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Evolution of Broadband Signal Measurement and Analysis

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The author describes how signal measurement has progressed from basic spectrum analysis to a combination of frequency and time domain analysis, including modulation

The bandwidth of signals has grown very quickly over the years, challenging the ability to effectively measure and analyze them. Traditionally, swept tuned spectrum analyzers have been used to measure bandwidth, amplitude, sidebands and harmonic distortion. In many cases this is all that is required to characterize a signal. The information from these measurements can then be viewed in several ways such as spectral density and spectral regrowth.

What is missing from the swept tuned measurements is the ability to analyze the information contained within these bandwidths. In order to analyze the information, the signal must be digitized at a high enough rate to capture the highest frequency component within the band. The challenge is to analyze these signals, which are also broadband in nature, at high center frequencies. Within this challenge is the issue of calibration over the bandwidth to insure the best possible system error vector magnitude performance.

Swept Tuned Measurements

Swept tuned measurements have been made for many years, and with the greatly improved computational power of newer spectrum analyzers, much information can be obtained about wide bandwidth signals. Channel power, occupied bandwidth, spectral density, adjacent channel power, multi-carrier power, power statistics (CCDF), harmonic distortion, and TOI can easily be measured.

The block diagram in Figure 1 shows a wideband signal being measured with a swept tuned spectrum analyzer. A ramp voltage is applied to the voltage-controlled oscillator, usually a YIG oscillator, and the oscillator signal is then mixed with the input signal. Whenever the difference of the input signal and the oscillator signal equals the frequency of the IF, a signal is present at the detector and a response is displayed. If the input signal is wideband then the response will also appear to be wideband.

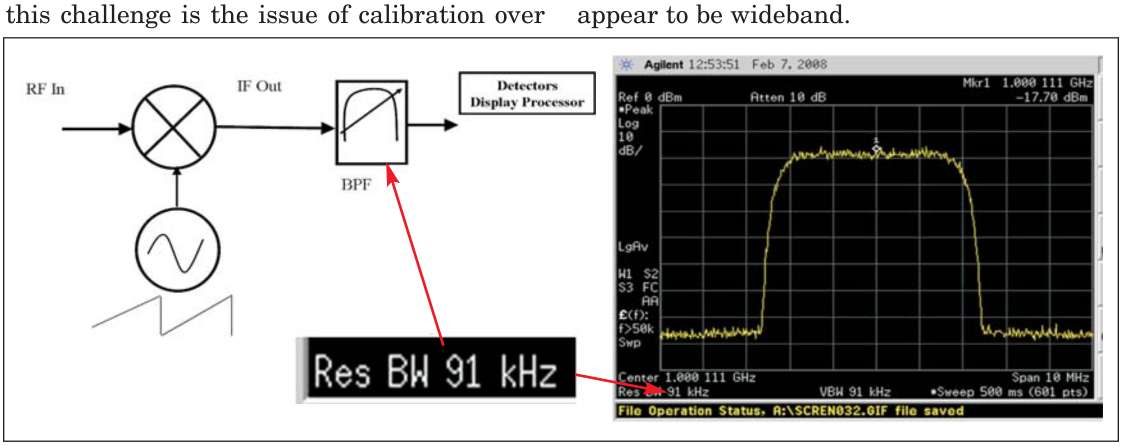

Figure 1 · Swept tuned spectrum analysis.

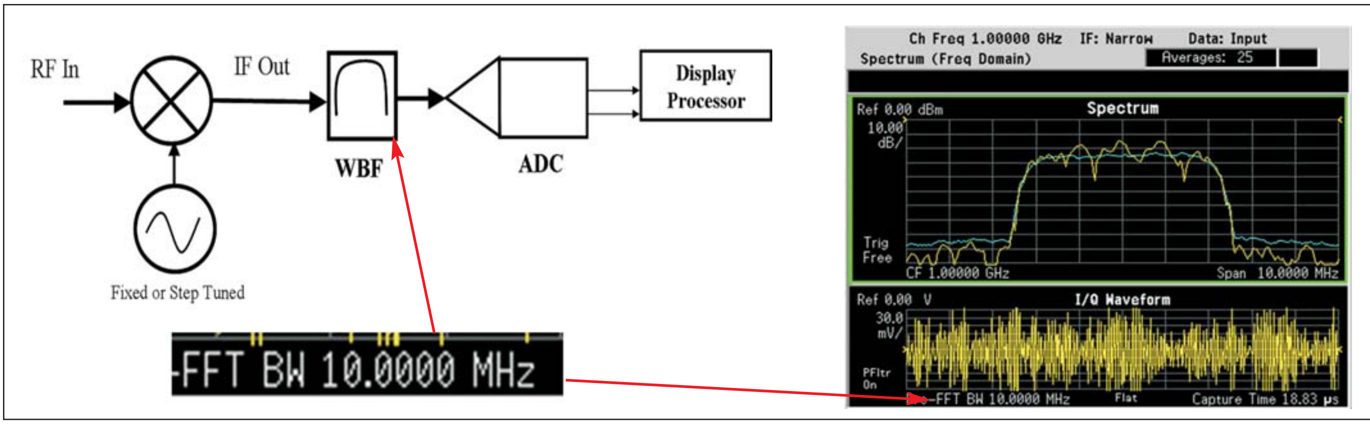

Figure 2 · Digitized data and FFT.

Wide Bandwidth Measurements

As mentioned previously, we can obtain a great deal of information about the signal. But what we do not know is the information that is contained within the wideband signal.

A different approach must be taken to extract the information within the wide bandwidth signal. Instead of making measurements in the frequency domain, we digitize the signal in the time domain and post process the digitized data. The digitizer must be fast enough to capture the highest frequency component within the band. The block diagram in Figure 2 shows a typical digitizer and post processor. The local oscillator is stepped and mixed with the incoming signal the result passes through a band pass filter then directly into the digitizer. In the post processor an FFT can be performed to view the signal in the frequency domain or, with the help of more sophisticated software, view the modulation within the digitized information. Figure 2 shows a typical digitized signal along with an FFT of the signal in the frequency domain.

The wider the bandwidth (faster data rates) the faster the digitizer must be to capture the information within the band. For example, to sufficiently capture an 80 MHz bandwidth signal a 200 MHz digitizer is required. As the signal bandwidth increases, so does the challenge of measuring it. An alternative method of measuring wideband signals at very high center frequencies is to use a down converter to translate the signal to lower frequencies. These lower frequency wide bandwidth signals then can be digitized using a high-speed oscilloscope. The digitized data can then be analyzed using vector signal analysis software. The block diagram in Figure 3 shows the interconnection of a spectrum analyzer, used as a down converter, an oscilloscope, used as the digitizer, and vector signal analysis (VSA) software residing on a PC. The spectrum analyzer down converts a wide bandwidth signal between 3 GHz and 50 GHz to 321.4 MHz. The down-converted signal is digitized using channel one on the 4 Gsa/s scope. The digitized data is then analyzed using the VSA software. The scope and the spectrum analyzer are controlled through the VSA software.

Figures 4 and 5 that follow are some examples of demodulated wide bandwidth signals, including measurements of satellite signals and linear chirp radar.

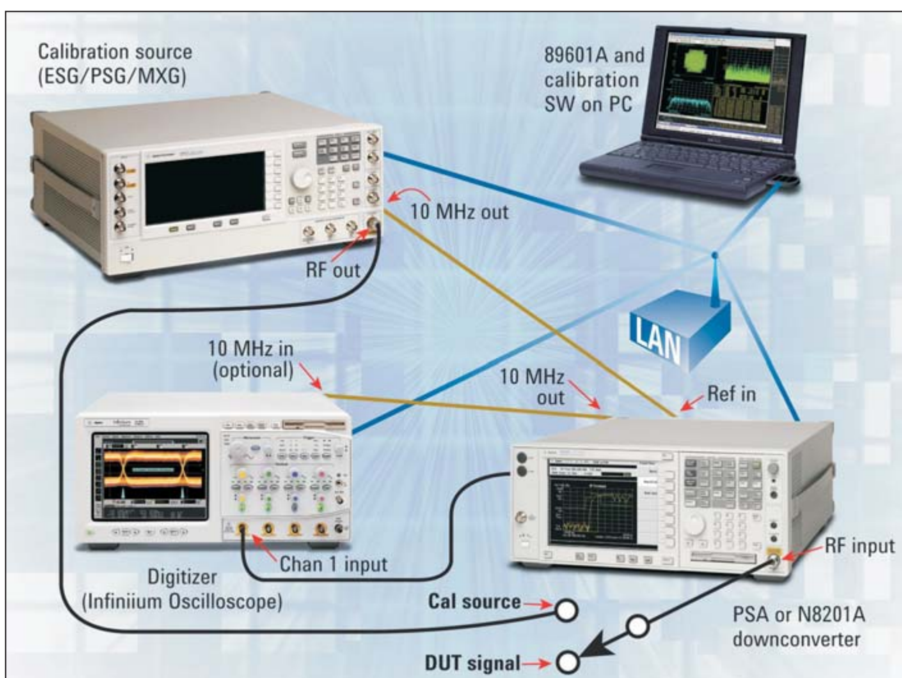

Figure 3 · Wideband measurement system.

Wide Bandwidth Calibration

When we deal with measuring signals having relatively narrow bandwidths (3 or 6 MHz), the measurement system amplitude flatness and phase linearity are very constant over the narrow band. Some calibration is still required. As the measurement bandwidth increases to wider bands (20 MHz and wider) the amplitude flatness and phase linearity of the system can affect the measurement accuracy (error vector magnitude, EVM). The goal is to measure the performance of the DUT and not the performance of the measuring system. The variations in amplitude flatness and phase linearity will add to the overall EVM measurement. The EVM of the measurement system cannot be completely removed. The system noise will add to the measured EVM. The signal-to-noise ratio (SNR) is measured and the best case EVM then can be determined as follows:

$$EVM = 10^{-SNR/20} \times 100$$

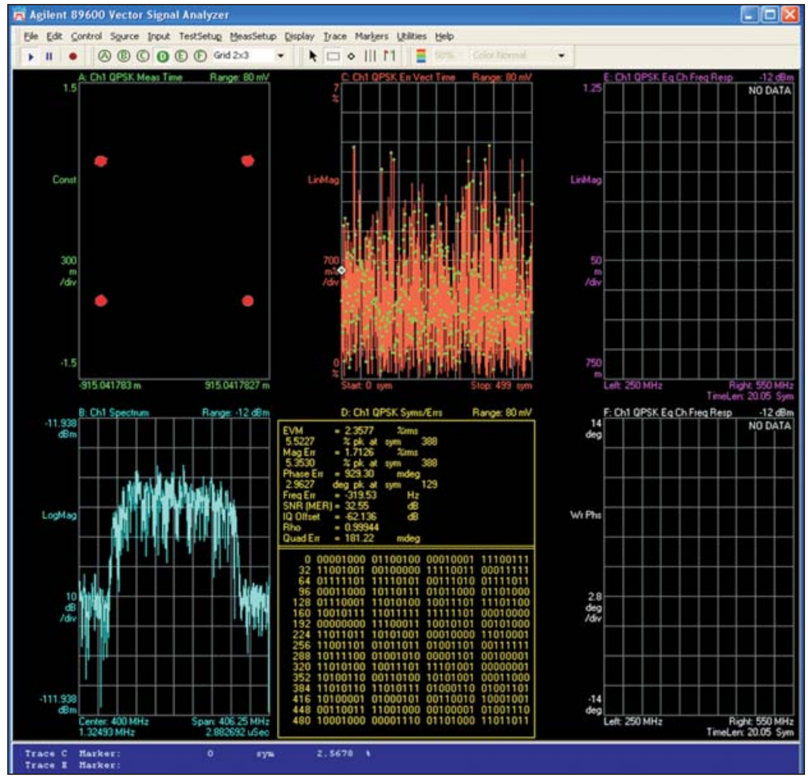

Figure 4 · Satellite signal, 300 MHz bandwidth.

Wideband Calibration

The purpose of the calibration process is to remove linear errors in the system. There are three different calibration processes used based on the bandwidth and the system configuration—a wideband calibration process internal to the spectrum analyzer and two calibration processes using an external source.

The block diagram in Figure 6 shows the wideband digitizer (200 Msa/s) and associated circuitry. The bandwidth of the digitizer is 80 MHz. The calibrator is an 80 MHz comb that is well characterized in both amplitude and in relative phase. The comb is applied to the digitizer as shown in the inner loop. The comb is then up converted to a center frequency of 300 MHz and is applied to the 3rd IF as shown in the middle loop. The comb is applied to the input which is the outer loop. The response to the comb is then measured and corrections are applied to compensate for any differences between the expected result and the measured result. The outer loop is calibrated at 300 MHz center frequency only.

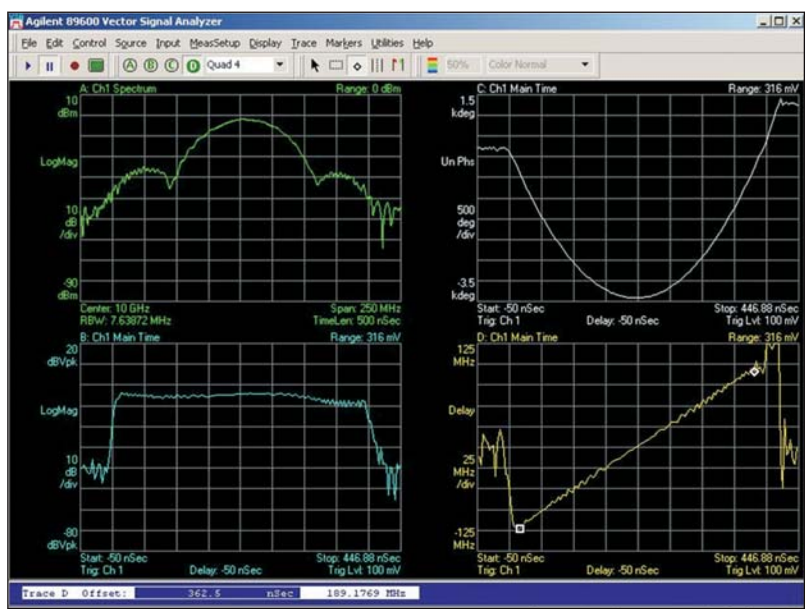

Figure 5 · Linear chirp radar.

Calibration Using an External Source

The next level of calibration is to calibrate over the 80 MHz bandwidth at the frequency that you are measuring your DUT using an external source. This method has many advantages. For example, you can compensate for amplitude and phase errors of external devices placed in front of the spectrum analyzer such as an amplifier or attenuator. Figure 7 shows a measurement system with an external amplifier and an external source connected for calibration.

Microwave spectrum analyzers incorporate a microwave preselector, which is a YIG tuned filter. Each

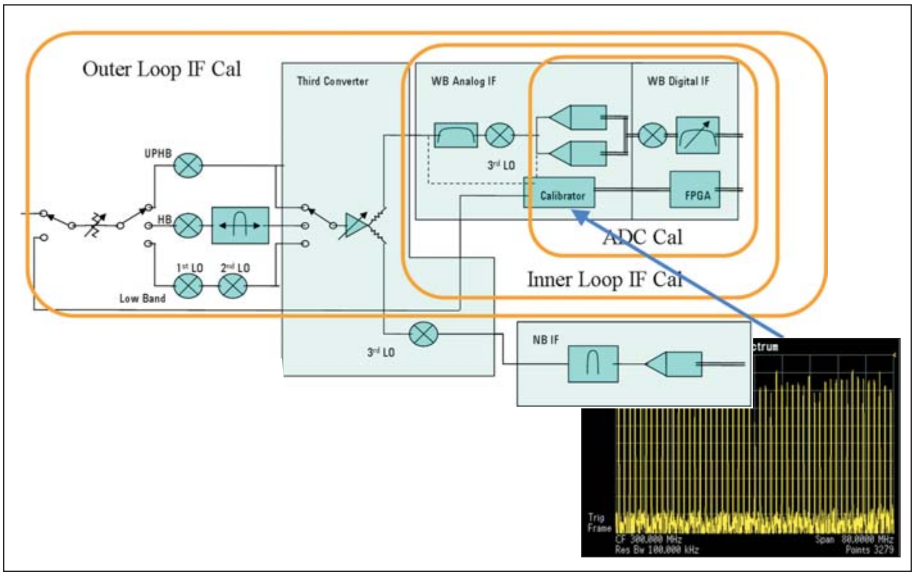

Figure 6 · Calibration process for 80 MHz information bandwidth.

time the spectrum analyzer is tuned to a different frequency the microwave preselector displays a different amplitude and phase linearity error. These errors can be compensated for by using an external source for calibration (see Figure 7).

The calibration process is automated using the extended calibration routine of the VSA software. In general the process requires that the software controls the signal source and the spectrum analyzer over LAN or GPIB. The source is connected to the input of the spectrum analyzer and time bases are tied together. Enter the frequency you wish to make measurement in the software, enter the source power in the extended calibration window. Make sure you have sufficient power to obtain a good signal-to-noise ratio. Enter the file in which the corrections will reside. The VSA software will prompt the signal source to generate a comb at the center frequency you have entered, the calibration process is then started, and a correction file is developed (see Figure 8).

300 MHz Bandwidth Measurements and Calibration

Performing 300 MHz bandwidth measurements uses a different approach. Instead of using the internal wideband digitizer of the spectrum analyzer, an external wideband digitizer is used such as a high-speed scope. In order to capture the information within the 300 MHz bandwidth a 4 Gsa/s or greater is recommended. Figure 3 shows the interconnection of the spectrum analyzer, scope (digitizer), signal source (for calibration) and a PC with the VSA software. If the scope has an internal Windows® XP operating system (Windows is a registered trademark of Microsoft Corporation in the United States and other countries.), the VSA software can reside in the scope eliminating the need of a PC. In this configuration the spectrum analyzer is used as the down converter with a maximum frequency range of 3 to 50 GHz.

A limiting factor in achieving 300 MHz bandwidth is the microwave preselector, which is part of microwave spectrum analyzers. A switch can be added to bypass the microwave preselector so that a usable 300 MHz bandwidth is available. The switch is controlled from the front panel of the spectrum analyzer or using a SCPI command. The

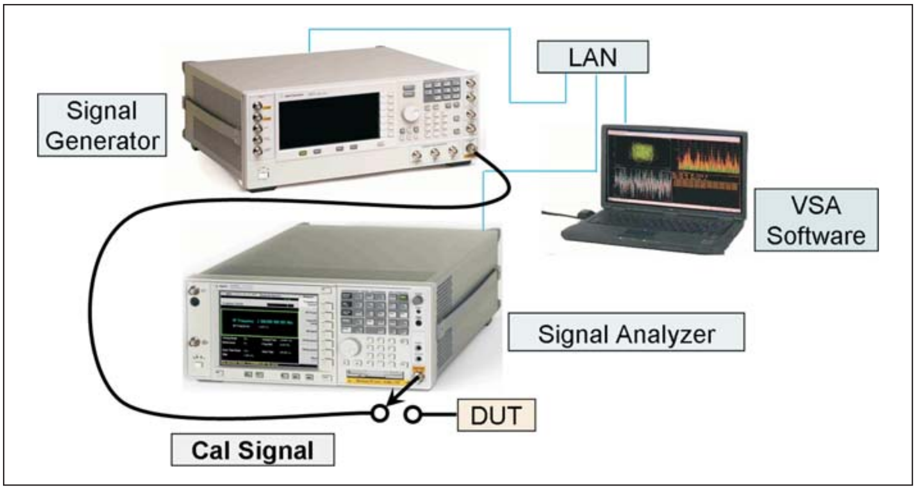

Figure 7 · Wideband calibration using an external source.

spectrum analyzer down converts the input signal to 321.4 MHz. The 321.4 MHz signal is applied to the digitizer (a high-speed oscilloscope). The digitized data is then analyzed by the VSA software.

The VSA software controls the system over LAN or GPIB. The operator selects the center frequency of the measurement and sets up the modulation format to be analyzed. The DUT is then connected to the spectrum analyzer.

Before the above measurements can be made, calibration across the band should be considered. Even though the microwave preselector is bypassed, there are amplitude and phase linearity errors caused by the down conversion process. These errors need to be corrected for. As always, the goal is to measure the performance of the DUT and not of the system.

The calibration process is also controlled by the VSA software. The operator connects the signal source and establishes the center frequency of the measurement using the VSA software and then uses the extended calibration menu to set up the signal source power. As stated earlier, a file location is identified to place the corrections. The calibration is somewhat different from the previous calibration in that the source is stepped across the band versus developing a comb. Upon completion of the calibration process an EVM of 2 to 4% can be realized.

Performing Measurements On Signals Greater than 300 MHz

Measuring signals with bandwidths greater than 300 MHz requires a different approach. If the center frequency of the signal is below 13 or 14 GHz a 40 Gsa/s high-speed scope along with VSA software will allow the digitization and analysis of very wide band signals. For wideband signals greater than 300 MHz BW and with center frequencies greater than 13 or 14 GHz, a block down converter can be used to translate the signal down to the range of a 40 Gsa/s oscilloscope.

Conclusion

The use of swept tuned spectrum analysis to analyze broadband signals can yield a great deal of information about the signal. However, the data contained within the wideband signal cannot be analyzed, requiring digitization and analysis of the data. Depending on the bandwidth and the center frequency of the signal, there are several methods available to analyze these signals. For signals with bandwidths less than 80 MHz and center frequencies

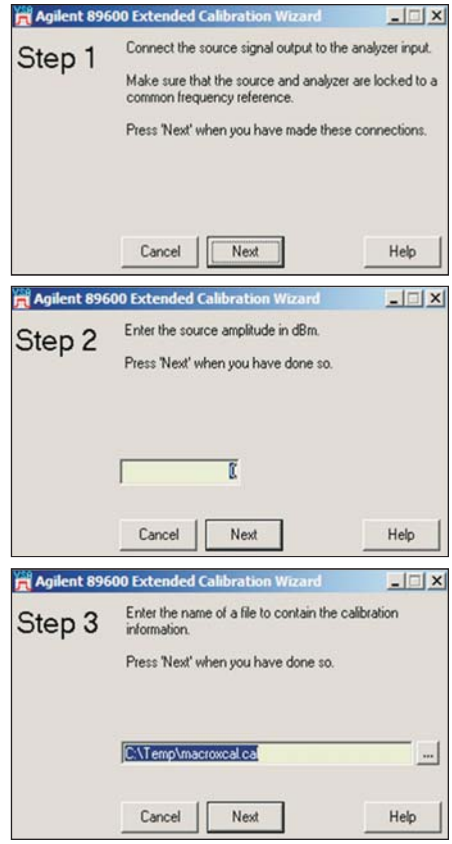

Figure 8 · Calibration process using VSA software.

less than 50 GHz, a spectrum analyzer will meet the requirement. For bandwidths less than 300 MHz, a spectrum analyzer used as a down converter and a scope as a digitizer can be used. For bandwidths greater than 300 MHz, a high-speed scope or a combination of a block down converter and a scope can be used to do signal analysis. Calibration is also very important to insure that the measurements are of the DUT and not the measurement system. Calibration is done internally in a wideband spectrum analyzer or with an external source if a multi-instrument system is used to make the measurements.

Author Information

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