Measurement Guide

Agilent Technologies PSA Spectrum Analyzers

This manual provides documentation for the following instrument:

Agilent Technologies PSA Series

E4440A (3 Hz – 26.5 GHz)

Agilent Technologies

Manufacturing Part Number: E4440-90012

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Where to Find the Latest Information

Documentation is updated periodically. For the latest information about Agilent PSA spectrum analyzers, including firmware upgrades and application information, see: http//www.agilent.com/find/psa.

Contents

1 Using This Document

This document explains how to make spectrum analyzer measurements.

Assumption

You know the basics of spectrum analyzer operation, and the location and function of front and rear panel keys and connectors. If *not*, refer to the Getting Started guide.

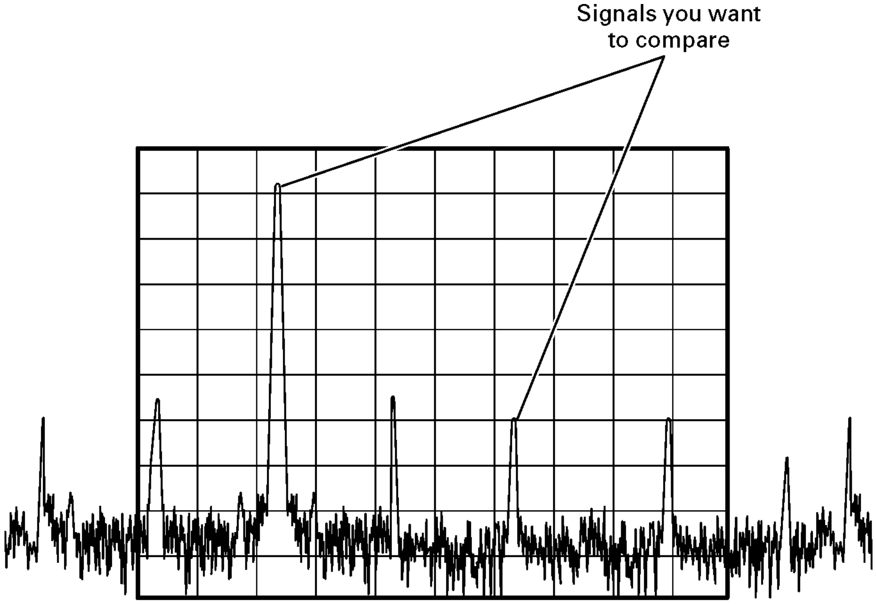
For detailed information on analyzer functions, refer to the Reference guide.

NOTE In this manual, preset means *factory* preset.

2 Comparing Two Signals: Frequency and Amplitude

This chapter provides the following examples:

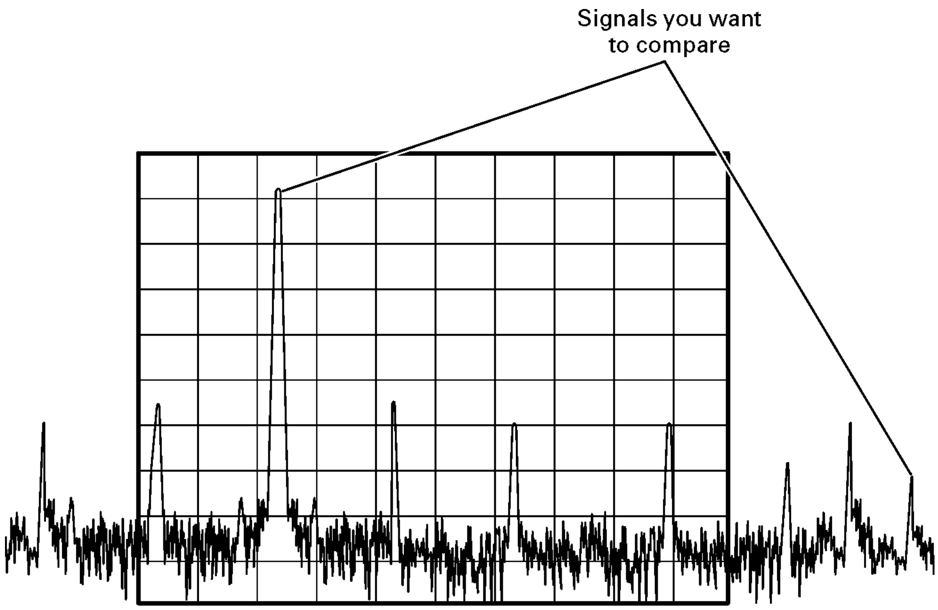
- "Comparing Signals on the Same Screen" on page 6



You can compare two signals whether they both appear on the screen at the same time (as shown above), or not (as shown in the following figure).

• "Comparing Signals not on the Same Screen" on page 10

The ability to compare signals when only one can be displayed at a time is useful for harmonic distortion tests, or any time narrow span and bandwidth are necessary to measure low-level signals.



Comparing Signals on the Same Screen

Signals with Constant Levels (using Marker Delta)

1. Preset the analyzer, then set the following:
   - Reference Level: 10 dBm
   - Center Frequency: 30 MHz
   - Span: 50 MHz
2. Ensure that the rear panel 10 MHz output is on:

   Press **Input/Output**. Check the **10MHz Out** softkey. If **Off** is selected (underlined), press the key to select **On**.
3. Connect the analyzer's rear panel `10 MHz OUT (SWITCHED)` to the front-panel RF input.
4. Place a marker on the 10 MHz peak: Press **Peak Search**.
5. Anchor the first marker and activate a second marker at the same position: Press **Marker**, **Delta**.

   Note that the label on the first marker changes to `1R`, indicating that it is the reference point.
6. Use the knob to move the second marker (labeled `1`) to a different peak (for this example, the 20 MHz peak).

   Because delta marker is now the active function, both the active function block and the marker annotation display the amplitude and frequency *difference* between the markers, as shown in Figure 2-1.
7. Turn the markers off: Press **Marker**, **Off**.

NOTE Alternate Methods

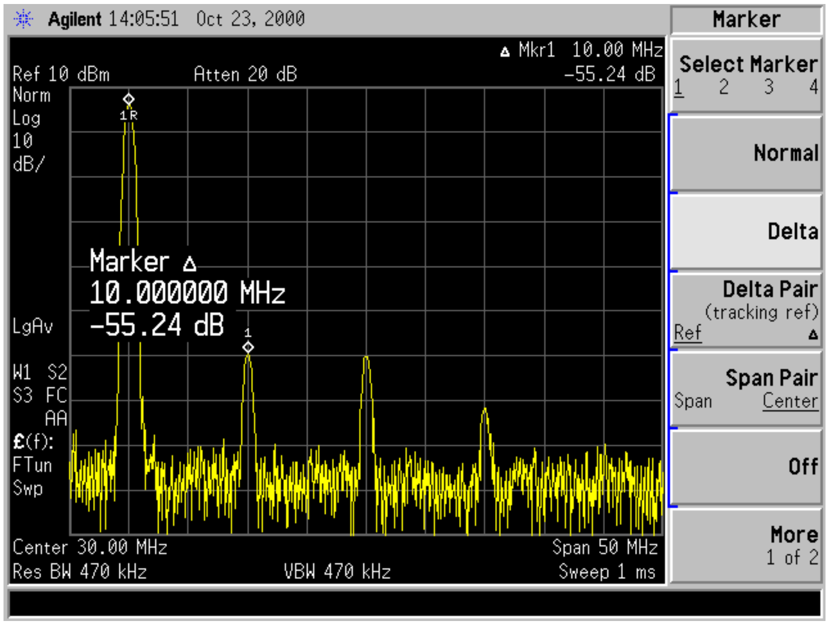
Replace the keystrokes in steps 4 through 6 with either:

- Press **Sweep**, **Single**, **Peak Search**, **Marker**, **Delta**, **Return** (or **Peak Search**), **Next Peak**.

  (the **Return** hardkey is located directly below the softkeys)

  Or
- Press **Marker** and use the knob to position the marker. Then press **Marker**, **Delta** and position the second marker.

Figure 2-1 Reading the Marker Delta Value



Signals with Varying Levels (using Delta Pair)

The Delta Marker function (described on page 6) anchors the *reference* marker in both frequency *and* amplitude. The Delta Pair function, described in this example, enables the reference marker to remain on the trace, and lets you adjust either the reference marker or the delta marker, or both.

1. Preset the analyze, then set the following:

   - Reference Level: 10 dBm
   - Center Frequency: 30 MHz
   - Span: 50 MHz

2. With the rear panel 10 MHz output on (as described on page 6, in Step 2.), connect the analyzer's rear panel `10 MHz OUT (SWITCHED)` to the front-panel RF input.
3. Place a marker on the 10 MHz peak: Press **Peak Search**.
4. Anchor the first marker and activate a second marker at the same position: Press **Marker**, **Delta.**
5. Use the knob to move the second marker (labeled `1`) to a different peak (for this example, the 20 MHz peak).

   The marker annotation shows the difference between the two peaks.
6. Remove the signal from the input.

   Note that the reference marker remains anchored at the former frequency and amplitude of the 10 MHz signal. The delta marker stays on the trace and now shows the difference between the noise level at the delta frequency and the original amplitude of the 10 MHz signal.
7. Reconnect the signal, then reset the marker to a single marker on the 10 MHz peak:

   Press **Marker**, **Normal**, **Peak Search**.

   Activate a second marker at the same position *without* anchoring the first marker: Press **Marker**, **Delta Pair**.
8. Select the second marker: Press **Delta Pair** again, to underline Δ.
9. Use the knob to move the second marker (labeled `1`) to a different peak (for this example, the 30 MHz peak).

   Because delta marker is the active function, both the active function block and the marker annotation display the amplitude and frequency difference between the markers (just as when using the Delta Marker function, as shown in Figure 2-1).
10. Select the reference marker: Press **Delta Pair** to select (underline) **Ref**.

11.Use the knob to move the reference marker to the 20 MHz peak.

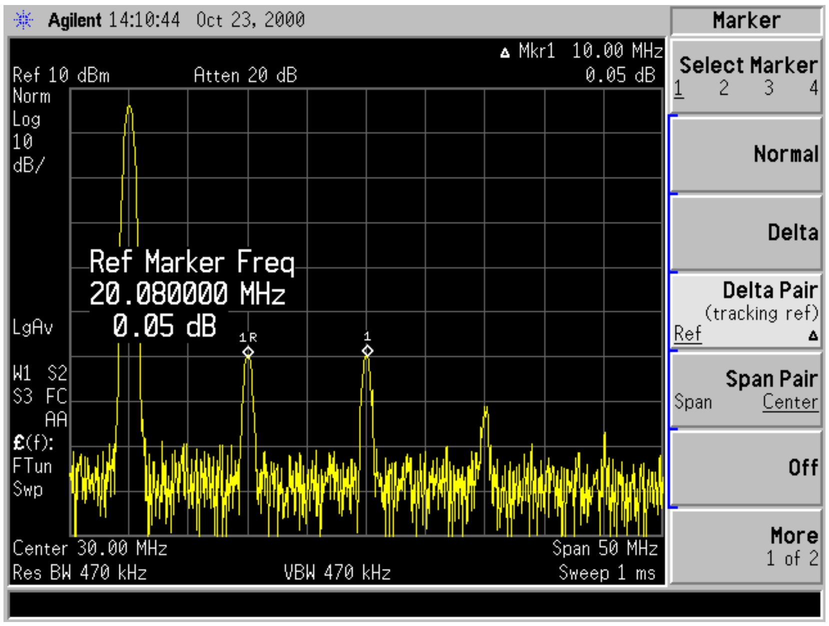
Note that as you move the marker, it stays on the trace.

Now the active function block and the marker annotation display the amplitude and frequency difference between the 20 MHz and 30 MHz peaks, as shown in Figure 2-2.

12.Disconnect the signal input. Note that *both* markers drop into the noise.

13.Turn the markers off: Press **Marker**, **Off**.

Figure 2-2 Reading the Marker Delta Value



Comparing Signals *not* on the Same Screen

1. Preset the analyzer, then set the following:

   - Reference Level: 10 dBm
   - Center Frequency: 10 MHz
   - Span: 5 MHz

2. With the rear panel 10 MHz output on (as described on page 6, in Step 2.), connect the analyzer's rear panel `10 MHz OUT (SWITCHED)` to the front-panel RF input.

3. Place a marker on the 10 MHz peak: Press **Peak Search**.

Setting Center Frequency Step Size

4. Set the center frequency step size equal to the marker frequency (in this example, 10 MHz): Press **Marker →**, **Mkr → CF Step**.

5. Activate the marker delta function: Press **Marker**, **Delta**.

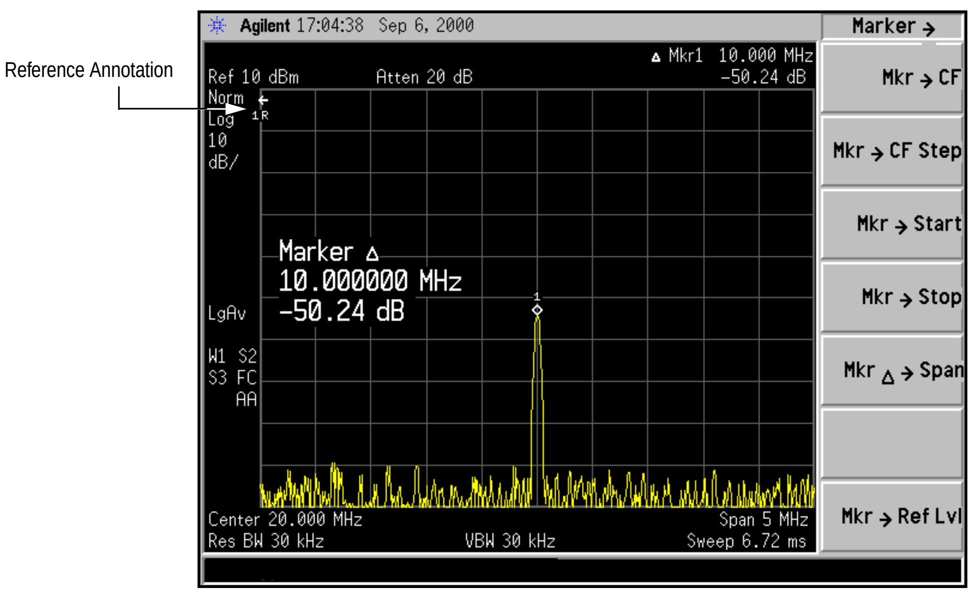
6. Increase the center frequency by 10 MHz:

   Press **FREQUENCY**, **Center Freq**, ⇑.

   Figure 2-3 shows the reference annotation for the delta marker (1R) at the left side of the display, indicating that the 10 MHz reference signal is at a lower frequency than the frequency range currently displayed.

   The delta marker appears on the peak of the 20 MHz component. The delta marker annotation displays the amplitude and frequency difference between the 10 and 20 MHz signal peaks.

Figure 2-3 Delta Marker with Reference Signal Off–Screen



3 Measuring a Low-Level Signal

The analyzer's ability to measure a low-level signal is limited by internally-generated noise. The measurement setup can be changed in several ways to improve the analyzer's sensitivity. Resolution bandwidth settings, when properly adjusted, affect the level of internal noise *without* affecting the signal amplitude.

This chapter provides the following examples:

- "Reducing Input Attenuation" on page 14

  The input attenuator affects the level of a signal passing through the instrument. If a signal is very close to the noise floor, reducing input attenuation can bring the signal out of the noise.

CAUTION Ensure that the total power of all input signals at the analyzer RF input does not exceed +30 dBm (1 watt).

- "Decreasing the Resolution Bandwidth" on page 16

  Resolution bandwidth settings affect the level of internal noise without affecting the signal level. Decreasing the RBW by a decade reduces the noise floor by 10 dB.

- "Using the Average Detector and Increased Sweep Time" on page 17

  When the analyzer's noise masks low-level signals, changing to the average detector and increasing the sweep time smooths the noise and improves the signal's visibility. Slower sweeps are required to average more noise variations.

- "Trace Averaging" on page 18

  Averaging is a digital process in which each trace point is averaged with the previous trace-point average. Selecting averaging changes the detection mode from normal (a type of peak detection) to sample, smoothing the displayed noise level. 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 may not measure a signal's amplitude as accurately as normal mode, because it may not find the true peak.

Reducing Input Attenuation

CAUTION Ensure that the total power of all input signals at the analyzer RF input does not exceed +30 dBm (1 watt).

1. Preset the analyzer, then set the following:

On a Signal Source		On the Analyzer	
• Frequency:	300 MHz	• Reference Level:	–40 dBm
• Amplitude:	–80 dBm	• Center Frequency:	300 MHz
• RF Output:	On	• Span:	5 MHz

2. Connect the signal source to the analyzer's RF input.
3. Move the desired peak (in this example, 300 MHz) to the center of the display:

   Press **Peak Search**, **Marker →**, **Mkr → CF**.
4. Reduce the span to 1 MHz (as shown in Figure 3-1):

   Press **Span**, **1**, **MHz**.

   If necessary, re-center the peak.
5. Set the attenuation to 20 dB:

   Press **AMPLITUDE**, **Attenuation**, **2**, **0**, **dB**.

   Note that increasing the attenuation moves the noise floor closer to the signal level.

   A "#" mark appears next to the `Atten` annotation at the top of the display, indicating that the attenuation is no longer coupled to other analyzer settings.
6. To see the signal more clearly, set the attenuation to 0 dB (as shown in Figure 3-2).

CAUTION When you finish this example, increase the attenuation to protect the analyzer's RF input:

Either press **Attenuation** so that **Auto** is selected, or press **Auto Couple**.

Figure 3-1 Low-Level Signal

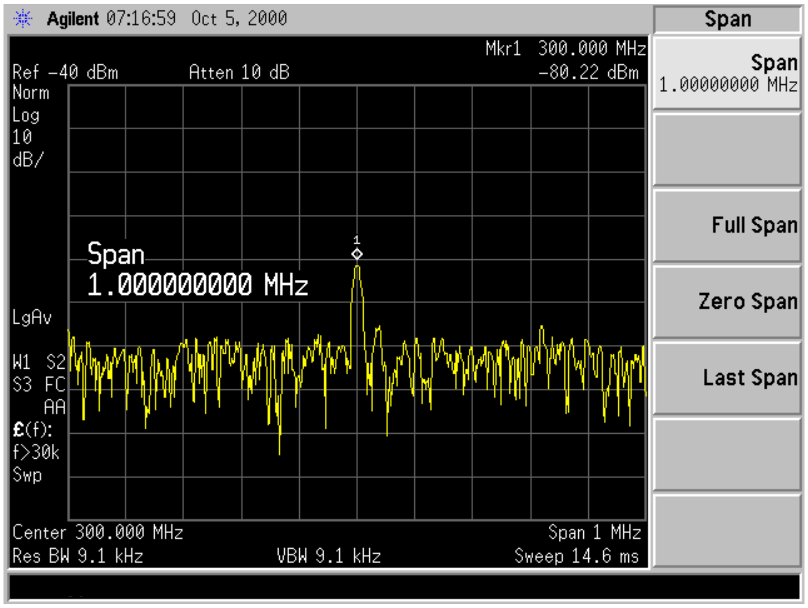
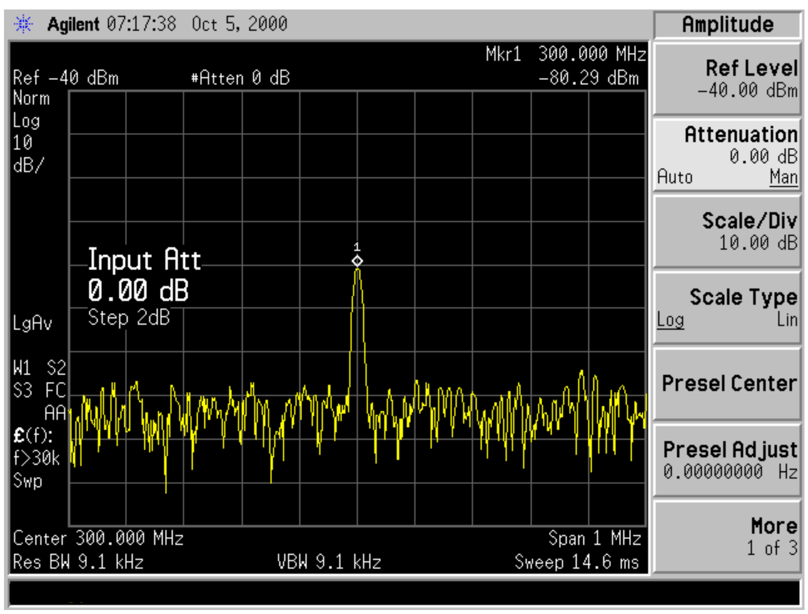


Figure 3-2 Using 0 dB Attenuation



Decreasing the Resolution Bandwidth

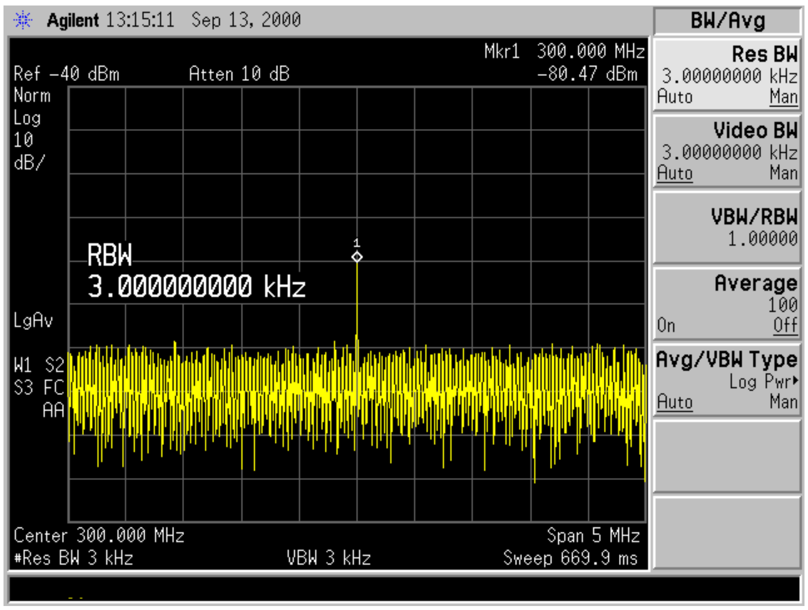
1. Preset the analyzer, then set the following:

On a Signal Source		On the Analyzer	
• Frequency:	300 MHz	• Reference Level:	–40 dBm
• Amplitude:	–80 dBm	• Center Frequency:	300 MHz
• RF Output:	On	• Span:	5 MHz

2. Connect the signal source signal source to the analyzer RF input.
3. Decrease the resolution bandwidth: Press **BW/Avg**, ⇓.

   The low-level signal appears more clearly because the noise level is reduced (see Figure 3-3).

Figure 3-3 Decreasing Resolution Bandwidth



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

RBW Selections

Using the step keys, you can change the RBW in a 1–3–10 sequence. Choosing the next lower RBW for better sensitivity increases the sweep time by about 10:1 for swept measurements, and about 3:1 for FFT measurements (within the limits of RBW).

Using the knob or keypad, you can select RBWs from 1 Hz to 3 MHz in approximately 10% increments, plus 4, 5, 6 and 8 MHz. This enables you to make the trade off between sweep time and sensitivity with finer resolution.

Using the Average Detector and Increased Sweep Time

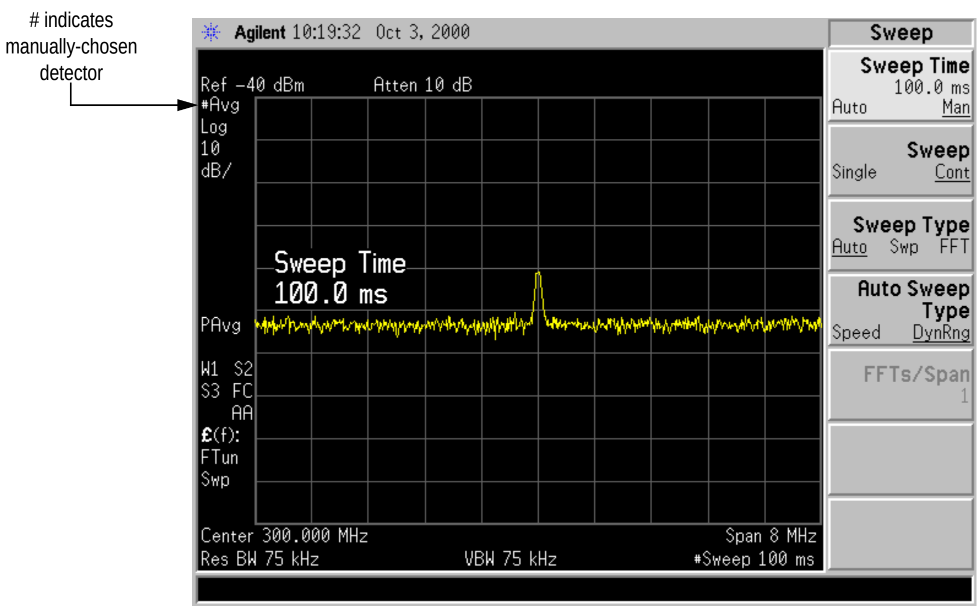
1. Preset the analyzer, then set the following:

On a Signal Source		On the Analyzer	
• Frequency:	300 MHz	• Reference Level:	–40 dBm
• Amplitude:	–80 dBm	• Center Frequency:	300 MHz
• RF Output:	On	• Span:	5 MHz

2. Connect the signal source to the analyzer's RF input.
3. Select the average detector: Press **Det/Demod**, **Detector**, **Average**.

   A "#" mark appears next to the Avg annotation, indicating that the detector has been chosen manually (see Figure 3-4).
4. Increase the sweep time and note how the noise smooths out, as there is time to average more noise values for each of the displayed data points: Press **Sweep**, **Sweep Time**, ⇑.
5. With the sweep time at 100 ms, change the Avg/VBW type to log averaging: Press **BW/Avg**, **Avg/VBW Type**, **Log-Pwr**.

Figure 3-4 The Effect of Sweep Time



Trace Averaging

Trace averaging is a digital process that averages each trace point with the previous trace-point average.

NOTE This is a trace processing function and is not the same as using the Average detector (as described on page 17).

1. Preset the analyzer, then set the following:

On a Signal Source		On the Analyzer	
• Frequency:	300 MHz	• Reference Level:	–40 dBm
• Amplitude:	–80 dBm	• Center Frequency:	300 MHz
• RF Output:	On	• Span:	5 MHz

2. Connect the signal source to the analyzer RF input.
3. Initiate video averaging: Press **BW/Avg**, **Average** (to select **On**).

   As the averaging routine smooths the trace, low level signals become more visible. `Average 100` (the default number of samples, or sweeps, to complete the averaging routine) appears in the active function block.

4. With average as the active function, set the number of samples to 25:

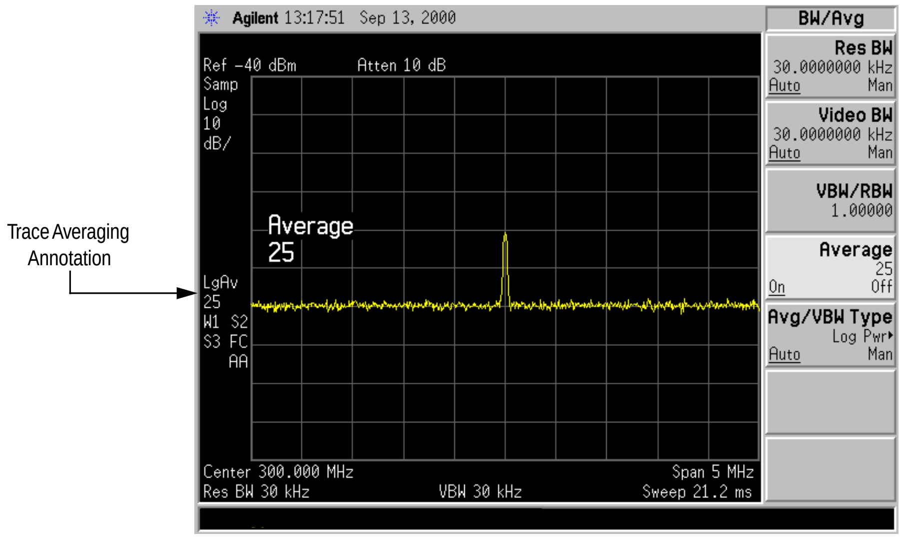
   Press **2**, **5**, **Enter**.

   Annotation on the left side of the graticule shows the type of averaging (LgAV in this example, as shown in Figure 3-5), and the number of traces averaged.

   Changing most active functions restarts the averaging, as does toggling the **Average** key. Once the set number of sweeps completes, the analyzer continues to provide a running average based on this set number.

NOTE If you want the measurement to stop after the set number of sweeps, use single sweep: Press **Sweep**, **Sweep** (to select **Single**), and then toggle the **Average** key.

Figure 3-5 Using Trace Averaging, Continuous Sweep



4 Resolving Signals

This chapter provides the following examples:

- "Separating Equal-Amplitude Signals" on page 24

  Two equal-amplitude input signals that are close in frequency can appear as one on the analyzer display. When the analyzer measures a single-frequency signal, it displays the signal with the shape of the selected internal resolution bandwidth filter. As you change the filter bandwidth, you change the width of the displayed response. If you use a wide filter, two equal-amplitude input signals that are close in frequency appear as one signal. The analyzer's internal filter bandwidths determine signal resolution (how close equal-amplitude signals can be and still be distinguished).

  The resolution bandwidth function selects the internal filter bandwidth, and is defined as the 3 dB bandwidth of the filter. To resolve two signals of equal amplitude, you must set the resolution bandwidth 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, you will see a dip of approximately 3 dB between the peaks of the two signals.

  For swept analysis, reducing the resolution bandwidth requires an increase in sweep time to keep a measurement calibrated. For best measurement times: set the sweep type (**Sweep**, **Sweep Type**) to **Auto**, and the auto sweep type (**Sweep**, **Auto Sweep Type**) to **Speed**. Use the widest resolution bandwidth that still permits resolution of all desired signals.

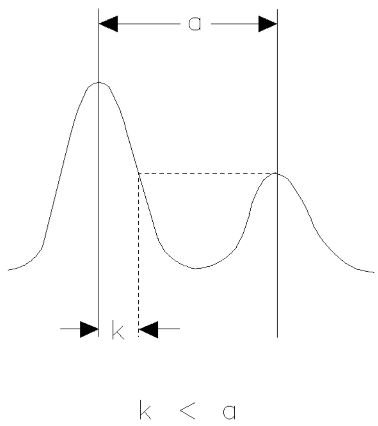
- "Finding a Small Signal Hidden by a Larger Signal" on page 26

  When signals are close together but *not* equal in amplitude, you must consider the shape of the analyzer's internal filter as well as its 3 dB bandwidth. If a small signal is too close to a larger signal, the smaller signal can be hidden by the skirt of the filter.

  To view the smaller signal, select a resolution bandwidth such that *k* is less than *a* (see Figure 4-1). 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.

  The digital filters in this instrument have filter widths about one-third as wide as typical analog RBW filters. This enables you to resolve close signals with a wider RBW (and consequently, a faster sweep).

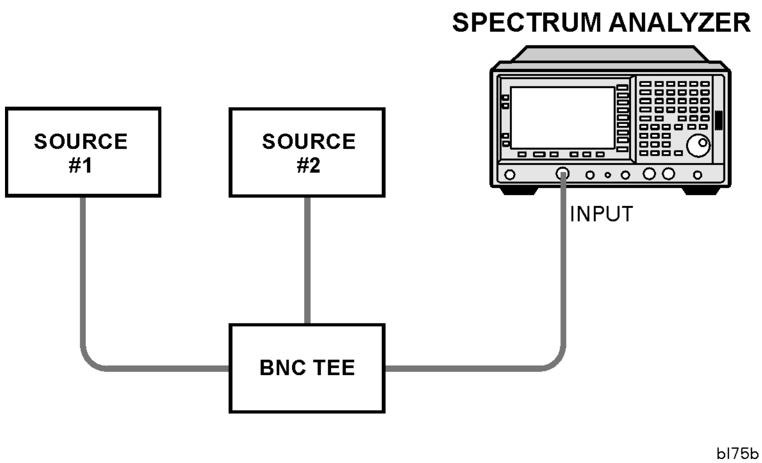
Figure 4-1 Resolution Bandwidth Requirements to Resolve Small Signals



Separating Equal-Amplitude Signals

The following example shows how to differentiate equal-amplitude signals separated by 100 kHz.

1. Connect two sources to the analyzer's RF input as follows:



2. Preset the analyzer, then set the following:

On Source 1		On Source 2	
• Frequency:	300 MHz	• Frequency:	300.1 MHz
• Amplitude:	–20 dBm	• Amplitude:	–20 dBm
• RF Output:	On	• RF Output:	On

On the Analyzer	
• Center Frequency:	300 MHz
• Span:	2 MHz
• Resolution bandwidth:	300 kHz

Press **BW/Avg**, **Resolution BW**, **3**, **0**, **0**, **kHz**.

A single signal peak should be visible.

NOTE If you cannot find the signal peak, increase the span to 20 MHz, then use signal tracking to bring the signal to the center of the screen:

Press **FREQUENCY**, **Signal Track** (press to underline **On**).

Reduce the span back to 2 MHz, then turn signal tracking off.

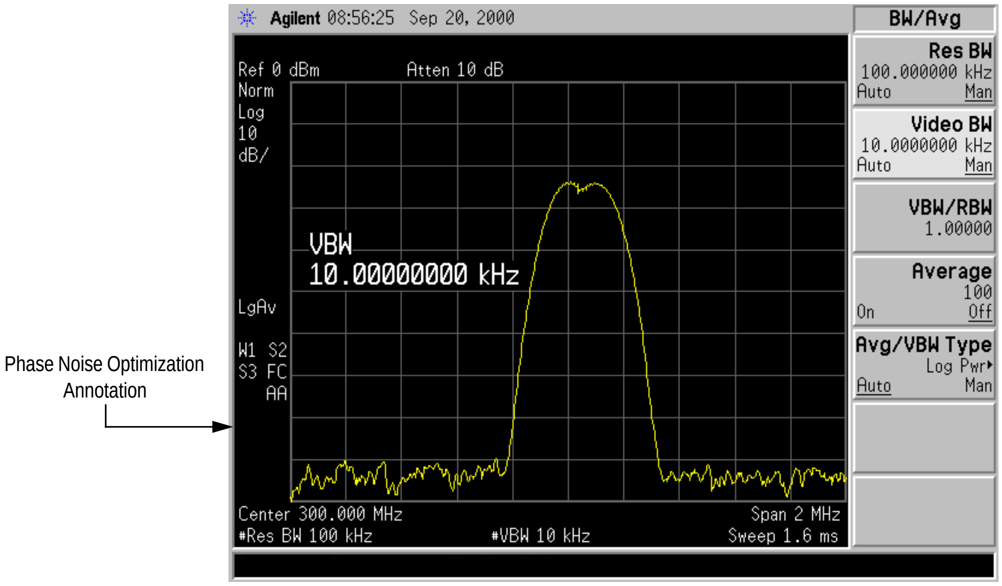
3. Because the resolution bandwidth must be less than or equal to the frequency separation of the two signals, change the resolution bandwidth to 100 kHz.

4. Decrease the video bandwidth to 10 kHz, as shown in Figure 4-2:

   Press **BW/Avg**, **Video BW**, **1**, **0**, **kHz**.

   Note that when you narrowed the span, the annotation for phase noise optimization changed. The optimization is now for viewing signals greater than 30 kHz away from the 300 MHz signal.

Figure 4-2 Resolving Signals of Equal Amplitude



You can experiment with reducing the resolution bandwidth further to better resolve the signals. As you reduce the resolution bandwidth, the resolution of the individual signals improves, but the sweep gets slower. For fastest measurement times, use the widest resolution bandwidth that still displays two distinct signals.

Under factory preset conditions, the resolution bandwidth is coupled (linked) to the span. Because you change the resolution bandwidth 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 PSA Reference Guide).

NOTE To resolve two signals of equal amplitude with a frequency separation of 200 kHz, you must use a resolution of 100 kHz because the resolution of next larger filter (300 kHz) is *greater* than the signal separation and will not resolve the signals.

Finding a Small Signal Hidden by a Larger Signal

The following example demonstrates how to resolve two signals separated by 50 kHz and 60 dB.

1. Connect the equipment as shown on page 24, then set the sources as follows:

Source 1:	300 MHz	–20 dBm	RF output on
Source 2:	300.05 MHz	–80 dBm	RF output on

2. Preset the analyzer, then set:

- Center Frequency: 300 MHz
- Span: 300 kHz
- Resolution Bandwidth: 10 kHz

3. Set the 300 MHz signal to the reference level (top graticule):

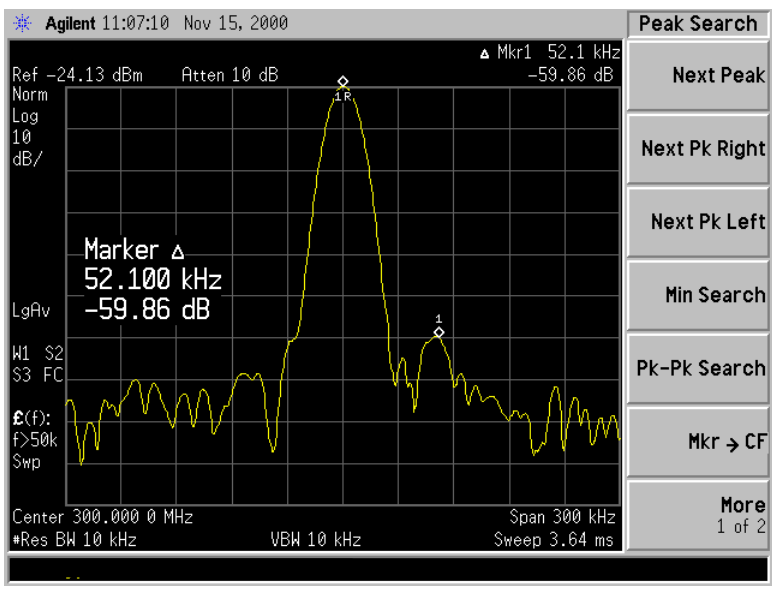
   Press **Peak Search**, **Marker →**, **Mkr → Ref Lvl**.

4. Place a marker on the smaller signal:

   Press **Marker**, **Delta**, **Peak Search**, **Next Pk Right**.

   When you use a 10 kHz filter with a typical shape factor of 4.1:1, the filter has a bandwidth of 41 kHz at the 60 dB point. Because the half-bandwidth value (20.5 kHz) is narrower than the frequency separation, the input signals are resolved, as shown in Figure 4-3.

Figure 4-3 Signal Resolution with a 10 kHz Resolution Bandwidth



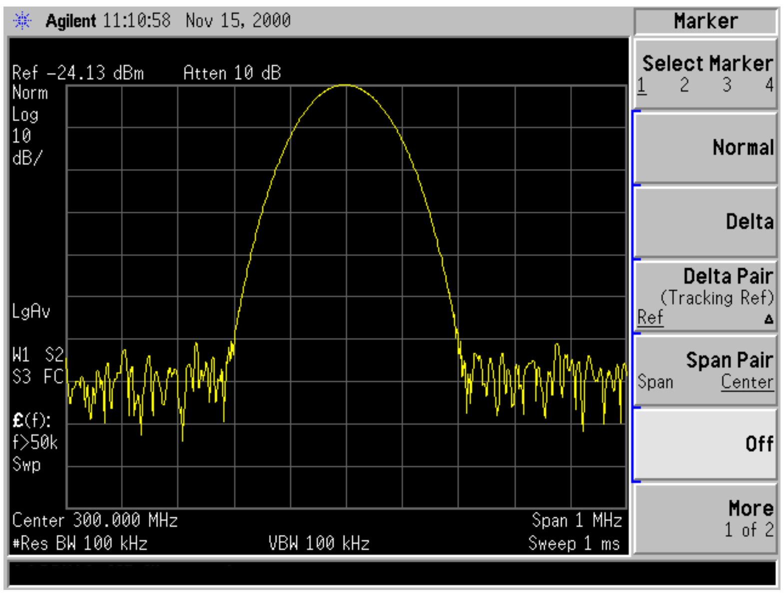
If you use a resolution bandwidth where the half-bandwidth value is wider than the frequency separation, the signals may not be resolved, as shown in Figure 4-4.

In this example, the signal amplitude difference is 60 dB. To determine the resolution capability for intermediate amplitude differences, assume the filter skirts between the 3 dB and 60 dB points are parabolic, like an ideal Gaussian filter. The resolution capability is approximately:

$$12.04\text{ dB} \bullet \left(\frac{\Delta f}{RBW}\right)^2$$

where Δf is the separation between the signals.

Figure 4-4 Signal Resolution with a 100 kHz Resolution Bandwidth



5 Tracking a Drifting Signal

This chapter provides the following examples:

- "Tracking a Signal" on page 32

  When you measure a signal peak and must repeatedly adjust the center frequency because the signal drifts, you can use the signal track function to automatically keep the selected peak in the center of the display.

- "Measuring a Source's Drift" on page 34

  You can use the maximum-hold function to display and hold the maximum amplitude level and frequency drift of an input signal trace. You can also use the maximum hold function to determine how much of the frequency spectrum a signal occupies.

Equipment Both examples require a signal source.

Tracking a Signal

1. Preset the analyzer, then set the following:

On a Signal Source		On the Analyzer	
• Frequency:	300 MHz	• Center Frequency:	301 MHz
• Amplitude:	–20 dBm	• Span:	10 MHz
• RF Output:	On		

2. Connect the signal source to the analyzer's RF input.

   Because you set the analyzer's center frequency to a different value than that of the source's output, the 300 MHz peak is not in the center of the display.

3. Turn on signal tracking: Press **FREQUENCY**, **Signal Track** (press to underline **On**).

   This does the following:

   - Places a marker on the highest-amplitude peak.
   - Brings the selected peak to the center of the display.
   - Adjusts the center frequency each sweep to keep the selected peak in the center.
   - Turns on the signal track annotation (see Figure 5-1).

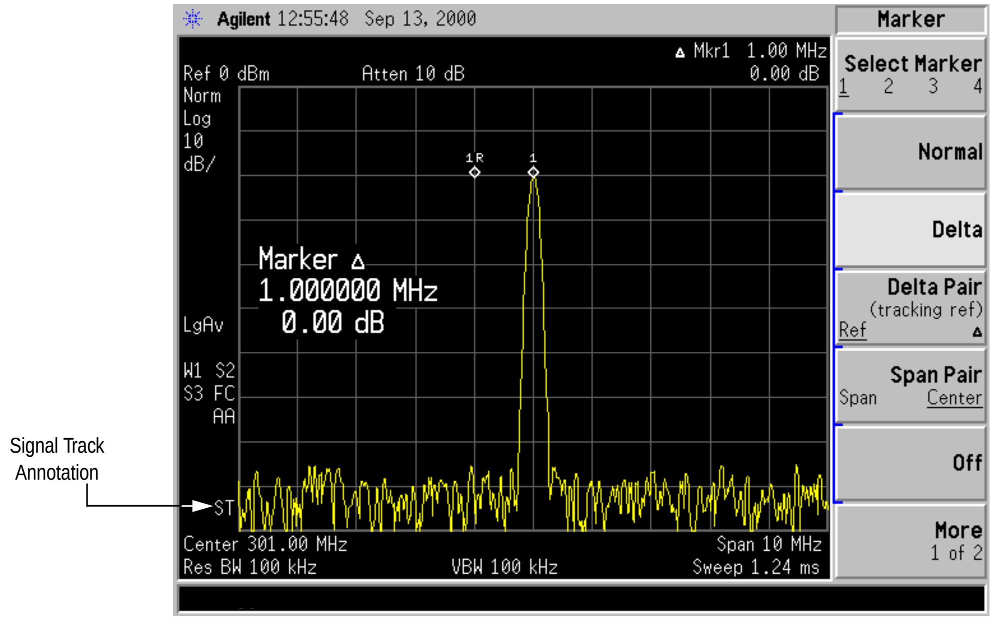
4. When you have both signal track and marker delta on, you can read any signal drift from the screen:

   Press **Marker**, **Delta**. The marker readout indicates any change in frequency and amplitude as the signal moves.

5. Slowly change the source's frequency, and note that the analyzer's center frequency changes, centering the signal with each change (see Figure 5-1).

6. Experiment with different spans, and with changing the frequency more slowly and more quickly, to see what happens.

Figure 5-1 Using Signal Tracking to Track a Drifting Signal



Measuring a Source's Drift

1. Preset the analyzer, then set the following:

On a Signal Source		On the Analyzer	
• Frequency:	300 MHz	• Center Frequency:	300 MHz
• Amplitude:	–20 dBm	• Span:	10 MHz
• RF Output:	On		

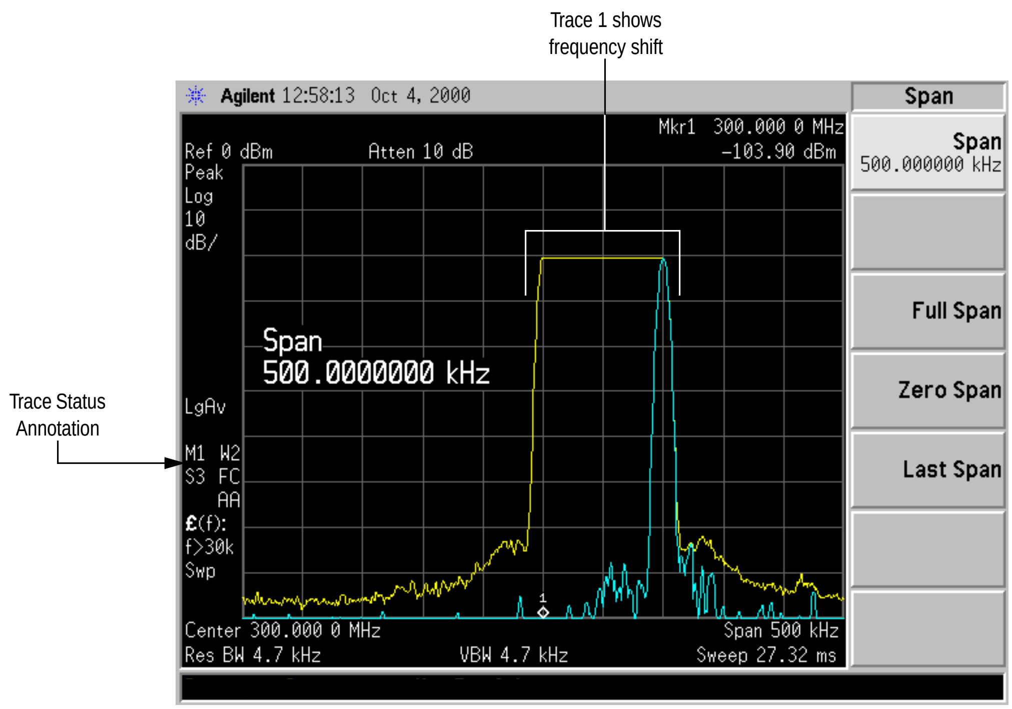
2. Connect the signal source to the analyzer's RF input, and place a marker on the peak of the signal: Press **Peak Search**.
3. Change the span to 500 kHz (if necessary, recenter the signal).
4. Measure the excursion of the signal: Press **Trace/View**, then **Max Hold**.

   As the input signal varies, maximum hold maintains the signal's maximum responses. The annotation on the left side of the screen (`M1 S2 S3`) shows that trace 1 is in maximum-hold mode; traces 2 and 3 are in store-blank mode.
5. Select trace 2: Press **Trace/View**, **Trace 1 2 3** (until 2 is underlined).
6. Clear trace 2 and have it continuously display during sweep:

   Press **Clear Write**.

   Trace 1, in maximum hold, shows any frequency shift in the signal.
7. Slowly change the source's frequency in 1 kHz steps. The analyzer display should look similar to Figure 5-2.

Figure 5-2 Viewing a Drifting Signal Using Max Hold



6 Making Distortion Measurements

This chapter provides the following examples:

- "Identifying Distortion from the Analyzer"
  - "Identifying Harmonic Distortion Products" on page 40

    High-level input signals can cause analyzer distortion products that mask input signal distortion.
  - "Measuring the Analyzer's Third-Order Intermodulation Distortion" on page 42

    Two-tone, third-order intermodulation distortion is a common test in communication systems. When two signals are present in a non-linear system (a system with components such as amplifiers and mixers), signals can interact and create distortion products close to the original signals.
- "Measuring Harmonics and Harmonic Distortion" on page 44

  This example describes how to make a harmonic measurement, and details the calculation of the total harmonic distortion for stable, modulated or unmodulated signals.

Identifying Distortion from the Analyzer

Identifying Harmonic Distortion Products

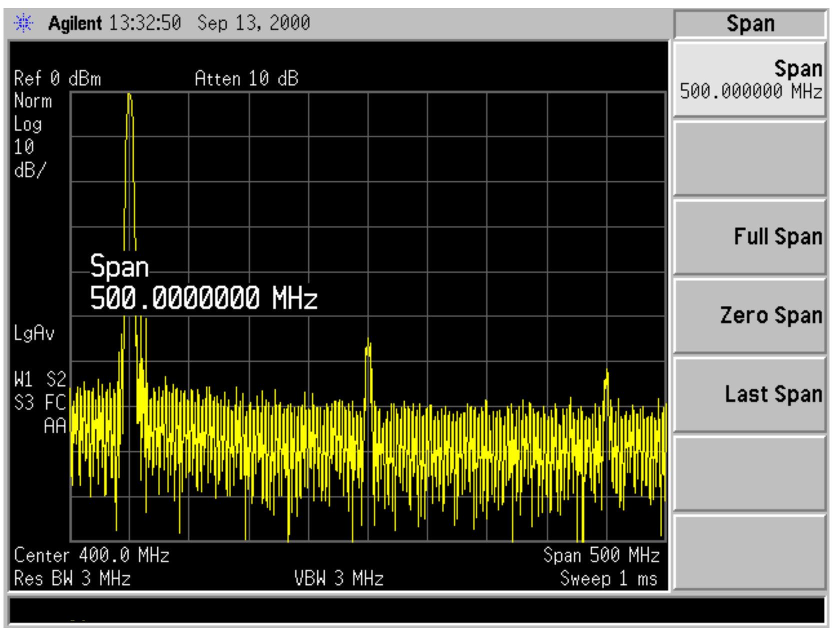
The following example uses an external signal, trace 2, and the RF attenuator to determine whether harmonic distortion products are generated by the analyzer.

1. Preset the analyzer, then set the following:

On a Signal Source		On the Analyzer	
• Frequency:	200 MHz	• Center Frequency:	400 MHz
• Amplitude:	0 dBm	• Span:	500 MHz
• RF Output:	On		

Connect the source to the analyzer. The analyzer displays the 200 MHz signal and harmonics spaced every 200 MHz (see Figure 6-1).

Figure 6-1 Harmonic Distortion



2. On the analyzer, place a marker on one of the observed harmonics, and change the center frequency to the value of that harmonic.

3. Change the span to 50 MHz.

4. Change the attenuation to 0 dB.

5. Save the screen data in trace 2:

   Press **Trace/View**, **Trace 1 2 3** (to underline 2), then **Clear Write**.

   Allow the trace to update (two sweeps), then press **View**.

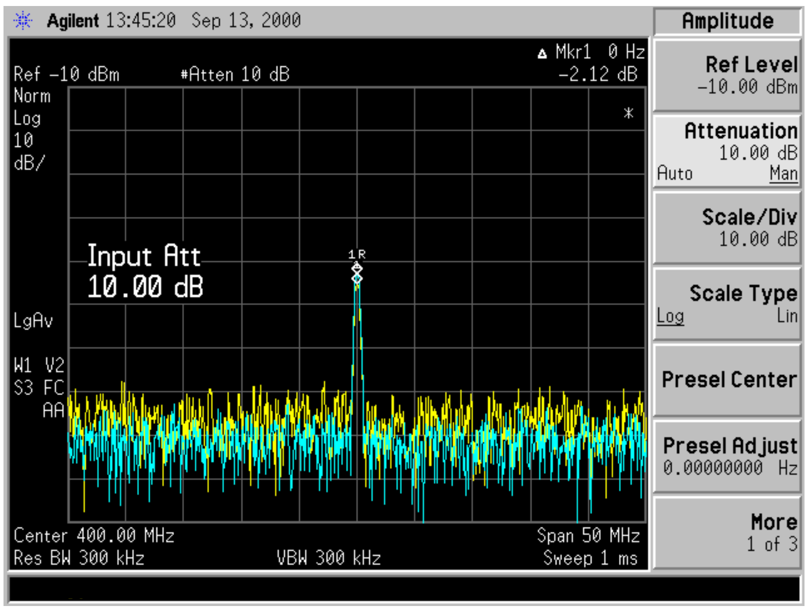
6. Place a delta marker on the harmonic:

   Press **Peak Search**, **Marker, Delta**.

   The analyzer display shows the stored data in trace 2 and the measured data in trace 1. The ΔMkr1 amplitude reading is the difference in amplitude between the reference and active markers.

7. Increase the RF attenuation to 10 dB. See Figure 6-2.

Figure 6-2 RF Attenuation of 10 dB



The ΔMkr1 amplitude reading comes from two sources:

- Increased input attenuation causes poorer signal-to-noise ratio. This can cause the ΔMkr1 to be positive.
- The reduced contribution of the analyzer circuits to the harmonic measurement can cause the ΔMkr1 to be negative.

Large ΔMkr1 measurements indicate significant measurement errors. For the best measurement accuracy, set the input attenuator to minimize the absolute value of ΔMkr1.

Measuring the Analyzer's Third-Order Intermodulation Distortion

The following example uses two sources at a frequency separation of 1 MHz. If you choose to use different frequencies, be sure to maintain the 1 MHz separation.

1. Set the sources for a frequency separation of 1 MHz:

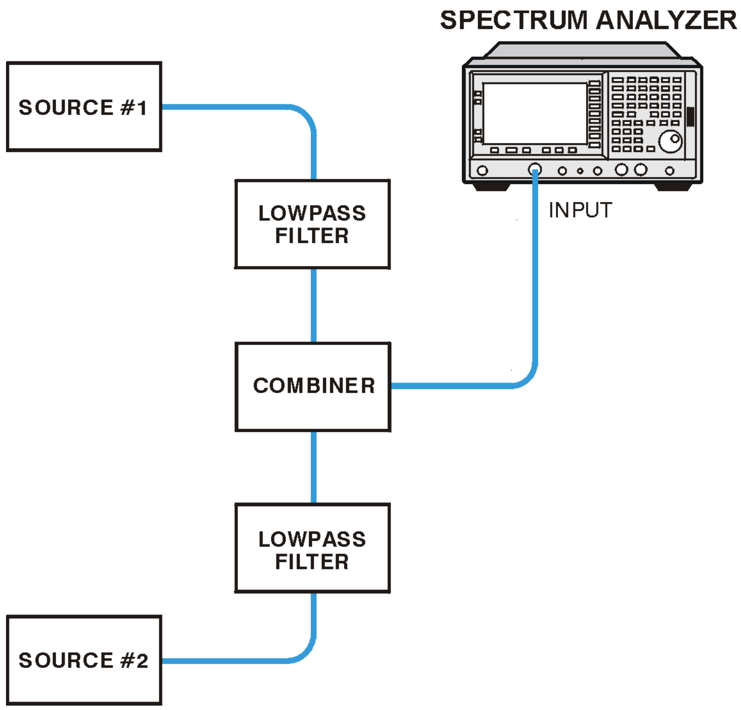
   Source 1: 300 MHz –5 dBm RF output on

   Source 2: 301 MHz –5 dBm RF output on

2. Connect the equipment as shown in Figure 6-3, and preset the analyzer.

CAUTION Ensure that the combiner has a high degree of isolation between the two input ports so the sources do not intermodulate.

Figure 6-3 Equipment Setup



3. On the analyzer, set:

   - Center Frequency: 300.5 MHz
   - Span: 5 MHz (wide enough to see the distortion products)

   To be sure the distortion products are resolved, adjust the resolution bandwidth as needed until the distortion products are visible.

4. Set the mixer input level to –30 dBm:

   Press **AMPLITUDE**, **More**, **More**, **Max Mixer Lvl**, **3**, **0**, –**dBm**.

5. Move the signal to the reference level:

   Press **Marker**, **Peak Search**, **Marker →**, **Mkr → Ref Lvl**.

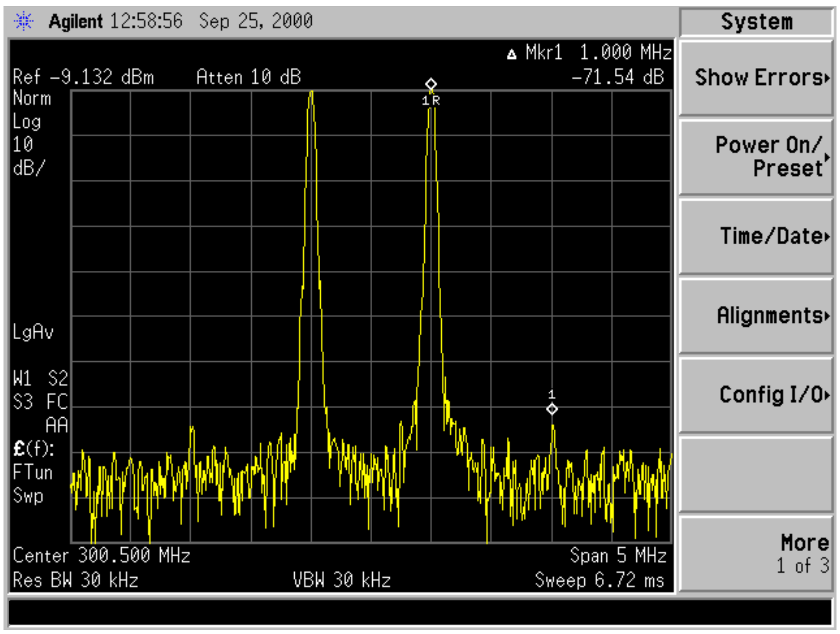
6. Reduce the resolution bandwidth until the distortion products are visible: Press **BW/Avg**, ⇓.

7. Use the delta marker function to measure the difference between the source signal and each distortion product (Figure 6-4 shows an example of this):

   Press **Marker**, **Delta**, then use the knob to move the delta marker to the distortion product you want to measure.

   For more information about measuring distortion products, see "Measuring Harmonics and Harmonic Distortion" on page 44.

Figure 6-4 Measuring a Distortion Product



Measuring Harmonics and Harmonic Distortion

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

The following example uses the 10 MHz Reference Output as the fundamental source, and measures harmonics and total harmonic distortion.

1. Preset the analyzer, then set the following:

   - Reference Level: 10 dBm
   - Center Frequency: 10 MHz
   - Span: 1 MHz
   - Resolution Bandwidth: 10 kHz (Press **BW/Avg**, **1**, **0**, **kHz**.)

   Resolution bandwidth and attenuation are adjusted to maximize dynamic range while maintaining a reasonable sweep time. Narrower resolution bandwidths provide greater dynamic range, but lengthen sweep time. You can use the dynamic range graph (Figure 6-5 on page 45) to help determine optimal settings. In this example, harmonics are within 50 dB of the fundamental, requiring a 50 dBc dynamic range; a 10 kHz resolution bandwidth provides more than enough dynamic range to view the second harmonic.

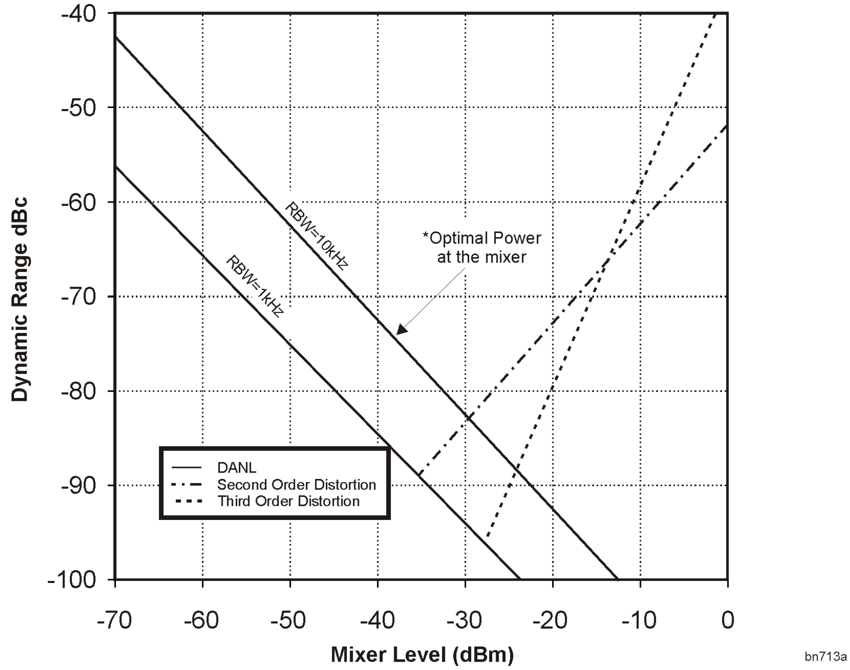
   When measuring the *N*th harmonic, the analyzer uses the narrowest resolution bandwidth that is *N* times the resolution bandwidth used to measure the fundamental. Widening the resolution bandwidth enables the measurement to capture all modulation on the harmonics. An asterisk (*) appears next to the amplitudes of measured harmonics for which the desired resolution bandwidth cannot be set. As long as the signal at the harmonic has less modulation width than the RBW, the measurement is accurate.

   - Attenuation: 40 dBm (Press **AMPLITUDE**, **Attenuation**, **4**, **0**, **dB**.)

   Attenuation is set for optimal power at the mixer, which occurs at the intercept of the second order harmonic line and the Displayed Average Noise Level (DANL) line for the resolution bandwidth selected (see the note inside Figure 6-5). This occurs at a mixer level of approximately –39 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 44 dB.

   Attenuation Setting (dB) = Input Level (dBm) – Mixer Level

Figure 6-5 Dynamic Range Graph



2. With the rear panel 10 MHz output on (as described on page 6, in Step 2.), connect the analyzer's rear panel `10 MHz OUT (SWITCHED)` to the front-panel RF input.

3. To calculate the total harmonic distortion of a signal, perform the following steps, in the following order:

   a. Determine the frequencies of the harmonics.

   b. For each harmonic:

      1. Select the harmonic: Press **Marker**, then use the knob to move the marker to the desired harmonic.

      2. Span down to zero span: Press **Span**, **Zero Span**.

      3. Measure the amplitude.

   c. Divide the root-sum-squares of the harmonic voltages by the fundamental signal voltage. Then multiply the results by 100 to arrive at 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 THD Calculation

Number of harmonics (Hmax) = 5; measured values are:

$$E_f = 5\text{ dBm} = 3.162\text{ mW} = 397.6\text{ mV}$$
$$E_2 = -42\text{ dBc} = -37\text{ dBm} = 199.5\text{ nW} = 3.159\text{ mV}$$
$$E_3 = -26\text{ dBc} = -21\text{ dBm} = 7.943\ \mu\text{W} = 19.93\text{ mV}$$
$$E_4 = -49\text{ dBc} = -44\text{ dBm} = 39.81\text{ nW} = 1.411\text{ mV}$$
$$E_5 = -36\text{ dBc} = -31\text{ dBm} = 794.3\text{ nW} = 6.302\text{ mV}$$

then,

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

NOTE Alternate Method

You can use the analyzer’s built-in harmonic distortion measurement capability: Press **Measure**, **Harmonic Distortion**.

7 Measuring Noise Signals

There are several ways to measure noise power. This chapter provides the following examples:

- "Measuring Noise at a Single Frequency" on page 50

  This example uses the marker noise function. In this example, you must pay attention to the potential errors due to a discrete signal (spectral components). This measurement uses the analyzer's 50 MHz reference signal.

- "Measuring Signal-to-Noise Levels" on page 52

  For this measurement, the signal (carrier) is a discrete tone (the 50 MHz amplitude reference signal).

  If the signal is a carrier that is modulated under normal operation, you can use the amplitude reference signal as the signal of interest and the noise of the analyzer for the noise measurement. In this example, however, you set the input attenuator such that both the signal and the noise are well within the calibrated region of the display.

- "Measuring Total Noise Power" on page 53

  This example uses markers to set the frequency span over which you measure power. Markers enable you to select and measure any portion of the displayed signal. The analyzer sets the sample display detection mode, but you must set all other parameters.

Measuring Noise at a Single Frequency

This example uses the analyzer's 50 MHz reference signal, and the analyzer's marker noise function.

1. With nothing connected to the RF input, preset the analyzer and set:

    - Attenuation 40 dB
    - Center Frequency: 49.98 MHz
    - Span: 100 kHz

2. Turn on the analyzer's 50 MHz amplitude reference signal:

    Press **Input/Output**, **Input Port**, **Amptd Ref (f=50MHz)**.

3. Activate the noise marker: Press **Mkr Fctn**, **Marker Noise**.

    Note that the display detection changes to Avg; the marker floats between the maximum and the minimum noise. The marker readout is in dBm(1Hz) or dBm per unit bandwidth (see Figure 7-1 on page 51).

    For noise power in a different bandwidth, add $10 \times \log(BW)$. For example, for noise power in a 1 kHz bandwidth, add 30 dB ($10 \times \log(1000)$) to the noise marker value.

4. To reduce the variations of the sweep-to-sweep marker value, change the sweep time to 3 seconds: Press **Sweep**, **3**, **s**.

NOTE Noise measurements are noisy. Increasing the sweep time enables the average detector to average over a longer time interval, thus reducing the variations in the results.

5. The noise marker value is based on the mean of 33 trace points centered at the marker. With a total of 601 points across the entire trace, the 33 points cover approximately half of a division.

    To see the effect, press **Marker** and use the knob to move the marker to the 50 MHz signal.

    The marker does not go to the peak of the signal because not all 33 trace points are at the peak of the signal.

6. Widen the resolution bandwidth to 10 kHz: Press **BW/Avg**, **1**, **0**, **kHz**.

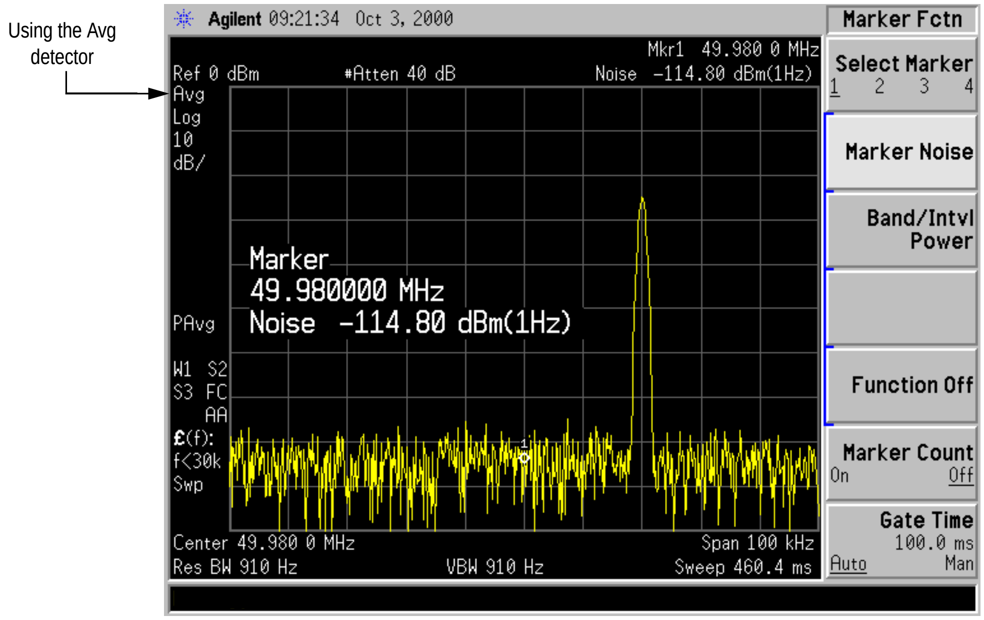
7. Again press **Marker** and move the marker to the signal.

    The 33 trace points still cover over 0.55 divisions, but the signal level is close to constant over this range, so the marker is closer to the peak of the signal.

8. Return the resolution bandwidth to automatic mode:

   Press **BW/Avg**,**Res BW** (until **Auto** is underlined).

Figure 7-1 Activating the Noise Marker



9. Press **Marker** and use the knob to place the marker at 49.99625 MHz to measure the noise very close to the signal.

   Note that the marker reads an incorrect value, because some of the trace points are on the skirt of the signal response.

10. Set the analyzer for zero span: Press **SPAN**, **Zero Span**, **Marker**.

    Note that the marker value is now correct.

Measuring Signal-to-Noise Levels

This example uses the analyzer's 50 MHz amplitude reference signal.

1. Preset the analyzer, then set:

• Reference Level:	–10 dBm	• Center Frequency:	50 MHz
• Attenuation	40 dB	• Span:	1 MHz

2. Turn on the analyzer's 50 MHz amplitude reference signal, as described on page 50, in Step 2.

3. Place a marker on the peak of the signal, then place a delta marker in the noise at a 200 kHz offset: Press **Marker**, **Delta**, ⇑, ⇑, **kHz**.

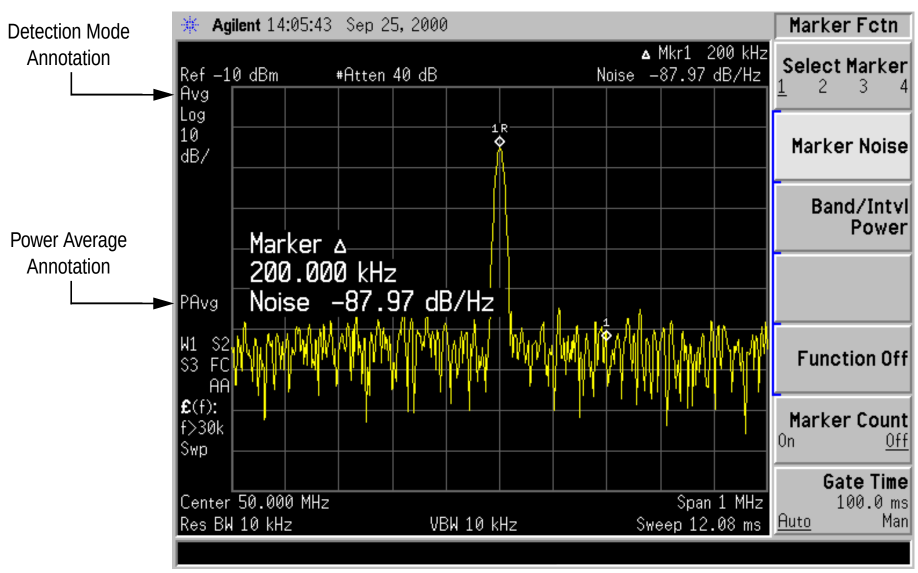
4. Turn on the marker noise function: Press **Mkr Fctn**, **Marker Noise**. This lets you view the results of the signal-to-noise measurement (Figure 7-2).

   Read the signal-to-noise in dB/Hz, which is the noise value determined for a 1-Hz noise bandwidth. For noise value at a different bandwidth, increase the ratio by $10 \times \log(BW)$. For example, if the analyzer reads –70 dB/Hz, but you used a channel bandwidth of 30 kHz: $S/N = -70dB/Hz + 10 \times \log(30kHz) = -25.2dB/30kHz$

   Note that the detection mode is now Avg, and that the power average (PAvg) display function is selected.

NOTE If the delta marker is within one-half a division of the response to a discrete signal (in this case, the amplitude reference signal), there is potential for measurement error.

Figure 7-2 Measuring the Signal-to-Noise



Measuring Total Noise Power

You can use markers to set the frequency span over which you measure power. Markers enable you to select and measure any portion of the displayed signal. The analyzer selects the average display detector, but you must set all other parameters.

1. Preset the analyzer, then set:

• Reference Level:	–20 dBm	• Center Frequency:	50 MHz
• Attenuation	40 dB	• Span:	100 kHz

2. Set the marker span to 40 kHz:

   Press **Marker**, **Span Pair** (until **Span** is underlined), **4**, **0**, **kHz**.

NOTE

Alternate Methods

You can also use **Delta Pair** to set the measurement start and stop points independently (as described on page 8).

   The resolution bandwidth should be about 1 to 3% of the measurement (marker) span (which is 40 kHz in this example). The analyzer's default resolution bandwidth is approximately 1 kHz.

3. Measure the power between markers:

   Press **Mkr Fctn**, **Band/Intvl Power**.

   The analyzer displays the total power between the markers, as shown in Figure 7-3 on page 54.

4. Add a discrete tone (the analyzer's 50 MHz amplitude reference signal) to see how it affects the reading (also see Figure 7-4 on page 54):

   Press **Input/Output**, **Input Port**, **Amptd Ref Out (f=50MHz)**

5. Move the measured span:

   Press **Marker**, **Span Pair** (**Center** underlines).

   Then use the knob to exclude the tone and note reading.

Figure 7-3 Viewing Power Between the Markers

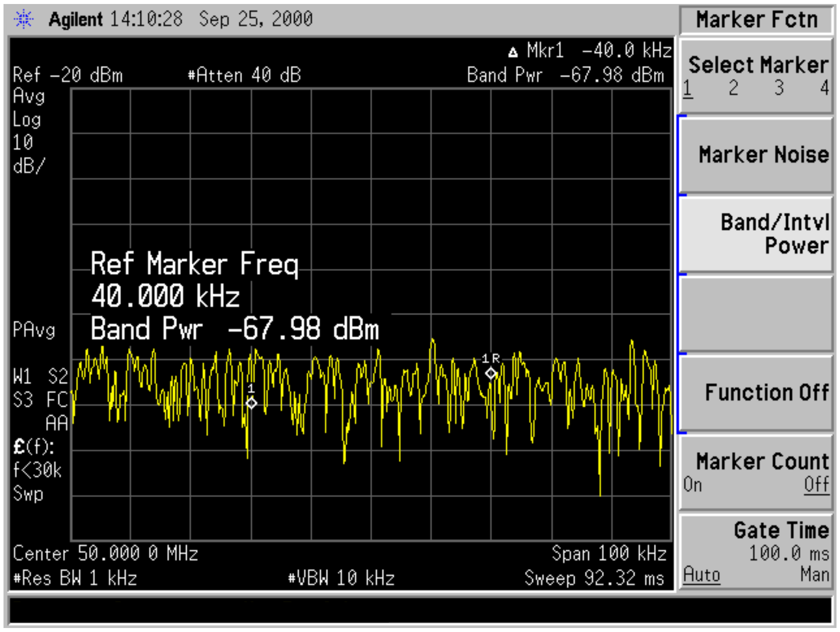
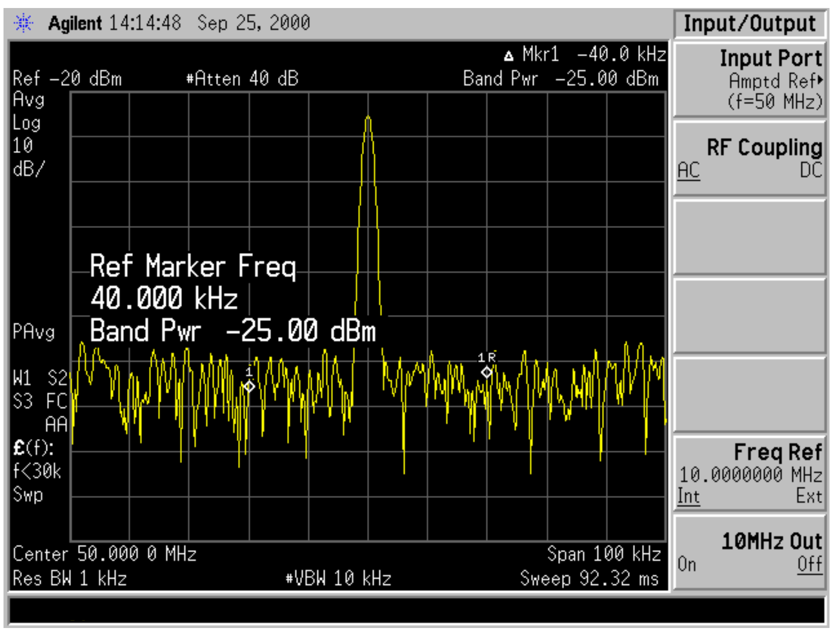


Figure 7-4 Viewing the 50 MHz Signal Between the Markers



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