. (See “Resolving Signals of Equal Amplitude” on page 1-6 example for more information.) The shape of a filter is defined by the selectivity, which is the ratio of the 60 dB bandwidth to the 3 dB bandwidth. (Generally, the IF filters in this analyzer have shape factors of 15:1 or less for resolution bandwidths ≥ 1 kHz and 5:1 or less for resolution bandwidths ≤ 300 Hz). If a small signal is too close to a larger signal, the smaller signal can be hidden by the skirt of the larger signal. To view the smaller signal, you must select a resolution bandwidth such that k is less than a. See Figure 1-6.

Figure 1-6 Resolution Bandwidth Requirements for Resolving Small Signals



The separation between the two signals (a) must be greater than half the filter width of the larger signal (k) measured at the amplitude level of the smaller signal.

Example:

Resolve two input signals with a frequency separation of 155 kHz and an amplitude separation of 60 dB.

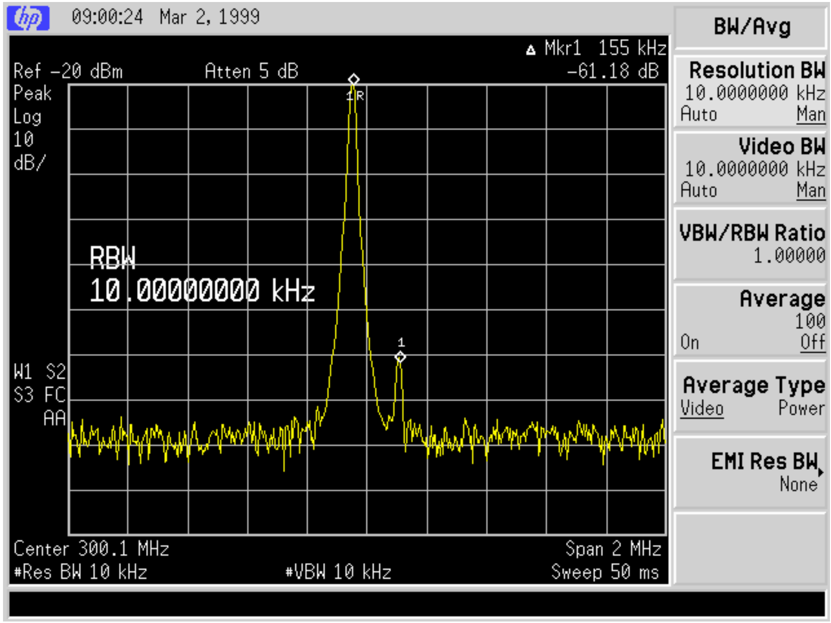
1. To obtain two signals with a 155 kHz separation, connect the equipment as shown in the previous section, “Resolving Signals of Equal Amplitude” on page 1-6. Set one source to 300 MHz at –20 dBm.
2. Set the analyzer center frequency to 300 MHz and the span to 2 MHz: press **FREQUENCY**, **300 MHz**, then **SPAN, 2 MHz**.

NOTE If the signal peak cannot be found, increase the span to 20 MHz by pressing **SPAN**, **20 MHz**. The signal should be visible. Press **Search**, **FREQUENCY**, **Signal Track (On)**, then **SPAN**, **2 MHz** to bring the signal to center screen. Then press **Signal Track (Off)** to turn the signal track function off.

3. Set the second source to 300.155 MHz, so that the signal is 155 kHz higher than the first signal. Set the amplitude of the signal to –80 dBm (60 dB below the first signal).
4. Set the 300 MHz signal to the reference level by pressing **Peak Search**, **Meas Tools**, then **Mkr** → **Ref Lvl**.
5. Place a marker on the smaller signal by pressing **Delta**, **Next Pk Right**.

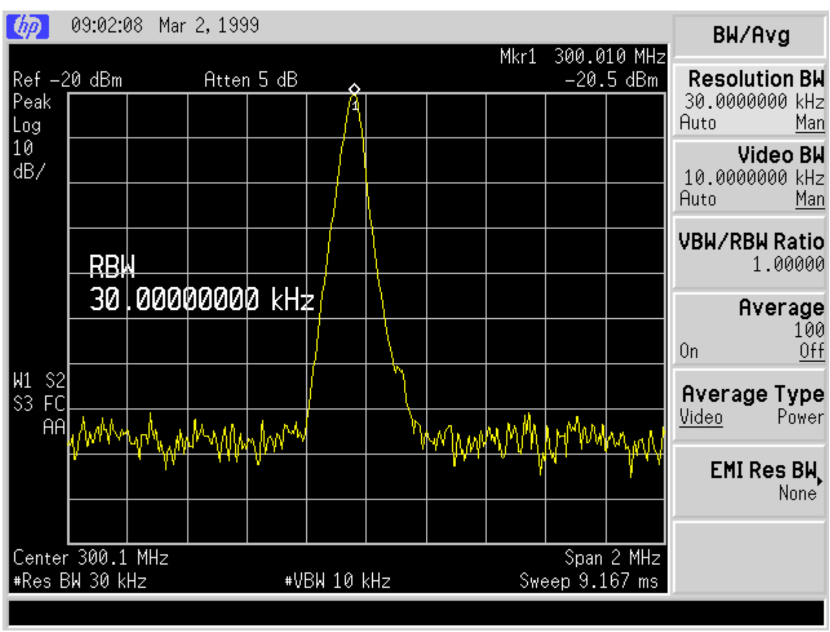
   If a 10 kHz filter with a typical shape factor of 15:1 is used, the filter will have a bandwidth of 150 kHz at the 60 dB point. The half-bandwidth (75 kHz) is narrower than the frequency separation, so the input signals will be resolved. See Figure 1-7.

Figure 1-7 Signal Resolution with a 10 kHz Resolution Bandwidth



If a 30 kHz filter is used, the 60 dB bandwidth could be as wide as 450 kHz. Since the half-bandwidth (225 kHz) is wider than the frequency separation, the signals most likely will not be resolved. See Figure 1-8. (In this example, we used the 60 dB bandwidth value. To determine resolution capability for intermediate values of amplitude level differences, assume the filter skirts between the 3 dB and 60 dB points are approximately straight.)

Figure 1-8 Signal Resolution with a 30 kHz Resolution Bandwidth



Making Better Frequency Measurements

A built-in frequency counter increases the resolution and accuracy of the frequency readout. When using this function, if the ratio of the resolution bandwidth to the span is too small (less than 0.002), the `Marker Count: Widen Res BW` message appears on the display. It indicates that the resolution bandwidth is too narrow.

Example:

Increase the resolution and accuracy of the frequency readout on the signal of interest.

1. Turn on the internal 50 MHz alignment signal of the analyzer (if you have not already done so).

   For the E4401B and E4411B, use the internal 50 MHz alignment signal of the analyzer as the signal being measured. Press **Preset**, **Factory Preset** (if present), **Input/Output**, **Amptd Ref (On)**.

   For all other models connect a cable between the front-panel AMPTD REF OUT to the analyzer INPUT, then press **Preset**, **Factory Preset** (if displayed), **Input/Output**, **Amptd Ref Out (On)**.

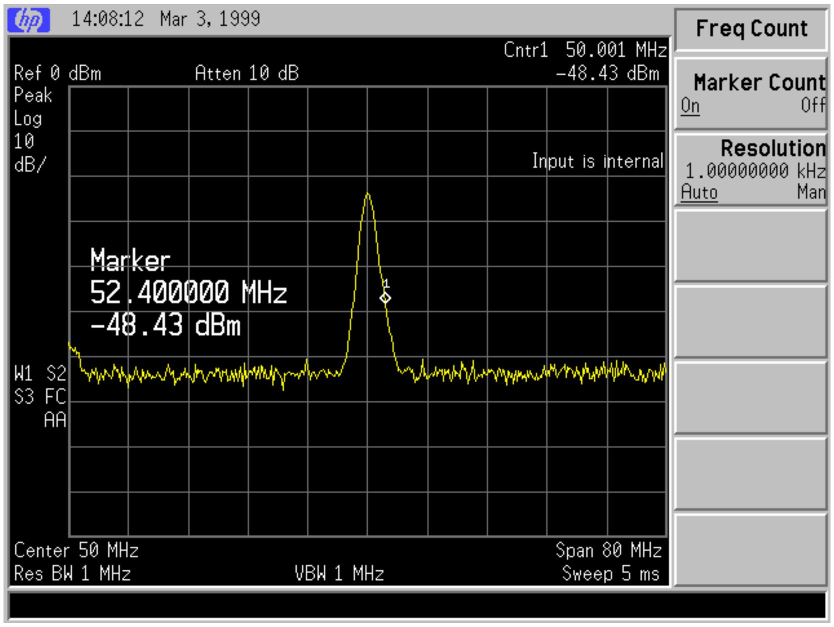
2. Set the center frequency to 50 MHz by pressing **FREQUENCY**, **50 MHz**.
3. Set the span to 80 MHz by pressing **SPAN**, **80 MHz**.
4. Press **Freq Count**. (Note that Marker Count On Off has On underlined turning the frequency counter on.) The frequency and amplitude of the marker and the word `Marker` will appear in the active function area (this is not the counted result). The counted result appears in the upper-right corner of the display.
5. Move the marker, with the front-panel knob, half-way down the skirt of the signal response. Notice that the readout in the active function changes while the counted result (upper-right corner of display) does not. See Figure 1-9. To get an accurate count, you do not need to place the marker at the exact peak of the signal response.

NOTE Marker count properly functions only on CW signals or discrete spectral components. Marker must be >26 dB above the noise.

6. Increase the counter resolution by pressing **Resolution (Man)** and then entering the desired resolution using the step keys or the numbers keypad. For example, press 1 kHz. The marker counter readout is in the upper-right corner of the screen. The resolution can be set from 1 Hz to 100 kHz.

7. The marker counter remains on until turned off. Turn off the marker counter by pressing **Freq Count**, then **Marker Count (Off)**. **Marker**, **Off** also turns the marker counter off.

Figure 1-9 Using Marker Counter



Decreasing the Frequency Span Around the Signal

Using the analyzer signal track function, you can quickly decrease the span while keeping the signal at center frequency. This is a fast way to take a closer look at the area around the signal to identify signals that would otherwise not be resolved.

Example:

Examine a signal in a 200 kHz span.

1. Turn on the internal 50 MHz alignment signal of the analyzer (if you have not already done so).

   For the E4401B and E4411B, use the internal 50 MHz alignment signal of the analyzer as the signal being measured. Press **Preset**, **Factory Preset** (if present), **Input/Output**, **Amptd Ref (On)**.

   For all other models connect a cable between the front-panel AMPTD REF OUT to the analyzer INPUT, then press **Preset**, **Factory Preset** (if present), **Input/Output**, **Amptd Ref Out (On)**.

2. Set the stop frequency to 1 GHz by pressing **FREQUENCY**, **Stop Freq**, **1 GHz**.

3. Press **Peak Search** to place a marker at the peak.

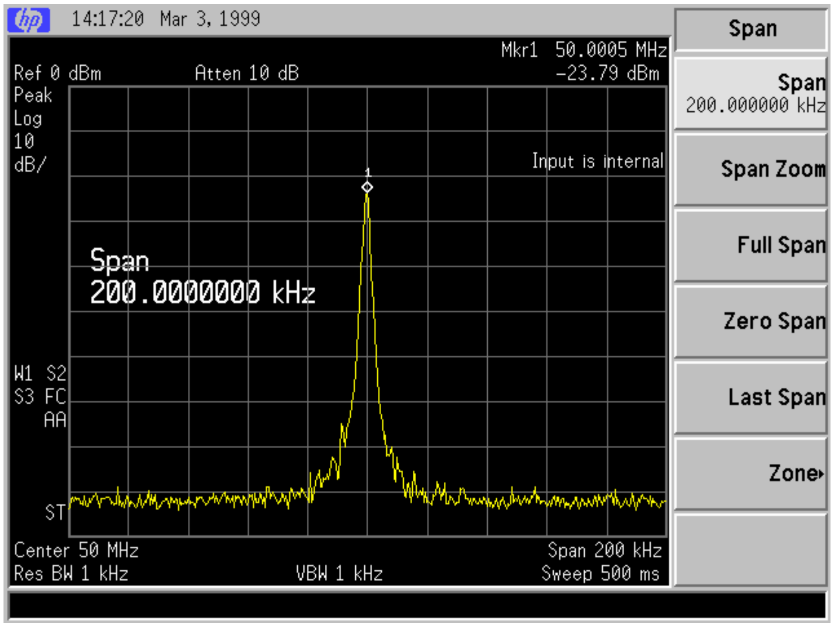
4. Press **FREQUENCY**, **Signal Track (On)** and the signal will move to the center of the screen, if it is not already positioned there. (Note that the marker must be on the signal before turning signal track on.) Because the signal track function automatically maintains the signal at the center of the screen, you can reduce the span quickly for a closer look. If the signal drifts off of the screen as you decrease the span, use a wider frequency span.

5. Press **SPAN**, 200 kHz. The span decreases in steps as automatic zoom is completed. See Figure 1-10. You can also use the knob or step keys to decrease the span or use the **Span Zoom** function under **SPAN**.

Press **Signal Track (Off)** again to turn off the signal track function.

NOTE When you are finished with the example, turn off the signal tracking function.

Figure 1-10 After Zooming In on the Signal



Tracking Drifting Signals

The signal track function is useful for tracking drifting signals that drift relatively slowly.

Signal Track On Off may be used to track these drifting signals. Use **Peak Search** to place a marker on the signal you wish to track. Pressing **FREQUENCY**, **Signal Track (On)** will bring that signal to the center frequency of the graticule and adjust the center frequency every sweep to bring the selected signal back to the center. (**Span Zoom**, in the **SPAN** menu, is a quick way to perform the **Search**, **FREQUENCY**, **Signal Track On Off**, **SPAN** key sequence.)

Note that the primary function of the signal track function is to track unstable signals, not to track a signal as the center frequency of the analyzer is changed. If you choose to use the signal track function when changing center frequency, check to ensure that the signal found by the tracking function is the correct signal.

Example 1:

Use the signal track function to keep a drifting signal at the center of the display and monitor its change.

This example requires a signal generator. The frequency of the signal generator will be changed while you view the signal on the display of the analyzer.

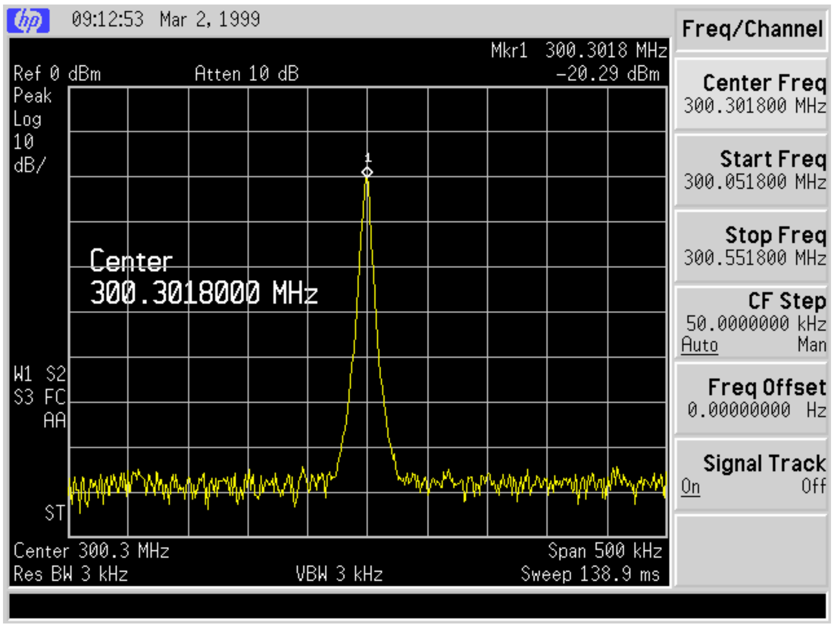
1. Connect a signal generator to the analyzer input. Press **Preset**, **Factory Preset** (if present).
2. Set the signal generator frequency to 300 MHz with an amplitude of –20 dBm.
3. Set the center frequency of the analyzer to 300 MHz by pressing **FREQUENCY**, **300 MHz**.
4. Press **Marker** and move the marker to the peak of your signal.
5. Set the span to 10 MHz by pressing **SPAN**, **10 MHz**.
6. Press **SPAN**, **Span Zoom**, **500 kHz**.

   Notice that the signal has been held in the center of the display.

7. The signal frequency drift can be read from the screen if both the signal track and marker delta functions are active. Press **Marker**, **Delta**. The marker readout indicates the change in frequency and amplitude as the signal drifts.

8. Tune the frequency of the signal generator. Notice that the center frequency of the analyzer changes in < 10 kHz increments, centering the signal with each increment. See Figure 1-11.

Figure 1-11 Using Signal Tracking to Track a Drifting Signal



Example 2:

The analyzer can measure the short and long-term stability of a source. The maximum amplitude level and the frequency drift of an input signal trace can be displayed and held by using the maximum-hold function. You can also use the maximum hold function if you want to determine how much of the frequency spectrum a signal occupies.

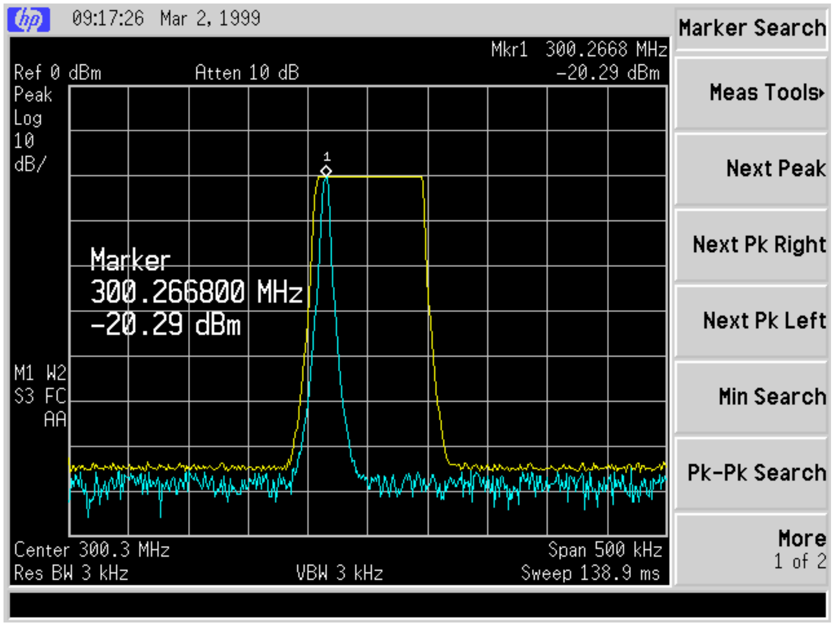
1. Connect a signal generator to the analyzer input. Press **Preset, Factory Preset** (if present).
2. Set the signal generator frequency to 300 MHz with an amplitude of –20 dBm.
3. Set the center frequency of the analyzer to 300 MHz by pressing **FREQUENCY**, **300 MHz**.
4. Press **Marker** and move the marker to the peak of your signal.
5. Set the span to 10 MHz by pressing **SPAN**, **10 MHz**.
6. Press **SPAN**, **Span Zoom**, **500 kHz**.
7. Turn off the signal track function by pressing **FREQUENCY**, **Signal Track (Off)**.
8. To measure the excursion of the signal, press **View/Trace** then **Max Hold**. As the signal varies, maximum hold maintains the maximum responses of the input signal.

   Annotation on the left side of the screen indicates the trace mode. For example, `M1 S2 S3` indicates trace 1 is in maximum-hold mode, trace 2 and trace 3 are in store- blank mode. See “Display Annotation” in Chapter 2 of the User’s Guide.

9. Press **View/Trace**, **Trace 1 2 3**, to select trace 2. (Trace 2 is selected when 2 is underlined.) Press **Clear Write** to place trace 2 in clear-write mode, which displays the current measurement results as it sweeps. Trace 1 remains in maximum hold mode, showing the frequency shift of the signal.

   Slowly change the frequency of the signal generator ± 50 kHz. Your analyzer display should look similar to Figure 1-12.

Figure 1-12 Viewing a Drifting Signal With Max Hold and Clear Write



Measuring Low Level Signals

The ability of the analyzer to measure low level signals is limited by the noise generated inside the analyzer. A signal may be masked by the noise floor so that it is not visible. This sensitivity to low level signals is affected by the measurement setup.

The analyzer input attenuator and bandwidth settings affect the sensitivity by changing the signal-to-noise ratio. The attenuator affects the level of a signal passing through the instrument, whereas the bandwidth affects the level of internal noise without affecting the signal. In the first two examples in this section, the attenuator and bandwidth settings are adjusted to view low level signals.

If, after adjusting the attenuation and resolution bandwidth, a signal is still near the noise, visibility can be improved by using the video bandwidth and video averaging functions, as demonstrated in the third and fourth examples.

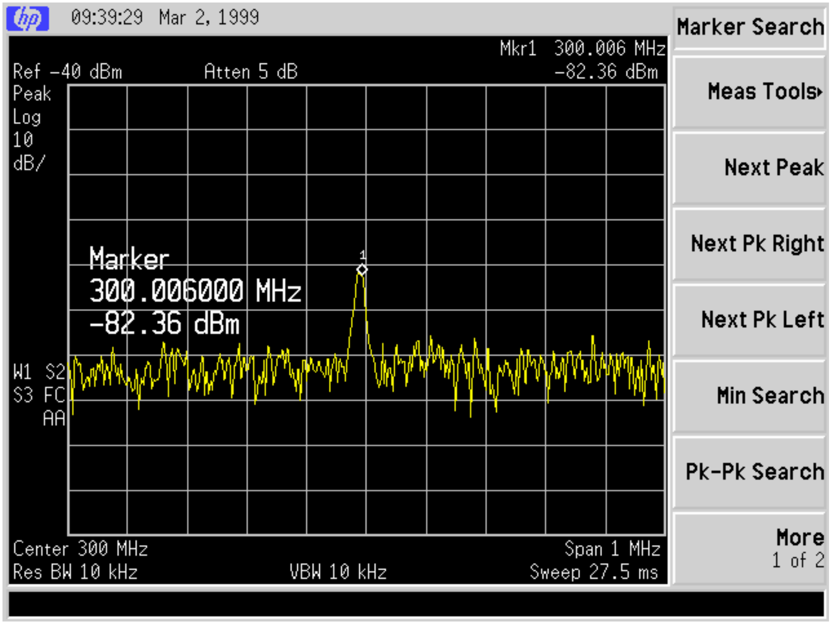
Example 1:

If a signal is very close to the noise floor, reducing input attenuation brings the signal out of the noise. Reducing the attenuation to 0 dB maximizes signal power in the analyzer.

CAUTION The total power of all input signals at the analyzer input must not exceed the maximum power level for the analyzer.

1. Connect a signal generator to the analyzer input. Press **Preset**, **Factory Preset** (if present).
2. Set the signal generator frequency to 300 MHz with an amplitude of –80 dBm.
3. Set the center frequency of the analyzer to 300 MHz by pressing **FREQUENCY**, **300 MHz**.
4. Set the span to 5 MHz by pressing **SPAN**, **5 MHz**.
5. Set the reference level to –40 dBm by pressing **AMPLITUDE**, **Ref Level**, **40** –**dBm**.
6. Place the signal at center frequency by pressing **Peak Search**, **Meas Tools**, **Mkr→CF**.
7. Reduce the span to 1 MHz. Press **SPAN**, and then use the step-down key (↓). See Figure 1-13.

Figure 1-13 Low-Level Signal



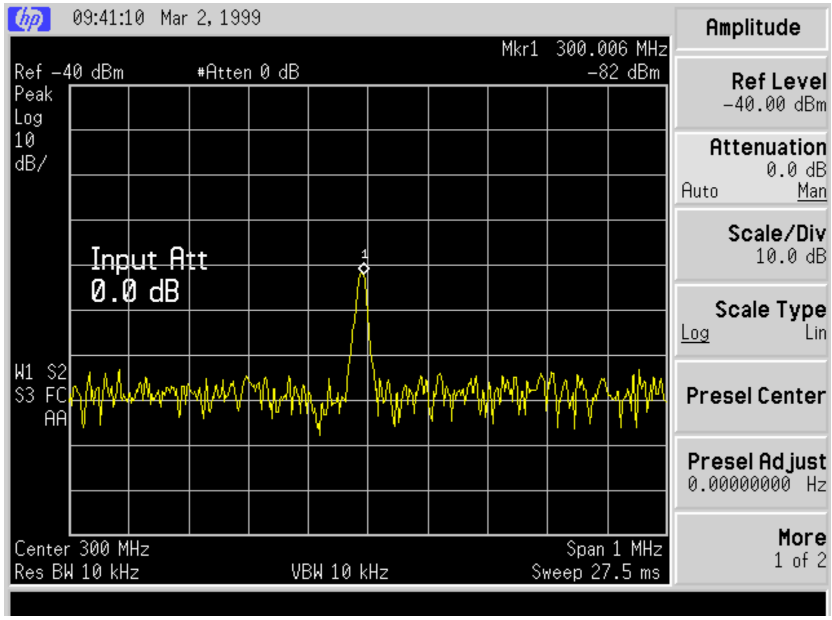
8. Press **AMPLITUDE**, **Attenuation (Man)**. Press the step-up key (↑) twice to select 20 dB attenuation. Increasing the attenuation moves the noise floor closer to the signal.

   A # mark appears next to the `Atten` annotation at the top of the display, indicating the attenuation is no longer coupled to other analyzer settings.

9. To see the signal more clearly, enter 0 dB. Zero attenuation makes the signal more visible. See Figure 1-14.

Before connecting other signals to the analyzer input, increase the RF attenuation to protect the analyzer input: press **Attenuation (Auto)** or press **Auto Couple**.

Figure 1-14 Using 0 dB Attenuation

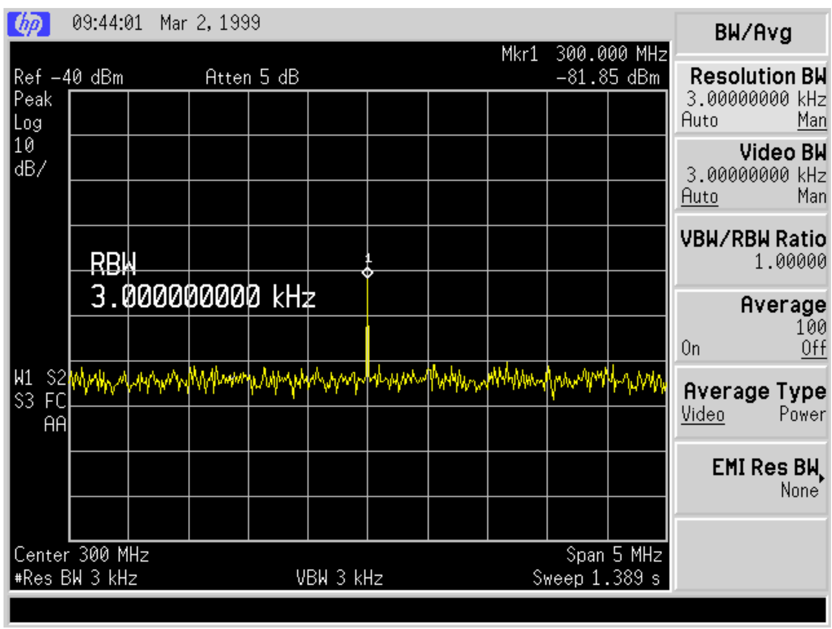


Example 2:

The resolution bandwidth can be decreased to view low level signals.

1. As in the previous example, set the analyzer to view a low level signal. Connect a signal generator to the analyzer input. Press **Preset, Factory Preset** (if present).
2. Set the signal generator frequency to 300 MHz with an amplitude of –80 dBm.
3. Set the center frequency of the analyzer to 300 MHz by pressing **FREQUENCY**, **300 MHz**.
4. Set the span to 5 MHz by pressing **SPAN**, **5 MHz**.
5. Set the reference level to –40 dBm by pressing **AMPLITUDE**, **Ref Level**, **40** –**dBm**.
6. Press **BW/Avg**, then ↓. The low level signal appears more clearly because the noise level is reduced. See Figure 1-15.

Figure 1-15 Decreasing Resolution Bandwidth



A # mark appears next to the **Res BW** annotation at the lower left corner of the screen, indicating that the resolution bandwidth is uncoupled.

As the resolution bandwidth is reduced, the sweep time is increased to maintain calibrated data.

Example 3:

Narrowing the video filter can be useful for noise measurements and observation of low level signals close to the noise floor. The video filter is a post-detection low-pass filter that smooths the displayed trace. When signal responses near the noise level of the analyzer are visually masked by the noise, the video filter can be narrowed to smooth this noise and improve the visibility of the signal. (Reducing video bandwidths requires slower sweep times to keep the analyzer calibrated.)

Using the video bandwidth function, measure the amplitude of a low level signal.

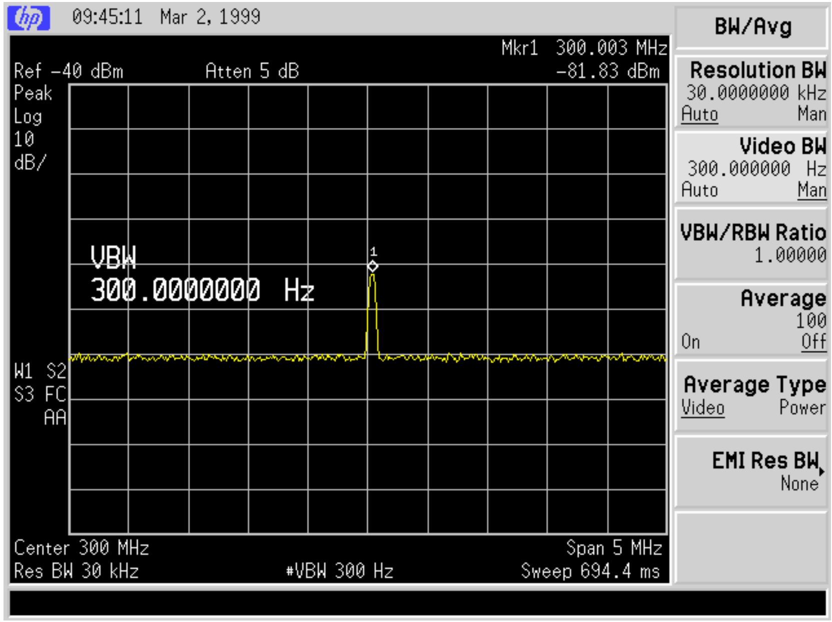
1. As in the previous example, set the analyzer to view a low level signal. Connect a signal generator to the analyzer input. Press **Preset, Factory Preset** (if present).
2. Set the signal generator frequency to 300 MHz with an amplitude of –80 dBm.
3. Set the center frequency of the analyzer to 300 MHz by pressing **FREQUENCY**, **300 MHz**.
4. Set the span to 5 MHz by pressing **SPAN**, **5 MHz**.
5. Set the reference level to –40 dBm by pressing **AMPLITUDE**, **Ref Level**, **40** –**dBm**.
6. Narrow the video bandwidth by pressing **BW/Avg**, **Video BW** , and the step-down key (↓). This clarifies the signal by smoothing the noise, which allows better measurement of the signal amplitude.

   A “#” mark appears next to the VBW annotation at the bottom of the screen, indicating that the video bandwidth is not coupled to the resolution bandwidth. See Figure 1-16.

   Factory preset conditions couple the video bandwidth to the resolution bandwidth so that the video bandwidth is equal to the resolution bandwidth. If the bandwidths are uncoupled when video bandwidth is the active function, pressing **Video BW (Auto)** recouples the bandwidths.

NOTE The video bandwidth must be set wider than the resolution bandwidth when measuring impulse noise levels.

Figure 1-16 Decreasing Video Bandwidth



Example 4:

If a signal level is very close to the noise floor, video averaging is another way to make the signal more visible.

NOTE The time required to construct a full trace that is averaged to the desired degree is approximately the same when using either the video bandwidth or the video averaging technique. The video bandwidth technique completes the averaging as a slow sweep is taken, whereas the video averaging technique takes many sweeps to complete the average. Characteristics of the signal being measured, such as drift and duty cycle, determine which technique is appropriate.

Video averaging is a digital process in which each trace point is averaged with the previous trace-point average. Selecting video averaging changes the detection mode from peak to sample. The result is a sudden drop in the displayed noise level. The sample mode displays the instantaneous value of the signal at the end of the time or frequency interval represented by each display point, rather than the value of the peak during the interval. Sample mode should not be used to measure signal amplitudes accurately because it may not find the true peak of the signal.

Video averaging clarifies low-level signals in wide bandwidths by averaging the signal and the noise. As the analyzer takes sweeps, you can watch video averaging smooth the trace.

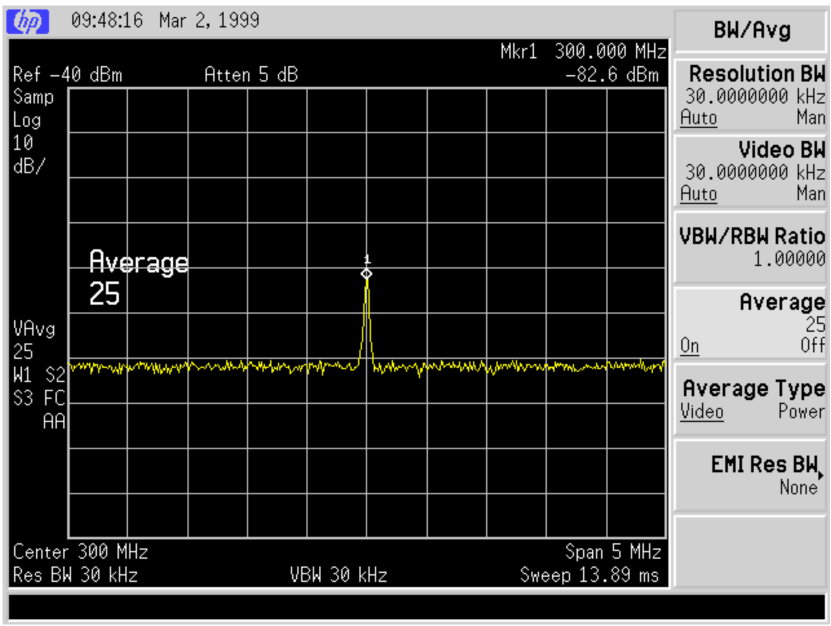
1. As in the previous example, set the analyzer to view a low level signal. Connect a signal generator to the analyzer input. Press **Preset, Factory Preset** (if present).
2. Set the signal generator frequency to 300 MHz with an amplitude of –80 dBm.
3. Set the center frequency of the analyzer to 300 MHz by pressing **FREQUENCY**, **300 MHz**.
4. Set the span to 5 MHz by pressing **SPAN**, **5 MHz**.
5. Set the reference level to –40 dBm by pressing **AMPLITUDE**, **Ref Level, 40** –**dBm**.
6. Press **BW/Avg**, **Average Type (Video)** then **Average (On)**. When **Average (On)** is pressed, the video averaging routine is initiated. As the averaging routine smooths the trace, low level signals become more visible. `Average 100` appears in the active function block. The number represents the number of samples (or sweeps) taken to complete the averaging routine.

7. To set the number of samples, use the numbers keypad. For example, press **Average (On)**, **25**, **Enter**. Turn video averaging off and on again by pressing **Average (Off)**, **Average (On)**. The number of samples equals the number of sweeps in the averaging routine.

   During averaging, the current sample number appears at the left side of the graticule. Changes in active functions settings, such as the center frequency or reference level, will restart the sampling. The sampling will also restart if video averaging is turned off and then on again.

   Once the set number of sweeps has been completed, the analyzer continues to provide a running average based on this set number.

Figure 1-17 Using the Video Averaging Function



Identifying Distortion Products

Distortion from the Analyzer

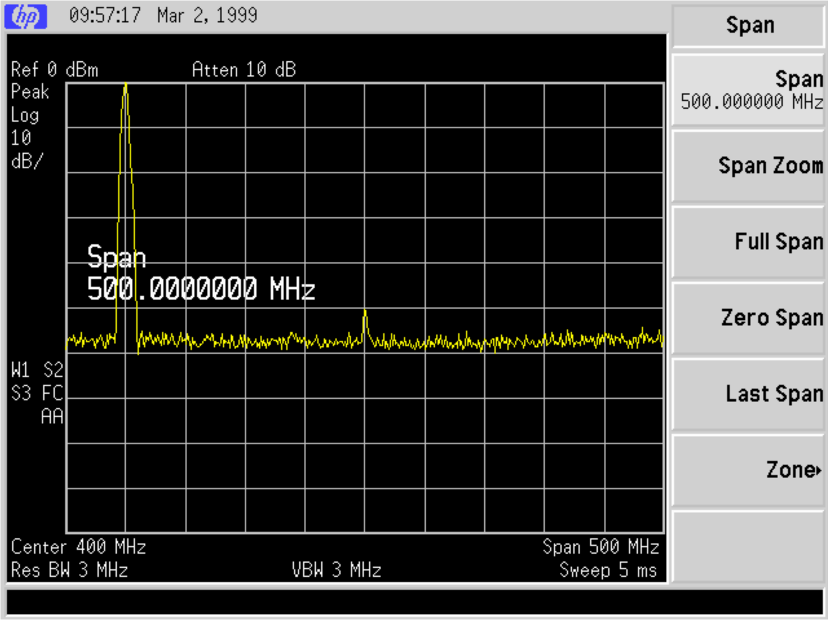
High level input signals may cause analyzer distortion products that could mask the real distortion measured on the input signal. Using trace 2 and the RF attenuator, you can determine which signals, if any, are internally generated distortion products.

Example:

Using a signal from a signal generator, determine whether the harmonic distortion products are generated by the analyzer.

1. As in the previous example, set the analyzer to view a low level signal. Connect a signal generator to the analyzer input. Press **Preset, Factory Preset** (if displayed).
2. Connect a signal generator to the analyzer INPUT. Set the signal generator frequency to 200 MHz and the amplitude to 0 dBm.
3. Set the center frequency of the analyzer to 400 MHz and the span to 500 MHz by pressing **FREQUENCY**, **400 MHz**, **SPAN, 500 MHz**. The signal shown in Figure 1-18 produces harmonic distortion products in the analyzer input mixer.

Figure 1-18 Harmonic Distortion



4. Change the center frequency to the value of one of the observed harmonics.

5. Change the span to 50 MHz: press **SPAN**, **50 MHz**.

6. Change the attenuation to 0 dB: press **AMPLITUDE**, **Attenuation (Man)**, **0 dB**.

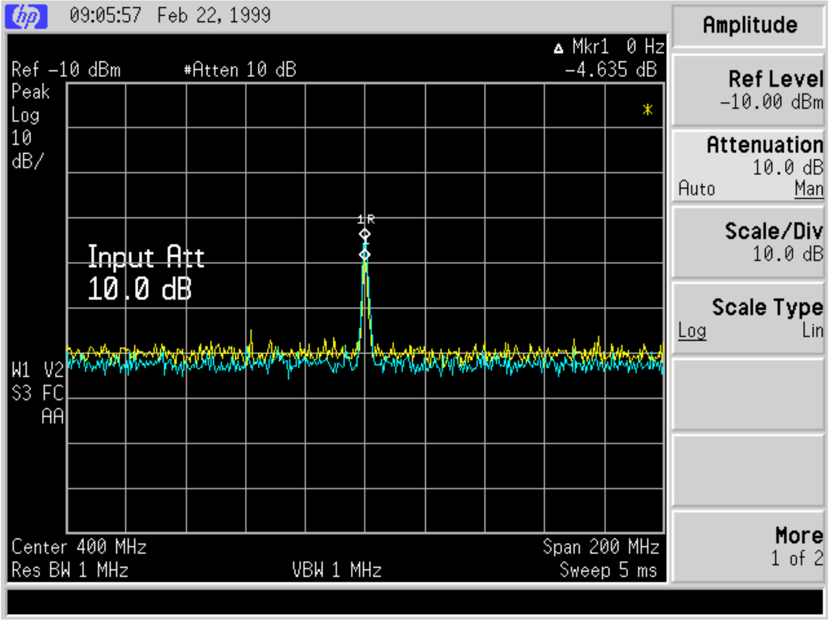
7. To determine whether the harmonic distortion products are generated by the analyzer, first save the screen data in trace 2.

   Press **View/Trace**, **Trace 1 2 3** (until trace 2 is underlined), then **Clear Write**. Allow the trace to update (two sweeps) and press **View**, **Peak Search**, **Marker**, **Delta**. The analyzer display shows the stored data in trace 2 and the measured data in trace 1.

8. Next, increase the RF attenuation by 10 dB: press **AMPLITUDE**, **Attenuation** , and the step-up key (↑) twice. See Figure 1-19.

   Notice the ΔMkr1 amplitude reading. This is the difference in the distortion product amplitude readings between 0 dB and 10 dB input attenuation settings. If the ΔMkr1 amplitude reading is approximately >1 dB for an input attenuator change, the distortion is being generated, at least in part, by the analyzer. In this case more input attenuation is necessary.

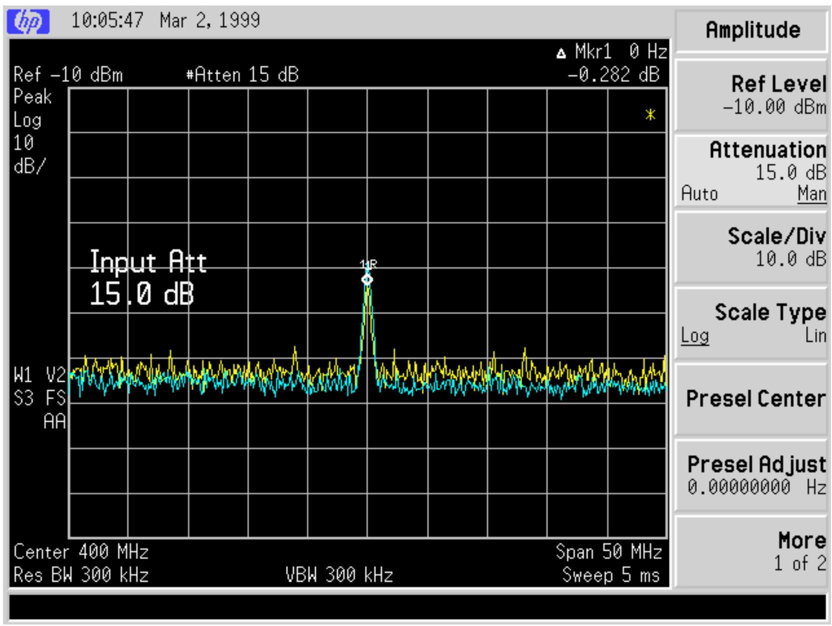
Figure 1-19 RF Attenuation of 10 dB



9. Press **Peak Search**, **Meas Tools**, **Delta**, then change the attenuation to 15 dB by pressing **Amplitude**, **Attenuation (Man)**, **15 dB**.

If the ΔMkr1 amplitude reading is approximately >1 dB as seen in Figure 1-19, then more input attenuation is required; some of the measured distortion is internally generated. If there is no change in the signal level, the distortion is not generated internally. For example, the signal that is causing the distortion shown in Figure 1-20 is not high enough in amplitude to cause internal distortion in the analyzer so any distortion that is displayed is present on the input signal.

Figure 1-20 No Internally-Generated Harmonic Distortion



Third-Order Intermodulation Distortion

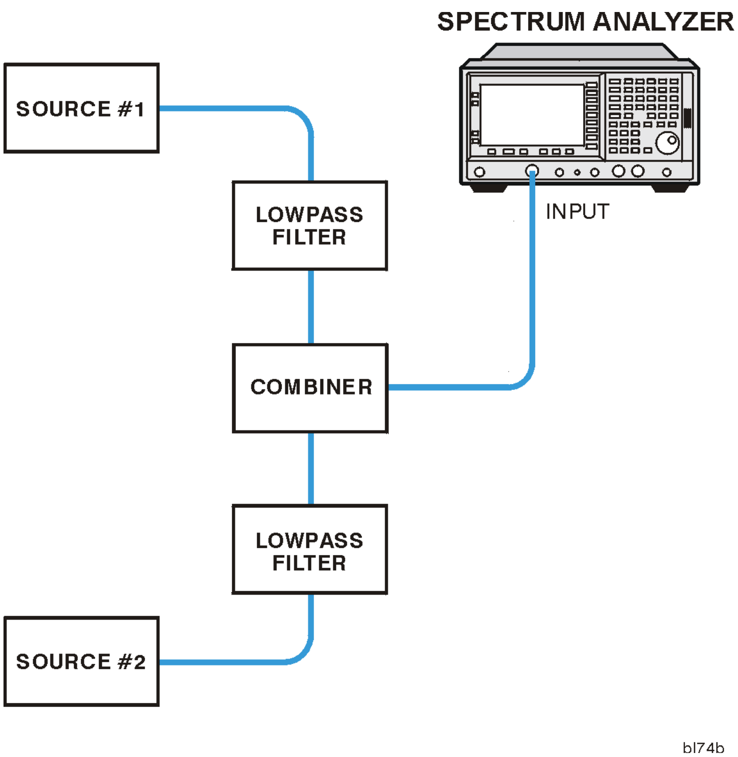
Two-tone, third-order intermodulation distortion is a common test in communication systems. When two signals are present in a non-linear system, they can interact and create third-order intermodulation distortion products that are located close to the original signals. These distortion products are generated by system components such as amplifiers and mixers.

Example:

Test a device for third-order intermodulation. This example uses two sources, one set to 300 MHz and the other to approximately 301 MHz. (Other source frequencies may be substituted, but try to maintain a frequency separation of approximately 1 MHz.)

1. Connect the equipment as shown in Figure 1-21. Press **Preset, Factory Preset** (if present).

Figure 1-21 Third-Order Intermodulation Equipment Setup



NOTE The combiner should have a high degree of isolation between the two input ports so the sources do not intermodulate.

2. Set one source to 300 MHz and the other source to 301 MHz, for a frequency separation of 1 MHz. Set the sources equal in amplitude (in this example, they are set to –5 dBm).

3. Tune both signals onto the screen by setting the center frequency 300.5 MHz. Then, using the knob, center the two signals on the display. Reduce the frequency span to 5 MHz. This is wide enough to include the distortion products on the screen. To be sure the distortion products are resolved, reduce the resolution bandwidth until the distortion products are visible.

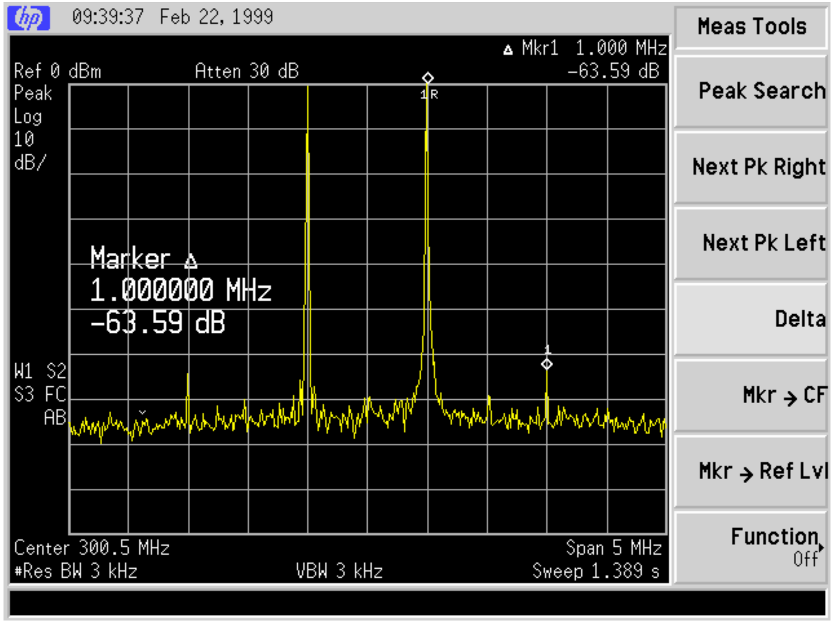
4. For best dynamic range, set the mixer input level to –30 dBm and move the signal to the reference level: press **AMPLITUDE**, **More**, **Max Mixer Lvl**, **30** **–dBm**.

   The analyzer automatically sets the attenuation so that a signal at the reference level will be a maximum of –30 dBm at the input mixer. Press **BW/Avg**, **Resolution BW**, and then use the step-down key (↓) to reduce the resolution bandwidth until the distortion products are visible.

5. To measure a distortion product, press **Peak Search** to place a marker on a source signal. To activate the second marker, press **Marker**, **Delta**. Using the knob, adjust the second marker to the peak of the distortion product that is beside the test signal. The difference between the markers is displayed in the active function area.

   To measure the other distortion product, press **Peak Search**, **Next Peak**. This places a marker on the next highest peak, which, in this case, is the other source signal. To measure the difference between this test signal and the second distortion product, press **Marker, Delta** and use the knob to adjust the second marker to the peak of the second distortion product. See Figure 1-22.

Figure 1-22 Measuring the Distortion Product



See "Measuring Harmonics and Harmonic Distortion" on page 2-19 for more information about measuring distortion products.

Measuring Signal-to-Noise

For this measurement the signal (carrier) is a discrete tone. If the signal is a carrier that is modulated under normal operation, you may use the amplitude reference signal as the signal of interest and the noise of the analyzer for the noise measurement. However, for this example, you will set the input attenuator such that both the signal and the noise are well within the calibrated region of the display. In this example the 50 MHz amplitude reference signal is used as the fundamental source.

Perform the steps below to measure the signal-to-noise.

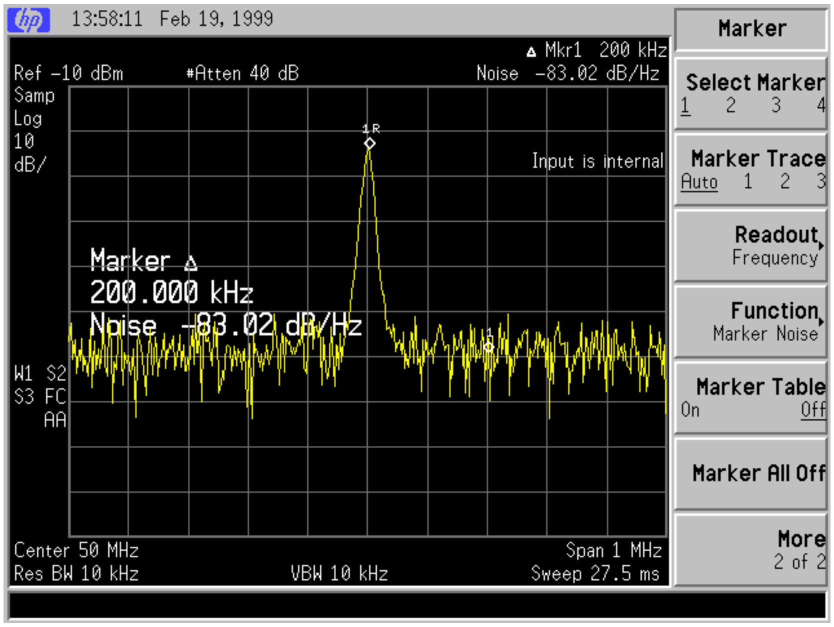
1. Turn on the 50 MHz amplitude reference signal of the analyzer (if you have not already done so).

   For the E4401B and E4411B, use the 50 MHz amplitude reference signal of the analyzer as the signal being measured. Press **Preset**, **Factory Preset** (if present), **Input/Output**, **Amptd Ref (On)**.

   For all other models connect a cable between the front-panel AMPTD REF OUT to the analyzer INPUT, then press **Preset**, **Factory Preset** (if present), **Input/Output**, **Amptd Ref Out (On)**.

2. Set the center frequency to 50 MHz and the span to 1 MHz: press **FREQUENCY**, **50 MHz**, **SPAN**, **1 MHz**.
3. Set the reference level to –10 dBm by pressing **AMPLITUDE**, **Ref Level**, **–10 dBm**.
4. Set the attenuation to 40 dB by pressing **AMPLITUDE**, **Attenuation**, **40 dB**.
5. Press **Peak Search** to place a marker on the peak of the signal.
6. Press **Marker**, **Delta**, **200 kHz** to put the delta marker in the noise at the specified offset, in this case 200 kHz.
7. Press **More 1 of 2**, **Function**, **Marker Noise** to view the results of the signal to noise measurement. See Figure 1-23.

Figure 1-23 Measuring the Signal-to-Noise



Read the signal-to-noise in dB/Hz, that is with the noise value determined for a 1-Hz noise bandwidth. If you wish the noise value for a different bandwidth, decrease the ratio by $10 \times \log(BW)$. For example, if the analyzer reading is –70 dB/Hz but you have a channel bandwidth of 30 kHz:

$$S/N = -70 \text{ dB/Hz} + 10 \times \log(30 \text{ kHz}) = -25.2 \text{ dB/30 kHz}$$

Note that the display detection mode is now sample. If the delta marker is within half a division of the response to a discrete signal, the amplitude reference signal in this case, there is a potential for error in the noise measurement. See “Making Noise Measurements” on page 36.

Making Noise Measurements

There are a variety of ways to measure noise power. The first decision you must make is whether you want to measure noise power at a specific frequency or the total power over a specified frequency range, for example over a channel bandwidth.

Example 1:

Using the marker function, **Marker Noise**, is a simple method to make a measurement at a single frequency. In this example, attention must be made to the potential errors due to discrete signal (spectral components). This measurement will be made near the 50 MHz amplitude reference signal to illustrate the use of **Marker Noise.**

1. Turn on the 50 MHz amplitude reference signal of the analyzer (if you have not already done so).

   For the E4401B and E4411B, use the 50 MHz amplitude reference signal of the analyzer as the signal being measured. Press **Preset**, **Factory Preset** (if present), **Input/Output**, **Amptd Ref (On).**

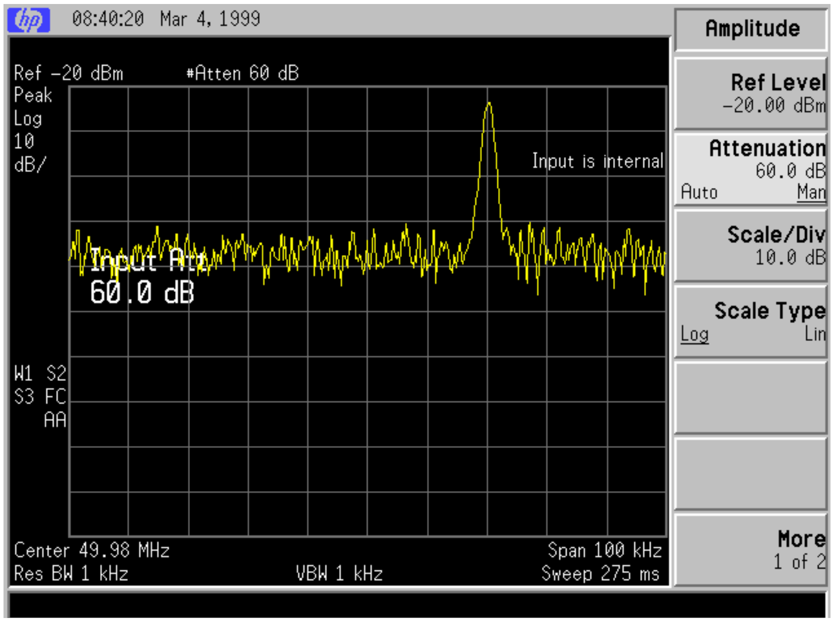
   For all other models connect a cable between the front-panel AMPTD REF OUT to the analyzer INPUT, then press **Preset**, **Factory Preset** (if present), **Input/output**, **Amptd Ref Out (On)**.

2. Tune the analyzer to the frequency of interest. In this example we are using the reference signal. Press **FREQUENCY**, **49.98 MHz**.

3. Set the span to 100 kHz by pressing **SPAN**, **100 kHz**.

4. Set the reference level to –20 dBm by pressing **AMPLITUDE**, **Ref Level**, –**20 dBm**. See Figure 1-24. Note that if the signal is much higher than shown, adjust the input attenuator. In this example the input attenuation was set to 60 dB by pressing **Attenuation**, **60 dB**.

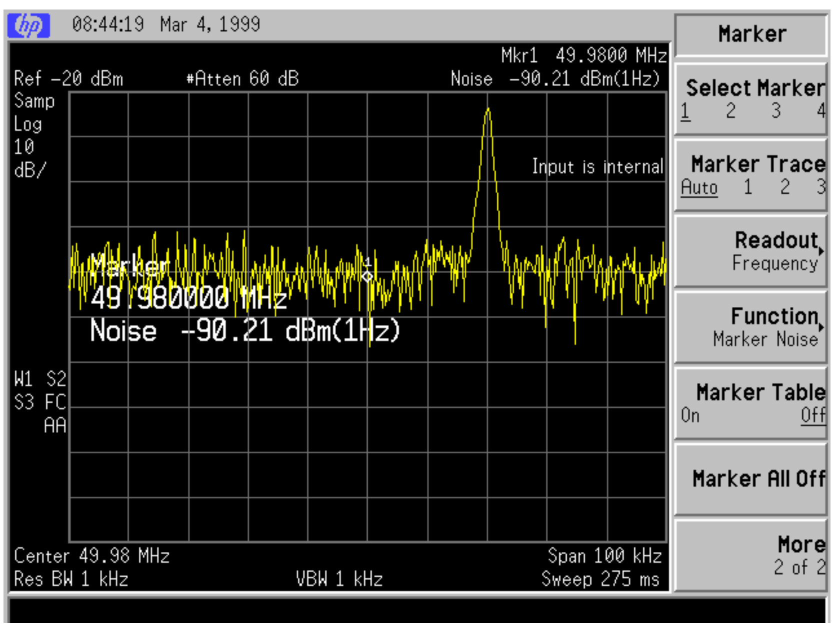
Figure 1-24 Setting the Reference Level



5. Activate the noise marker by pressing **Marker**, **More 1 of 2**, **Function**, **Marker Noise**.

   Note that the display detection has changed to sample, the marker floats between the maximum and the minimum of the noise. The marker readout is in dBm(Hz) or dBm per unit bandwidth. See Figure 1-25. For noise power in a different bandwidth, add $10 \times \log(\mathrm{BW})$. For example, for noise power in a 1 kHz bandwidth, add $10 \times \log(1000)$ or 30 dB to the noise marker value.

Figure 1-25 Activating the Noise Marker



6. Video filtering can be introduced to reduce the variations of the sweep-to-sweep marker value. Set the video filter by pressing **BW/Avg**, **Video BW (Man)**, **100 Hz**.

   Notice that these variations are to be expected due to the nature of the signal. We can reduce the variations by introducing video filtering. Since reducing the video bandwidth filter impacts sweep time, it is recommended to limit the degree of filtering.

7. The noise marker value is based on the mean of 33 trace points centered at the marker. With a total of 401 points across the entire trace, the 33 points span almost a full division. To see the effect, move the marker to the 50 MHz signal by pressing **Marker**, **50 MHz** (or use the knob to place marker at 50 MHz).

8. The marker does not go to the peak of the signal because not all 33 points are at the peak of the signal. Widen the resolution bandwidth by pressing **BW/Avg**, **Resolution BW (Man)**,**10 kHz** (or up arrow) to see what happens. The marker is now much closer to the peak of the signal.

9. Return the resolution bandwidth to automatic mode by pressing **Resolution BW (Auto)**.

10. Measure the noise very close to the signal by pressing **Marker**, **49.99625 MHz** (or use the knob to place the marker).

    Note that the marker reads a value that is too high because some of the 33 trace points are on the skirt of the signal response.

11. Set the analyzer for zero span by pressing **SPAN**, **Zero Span**, **Marker**. Note that the marker value is now correct.

Example 2:

The Normal marker can also be used to make a single frequency measurement as described in the previous example, again using video filtering or averaging to obtain a reasonably stable measurement. While video averaging automatically selects the sample display detection mode, video filtering does not. With sufficient filtering that results in a smooth trace, there is no difference between the sample and peak modes because the filtering takes place before the signal is digitized.

Be sure to account for the fact that the averaged noise is displayed approximately 2 dB too low for a noise bandwidth equal to the resolution bandwidth. Therefore, you must add 2 dB to the marker reading. For example, if the marker indicates –100 dBm, the actual noise level is –98 dBm.

Example 3:

You may want to measure the total power of a noise-like signal that occupies some bandwidth. For example, you may want to determine the power in a communications channel. If the signal is noise and is flat across the band of interest, you can use the noise marker as described in example 1 and add $10 \times \log(\text{channel BW})$. However, if you are not certain of the characteristics of the signal, or if there are discrete spectral components in the band of interest, we can use the Channel Power routine. In this example, you will use the noise of the analyzer, then add a discrete tone to see what happens and assume a channel bandwidth of 50 kHz. If desired, a specific signal may be substituted.

1. Reset the analyzer by pressing **Preset**, **Factory Preset** (if present).
2. Tune the analyzer to the frequency of 50 MHz. In this example we are using the amplitude reference signal. Press **FREQUENCY**, **50 MHz**.
3. Set the span to 100 kHz by pressing **SPAN**, **100 kHz**.
4. Set the reference level to –20 dBm by pressing **AMPLITUDE**, **Ref Level**, **–20 dBm**.
5. Set the input attenuation to 40 dB by pressing **Attenuation**, **40 dB**.
6. Set the analyzer to setup the channel-power measurement by pressing **MEASURE**, **Channel Power**, **Meas Setup**.
7. Set the integration bandwidth to 50 kHz by pressing **Integration BW**, **50 kHz**.
8. Set the channel-power span to 100 kHz by pressing **Chan Pwr Span**, **100 kHz**.

NOTE The display detection mode has been set to sample and the video bandwidth has been set to be ten times wider than the resolution bandwidth. This setting is important to prevent any averaging. You can reduce the sweep-to-sweep variation in the power reading by averaging over a number of sweeps.

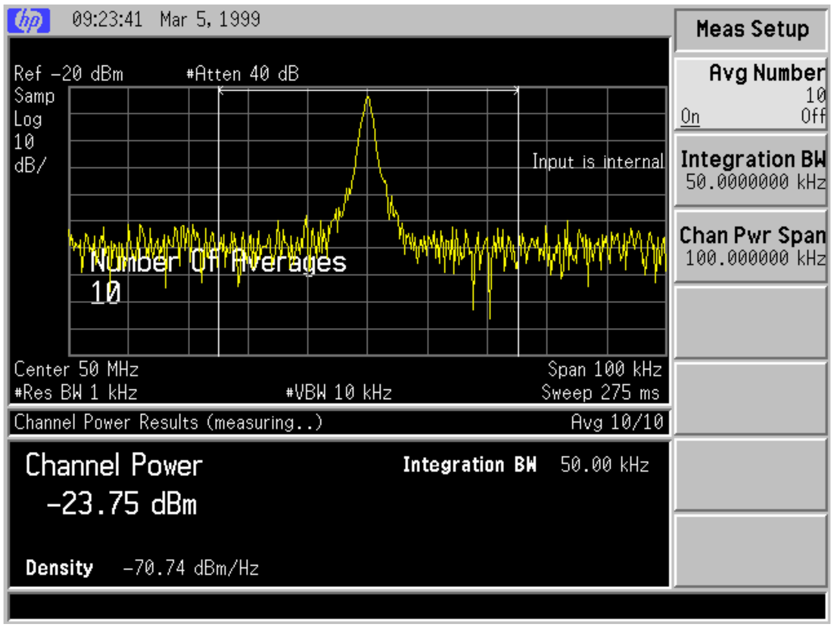
9. Turn average number on by pressing **Avg Number (On)**. 10 is an acceptable number.

10.Add a discrete tone to see the affects of the reading. Turn on the 50 MHz amplitude reference signal of the analyzer (if you have not already done so).

For the E4401B and E4411B, use the 50 MHz amplitude reference signal of the analyzer as the signal being measured. Press **Input/Output**, **Amptd Ref (On)**.

For all other models connect a cable between the front-panel AMPTD REF OUT to the analyzer INPUT, then press **Input/Output**, **Amptd Ref Out (On)**. Your display should be similar to Figure 1-26.

Figure 1-26 Measuring Channel Power



The power reading is essentially that of the tone; that is, the total noise power is far enough below that of the tone that the noise power contributes very little to the total.

The algorithm that computes the total power compensates for the fact that some of the trace points on the response to the continuous wave tone may be at or very close to the peak value of the tone and so yields the correct value whether the signal comprises just noise, a tone, or both.

Example 4:

The functions described in example 3 also allow you to measure the total power of noise-like signals, tones, or both. A difference is that you use adjustable markers to set the frequency span over which power is measured. The markers allow you to easily and conveniently select any arbitrary portion of the displayed signal for measurement. However, while the analyzer does select the sample display detection mode, you must set all of the other parameters.

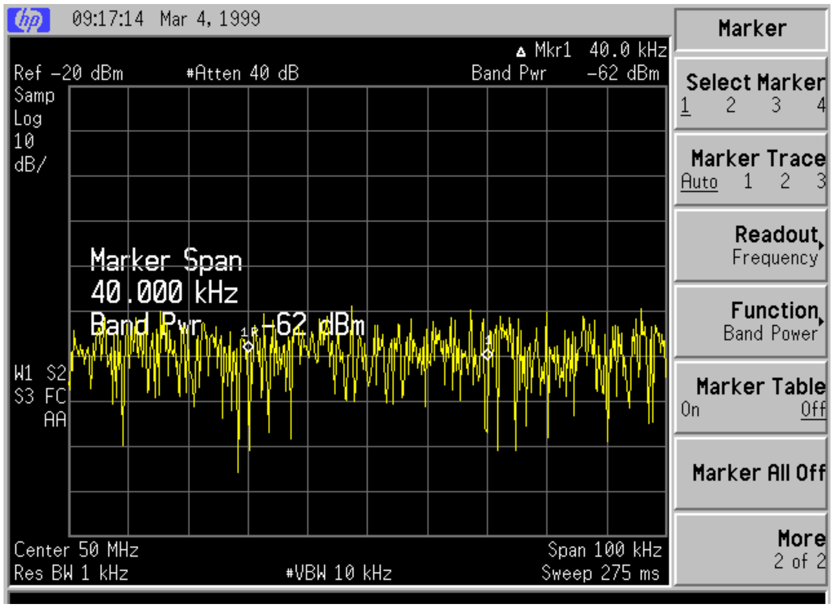
1. Reset the analyzer by pressing **Preset**, **Factory Preset** (if present).
2. Tune the analyzer to the frequency of 50 MHz. In this example we are using the amplitude reference signal. Press **FREQUENCY**, **50 MHz**.
3. Set the span to 100 kHz by pressing **SPAN**, **100 kHz**.
4. Set the reference level to –50 dBm by pressing **AMPLITUDE**, **Ref Level**, –**20 dBm**.
5. Set the input attenuator to 40 dB by pressing **Attenuation**, **40 dB**.
6. Set the marker span to 40 kHz by pressing **Marker**, **Span Pair (Span)**, **40 kHz**.

   The resolution bandwidth should be about 1 to 3% of the measurement (marker) span, 40 kHz in this example. The 1 kHz resolution bandwidth that the analyzer has chosen is fine. The video bandwidth should be ten times wider.
7. Set the video bandwidth to 10 kHz by pressing **BW/Avg**, **Video BW (Man)**,**10 kHz**.
8. Measure the power between markers by pressing **Marker**, **More 1 of 2, Function**, **Band Power**. The analyzer displays the total power between the markers. See Figure 1-27.
9. Add a discrete tone to see the affects of the reading. Turn on the 50 MHz amplitude reference signal of the analyzer (if you have not already done so).

   For the E4401B and E4411B, use the 50 MHz amplitude reference signal of the analyzer as the signal being measured.
   Press **Input/Output**, **Amptd Ref (On)**.

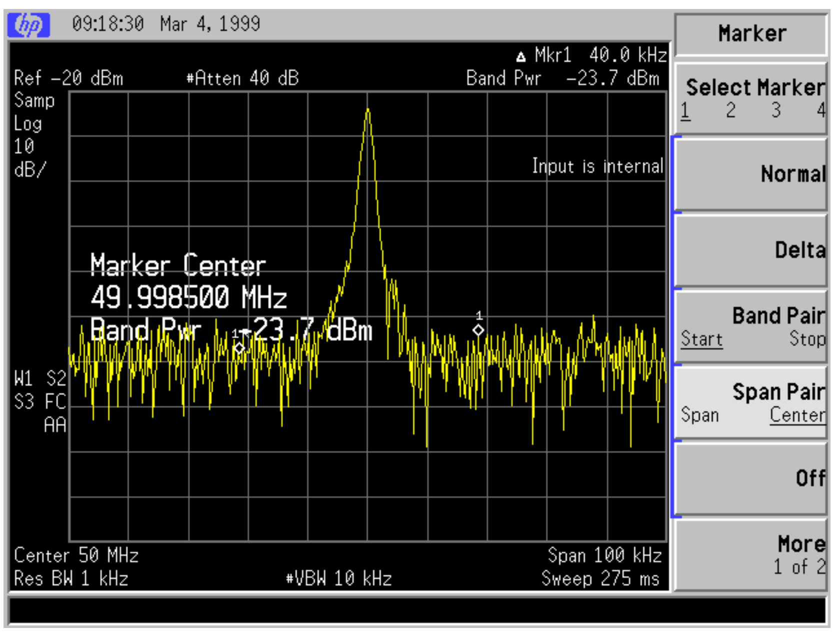
   For all other models connect a cable between the front-panel AMPTD REF OUT to the analyzer INPUT, then press **Input/Output**, **Amptd Ref Out (On)**.

Figure 1-27 Viewing Power Between Markers



10.Move the measured span by pressing **Marker**, **Span Pair (Center)**. Then use the knob to exclude the tone and note reading. You could have also used **Band Pair** to set the measurement start and stop points independently. See Figure 1-28.

Figure 1-28 Measuring the Power of the Span



Demodulating AM Signals (Using the Analyzer As a Fixed Tuned Receiver)

The zero span mode can be used to recover amplitude modulation on a carrier signal. The analyzer operates as a fixed-tuned receiver in zero span to provide time domain measurements.

Center frequency in the swept-tuned mode becomes the tuned frequency in zero span. The horizontal axis of the screen becomes calibrated in time only, rather than both frequency and time. Markers display amplitude and time values.

The following functions establish a clear display of the waveform:

- Trigger stabilizes the waveform trace on the display by triggering on the modulation envelope. If the modulation of the signal is stable, video trigger synchronizes the sweep with the demodulated waveform.
- Linear mode should be used in amplitude modulation (AM) measurements to avoid distortion caused by the logarithmic amplifier when demodulating signals.
- Sweep time adjusts the full sweep time from 5 ms to 2000 s. (20 us to 2000 s if Option AYX is installed). The sweep time readout refers to the full 10-division graticule. Divide this value by 10 to determine sweep time per division.
- Resolution and video bandwidth are selected according to the signal bandwidth.

Each of the coupled function values remains at its current value when zero span is activated. Video bandwidth is coupled to resolution bandwidth. Sweep time is not coupled to any other function.

NOTE Refer to "Demodulating and Listening to an AM Signal" on page 2-15 for more information on signal demodulation.

Example:

View the modulation waveform of an AM signal in the time domain.

1. Connect an RF signal source to the analyzer INPUT. For this example, an HP/Agilent ESG-4000A Signal Generator (Model E4422A) was used with the following settings:

   RF Frequency 300 MHz, RF Output Power –10 dBm,
   AM On, AM Rate 1 kHz
   AM Depth 80%

2. Preset the analyzer by pressing **Preset, Factory Preset** (if present).

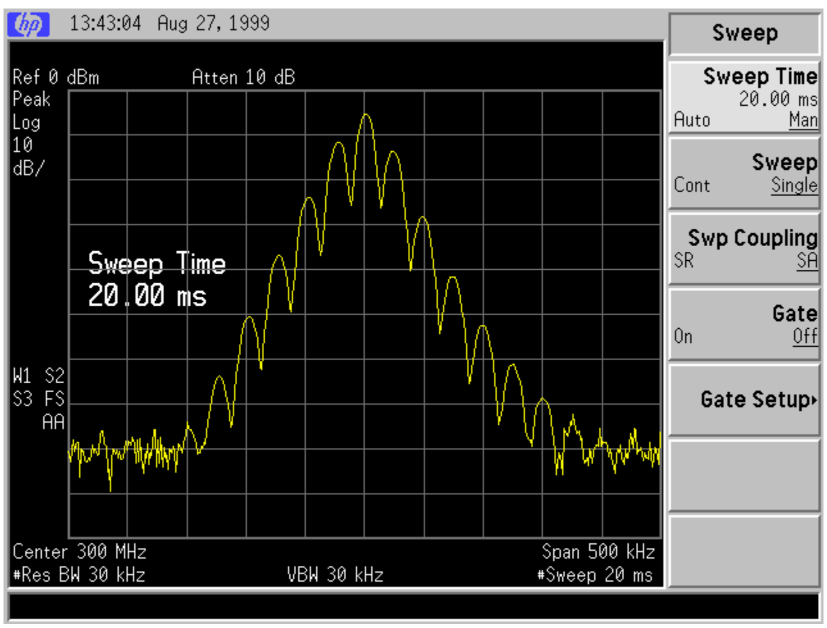
3. Set the center frequency of the analyzer to 300 MHz by pressing **FREQUENCY**, **300 MHz**.

4. Set the Span to 500 kHz by pressing **SPAN**, **500 kHz**. If necessary, adjust the analyzer center frequency to center the signal horizontally on the display by pressing **FREQUENCY**, **Center Freq**, and rotating the knob.

5. Set the resolution bandwidth to 30 kHz by pressing **BW/Avg**, **Resolution BW**, **30 kHz**. This setting is wide enough to include both 1 kHz AM sidebands of the RF carrier well within the 1 dB passband of the analyzer.

6. Change the analyzer sweep to 20 ms by pressing **Sweep**, **Sweep Time**, **20 ms**. The 1 kHz amplitude modulation is now clearly visible as amplitude variations of the trace with 1 ms peak-to-peak spacing. See Figure 1-29.

Figure 1-29 Viewing an AM Signal



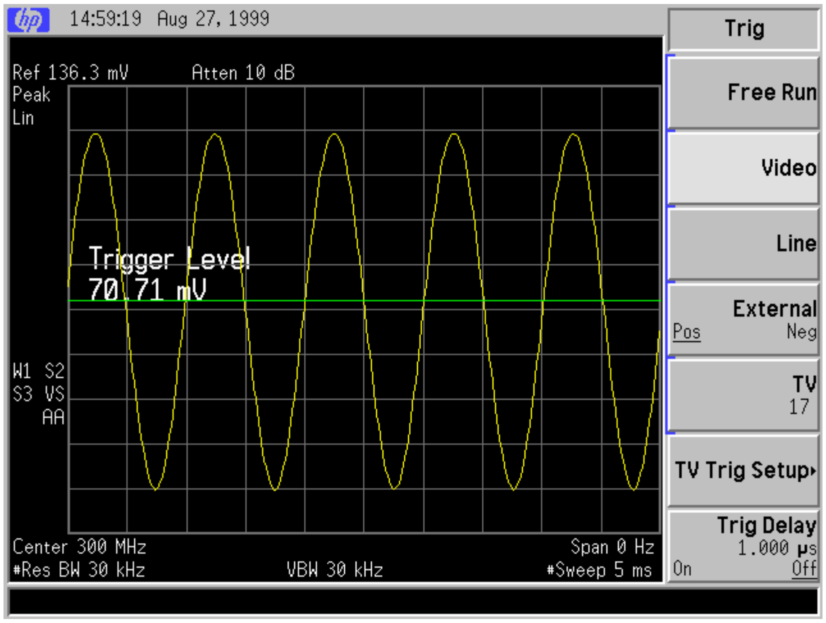
7. Position the signal peak near the reference level by pressing **AMPLITUDE** and rotating the knob.

8. Change the amplitude scale type to linear by pressing **AMPLITUDE**, **Scale Type (Lin)**.

9. To select zero span, press either **SPAN**, **0 Hz**, or **SPAN**, **Zero Span**. Change the sweep time to 5 ms by pressing **Sweep**, **Sweep Time (Man)**, **5 ms**. See Figure 1-30. Since the modulation is a steady tone, you can use video trigger to trigger the analyzer sweep on the waveform and stabilize the trace, much like an oscilloscope (press **Trig**, **Video**, and adjust the trigger level with the knob).

Use markers and delta markers to measure the time parameters of the waveform. Adjust the sweep time to change the horizontal scale. Adjust the reference level to change the vertical scale.

Figure 1-30 Measuring Modulation In Zero Span



Demodulating FM Signals (Without Option BAA)

As with amplitude modulation (see page 1-43) you can utilize zero span to demodulate an FM signal. However, unlike the AM case, you cannot simply tune to the carrier frequency and widen the resolution bandwidth. The reason is that the envelope detector in the analyzer responds only to amplitude variations, and there is no change in amplitude if the frequency changes of the FM signal are limited to the flat part of the resolution bandwidth.

On the other hand, if you tune the analyzer slightly away from the carrier, you can utilize slope detection to demodulate the signal by performing the following steps.

1. Determine the correct resolution bandwidth.
2. Find the center of the linear portion of the filter skirt (either side).
3. Tune the analyzer to put the center point at mid screen of the display.
4. Select zero span.

The demodulated signal is now displayed; the frequency changes have been translated into amplitude changes. To listen to the signal, turn on AM demodulation and the speaker.

In this example you will demodulate a broadcast FM signal that has a specified 75 kHz peak deviation.

Example:

Determine the correct resolution bandwidth. With a peak deviation of 75 kHz, your signal has a peak-to-peak excursion of 150 kHz. So we must find a resolution bandwidth filter with a skirt that is reasonably linear over that frequency range.

1. Turn on the 50 MHz amplitude reference signal of the analyzer (if you have not already done so).

   For the E4401B and E4411B, use the 50 MHz amplitude reference signal of the analyzer as the signal being measured. Press **Preset**, **Factory Preset** (if present), **Input/Output**, **Amptd Ref (On)**.

   For all other models connect a cable between the front-panel AMPTD REF OUT to the analyzer INPUT, then press **Preset**, **Factory Preset** (if present), **Input/Output**, **Amptd Ref Out (On)**.

2. Tune the analyzer to the frequency of 50 MHz. In this example we are using the amplitude reference signal. Press **FREQUENCY**, **50 MHz**.

3. Set the span to 1 MHz by pressing **SPAN**, **1 MHz**.

4. Set the reference level to –20 dBm by pressing **AMPLITUDE**, **Ref Level**, **–20 dBm**.

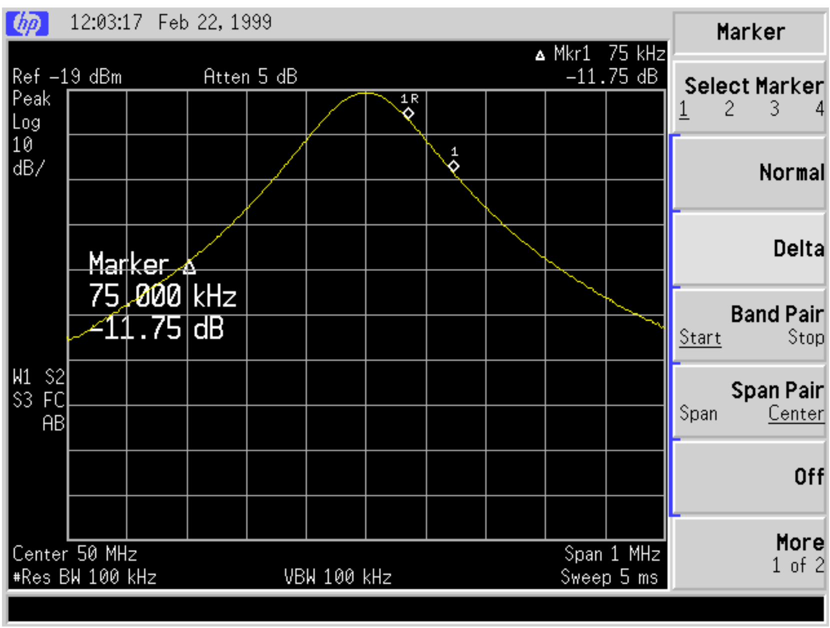
5. Set the resolution bandwidth to 100 kHz by pressing **BW/Avg**, **Resolution BW**, **100 kHz**. The skirt is reasonably linear starting about half a division down from the peak.

6. Select a marker by pressing **Marker**, then move the marker approximately one division down the right of the peak (high frequency) using the front-panel knob.

7. Place a delta marker 150 kHz from the first marker by pressing **Delta**, **150 kHz**. The skirt looks reasonably linear between markers.

8. Determine the offset from the signal peak to the desired point on the filter skirt by moving the delta marker to the midpoint. Press **75 kHz** to move the delta marker to the midpoint. See Figure 1-31.

Figure 1-31 Determining the Offset



9. Press **Delta** to make the active marker the reference marker.

10. Press **Search** to move the delta marker to the peak. The delta value is the desired offset, for example 140 kHz.

Demodulate the FM Signal

1. Connect an antenna to the analyzer INPUT.
2. Reset the analyzer by pressing **Preset, Factory Preset** (if present).
3. Tune the analyzer to the peak of one of your local FM broadcast signals, for example 97.7 MHz by pressing **FREQUENCY**, **97.7 MHz**.
4. Tune above or below the FM signal by the offset noted above in step 11, in this example 140 kHz. Press **FREQUENCY**, **CF Step** 140 kHz, then use the step-up key (↑) or step-down key (↓).
5. Set the resolution bandwidth to 100 kHz, then go to zero span by pressing **BW/Avg**, **Resolution BW**, **100 kHz**, **SPAN**, **Zero Span**.
6. Turn off the automatic alignment by pressing **System**, **Alignments**, **Auto Align**, **Off**.
7. Activate single sweep by pressing **Single**.
8. Listen to the demodulated signal through the speaker by pressing **Det/Demod**, **Demod**, **AM**, **Return**, **Speaker (On)**, then adjust the volume using the front-panel volume knob.

2 Making Measurements

What's in This Chapter

This chapter provides information for making complex measurements. The procedures covered in this chapter are listed below.

- "Making Stimulus Response Measurements" on page 2-3
- "Making a Reflection Calibration Measurement" on page 2-12
- "Demodulating and Listening to an AM Signal" on page 2-15
- "Measuring Harmonics and Harmonic Distortion" on page 2-19
- "Demodulating and Viewing Television Signals (Option B7B)" on page 2-25
- "Using External Millimeter Mixers (Option AYZ)" on page 2-33

To find descriptions of specific analyzer functions refer to the user's guide for your instrument.

Making Stimulus Response Measurements

What Are Stimulus Response Measurements?

Stimulus response measurements require a source to stimulate a device under test (DUT), a receiver to analyze the frequency response characteristics of the DUT, and, for return loss measurements, a directional coupler or bridge. Characterization of a DUT can be made in terms of its transmission or reflection parameters. Examples of transmission measurements include flatness and rejection. Return loss is an example of a reflection measurement.

A spectrum analyzer combined with a tracking generator forms a stimulus response measurement system. With the tracking generator as the swept source and the analyzer as the receiver, operation is the same as a single channel scalar network analyzer. The tracking generator output frequency must be made to precisely track the analyzer input frequency for good narrow band operation. A narrow band system has a wide dynamic measurement range. This wide dynamic range will be illustrated in the following example.

Using An Analyzer With A Tracking Generator

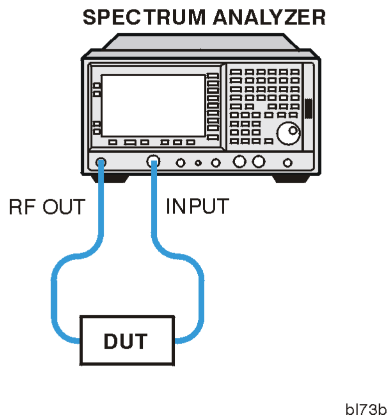
There are three basic steps in performing a stimulus response measurement, whether it is a transmission or a reflection measurement. The steps are to set all the analyzer settings, normalize, and measure.

The procedure below describes how to use a built in tracking generator system to measure the rejection of a bandpass filter, a type of transmission measurement. Illustrated in this example are functions in the tracking generator menu such as adjusting the tracking generator output power. Normalization functions located in the trace menu are also used. Making a reflection measurement is similar and is covered in “Making a Reflection Calibration Measurement” on page 2-12.

Stepping Through a Transmission Measurement

1. To measure the rejection of a bandpass filter, connect the equipment as shown in Figure 2-2. This example uses a 177 MHz bandpass filter.

Figure 2-1 Transmission Measurement Test Setup

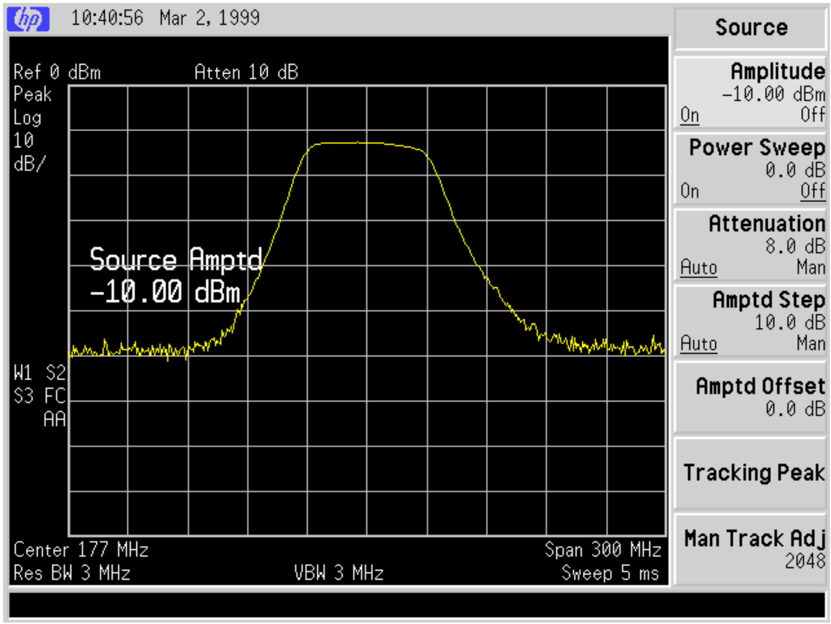


2. Access the tracking generator functionality using the source key on the analyzer. To activate the tracking generator power level, press **Source**, **Amplitude (On)**. See Figure 2-2.

CAUTION Excessive signal input may damage the DUT. Do not exceed the maximum power that the device under test can tolerate.

NOTE To reduce ripples caused by source return loss, use 10 dB (E4401B or E4411B) or 8 dB (all other models) or greater tracking generator output attenuation. Tracking generator output attenuation is normally a function of the source power selected. However, the output attenuation may be controlled in the **Source** menu. Refer to specifications and characteristics in your user's and calibration guide for more information on the relationship between source power and source attenuation.

Figure 2-2 Tracking Generator Output Power Activated



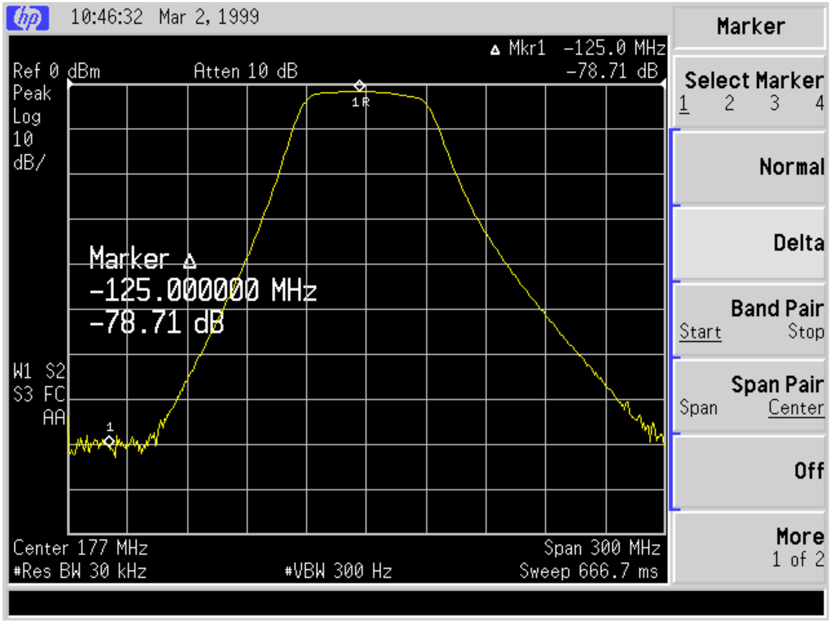
3. Put the sweep time of the analyzer into stimulus response auto coupled mode by pressing **Sweep**, then **Swp Coupling (SR)** (for stimulus response mode). Auto coupled sweep times are usually much faster for stimulus response measurements than they are for spectrum analyzer (SA) measurements. Adjust the reference level if necessary to place the signal on screen.

NOTE In the stimulus response mode, the Q of the DUT can determine the fastest rate at which the analyzer can be swept. (Q is the quality factor, which is reactance versus resistance.) To determine whether the analyzer is sweeping too fast, slow the sweep and note whether there is a frequency or amplitude shift of the trace. Continue to slow the sweep until there is no longer a frequency or amplitude shift.

Since we are only interested in the rejection of the bandpass filter ±125 MHz from the center of the bandpass, tune the analyzer center frequency and span to center the bandpass response and display the rejection ±150 MHz from the center of the bandpass.

4. Decrease the resolution bandwidth to increase sensitivity, and narrow the video bandwidth to smooth the noise. In Figure 2-3, the resolution bandwidth has been decreased to 30 kHz.

Figure 2-3 Decrease the Resolution Bandwidth to Improve Sensitivity



5. You might notice a decrease in the displayed amplitude as the resolution bandwidth is decreased, (if the analyzer is an E4402B, E4403B, E4404B, E4405B, E4407B, or E4408B). This indicates the need for performing a tracking peak. Press **Source**, **Tracking Peak**. The amplitude should return to that which was displayed prior to the decrease in resolution bandwidth.

6. To make a transmission measurement accurately, the frequency response of the test system must be known. Normalization is then used to eliminate this error from the measurement. To measure the frequency response of the test system, connect the cable (but not the DUT) from the tracking generator output to the analyzer input. Press **View/Trace**, **More 1 of 2**, **Normalize**, **Store Ref** (if present), **Normalize (On)**. The frequency response of the test system is now stored in normalize trace and a normalization is performed. This means that the active displayed trace is now the ratio of the input data to the data stored in the normalized trace (Trace 3 with firmware revision A.04.00 and later).

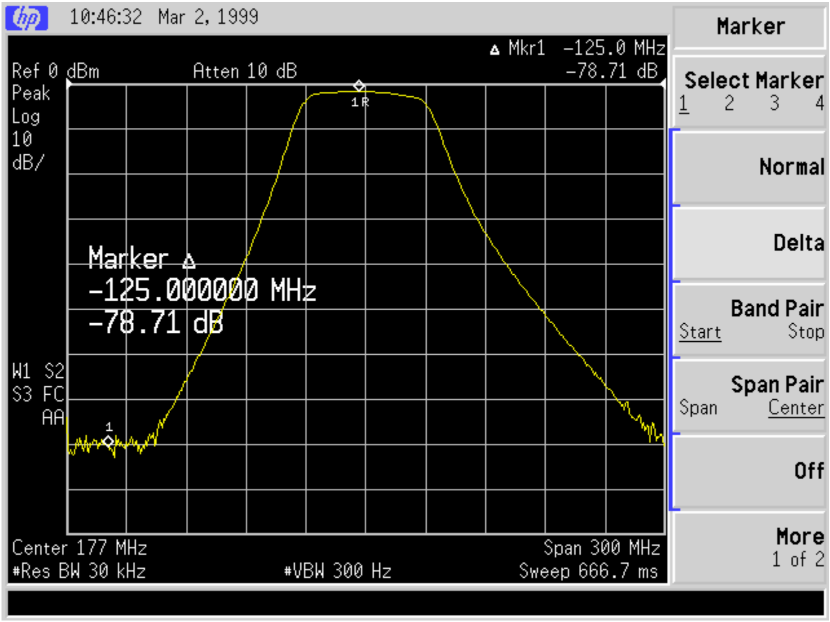
   When normalization is on, trace math is being performed on the active trace. The trace math performed is (trace 1 – normalized trace + the normalized reference position), with the result placed into trace 1. Remember that trace 1 contains the measurement trace, normalized trace contains the stored calibration trace of the system frequency response, and normalized reference position is indicated by arrowheads at the edges of the graticule.

7. Reconnect the DUT to the analyzer. Note that the units of the reference level have changed to dB, indicating that this is now a relative measurement. Press **Norm Ref Posn** to change the normalized reference position. Arrowheads at the left and right edges of the graticule mark the normalized reference position, or the position where 0 dB insertion loss (transmission measurements) or 0 dB return loss (reflection measurements) will normally reside. Using the knob results in a change in the position of the normalized trace, within the range of the graticule.

8. To measure the rejection of the filter 125 MHz below the center of the bandpass, press **Peak Search**, **Marker**, **Delta**, –**125 MHz**, and enter the frequency. The marker readout displays the rejection of the filter at 125 MHz. See Figure 2-4.

NOTE Because the default number of sweep points per trace is 401, the indicated marker frequency may differ slightly from the frequency that you entered. Due to the horizontal resolution of the trace, the marker frequency value will be rounded to within 0.25% of the span of the value entered. If the analyzer is an ESA-E series with firmware revision A.04.00 or later, the number of sweep points may be set to any value between 101 and 8192.

Figure 2-4 Measure the Rejection Range



Tracking Generator Unleveled Condition

When using the tracking generator, the message **`TG unleveled`** may appear. The **`TG unleveled`** message indicates that the tracking generator source power (**Source**, **Amplitude On Off**) could not be maintained at the selected level during some portion of the sweep. If the unleveled condition exists at the beginning of the sweep, the message will be displayed immediately. If the unleveled condition occurs after the sweep begins, the message will be displayed after the sweep is completed. A momentary unleveled condition may not be detected when the sweep time is short. The message will be cleared after a sweep is completed with no unleveled conditions.

The unleveled condition may be caused by any of the following:

- Start frequency is too low or the stop frequency is too high. The unleveled condition is likely to occur if the true frequency range exceeds the tracking generator frequency specification (especially the low frequency specification).
- Source attenuation may be set incorrectly (select **Attenuation (Auto)** for optimum setting).
- The source power may be set too high or too low, use **Amplitude** to reset it.
- The source power sweep may be set too high, resulting in an unleveled condition at the end of the sweep. Use **Power Sweep** to decrease the amplitude.
- Reverse RF power from the device under test detected by the tracking generator ALC (automatic level control) system.

Measuring Device Bandwidth

It is often necessary to measure device bandwidth, such as when testing a bandpass filter. There is a key in the **Peak Search** menu that will perform this function. The device signal being measured must be displayed before activating the measurement. The span must include the full response.

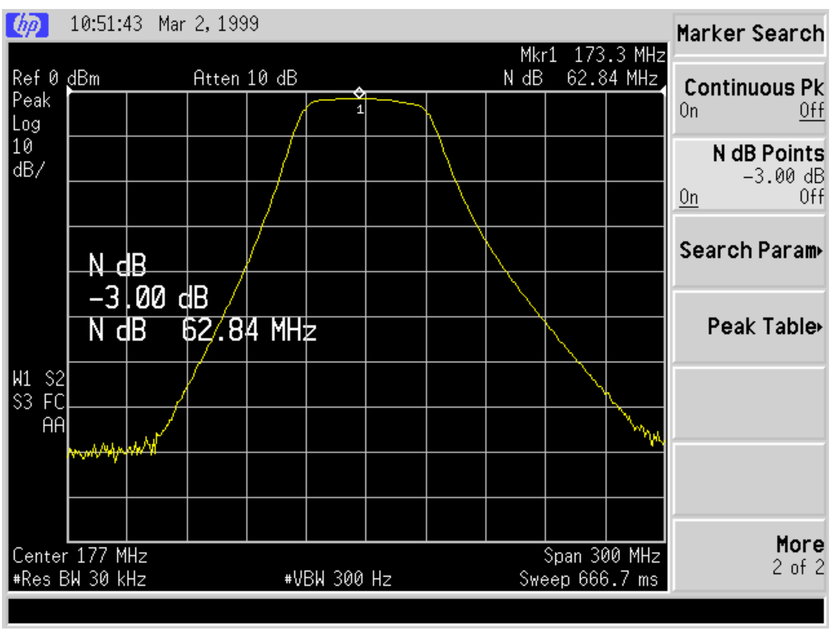
Activate the measurement by pressing **N dB Points (On)**. The analyzer places arrow markers at the –3 dB points on either side of the response and reads the bandwidth. For other bandwidth responses enter the number of dB down desired, from –1 dB to –80 dB.

No other signal can appear on the display within N dB of the highest signal. The measured signal cannot have more than one peak that is greater than or equal to N dB. A signal must have a peak greater than the currently defined peak excursion to be identified. The default value for the peak excursion is 6 dB.

Measurements are made continuously, updating at the end of each sweep. This allows you to make adjustments and see changes as they happen. The single sweep mode can also be used, providing time to study or record the data.

The N dB bandwidth measurement error is typically ±1% of the span.

Figure 2-5 N dB Bandwidth Measurement

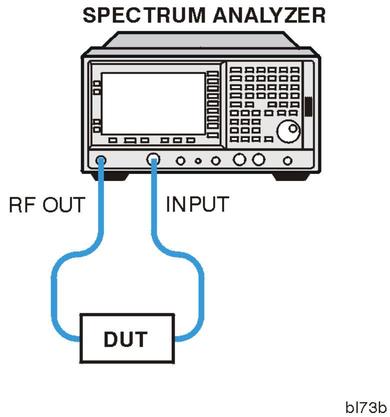


Example:

Measure the 3 dB bandwidth of a 177 MHz bandpass filter.

1. To measure the rejection of a bandpass filter, connect the equipment as shown in Figure 2-6. This example uses a 177 MHz bandpass filter.

Figure 2-6 Transmission Measurement Test Setup

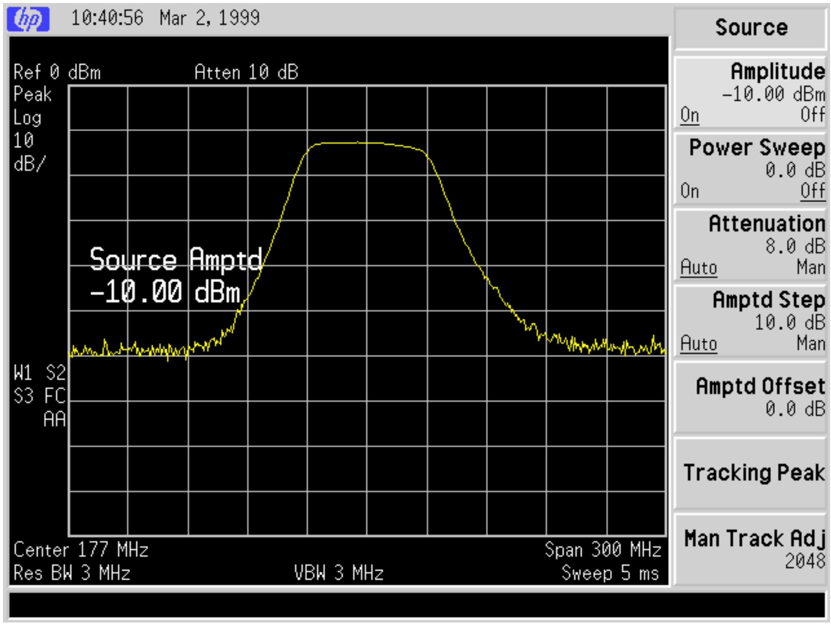


2. Access the tracking generator functionality using the source key on the analyzer. To activate the tracking generator power level, press **Source**, **Amplitude (On)**. See Figure 2-2.

CAUTION Excessive signal input may damage the DUT. Do not exceed the maximum power that the device under test can tolerate.

NOTE To reduce ripples caused by source return loss, use 10 dB (E4401B or E4411B) or 8 dB (all other models) or greater tracking generator output attenuation. Tracking generator output attenuation is normally a function of the source power selected. However, the output attenuation may be controlled in the **Source** menu. Refer to specifications and characteristics in your user's and calibration guide for more information on the relationship between source power and source attenuation.

Figure 2-7 Tracking Generator Output Power Activated



3. Put the sweep time of the analyzer into stimulus response auto coupled mode by pressing **Sweep**, then **Swp Coupling SR SA** until SR (stimulus response mode) is underlined. Auto coupled sweep times are usually much faster for stimulus response measurements than they are for spectrum analyzer (SA) measurements. Adjust the reference level if necessary to place the signal on screen.

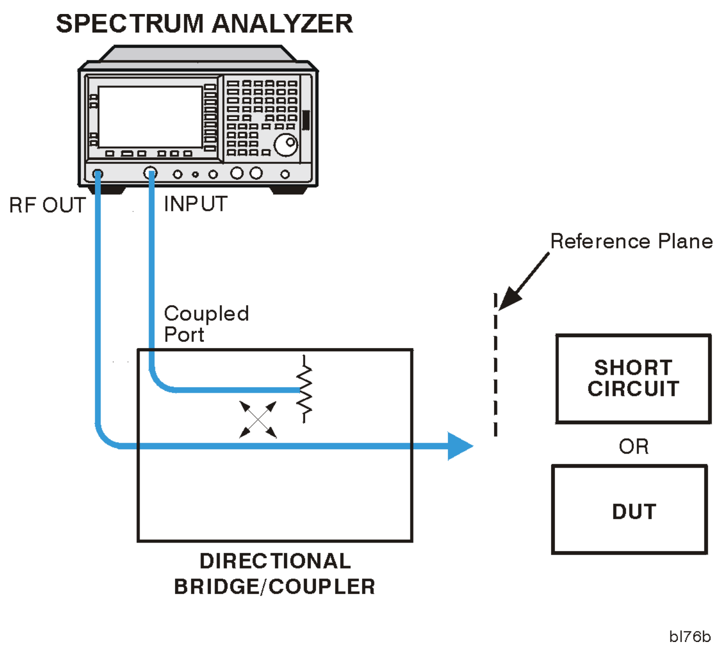
NOTE In the stimulus response mode, the Q of the DUT can determine the fastest rate at which the analyzer can be swept. (Q is the quality factor, which is reactance versus resistance.) To determine whether the analyzer is sweeping too fast, slow the sweep and note whether there is a frequency or amplitude shift of the trace. Continue to slow the sweep until there is no longer a frequency or amplitude shift.

4. Press **Peak Search**, **More 1 of 2**, then **N dB Points (On)** to activate the N dB bandwidth function.
5. Read the measurement results displayed on the screen.
6. The knob or the data entry keys can be used to change the N dB value from –3 dB to –60 dB to measure the 60 dB bandwidth of the filter.
7. Press **N dB Points (Off)** to turn the measurement off.

Making a Reflection Calibration Measurement

The calibration standard for reflection measurements is usually a short circuit connected at the reference plane (the point at which the test device will be connected.) See Figure 2-8. A short circuit has a reflection coefficient of 1 (0 dB return loss). It reflects all incident power and provides a convenient 0 dB reference.

Figure 2-8 Reflection Measurement Short Calibration Test Setup



Example:

Measure the return loss of a filter. The following procedure makes a reflection measurement using a coupler or directional bridge.

Reflection Calibration

NOTE The analyzer center frequency and span for this measurement can easily be set up using the transmission measurement setup in "Making Stimulus Response Measurements" on page 2-3. Tune the analyzer so that the passband of the filter comprises a majority of the display, then proceed with the steps outlined below.

1. Connect the DUT to the directional bridge or coupler as shown in Figure 2-8. Terminate the unconnected port of the DUT.

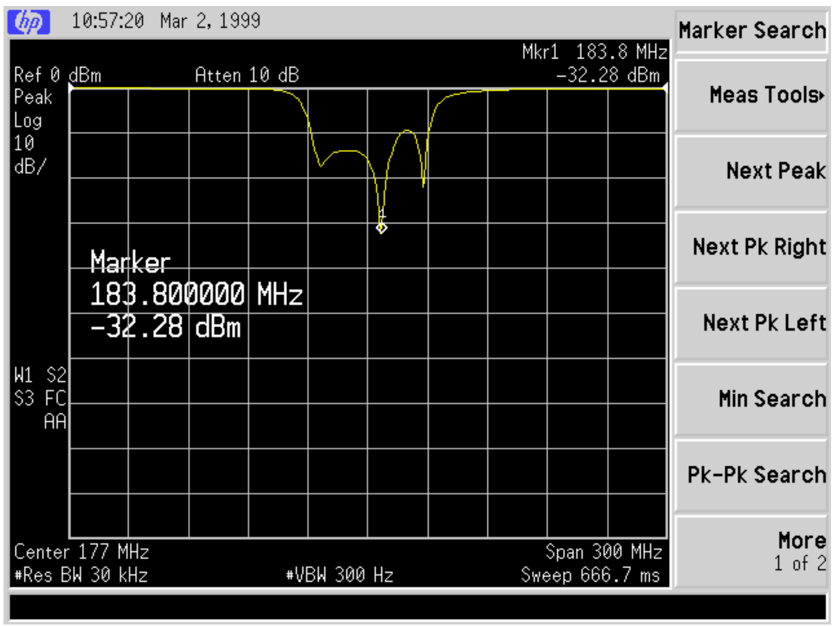
NOTE If possible, use a coupler or bridge with the correct test port connector for both calibrating and measuring. Any adapter between the test port and DUT degrades coupler/bridge directivity and system source match. Ideally, you should use the same adapter for the calibration and the measurement. Be sure to terminate the second port of a two port device.

2. Connect the tracking generator output of the analyzer to the directional bridge or coupler.
3. Connect the analyzer input to the *coupled* port of a directional bridge or coupler.
4. Set center frequency, span, and other analyzer settings. Turn on the tracking generator and set the amplitude level by pressing **Source**, **Amplitude (On)**.
5. Replace the DUT with a short circuit.
6. Normalize the trace by pressing **View/Trace**, **More 1 of 2**, **Normalize**, **Store Ref** (if present). Then press **Normalize (On)**, to activate the trace 1 minus normalized trace function and display the results in trace 1. The normalized trace or flat line represents 0 dB return loss. Normalization occurs each sweep. Replace the short circuit with the DUT.

Measuring the Return Loss

1. After calibrating the system with the above procedure, reconnect the filter in place of the short circuit without changing any analyzer settings.
2. Use the marker to read return loss. Press **Marker** and position the marker with the knob to read the return loss at that frequency. Or you can use the **Min Search** function to measure return loss by pressing **Peak Search**, **Min Search**, the analyzer will place a marker at the point where the return loss is maximized. See Figure 2-9.

Figure 2-9 Measuring the Return Loss of the Filter



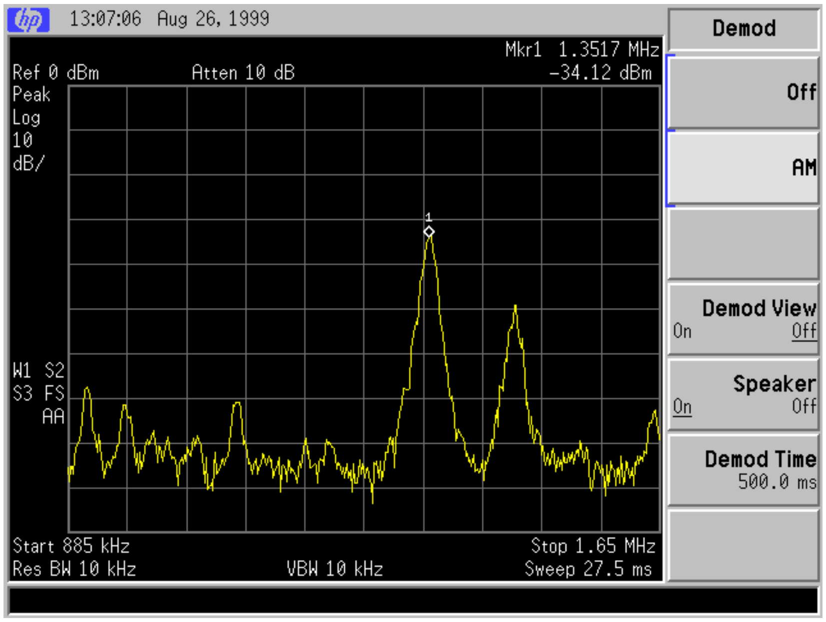
Demodulating and Listening to an AM Signal

The functions listed in the menu under **Det/Demod** allow you to demodulate and hear signal information displayed on the analyzer. Simply place a marker on a signal of interest, activate AM demodulation, turn the speaker on, and then listen.

Example 1:

1. Connect an antenna to the analyzer input.
2. Select a frequency range on the analyzer, such as the range for AM radio broadcasts. For example, the frequency range for AM broadcasts in the United States is 550 kHz to 1650 kHz. Press **Preset**, **Factory Preset** (if present), **FREQUENCY**, **Start Freq**, **550 kHz**, **Stop Freq**, **1650 kHz**.
3. Place a marker on the signal of interest by pressing **Peak Search** to place a marker on the highest amplitude signal, or by pressing **Marker**, **Normal** and moving the marker to a signal of interest.
4. Press **Det/Demod**, **Demod**, **AM**. Use the front-panel volume knob to control the speaker volume.

Figure 2-10 Demodulation of an AM Signal



5. The signal is demodulated at the marker position only for the duration of the demod time. Use the step keys, knob, or numbers keypad to change the demod time. For example, press the step up key (↑) to increase the demod time to 2 seconds.
6. The marker search functions can be used to move the marker to other signals of interest. Press **Peak Search** to access **Next Peak**, **Next Pk Right**, or **Next Pk Left**.

NOTE Prior to each occurrence of the AM Demod Time period, the analyzer automatically adjusts the marker level to the reference level, tunes the analyzer center frequency to the marker frequency (zero span) and sets the resolution bandwidth and video bandwidth to 30 kHz. The original analyzer settings are restored prior to each sweep.

Example 2:

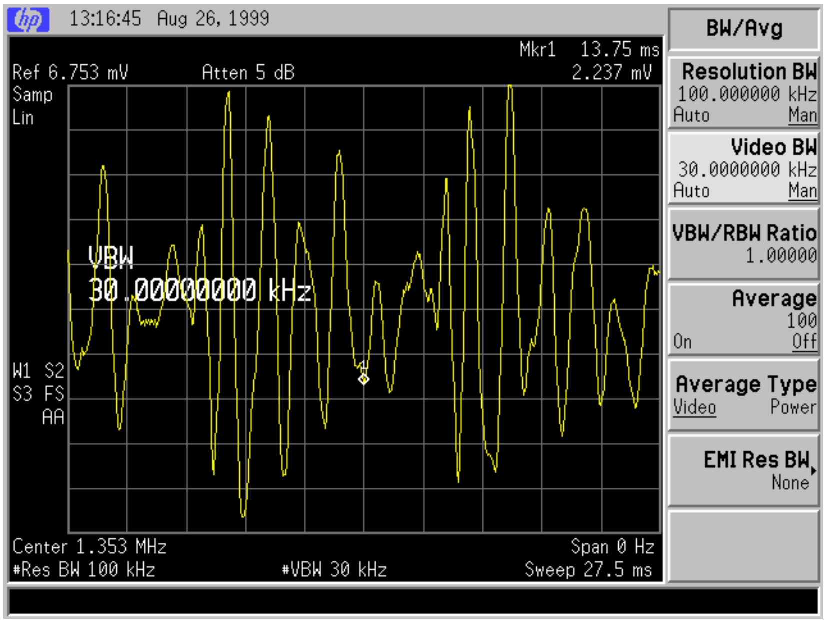
1. Place the marker on a signal of interest as in steps 1 through 3 of the previous example.
2. If the signal of interest is the highest amplitude on screen signal, set the frequency of the signal to center frequency by pressing **FREQUENCY** then **Signal Track (On)**. If it is not the highest amplitude signal on screen, move the signal to center screen by pressing **Peak Search** and **Mkr→CF**.
3. If signal track function is on, press **SPAN** and 1 MHz to reduce the span to 1 MHz. If signal track is not used, use the step down key (↓) to reduce the span and use **Mkr→CF** to keep the signal of interest at center screen.
4. Set the span to zero by pressing **SPAN**, **Zero Span**. **Zero Span** turns off the signal track function.
5. Change the resolution bandwidth to 100 kHz by pressing **BW/Avg**, **Resolution BW (Man)**, then enter 100 kHz.
6. Set the signal in the top two divisions of the screen by changing the reference level. Press **AMPLITUDE**, and then the step down key (↓) until the signal is in the top two divisions. Set the amplitude scale to linear by pressing **Scale Type (Lin)**.
7. Press **Det/Demod**, **Detector**, **Sample** to set the detector mode of the analyzer to Sample.
8. Press **Det/Demod**, **Demod**, **AM**. Use the front panel volume knob to control the speaker volume. (**Speaker On Off** is set to Off by the preset function.)

   You can turn your analyzer into a % AM indicator by setting the video bandwidth to 30 Hz, changing the reference level to position the trace at midscreen, and resetting the video bandwidth to a high value. The center horizontal line of the graticule now represents 0% AM; the top and bottom lines, 100% AM.

NOTE The signal to the speaker will be interrupted during retrace because the analyzer is performing automatic alignment routines. You can turn off the alignment by pressing **System**, **Alignments**, **Auto Align**, **Off**. Refer to the specifications for information about operating the analyzer with the alignments turned off.

9. To eliminate the clicks between sweeps, turn the auto alignment function off by pressing **System**, **Alignments**, **Auto Align**, **Off**.

Figure 2-11 Continuous Demodulation of an AM Signal



Measuring Harmonics and Harmonic Distortion

The analyzer provides a measurement key that automates harmonic measurements and provides a calculation of the total harmonic distortion for stable modulated or unmodulated signals.

Before the harmonic distortion measurement is turned on, a signal should be present at the analyzer input and visible on the display. The reference level of the analyzer should be set to the input signal level. The span should be set appropriately to view the signal or the signal and its harmonics on the display.

NOTE The measurement assumes that the highest amplitude signal displayed is the desired fundamental frequency.

When the harmonic distortion measurement is activated, the analyzer searches for the fundamental and determines the frequencies of the harmonics. The analyzer then spans down to zero span, then measures the amplitude of each harmonic. The analyzer calculates the total harmonic distortion by dividing the root-sum-squares of the harmonic voltages by the fundamental signal voltage and then provides the result as a percentage.

$$\%THD = 100 \times \frac{\left(\sqrt{\sum_{h=2}^{H_{max}} {E_h}^2}\right)}{E_f}$$

Where:

%THD = Total Harmonic Distortion as a percentage
h = harmonic number
H_{max} = Maximum Harmonic Value listed
E_h = voltage of harmonic h
E_f = voltage of fundamental signal

Example of a THD calculation:

If the number of harmonics selected is 5 (Hmax = 5) and the measured values are as follows:

$$E_f = 5\text{ dBm} = 3.162\text{ mW} = 397.6\text{ mV}$$

$$E_2 = -42\text{ dBc} = -37\text{ dBm} = 199.5\text{ nW} = 3.159\text{ mV}$$

$$E_3 = -26\text{ dBc} = -21\text{ dBm} = 7.943\ \mu\text{W} = 19.93\text{ mV}$$

$$E_4 = -49\text{ dBc} = -44\text{ dBm} = 39.81\text{ nW} = 1.411\text{ mV}$$

$$E_5 = -36\text{ dBc} = -31\text{ dBm} = 794.3\text{ nW} = 6.302\text{ mV}$$

then,

$$\text{THD} = 100 \times \frac{\sqrt{3.159\text{ mV}^2 + 19.93\text{ mV}^2 + 1.411\text{ mV}^2 + 6.301\text{ mV}^2}}{397.6\text{ mV}} = 5.33\%$$

Example:

In this example, the 10 MHz Reference Output is used as the fundamental source. The harmonics and total harmonic distortion are measured.

1. Reset the analyzer by pressing **Preset**, **Factory Preset** (if present).
2. Connect the 10 MHz Reference Output from the rear of the analyzer to the analyzer INPUT with a BNC Cable.
3. Press **Frequency, 10 MHz**.
4. Set the span by pressing **SPAN**, **1 MHz**.
5. Set the reference level to +5 dBm by pressing **AMPLITUDE**, **Ref Level**, **5 dBm**.
6. Set the resolution bandwidth to 10 kHz by pressing **BW/Avg**, **Resolution BW (Man)**, **10 kHz**.
7. Set the attenuation to 40 dB by pressing **AMPLITUDE**, **Attenuation (Man)**, **40 dB.**

   The resolution bandwidth and attenuation should be selected to maximize the dynamic range while maintaining a reasonable sweep time. Narrower resolution bandwidths provide greater dynamic range but lengthen the sweep time. In this example, the harmonics are all within 50 dB of the fundamental; therefore a dynamic range of 50 dBc is required. The dynamic range graph can be used to help determine the optimal settings. In this case, a 10 kHz resolution bandwidth provides more than ample dynamic range to resolve the harmonics.

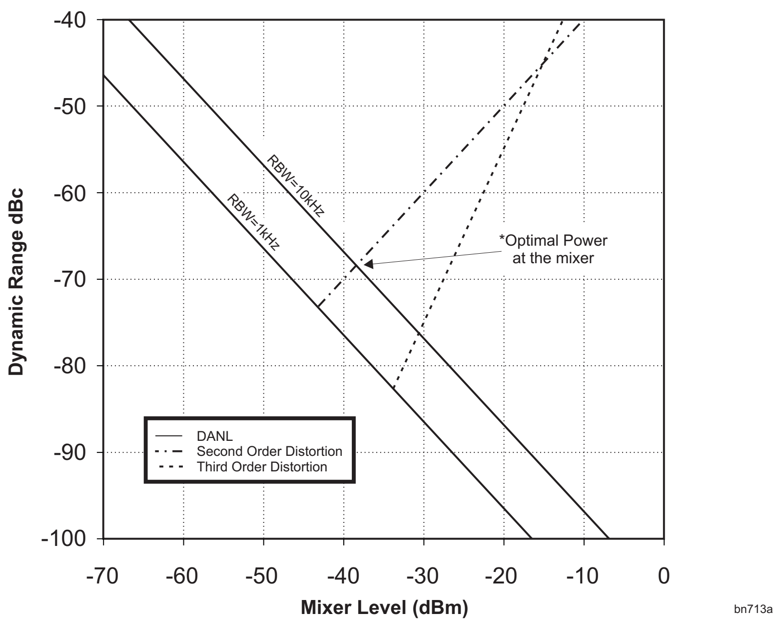
NOTE The resolution bandwidth selected will be increased by two steps (to 100 kHz) during the measurement; therefore a resolution bandwidth which is one step narrower than required should be selected.

When measuring the Nth harmonic, the analyzer will choose the narrowest resolution bandwidth that is greater than or equal to N times the resolution bandwidth used to measure the fundamental. Widening the resolution bandwidth allows the measurement to capture all modulation on the harmonics. An asterisk (*) will appear next to the amplitudes of measured harmonics for which the desired resolution bandwidth could not be set. The measurement will still be accurate as long as the signal has little or no modulation.

Set the attenuator to achieve the optimal power at the mixer, which occurs at the intercept (*) (refer to Figure 3-12, below) of the second order harmonic line and the Displayed Average Noise Level (DANL) line for the resolution bandwidth selected. This occurs at a mixer level of approximately –35 dBm. The input level from the 10 MHz Reference Output is +5 dBm in this example. Using the mixer level and the input level in the equation below provides us with an optimal attenuation setting of 40 dB.

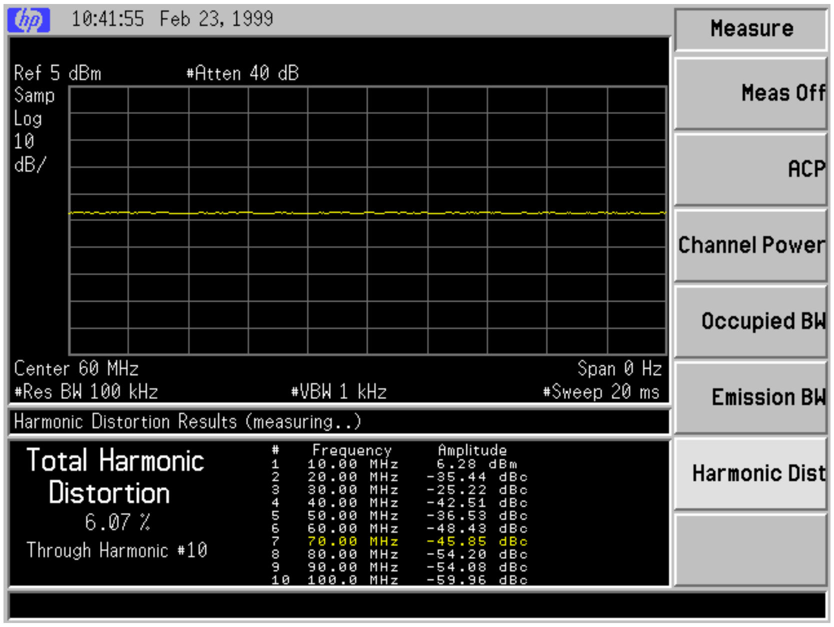
$$\text{Mixer Level} = \text{Input Level(dBm)} - \text{Attenuation Setting(dB)}$$

Figure 2-12 E4403B Dynamic Range Graph



8. Activate the harmonic distortion measurement by pressing **MEASURE**, **Harmonic Dist**. The Harmonic Distortion measurement screen will be displayed. See Figure 2-13.

Figure 2-13 Measuring the Harmonic Distortion

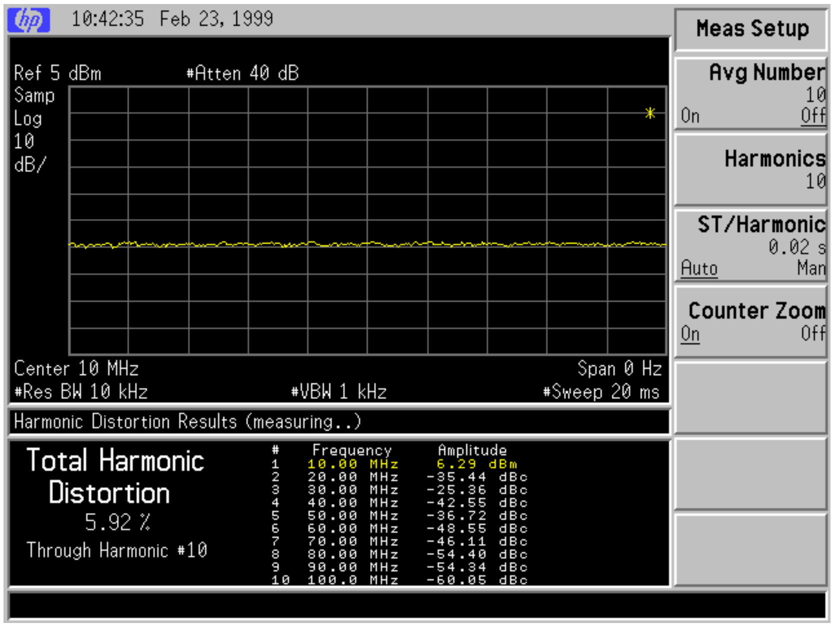


9. The amplitudes of the harmonics will be listed relative to the fundamental frequency. The total harmonic distortion (%THD) is also displayed.

Measurement Setup

The harmonic distortion measurement tool allows you to customize certain measurement settings. Press **Meas Setup** to view the Measurement Setup screen. See Figure 2-14.

Figure 2-14 Measurement Setup



Avg Number allows averaging to be enabled for the harmonics. Select the number of averages to be taken by pressing **Avg Number**, 3, **Enter**. If 3 is selected for the average number, the function will average the last three harmonic distortion readings. The default setting is off (no averaging). See "ST/Harmonic" below for additional information on averaging.

Harmonics allows the number of harmonics to be defined. Press **Harmonics**, **5**, **Enter**, **Restart**, to display the fundamental along with the second through fifth harmonics. The number of harmonics selected is used to calculate the total harmonic distortion value and each harmonic value is displayed. The default value is 10.

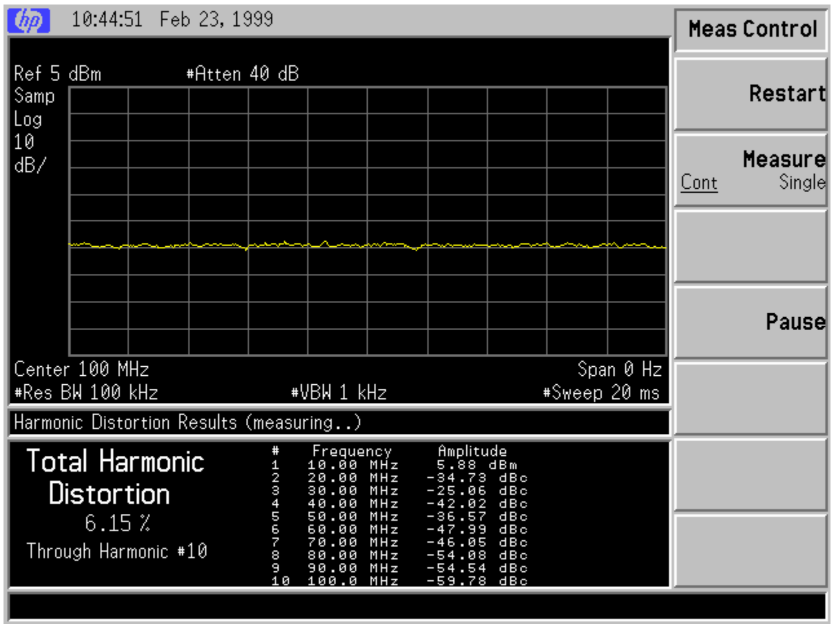
ST/Harmonic allows the sweep time per harmonic to be modified. Since the analyzer is placed in zero span during the measurement, the sweep time only affects the sampling period. The longer the sweep time, the more averaging is provided. ST/Harmonic provides the same functionality as Avg Number, but uses a more efficient method. Press **ST/Harmonic**, **400 ms**, **Enter** to increase the averaging. The range for this value is from 10 ms to the upper sweep time limit of the instrument.

Counter Zoom allows the analyzer to automatically zoom in on the span while searching for the fundamental signal so that it can more accurately determine its frequency value. The default position is ON.

Measurement Control

The harmonic distortion measurement tool provides several control features. Press **Meas Control** to view the Measurement Control screen. See Figure 2-15.

Figure 2-15 Measurement Control



Restart allows you to restart the measurement, press **Meas Control**, **Restart**. This has the same functionality as the front-panel **Restart** key.

Cont vs Single allows either continuous measurements that repeat until the measurement mode is exited or a single measurement in which the analyzer stops taking data after the completion of a measurement. The default setting is continuous mode. Press **Meas Control**, **Measure (Single)** to change to single measurement mode. In single measurement mode, press **Restart** for a new measurement. Press **Meas Control**, **Measure (Cont)** to change back to continuous measurement mode.

Pause/Resume provides the ability to pause and resume the measurement. Press **Meas Control**, **Pause** to pause the measurement. Press **Meas Control**, **Resume** to resume the measurement.

End of Measurement

The measurement is complete, to exit the measurement, press **Measure**, **Meas Off**.

Demodulating and Viewing Television Signals (Option B7B)

Option B7B (TV Trigger and Picture on Screen) allows you to trigger the sweep of the analyzer on a specific television line of a demodulated TV waveform. Option B7B also allows you to view the television picture represented by the TV waveform on the color LCD display of the analyzer.

The following examples describe how to set the analyzer for viewing the demodulated TV waveform, viewing the TV picture, and measuring the depth of modulation of the RF carrier.

Example 1:

To set up the TV video waveform for triggering and picture viewing on the analyzer, perform the following:

1. Connect a source which contains suitable TV carrier signals (for example, terrestrial broadcast or CATV signals).
2. Press **System**, **Alignments**, **Auto Align**, **Off** to disable the background alignment process while viewing TV waveforms and TV pictures. This is necessary to prevent the background alignment process from interrupting the signal paths of the analyzer during the sweep retrace period so as to maintain a constant, uninterrupted video waveform.

NOTE After viewing the TV waveform or picture, re-enable the background alignment process by pressing **System**, **Alignments**, **Auto Align**, **All**. If the background alignment has been disabled for more than 60 minutes or the ambient temperature has changed more than 3 °C, press **System**, **Alignments**, **Align Now**, **All** to ensure measurement accuracy. See the Specifications and Characteristics Chapter for your analyzer model in the *Agilent Technologies ESA Spectrum Analyzers Specifications Guide*, for information about calibration requirements.

3. Set the center frequency of the analyzer to match the TV video carrier frequency by pressing **FREQUENCY**, then entering the desired value and units.
4. Set the span to 20 MHz by pressing **SPAN**, **20 MHz**.
5. Press **Auto Couple**.
6. Adjust the reference level of the analyzer to the peak video carrier level by pressing **AMPLITUDE** and using the knob or step keys.

NOTE If the signal is weak and accompanied by excessive noise, you may choose to enable the internal preamp, if installed, to improve the signal-to-noise ratio. Press **AMPLITUDE**, **More 1 of 2**, **Int Preamp (On)**.

7. View the spectrum. There should be a strong, “noise-like” video carrier at the center frequency, a weaker, “noise-like” chrominance sub-carrier located 3.58 MHz (NTSC standard) or 4.3 to 4.4 MHz (PAL or SECAM standards) above the video carrier, and a tightly-grouped sound carrier located 4.5 to 6.5 MHz above the video carrier. If you are viewing broadcast or cable TV signals, the lower adjacent channel sound carrier may be very close to the video carrier at the center frequency.
8. Press **BW/Avg**, **Resolution BW**, **3 MHz** to change the resolution bandwidth of the analyzer to 3 MHz. If the test signal does not have adjacent channels present, change the resolution bandwidth to 5 MHz. However, if strong adjacent channel signals are present (primarily the sound carrier of the lower adjacent channel), set the resolution bandwidth and video bandwidth to 1 MHz.
9. Press **AMPLITUDE**, **Scale Type (Lin)** to set the amplitude scale type of the analyzer to Linear.
10. Press **Det/Demod**, **Detector**, **Sample** to set the detector mode of the analyzer to Sample.
11. Set the span to 0 Hz by pressing **SPAN**, **Zero Span**.
12. Press **AMPLITUDE** and using the knob or arrow keys, adjust the reference level so that the signal peaks are within half of a division of the top of the display.
13. Press **Trig**, **TV Trig Setup** and set the following in the TV Trig Setup menu: Press **Field**, **Entire Frame**. Press **Sync (Pos)** (**Sync (Neg)** if viewing a SECAM broadcast). Press **Standard** and then select the appropriate standard for the video signal. Press **TV Source**, **SA**.
14. Press **Trig**, **TV** to enable the TV trigger. The default line number for triggering is 17, but this can be changed to any value from 1 to 525 or from 1 to 625, depending on the selected video standard.
15. If you have Option AYX (Fast Digitized Time Domain Sweeps) or Option B7D (DSP and Fast ADC), press **Sweep**, **Sweep Time**, **500 µs**. This allows you to view several TV lines.

A time domain display of the demodulated TV waveform will now be visible. The signals used for Figure 2-16 and Figure 2-17 were produced by a Philips PM 5518-TX Colour TV Pattern Generator.

Figure 2-16 Demodulated RF Waveform (NTSC; PAL is Similar)

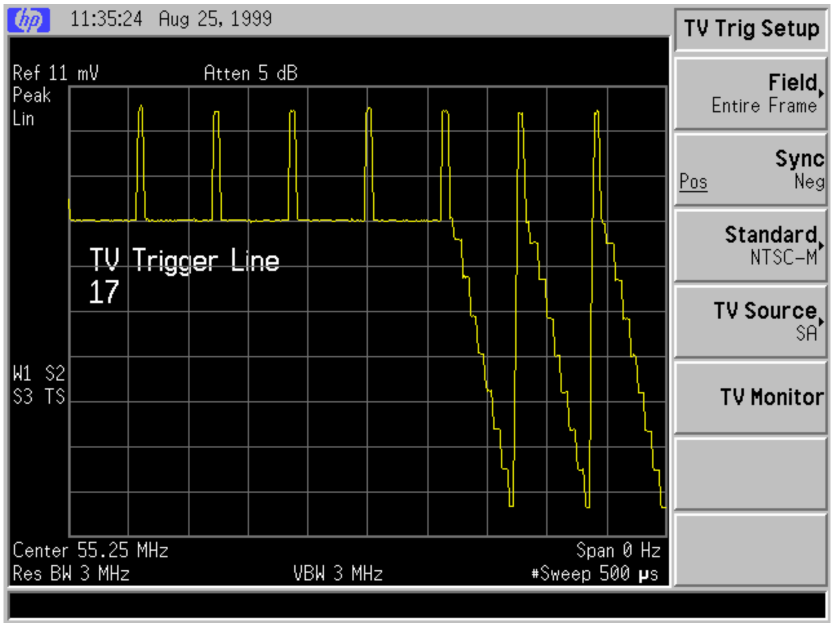
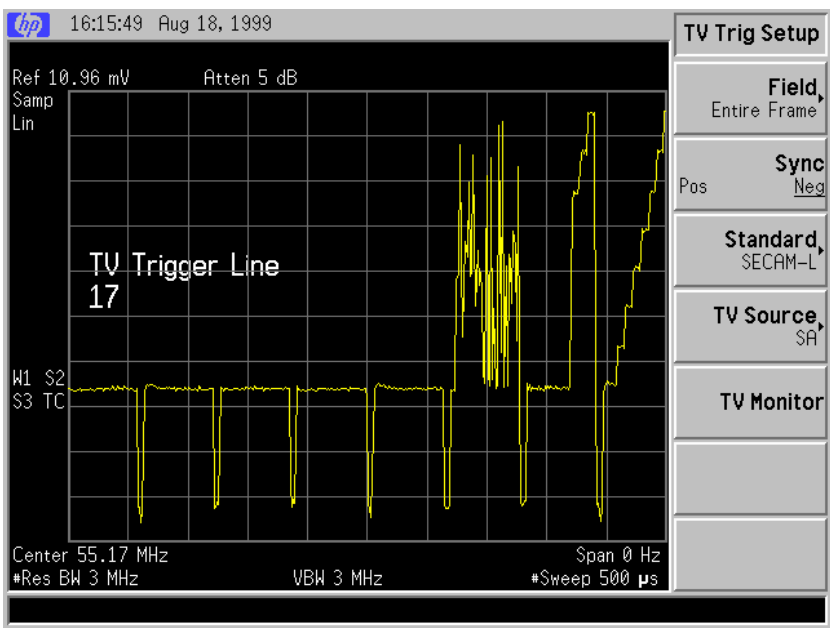


Figure 2-17 Demodulated RF Waveform (SECAM)



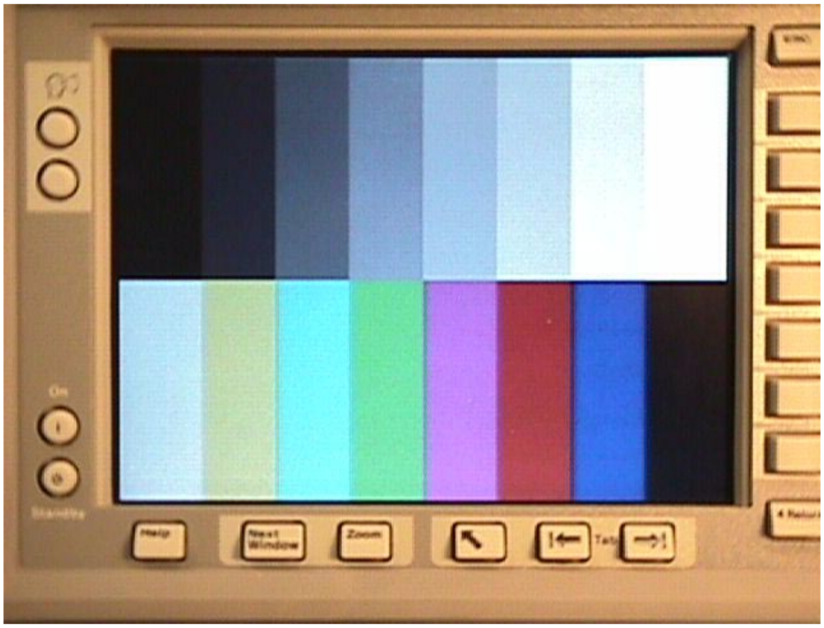
If **Trig**, **TV** is the active function, the line number used to trigger the analyzer sweep can be changed to examine the different parts of the video waveform. The line numbering scheme varies with TV standard, but TV test patterns will often be inserted in or near line 17.

Viewing the TV Picture

To view the TV picture, perform the following:

1. Press **Sweep**, **Sweep Time**, **100 s** to set the sweep time to 100 seconds. The long sweep time is necessary to minimize disruption of the analog signal path during instrument retrace, which optimizes picture quality.
2. Press **Trig**, **TV Trig Setup**, **TV Monitor**.

Figure 2-18 TV Picture Display



When the picture is active, you can adjust the value of the function that was active prior to enabling the picture. For example, if center frequency was the active function and the frequency step size was set to the TV channel frequency spacing, you can increment or decrement through the TV channels by pressing the step keys (⇓ ⇑) of the analyzer. If resolution bandwidth was the active function, you can increase or decrease the amount of filtering to deal with strong adjacent channel signals.

NOTE When using the knob to vary the value of the active function, be aware that the instrument settings will not be updated until you stop turning the knob. Make small movements of the knob with frequent pauses.

Example 2:

Measure Depth of Modulation

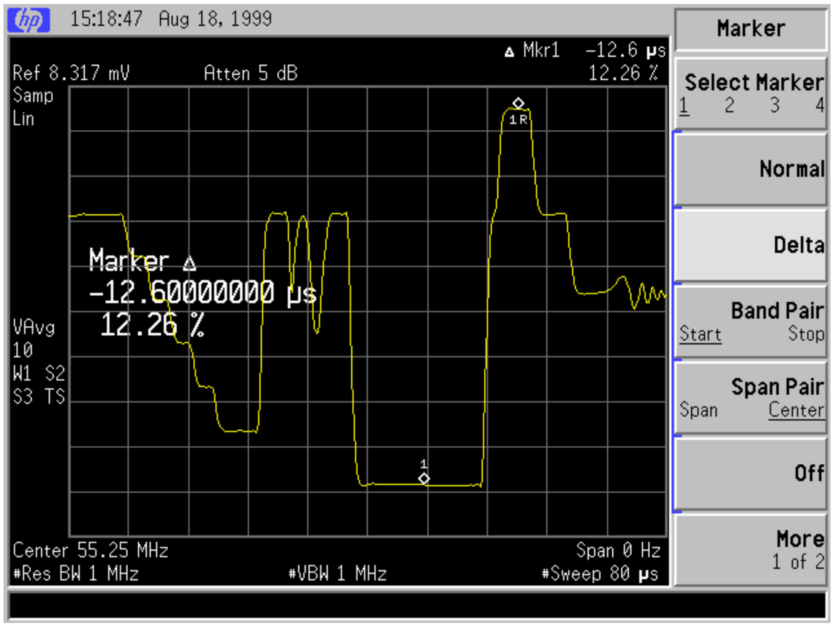
The depth of modulation provides a measure of the percentage of amplitude modulation (AM) on the visual carrier. With Option B7B, the analyzer can be used to measure the horizontal synchronization pulse level and vertical interval test signal (VITS) white level on an individual TV line from which a calculation of percent AM can be made. Note that this measurement method will not be valid for some types of scrambled video signals.

To perform a measurement of depth of modulation on an individual TV line, perform the following steps:

NOTE Before continuing, be sure you have performed the steps in Example 1 at the beginning of this section, "Demodulating and Viewing Television Signals (Option B7B)" on page 2-25 to display a TV waveform on the analyzer display with linear scaling.

1. Press **Trig**, **TV**, and enter a line number which has a TV test signal containing the reference white level within the waveform (100 IRE) such as the FCC, NTC-7 or ITU Composite Test Signal (typically found at or near line 17 within field 1 or field 2).
2. Set the sweep time to 80 µs (Option AYX or B7D required) by pressing **Sweep**, **Sweep Time**, 80 µs. This allows viewing of a complete TV line.
3. Set the resolution bandwidth and the video bandwidth to 1 MHz by pressing **BW/Avg**, **Resolution BW**, **1 MHz** and **Video BW**, **1 MHz**.
4. Turn on video averaging by pressing **BW/Avg, Average (On)**, and entering a value of **10**. This minimizes the waveform variations caused by the presence of additional RF signals near the picture carrier, as well as waveform noise or jitter.
5. Enable the marker by pressing **Marker**, **Normal**. Using the knob, locate the marker within the sync tip (NTSC or PAL waveforms) or the white level (SECAM waveforms) at the top of the waveform. Alternatively, you may press **Peak Search** to locate the marker on the peak excursion.
6. Enable delta marker mode by pressing **Marker**, **Delta**. Using the knob, locate the delta marker within the white level (NTSC or PAL waveforms) or the sync tip (SECAM waveforms) at the bottom of the waveform. Alternatively, you may press **Peak Search**, **Min Search** to locate the delta marker on the minimum excursion of the waveform. The delta marker readout will be in percent and may have a value near 12.5%.

Figure 2-19 Measuring Marker Delta (%) for Depth of Modulation (NTSC)



The depth of modulation (in percent) can now be determined by subtracting the marker readout (in percent) from 100. A typical value would be 87.5%.

TV Trig Setup Menu Functions

- **TV Source**

  When **TV Source** is set to **SA**, the analyzer serves to demodulate the TV signal, thus using the analyzer as a fixed tuned receiver. This allows stable, zero span sweeps of the baseband video waveform (although somewhat bandlimited by the RBW and VBW filters).

  When **TV Source** is set to **EXT VIDEO IN**, an external baseband video signal may be used to produce the TV line trigger. In this case, one may use an external TV tuner to obtain the baseband waveform of the given RF carrier for triggering the analyzer sweep, allowing the analyzer to be used in a swept mode for measurements of the RF spectrum, allowing the sweep to be synchronized to the video modulation. The **EXT VIDEO IN** connector is located on the rear panel of the analyzer.

- **TV Standard**

  Selection of a TV standard establishes the number of TV lines and the kind of color encoding method that is used. The number of TV lines establishes the defaults for the TV line counting circuits of the analyzer and the color encoding method is used to properly set up the TV picture display circuits. Option B7B supports both 525 line and 625 line systems and can provide a color TV picture for NTSC and PAL color encoding methods. A black and white picture is provided for the SECAM method.

The ability to display a color picture is limited by the bandwidth settings of the analyzer (resolution bandwidth and video bandwidth). However, baseband video signals input to the EXT VIDEO IN connector on the rear panel of the analyzer are minimally filtered, allowing a full color display of NTSC or PAL TV signals.

Table 2-1

TV Standard	Number of Lines per Frame	Approximate Field Rate	Color Encoding Method	Color Subcarrier Frequency
NTSC-M	525	60 Hz	NTSC	3.58 MHz
NTSC-Japan (no pedestal)	525	60 Hz	NTSC	3.58 MHz
PAL-M	525	60 Hz	PAL	4.43 MHz
PAL-B,D,G,H,I	625	50 Hz	PAL	4.43 MHz
PAL-N	625	50 Hz	PAL	4.43 MHz
PAL-N Combination	625	50 Hz	PAL	3.58 MHz
SECAM	625	50 Hz	SECAM	4.406 MHz, 4.250 MHz

- **Field**

  A television image or frame is composed of 525 (or 625 lines) delivered in two successive fields of 262.5 (or 312.5 lines) interlaced together on a CRT when displayed.

  When **Field** is set to **Entire Frame**, the line count starts at line one in field one (often referred to as the “odd field”) and ends at 525 (or 625) in field two (often referred to as the “even field”).

  When **Field** is set to **Field One** or **Field Two**, the line count begins at “1” with the first full line in the selected field and ends at count 263 (or 313) for Field One, and 262 (or 312) for Field Two.

- **Sync**

  Analog broadcast or cable television signals are usually amplitude modulated on an RF carrier. For NTSC and PAL broadcasts, typically the RF carrier amplitude is maximized at the sync tips of the baseband video waveform and minimized at the “white” level. This results in a demodulated waveform on the analyzer where the sync pulses are on top, or positive (**Sync (Pos)**).

With SECAM broadcasts, typically the RF carrier amplitude is minimized at the sync tips of the video waveform and maximized at the “white” level. This results in a waveform on the analyzer where the sync pulses are at the bottom, or negative (**Sync (Neg)**).

A normal baseband video waveform for all TV standards will have the sync tips on the bottom. When **TV Source** is set to **Ext Video In**, **Sync** should be set to **Neg**.

- **TV Monitor**

  When **TV Monitor** is pressed, the picture represented by the video waveform selected with **TV Source** is presented on the LCD display of the analyzer. The picture can only be viewed, not printed or saved. Pressing a key that normally brings up a menu restores the original graphical display with the selected menu enabled.

Fast Time Domain Sweeps

Trigger delay can be used to move the sweep trigger point arbitrarily across a given TV line or lines to allow closer examination of waveform patterns (Press **Trig**, **Trig Delay**, and enter a delay time).

In fast sweeps (20 µs to less than 5 ms), there may be up to one trace point of variation in the start time of the waveform digitization process with respect to the actual TV trigger pulse. This randomness leads to the appearance of visual jitter on the LCD display of the analyzer. In this situation, video averaging may be used (N = 5, for example) to improve the “visual stability” of the displayed waveform. This type of jitter does not occur when sweep times are set greater than or equal to 5 ms where digitization begins less than 100 ns after the trigger pulse in that mode (much less than 1 trace point of jitter).

Using External Millimeter Mixers (Option AYZ)

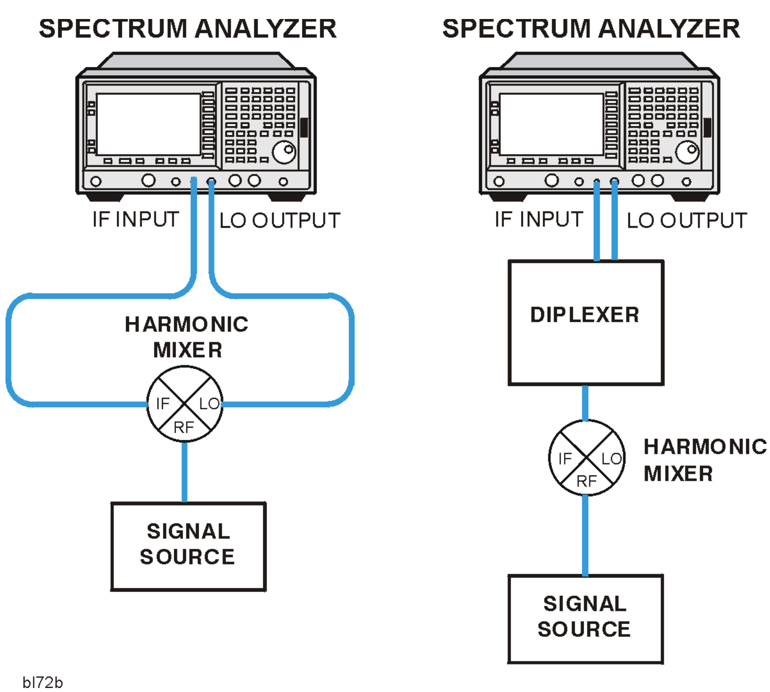
External millimeter mixers can be used to extend the frequency coverage of the E4407B spectrum analyzer. Agilent Technologies manufactures external mixers that do not require biasing and cover frequency ranges from 18 GHz to 110 GHz. Other manufacturers sell mixers that extend the range to 325 GHz, but may require biasing. The Agilent Technologies E4407B spectrum analyzer will support both types of mixers.

The Agilent Technologies E4407B spectrum analyzer contains an extensive menu of functions that help with millimeter measurements. The following examples explain how to connect external mixers to the spectrum analyzer, how to choose the band of interest, how to store and activate conversion-loss factors, and how to use the signal-identification functions.

Example 1: Making measurements with unpreselected millimeter-wave mixers

1. Connect the signal source and harmonic mixer to the analyzer as shown in Figure 2-20.

Figure 2-20



CAUTION The analyzer local oscillator output power is approximately +16 dBm. Be sure that your external harmonic mixer can accommodate the power level before connecting it to the analyzer.

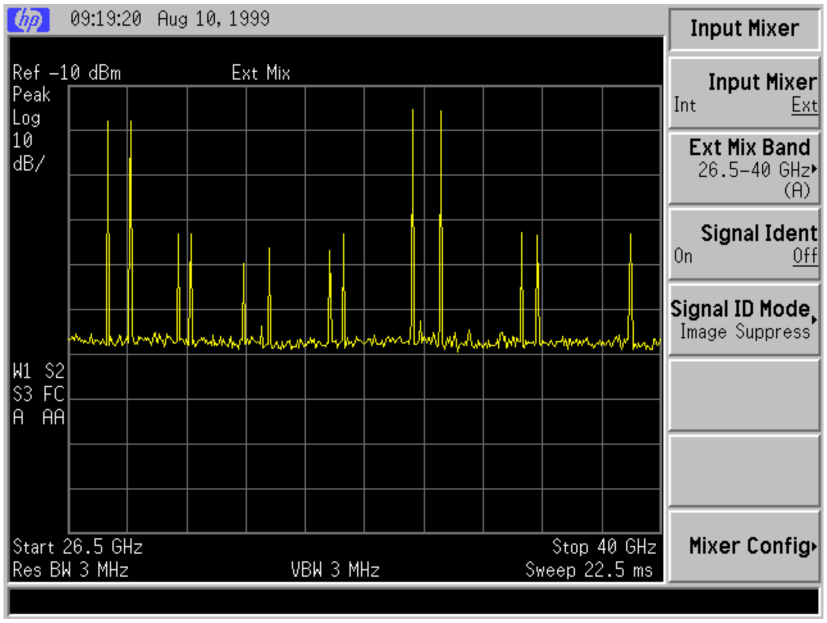
NOTE HP/Agilent 5061-5458 SMA type cables should be used to connect the mixer IF and LO ports to the analyzer. Do not over-tighten the cables. The maximum torque should not exceed 112 N-cm (10 in-lb.)

2. On the analyzer, press **Preset**, **Factory Preset**, if present. Select external mixing by pressing **Input/Output**, **Input Mixer**, **Input Mixer (Ext)**. The analyzer frequency band will be set to **26.5 – 40 GHz (A)**. To choose a different band, press **Ext Mix Band** and then press the desired band frequency range/letter key. For this example, we will use band A, which ranges from 26.5 GHz to 40 GHz.

3. To correct for the conversion-loss of the harmonic mixer in use, the analyzer amplitude correction feature is used. Access this feature by pressing, **AMPLITUDE Y Scale**, **More 1 of 2**, **Corrections**, **Modify**, **Select**. Select a correction set for use with external mixing. The recommended set to use is **Other** although any available set could be used. Press **Edit** to enter the appropriate conversion loss data for the mixer in use. On the HP/Agilent 11970 harmonic mixers, these values are listed on the mixer. A single average value could be entered for the entire band by using only a single correction value. More correction points entered across the band in use will improve frequency response accuracy. Up to 200 points may be defined for each set. Once the desired correction points are entered, press **Return**, **Correction (On)** to activate correction set **Other**. This will also turn corrections on resulting in a calibrated display. It is recommended that the correction set entered be saved on the internal memory or the floppy drive for future reference.

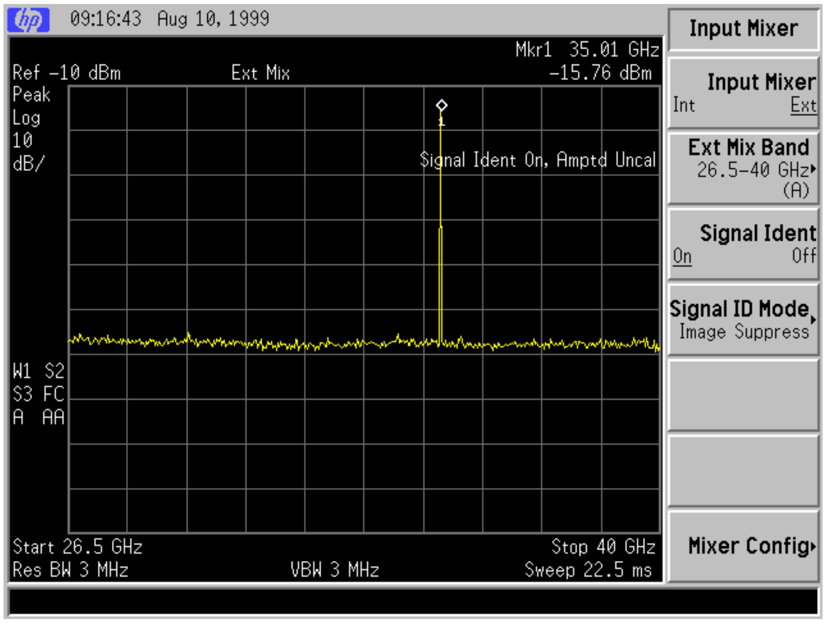
4. The IF output of a harmonic mixer will contain a signal at the intermediate frequency of the analyzer whenever the harmonic frequency of the LO and the frequency of the RF differ by the intermediate frequency. As a result, within a single harmonic band, a single input signal can produce multiple responses on the analyzer display, only one of which is valid (see Figure 2-21). These responses come in pairs, where members of the valid response pair are separated by 642.8 MHz and either the right-most (for negative harmonics) or left-most (for positive harmonics) member of the pair is the correct response.

Figure 2-21



5. Identification of valid responses is achieved by simply turning on the signal-identification feature. (**Preset** selects the **Image Supress** signal identification mode.) Press **Input/Output**, **Input Mixer**, **Signal Ident (On)** and note that now only the valid response (35 GHz) remains. Refer to Figure 2-22. Press **Peak Search** to place a marker on the remaining response. The signal-identification routine can introduce slight amplitude errors which is indicated by the message **`Signal Ident On, Amptd Uncal`**. After identifying a signal of interest, press **Signal Ident (Off)** before making final amplitude measurements.

Figure 2-22



6. The HP/Agilent 11970 Series harmonic mixers do not require bias. Mixers requiring bias can also be used with the E4407B. Generally, the conversion loss calibration data for mixers requiring bias, will be most accurate when the correct bias conditions are present. Set the bias as follows:

   a. To measure a signal, access external mixing and set the band as described previously.

   b. To activate bias press **Input/Output**, **Input Mixer**, **Mixer Config**, **Mixer Bias (On)**. A **+I** or **–I** will appear in the display annotation indicating bias is on.

   c. Enter the desired bias current in mA with the data control keys.

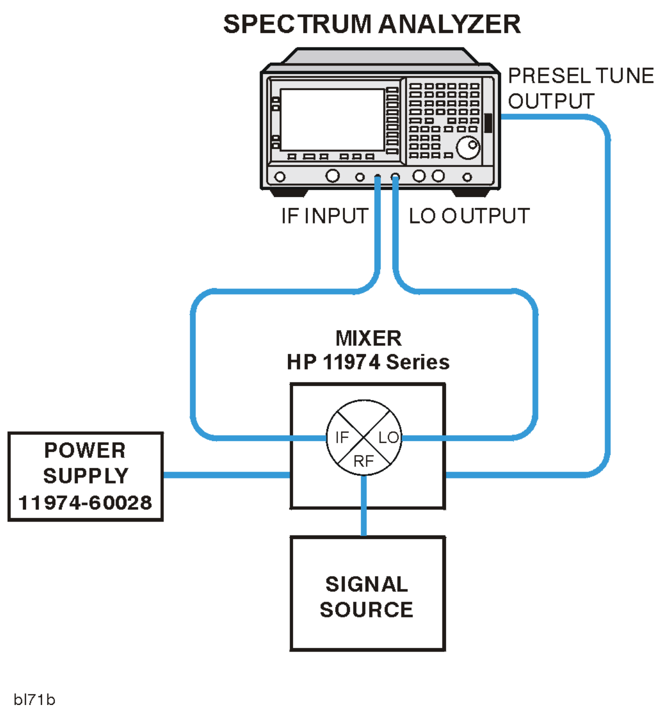
WARNING **The open-circuit bias voltage can be as great as ±3.5V through a source resistance of 500 ohms. Such voltage levels may appear when recalling an instrument state in which a bias setting has been stored.**

NOTE The bias value that appears on the analyzer display is expressed in terms of short-circuit current (that is, the current that would flow if the **IF INPUT** were shorted to ground). The actual current flowing into the mixer will be less.

Example 2: Making Measurements with HP/Agilent 11974 Series Preselected Millimeter-Wave Mixers

1. Connect the signal source and preselected mixer to the analyzer as shown in Figure 2-23.

Figure 2-23



Frequency Tracking Calibration

This procedure is used to align the frequency of the preselector filter of the HP/Agilent 11974 to the tuned frequency of the analyzer. This procedure should be followed any time that the HP/Agilent 11974 is connected to a different analyzer. The calibration should be periodically checked.

1. Set the HP/Agilent 11974 rear-panel switches “HP/Agilent 70907B” and “LEDS” to the ON position, and the other two switches to the OFF position, in order for the HP/Agilent 11974 to properly scale to the tune signal of the analyzer.
2. Configure the analyzer for a preselected external mixer by pressing the following keys:

   Preset, **Factory Preset** (if present), **Input/Output**, **Input Mixer (Ext)**, **Mixer Config**, **Mixer Type (Presel)**
3. Set the desired band of operation. Press **Ext Mix Band**, **A**, **Q**, **U**, or **V**. (Note that only A,Q,U, and V bands are available.)

4. Set the Presel Adjust to 0 MHz by pressing **AMPLITUDE**, **Presel Adjust**, **0 MHz**.

5. Set the analyzer to zero span by pressing **SPAN**, **Zero Span**.

6. Set the analyzer center frequency by pressing **FREQUENCY**, **Center Freq**, and enter the corresponding value for the appropriate mixer. (Refer to Table 2-2) On the rear panel of the HP/Agilent 11974, adjust the corresponding potentiometer until one or both of the green LEDs are lit.

Table 2-2

Mixer HP/Agilent P/N	Analyzer Center Frequency	Potentiometer
11974A	26.5 GHz	“26.5 GHz Adjust”
11974Q	33.0 GHz	“33.0 GHz Adjust”
11974U	40.0 GHz	“40.0 GHz Adjust”
11974V	50.0 GHz	“50.0 GHz Adjust”

7. Change the analyzer center frequency to the value indicated in Table 2-3 and again adjust the corresponding potentiometer on the rear panel of the HP 11974 until one or both of the green LEDs are lit.

Table 2-3

Mixer HP/Agilent P/N	Analyzer Center Frequency	Potentiometer
11974A	40.0 GHz	“40.0 GHz Adjust”
11974Q	50.0 GHz	“50.0 GHz Adjust”
11974U	60.0 GHz	“60.0 GHz Adjust”
11974V	75.0 GHz	“75.0 GHz Adjust”

8. Repeat steps 6 and 7 until the green LEDs are lit at both frequencies without additional adjustments.

Band Selection

1. If necessary, configure the analyzer for preselected external mixing by pressing the following keys:

   Input/Output, **Input Mixer (Ext)**, **Mixer Config**, **Mixer Type (Presel)**

2. If necessary, adjust the tracking of the HP/Agilent 11974 to the analyzer being used for preselected external mixing, by using the Frequency Tracking Calibration procedure above.

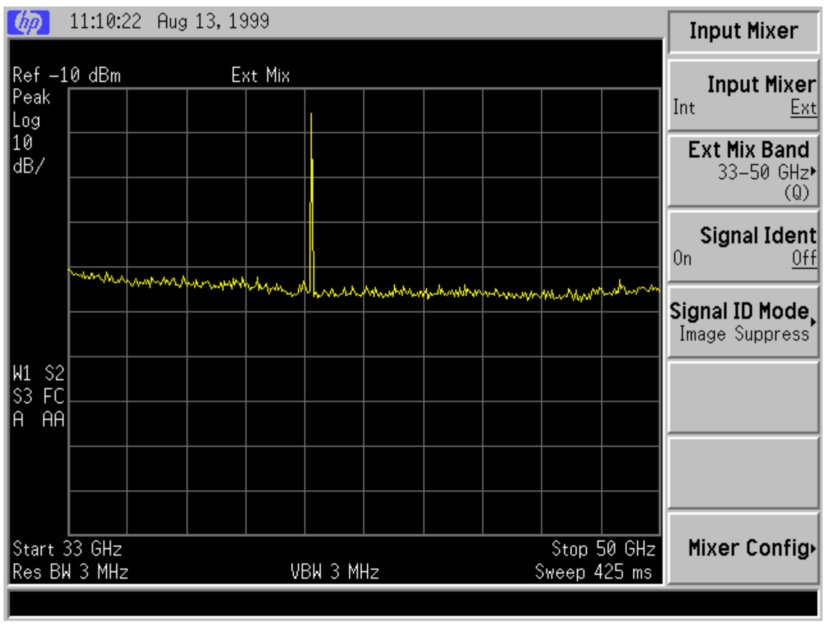
3. Press the following keys to select the desired mixing band: (In this example, we will use an HP/Agilent 11974Q (33.0 to 50.0 GHz) to view a 40 GHz, -15 dBm signal.)

   Input/Output, **Input Mixer**, **Ext Mix Band**, **33-50 GHz (Q)**

Amplitude Calibration

1. Enter the conversion-loss versus frequency data from either the calibration label on the bottom of the HP/Agilent 11974, or the supplied calibration sheet by using the procedure in step 3 of Example 1. The full Q-band is displayed in Figure 2-24.

Figure 2-24



2. To complete the amplitude calibration process, the preselector must be adjusted at each frequency of interest. Before making final amplitude measurements with the analyzer, perform the following:

   a. Place a marker on the signal of interest.

   b. Press **SPAN**, **Span Zoom**, **10 MHz** to zoom in on the signal.

   c. Press **AMPLITUDE**, **Presel Center**.

   The final amplitude measurement can now be read out with the marker. See Figure 2-25.

Figure 2-25