
Frequency and Time-Selective Power Measurements with the HP 89400 Series Vector Signal Analyzers

Product Note 89400-1

When you need to measure the power of signals or noise, the HP 89400 Series vector signal analyzers (VSAs) offer several unique advantages over other types of instruments. Excellent level accuracy, true RMS power detection, and precise noise bandwidths combine to produce exceptionally accurate power measurements. Accuracy is coupled with advanced features such as time-gating, arbitrary resolution bandwidth, and band-power markers to create an instrument that performs complex power measurements with unprecedented versatility and ease. Such versatility is essential for measuring the power of time-varying signals found in communication and video applications.

Limitations of Traditional Instruments

You may have used power meters, voltmeters, noise figure meters, or oscilloscopes to measure power. These instruments are adequate for many types of signals but they also have several limitations including inadequate dynamic range, accuracy, or both. In addition, these instruments are not frequency selective—they only provide a reading of the total power across the instrument's entire bandwidth. A vector signal analyzer's frequency selectivity not only allows you to measure the power at one frequency, but by measuring the noise over a frequency band, it allows you to determine the "shape" of the power in the frequency domain. For example, frequency selectivity and dynamic range allow you to measure noise power independently from signals that may accompany the noise.

Traditional swept spectrum analyzers are frequency-selective and have excellent dynamic range, but, when it comes to measuring noise power, they have distinct disadvantages. First, the analog detectors found in most swept spectrum analyzers are designed

to measure the spectral components of deterministic signals, not random noise. When measuring random noise, a correction factor must be applied to the analyzer's displayed noise level. Second, traditional swept spectrum analyzers have analog resolution bandwidth (RBW) filters that typically have a bandwidth accuracy of $\pm 20\%$. When you make noise-power measurements with these analyzers and calculate the noise-power bandwidth using the nominal value of the RBW (or use the built-in noise level function), errors of up to 1 dB will result. Third, after the signal is detected, a swept spectrum analyzer normally implements some type of peak detection to ensure that the peak of a signal will always be displayed. The average value of peak-detected noise is biased, so most swept spectrum analyzers will allow you to turn peak detection off by selecting a "sample" detector mode. However, with a sample detector the level of a single tone cannot be measured accurately.

VSAs Overcome Traditional Constraints

Vector signal analyzers do not have these constraints. In vector mode, these analyzers accurately digitize the signal and then calculate the frequency spectrum using the fast Fourier transform (FFT). You can measure the power of the signal in either the time domain or the frequency domain. The FFT calculation results in the true RMS power of the signal whether it is a single tone, noise, or any complex signal. In addition, the noise-power bandwidth at each frequency is the same as the RBW which is precisely known and repeatable. Finally, there is no need for peak detection and the signal can be averaged without biasing the results. In scalar mode, the VSA implements very narrow RBWs by performing several stepped FFTs and there may be more information than can be displayed and stored. In this case a data reduction or detection must occur (several detector schemes are provided). For noise measurements in scalar mode, use the sample detector.

The FFT algorithm also gives the VSA an advantage when it comes to measurement speed. In vector mode, the HP 89400 Series VSAs are typically tens to hundreds of times faster than traditional swept spectrum analyzers at a given frequency span and RBW setting. This speed advantage is significant if you want to reduce the variance in your noise-power measurement by averaging hundreds or even thousands of measurements.

Basic Noise Measurements Made Simple

The noise level measured by a signal analyzer is directly proportional to the analyzer's RBW setting. Often, you will want to normalize the measurement to a 1-Hz bandwidth by dividing the measured noise level by the noise-power bandwidth of the RBW setting. The HP 89400 Series VSAs make this normalization easy by having precisely known, repeatable noise bandwidths. Moreover, when you select the power spectral density (PSD) measurement data, the entire trace is normalized for you. Figure 1 depicts a PSD measurement (with 1000 averages) performed using the HP 89410A. Rotating the knob moves the marker along the trace and displays the normalized power at each frequency point.

You can normalize the noise power to a bandwidth other than 1 Hz, or integrate power over a range of frequencies, by using the band-power markers to select the frequency band of interest. The HP 89400 Series VSAs calculate the total power in the selected frequency band and display the result in the lower, left-hand corner of the display. In figure 2, the HP 89440A was used to measure noise power in a frequency band near a carrier.

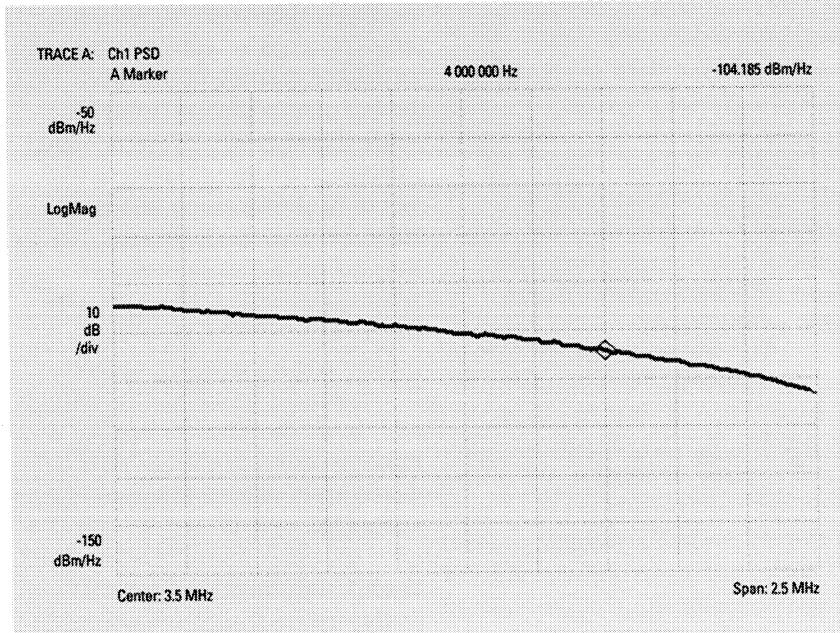


Figure 1 — Select the PSD measurement data to display the power density of the signal as a function of frequency. The trace data and marker readout are automatically normalized to 1 Hz.

Time-Variant Measurements Made Easy

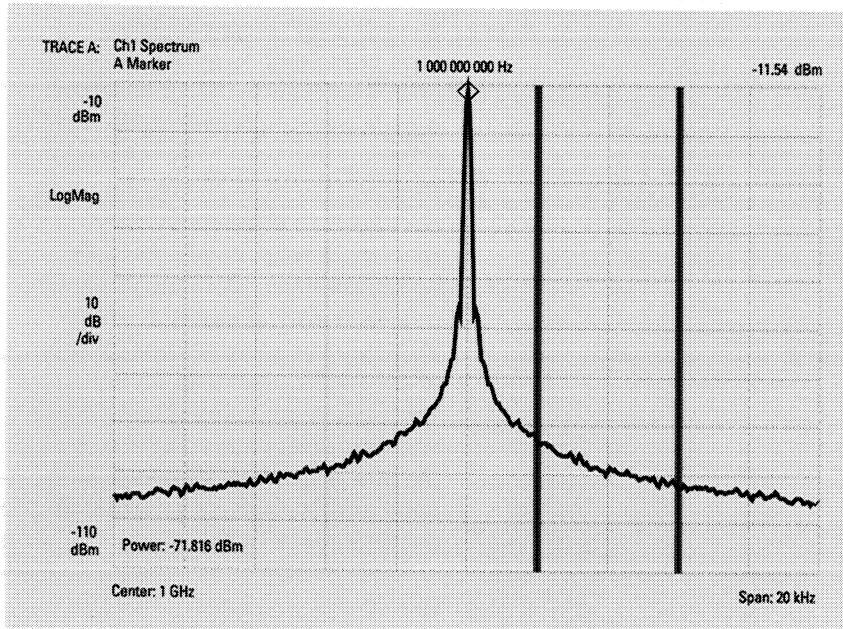


Figure 2 — Use the band-power markers to calculate the total power in a user-selected frequency band.

To perform carrier-to-noise or signal-to-noise measurements, use the main marker to measure the signal power, and use the C/N or C/No band-power markers to select the frequency band of interest, as shown in figure 3.

The C/N marker function calculates and displays the total power in the selected frequency band relative to the signal power. The C/No marker function normalizes the power in the band to a 1-Hz bandwidth.

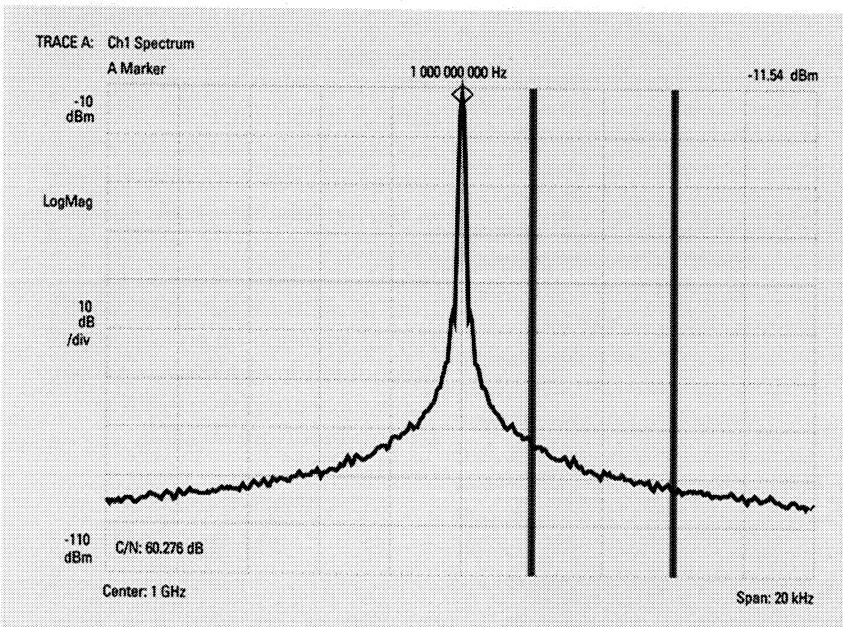


Figure 3 — The C/N and C/No band-power markers display the power in the band relative to a signal.

In many of today's applications, the signals that need to be measured are not stationary but are time-varying, burst or transient. In these applications the most significant attribute of the HP 89400 Series VSAs is the ease in which they make time-selective measurements. They capture your burst or transient signal, let you examine the entire time-record, and then let you select the portion of the signal you are interested in for further analysis. All the features mentioned previously can be used to measure the power of the selected portion of the time-record. If the signal is recurring, then a variety of triggering modes allow you to make averaged power measurements.

You may want to use the time-record of the signal to determine the peak instantaneous power or to calculate the RMS power of the signal over a specific period of time. You should enable the VSA's time-domain calibration when you are making time-domain measurements. The displayed time-record is a filtered version of the input signal that only includes the spectral energy within and near the VSA's measurement span. For time-domain measurements, the 3-dB bandwidth of the VSA is 12 to 17 percent greater than the VSA's frequency span. In figure 4 the HP 89440A was used to capture a time-division multiple access (TDMA) signal as the transmitter was turned on. The selected data format is linear magnitude. This measurement is similar to a zero-span measurement with a swept spectrum analyzer or to a peak power meter measurement. Band-power markers select the portion of the time-record over which the power is calculated. Moving the band-power markers along the trace will reveal how the power changes as a function of time.

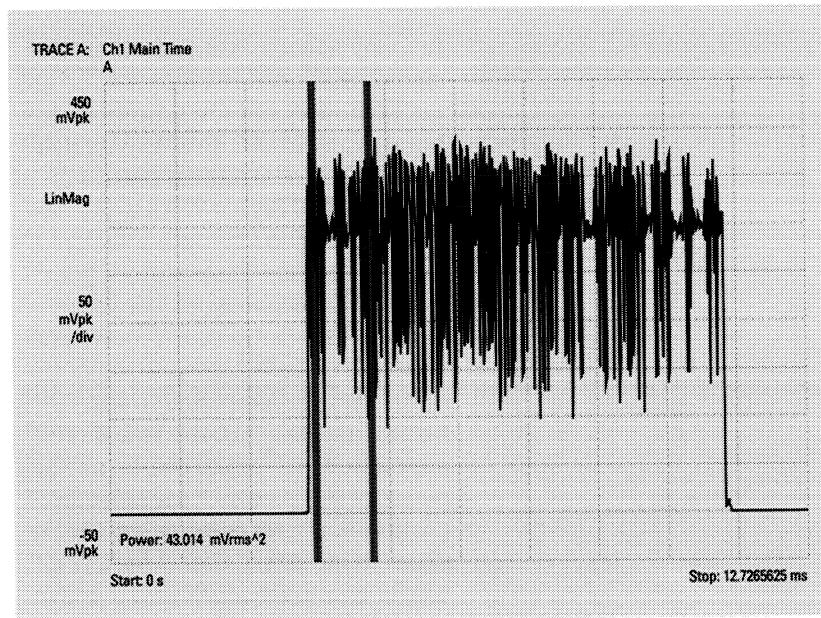


Figure 4 — Use time-domain band-power markers to calculate the power over a selected portion of the time-record.

Suppose you want to measure the power in a frequency band adjacent to the TDMA transmission, but only while the transmitter is on. In figure 5, time-gate markers in the upper trace select the portion of the time-record corresponding to the "on" time. The lower trace displays the frequency spectrum of the

selected portion of the time-record. The band-power markers in the lower trace calculate the noise power in a 30-kHz band centered 30 kHz away from the center frequency. You can simulate the response of a receiver by using Trace Math to apply your own filter shape to the measured data.

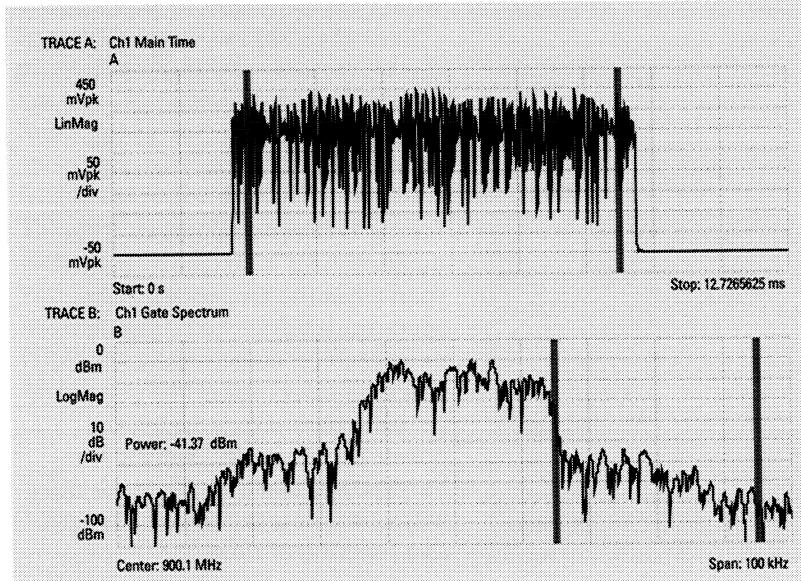


Figure 5 — Time-gate markers select the desired portion of the time-record to use for further analysis.

The HP 89400 Series VSAs perform complex power and noise-power measurements of baseband signals with unprecedented accuracy and ease. You can use the VSA's inherent frequency selectivity to measure power spectral density, band power, or carrier-to-noise. With the unique time-selective capabilities of the VSA, you can measure peak power or the RMS power over a burst. You can even combine frequency and time-selectivity to measure the power in a specific frequency band during a selected portion of the time-record.

But what if you want to measure the power of a signal that is modulating a carrier? The modulating signal may consist of intentional modulation and unintentional modulation such as noise. With most other instruments you have to externally demodulate the carrier before the modulating signal can be measured. However, the HP 89400 Series VSAs will analyze amplitude-, frequency-, and phase-modulated signals directly in both time and frequency domains. When you select the desired demodulation mode, the VSA mathematically demodulates the carrier and creates a time-record of the modulating signal. All the power measurement features that have been illustrated here can be used to measure this time-record. For information on an important demodulation application, phase noise measurements, refer to HP Product Note 89400-2 (5091-7193E).