# Agilent PN 89400-5

# Measuring Transmitter Transients with the 89400 Series Vector Signal Analyzers

Product Note


*Understanding and controlling the transient behavior of transmitters has become increasingly important with the introduction of TDMA and spread spectrum systems. In these systems and others, the carrier power is continuously changing in order to maximize spectrum utilization and conserve battery power. The transients that occur because of changes in carrier power and frequency can cause interference to other stations. Unsettled carriers can also cause high bit-error rates.*

*The Agilent Technologies 89400 Series vector signal analyzers (VSAs) can capture a single transient event and repeatedly analyze it in the time, frequency, and modulation domains. Phase, frequency, and amplitude transients, or transitions, can be viewed directly. Also, the spectrum can be displayed simultaneously with the transient displays, providing a unique look at the relationships between transients and spectrum occupancy. One of the analyzer's unique features, overlap processing, allows captured transients to be played back in "slow motion" for easier analysis.*


**Capturing the Transient**

Before a transient can be analyzed, it must be captured into the analyzer's time-capture buffer. Only the raw time-data is held in memory; the final processing of the data into a measured result is performed after the capture process is complete. Because the raw data is always available, many different types of analysis can be performed on the same transient event. These include calculating the spectrum, instantaneous power, phase, amplitude, or frequency deviation versus time, to name a few. The time-capture buffer can also be stored to disk, allowing the analysis to be performed later, at a more convenient time and location.

There are three steps to capturing data. The first is to select a center frequency and span. The span must be wide enough to allow all of the transmitter's power to be measured, yet narrow enough to prevent interference from other signals that might be present (such as another station). The VSA's information bandwidth (span) can be adjusted with nearly infinite resolution. Setting the span automatically band limits the analysis.

The second step is to select the amount of data to be captured. The length of the time-capture buffer is a function of span, the number of input channels enabled, and the amount of capture memory installed in the instrument. The standard time-capture buffer can hold up to 65K samples. On a 5-MHz span with one channel enabled, this allows roughly 10 msec of data to be captured. Decreasing the span by a factor of two doubles the length of the capture buffer in seconds. Option AY9 increases the capture memory length to 1M sample.

The final step in capturing the transient is to select the type of triggering and an appropriate amount of trigger delay. The IF trigger is the most convenient for transmitter measurements because it allows the measurement to be triggered on a change in transmitter power level. The trigger delay is typically set to a negative number so the measurement is pre-triggered. The use of pre-trigger delay allows events leading up to the transient to be included in the analysis, and provides for settling in the overlapped measurements described later.

**Power Transients**

Instantaneous power measurements are one of the most common measurements made today. The measurement is made to find the peak power in a digitally modulated signal, to set signal levels into the power amplifier, or to test a transmitter pulse against an amplitude mask found in a communication standard.

Traditionally, instantaneous power measurements were made with a swept spectrum analyzer in zero-span mode or with a peak power meter.

Measurements made by the Agilent 89400 Series VSAs closely resemble a zero-span measurement because the power measurement is made over a finite bandwidth. In the case of the swept analyzer, the bandwidth is set by the selected RBW filter. In the VSA the span determines the information bandwidth. By combining excellent level accuracy, true RMS power detection, and precise noise bandwidths, the VSA produces exceptionally accurate power measurements.


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To display instantaneous power as a function of time, simply select the measurement data type of *main time* (in vector mode) and set the data format to display the trace in *log magnitude* coordinates. A variety of engineering units are available, the most common being dBm or watts. Once displayed, markers measure instantaneous and peak power. Offset markers can determine rise-time, overshoot, and settling. In addition, the RMS power over a selected portion of the time record can be computed using band-power markers.

Figure 1 shows an example of a power measurement made on a small hand held FM transmitter. The marker is displaying the peak power in watts. The band-power markers show the RMS power over the latter part of the transient (annotated at the bottom of the screen). The top traces in Figures 2 and 3 also show power transients.

**Frequency Transients**

When a transmitter changes power levels, the carrier frequency should remain stable. If a frequency change is intentional, as in a change of channels, the carrier should not overshoot its intended frequency, and should settle quickly to its final value. Traditionally, measuring instantaneous frequency versus time has been performed using time interval analyzers.

There are three major differences between time interval analyzers and the 89400 Series VSAs. First, time interval analyzers are broadband instruments. Unless external filters are added, the time interval analyzer is subject to more noise power as well as contamination from other signals. Since the information bandwidth of the vector signal analyzer is determined by the span, other signals (such as an adjacent carrier) can be easily removed from the measurement. Also, as the span is narrowed, the total amount of noise power in the measurement decreases allowing improved frequency resolution. The RF VSA provides band-limited measurements with a maximum span of 7 MHz. Frequency transitions greater than 7 MHz cannot be completely analyzed from start to finish, but the final setting can be observed with the VSA. Time interval analyzers can characterize frequency transitions greater than 7 MHz directly. The second major difference between time interval analyzers and VSAs is sensitivity. The VSAs' increased sensitivity makes measurements easy without physically connecting the instrument to the transmitter. Good sensitivity and excellent frequency selectivity make off-the-air transient measurements very easy to perform.

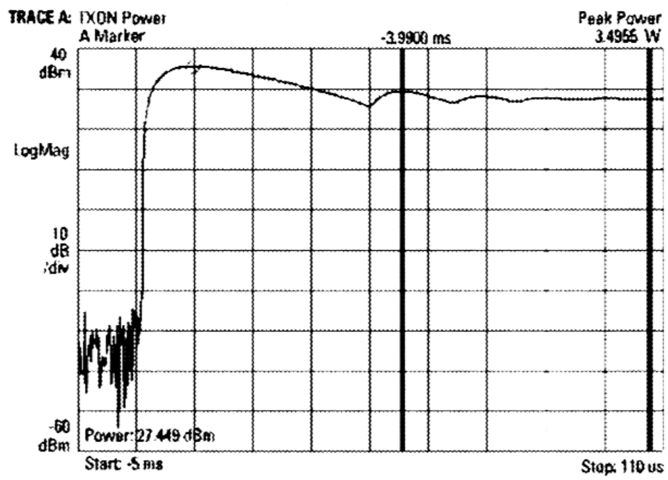


**Figure 1. Power during a transmitter's turn-on transient. The marker indicates the peak power level. The RMS power during the time interval between the two cursors is shown in the lower left-hand corner.**

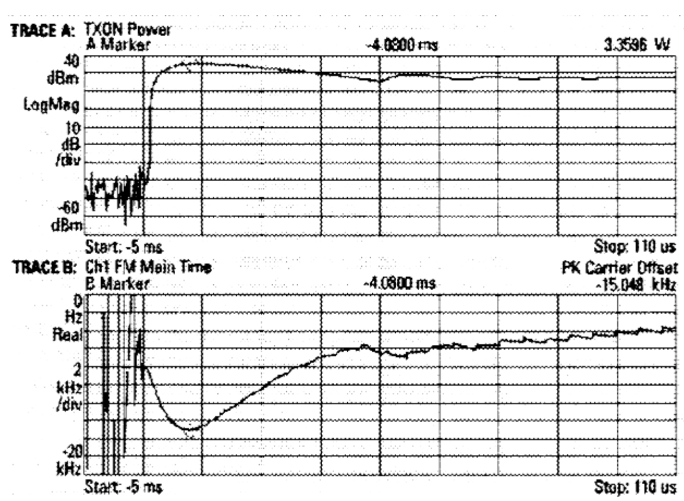


**Figure 2. The lower trace shows frequency deviation of the carrier over time. Note that the carrier power (upper trace) is stable long before the carrier frequency.**

The third major difference is the manner in which the information is extracted from the signal. The time interval analyzer uses counter technology which is based on the detection of zero crossings in the measured signal. In the VSA, the FM demodulator is a true demodulator, implemented as a DSP algorithm. The algorithm is insensitive to any AM which may be present on the signal.

To measure frequency transients with the VSA, the instrument mode is changed to demodulation and an FM demodulator selected. The measurement data is the *main time* record with *real* trace coordinates. The auto-carrier detector should be disabled so that the displayed frequency is relative to the center frequency of the measurement. The time record will show carrier frequency deviation versus time.

The VSA makes it possible to observe the interaction between instantaneous power and instantaneous frequency—something no other instrument can do. Figure 2 shows how data registers make it possible to simultaneously view results from previous measurements, such as the power measurement described earlier, with the current result which is based on the same raw data.

As with the power measurement, markers can be used to determine peak and RMS frequency, as well as frequency overshoot and settling.

### Phase Transients

After a change in carrier power, the carrier phase must settle before digital data transmission can begin. The traditional way of measuring phase transients, although relatively straightforward, usually provides uncalibrated results that can be difficult to interpret. The measurement technique involves using a mixer and a reference source to mix the measured signal to dc, so the phase difference between the two signals can be observed observed by an oscilloscope. This technique has the limitation of requiring that the reference signal and measured signal a common frequency reference. Also, if the measurement is not properly set up, the display on the oscilloscope is difficult to interpret.

The VSA measures instantaneous phase over time through the use of a phase demodulator implemented as a DSP algorithm. For transient measurements, it’s best for the instrument and the measured signal to share a common frequency reference, though it's not absolutely necessary. If a frequency reference is shared, then the measurement center frequency should exactly match the carrier frequency and the auto-carrier detect mode set to *phase-only*.

The phase measurement is performed by setting the instrument mode to demodulation and selecting a PM demodulator. The measurement data is in *main time*, and can be viewed with the data format set to *real* or *phase* (wrap or unwrap). The results are displayed in units of degrees or radians versus time.

As with the FM demodulator, the phase resolution is a function of span. The narrower the span, the better the resolution.

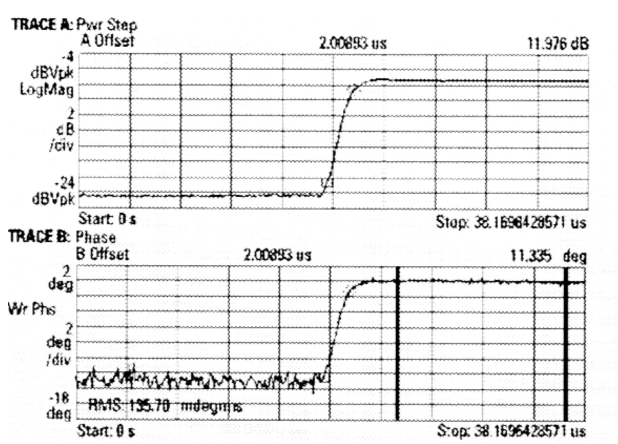


**Figure 3. Phase settling (lower trace) of a carrier undergoing a change in power level (upper trace).**

Figure 3 shows the phase settling of a carrier undergoing a change in power level. The upper trace shows the carrier power; the lower trace, instantaneous phase. Notice how the change in power level causes a 13-degree shift in phase.

As with the other modulation measurements, markers can be used to measure peak-phase error, phase settling time, or the RMS phase over a specified time interval. The band-power markers show the RMS phase noise after the carrier-power level has settled at 0.136 degrees.

### Overlap Processing for Transient Analysis

It is often important for a designer to understand how a specific transmitter transient affects the occupied bandwidth of a carrier. In other words, which transients are most likely to cause interference on adjacent channels? For example, is spectral splatter caused by the turn-on power transient or a phase transient that occurs at the start of data transmission? Using the overlap processing capability of the VSA, it is possible to observe the effects of various transients in the signal to determine how the spectrum changes with time.

The best way to understand this measurement is to imagine the same signal being applied to a parallel bank of several hundred (or thousand) bandpass filters. Each filter has the same bandwidth, but a slightly different center frequency. The output of each filter is detected and then sampled. At each point in time, the collection of output samples is used to create an estimate of the power spectrum. Each filter is designed with a narrow bandwidth to provide the necessary frequency resolution, and a short, well behaved impulse response to provide adequate time resolution.

This measurement could be made with a swept spectrum analyzer configured for zero-span operation. As described, the measurement requires compiling the results of 400 zero-span measurements, each at a slightly different frequency, into a single result. Obviously, the device being measured needs to generate the same transient 400 times—once per measurement. The VSA generates the same result, in one measurement of a single transient.

To make the measurement using the VSA, the analyzer is configured for vector mode operation with overlap processing. Overlap processing is a term that describes the analyzer's ability to process, overlapping blocks of time-domain data. Normally, the percentage of overlap used for this measurement is close to the 99% limit. This means each display update uses 99% old data plus 1% new data, allowing more spectra to be generated from the transient, which improves resolution.

Compared to the parallel filter example, here's how the various measurement setup parameters affect the result. The impulse response is determined by the selected FFT window. The best window to use is the Gaussian-top window. The length of the impulse response is simply the length of the time record used in the measurement. Set this directly (in the time menu), or indirectly by setting the RBW. The percent of measurement overlap corresponds roughly to the frequency at which the output of the filters is sampled. As the percentage of overlap increases, more spectrums are computed for a given amount of time data in the time-capture buffer.

The overlapped measurements on a time-capture buffer can produce hundred or thousands of spectrum measurements. The Agilent 89400 Series VSAs can display these measurements in several different ways. The simplest approach is to show the measurements one after the other using a standard spectrum display. Each measurement is like a frame in a movie, with the overall effect of a slow motion picture of the rapidly changing spectrum. With option AYB, multiple spectrum measurements can be viewed on a single grid in a *waterfall* or *spectogram* display. Each row of pixels in the spectrogram shown in Figure 4 corresponds to a spectrum measurement. The intensity (or color) of the pixel is determined by the amplitude of the spectrum at the frequency indicated by the horizontal axis.

**Summary**

Until now, transient measurements have been difficult to make or have required several different instruments. The 89400 Series VSAs make all of these measurements with one instrument—easily and with a high degree of accuracy.

The Agilent 89400 Series VSAs' time-capture capability can capture a single transient and analyze it in a variety of ways. It is no longer necessary to put the transmitter in a special test mode to provide the instrumentation with repeated signal access.

Excellent sensitivity and selectivity along with frequency coverage to dc allow measurements at any point in the transmitter's block diagram—from the baseband modulation data, to local oscillators, to off-the-air measurements of the transmitted signal.

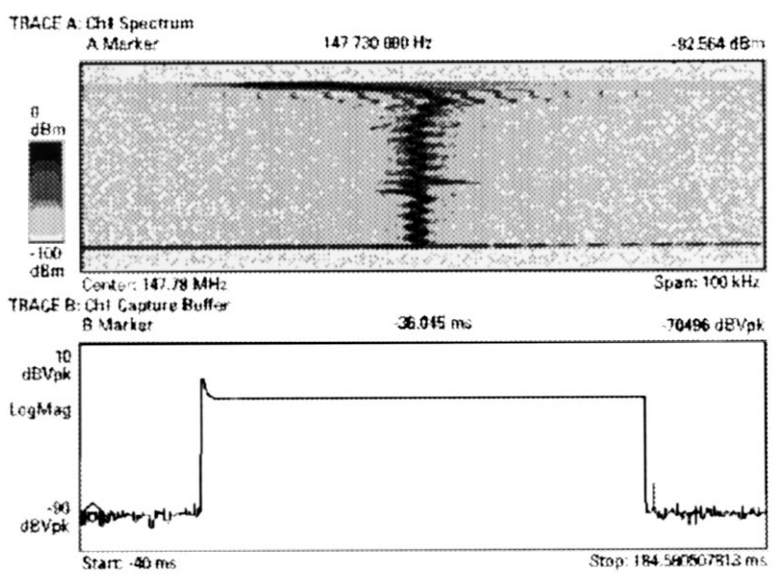


**Figure 4. A spectrogram can be used to simultaneously display several hundred overlapped spectrum measurements. Note the frequency instability and sidelobe structure when the transmitter is first turned on (top of the spectrogram). Also note the mid-burst transient which is not apparent in the time-capture buffer (lower trace).**

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