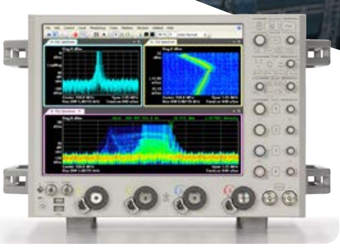
Solutions for

Wideband Radar and Satcom Measurements

Using wide bandwidth oscilloscopes to directly measure and analyze X, Ku, and Ka-band Radar and Satcom transmitter outputs up to 62 GHz

Application Brief



Overview

A growing trend in Satellite communication (Satcom) and Radar systems in the aerospace and defense market is the need for increased signal and analysis bandwidth and processing gain. Satcom systems are being driven by demands for increased data rates, while modern Radar systems require more processing gain to improve range resolution, which in turn drives wider modulation bandwidths. Modern Radar systems also employ more complex pulse modulation signal formats to improve range resolution and lower the probability of intercept and jamming. Many Radar and Satcom systems operate at microwave frequencies (e.g., X, Ku and Ka bands), which helps to support wider modulation bandwidths, increased capacity, and also offers the benefit of smaller antennas.

In some cases, the wide bandwidths required exceed the intermediate frequency (IF) bandwidths of commercially available RF spectrum analyzers and vector (or FFT) signal analyzers. Coupled with the higher operating frequencies, this creates a significant set of challenges for RF engineers testing Radar and Satcom transmitters.

Problem

Quickly, accurately and cost-effectively measuring the performance of RF/microwave transmitters in today's Radar and Satcom applications is a challenging task. In some cases (e.g., to measure a Satcom transmitter's Error Vector Magnitude (EVM)), the transmitter output can't always be measured directly. Engineers often have to rely on custom-built down-converter hardware to down-convert the RF/microwave frequencies to an IF frequency that can then be measured with commercial off-the-shelf (COTS) test equipment.

Unfortunately, the non-recurring engineering costs associated with designing, building and testing the hardware can be counterproductive. The down-converter hardware also adds its own RF impairments that can mask the actual performance of the RF/microwave transmitter under test. Moreover, distortion may occur that contributes to the overall EVM being measured, making it difficult to discern how much EVM is from the actual transmitter output. With no other available option, many RF engineers are left with the measurement accuracy uncertainty that comes from this less than ideal approach.

Solution

The answer to this dilemma lies in finding a solution that enables direct measurement and analysis of the RF/microwave transmitter's output, without the need for custom down-converter hardware. An ideal solution for this task is the wide-bandwidth oscilloscope, which can directly measure and analyze X-, Ku- and Ka-band signals (up to 62 GHz) from today's Radar and Satcom transmitters. Using the wide-bandwidth oscilloscope not only eliminates the time and cost associated with use of custom down-converter hardware, but also relieves the engineer from having to deal with other issues such as hardware calibration, corrections for system impairments and uncertainty in measurement results.

Other aspects of wideband Radar and Satcom measurements that typically pose some level of difficulty for RF engineers include:

- Creation of custom/proprietary wide-bandwidth signals. Traditionally, creating such signals for transmitter testing has been difficult since often times they are not supported with COTS equipment. As a result, engineers are forced to develop custom test equipment, a costly and time-consuming proposition.
- Analysis of custom/proprietary wide-bandwidth signals. Radar and Satcom signal formats may be custom or proprietary, and may require some level of custom signal analysis.

Finding a COTS test solution that can create and analyze custom/proprietary signals with integrated software is therefore paramount.

One such solution comes from Agilent Technologies and encompasses the Infiniium 90000 X-Series (up to 33 GHz) or 90000 Q-Series (up to 62 GHz) high-performance oscilloscope, PSG vector signal generator, M8190A arbitrary waveform generator (AWG), and Vector Signal Analysis (VSA) software. Together, these solutions provide RF engineers with the capabilities and flexibility they need to perform wideband Radar and Satcom measurements.

The wide-bandwidth oscilloscope allows RF engineers to directly measure and analyze wideband Radar and Satcom transmitter outputs. With up to 33 GHz and 62 GHz of analog bandwidth respectively, the 90000 X-Series and 90000 Q-Series deliver real-time measurement accuracy for direct measurement of transmitter outputs—without the need for external down-conversion hardware. Time-domain analysis can be performed to measure transmitter pulsed-RF characteristics (e.g., rise time, fall time and pulse width).

The M8190A is a modular instrument packaged in the AXIe form factor. It is used to generate the wideband waveforms needed to test today's emerging Radar and Satcom systems. As a precision 1- or 2-channel AWG with a DAC resolution of 14 bits up to 8 GS/s and 12 bits up to 12 GS/s (2 to 4 bits more than what's currently available today), it offers excellent signal performance. The M8190A also includes up to 2 GSa of waveform memory per channel (a 30X improvement over commercially available AWGs), which allows engineers to build long, realistic scenarios such as radar simulations. An output path with a 3 dB bandwidth of about 5 GHz enables it to be used as both an I/Q baseband and IF generator.

The PSG signal generator delivers high quality test signals. Wideband IQ inputs make it ideal for use with wideband Radar and Satcom measurements. When the PSG and M8190A are combined, they provide the flexibility necessary to create custom/proprietary Radar signals and wideband modulated signals (e.g., QPSK and 16QAM) for Satcom applications. These signals can be used for device under test (DUT) testing in the lab environment, without the need for costly custom test equipment.

When used for component DUT testing, the M8190A generates wideband IQ signals that are fed into the PSG's wideband IQ inputs. The PSG then generates the microwave test signal that will be used as DUT stimulus. Next, the DUT's output is connected to the wide-bandwidth oscilloscope where the Radar and Satcom measurements are made (Figure 1). To measure a standalone transmitter, the RF engineer simply connects the oscilloscope directly to the transmitter output.

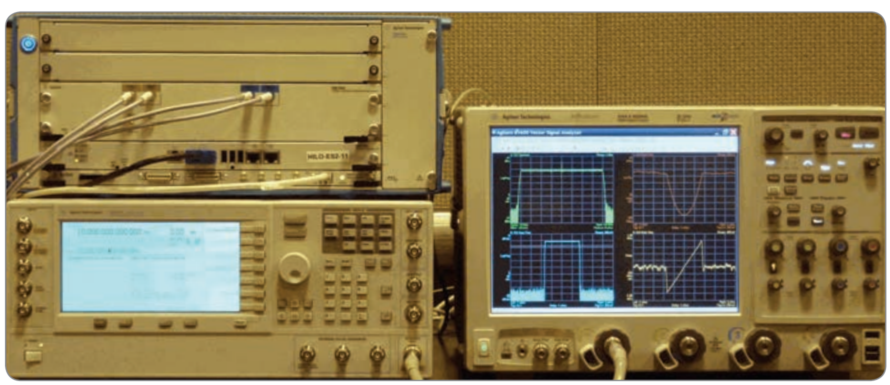


FIGURE 1: *Shown here is the typical hardware test setup used to create and analyze wideband Radar and Satcom signals. An M8190A wide bandwidth AWG is shown on the upper-left, a PSG with wideband I/Q inputs is shown on the lower-left, and a wide bandwidth 90000 X-Series oscilloscope with VSA software is shown on the right.*

Custom/proprietary measurements

Creating custom/proprietary waveforms and performing custom/proprietary measurements on Radar and Satcom applications is a task that can be made significantly easier using MATLAB. It can be used for signal generation to create simulated waveforms that are then downloaded to the M8190A AWG. Here, they are synthesized into differential IQ waveforms that are fed into the external I/Q inputs on the PSG signal generator. The modulated RF/microwave test signals are then generated.

Custom, user-defined MATLAB functions can also be used inside the 90000 X-Series and 90000 Q-Series oscilloscope and applied to the trace waveform (e.g., to calculate the pulsed RF envelope) so the pulsed RF waveform envelope can be measured and displayed. Pre-configured oscilloscope measurements are used to measure the rise time, fall time, pulse width, and overshoot on RF radar pulses (Figure 2). In this case, the deep capture memory (2 GSa) available on X and Q-Series oscilloscopes plays a critical role in allowing it to capture and analyze a large number of radar pulses.

Segmented memory further optimizes the number of radar pulses that can be captured and analyzed with the available oscilloscope memory. Essentially, it enables the user to zoom in on a pulse and capture only the "ON" time of the pulse, while ignoring the "OFF" time of the pulse. Note that while segmented memory can be used with MATLAB user defined functions, this capability is not available with the VSA software.

Easing migration to the oscilloscope

While spectrum analyzer and vector signal analyzers have traditionally been used for RF testing, the challenges with performing today's Radar and Satcom measurements have become a catalyst for RF engineers migrating to wide-bandwidth oscilloscopes. Fortunately, Agilent's VSA software runs inside 90000 X and Q-Series oscilloscopes and helps ease this migration by providing RF engineers the best of both worlds: the functionality and user-interface of a vector signal analyzer, and access to the oscilloscope's wide-bandwidth capabilities, which enables measurements up to 62 GHz for wideband Radar and Satcom applications.

With its familiar user-interface, the VSA software enables RF engineers to specify traditional RF parameters (e.g., frequency span and resolution bandwidth) on the oscilloscope. It then processes the data from the oscilloscope and displays the digitized results using vector signal analyzer amplitude and phase displays. VSA software can also perform frequency-domain analysis to measure characteristics like the RF/microwave spectrum, frequency and phase characteristics (e.g. chirped phase and frequency or frequency hopping characteristics displayed on a RF spectro- gram), and EVM (Figure 3). In addition, the VSA software supports many signal standards and modulation types, to demodulate signal formats such as QPSK, 16QAM and 64 QAM for Satcom and other applications. Such analysis provides the engineer with greater visibility into the actual Radar and Satcom transmitter hardware performance.

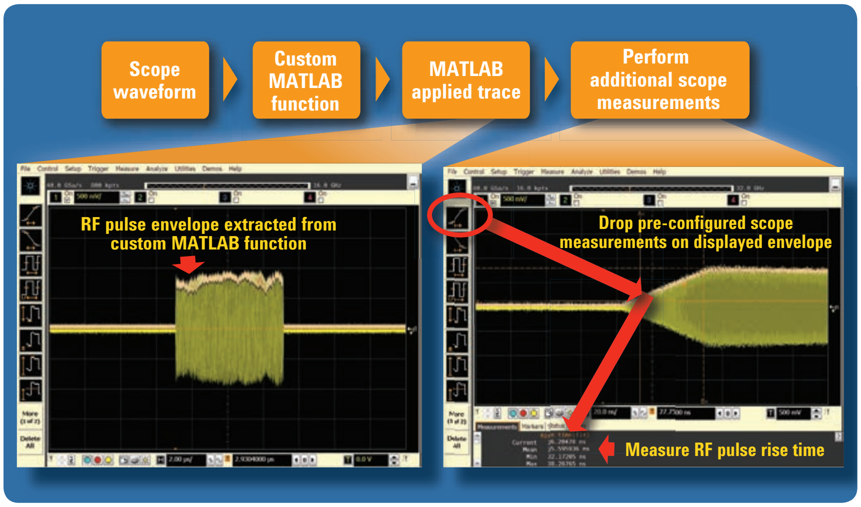


FIGURE 2: *Pulsed RF envelope and rise time measurements performed on the envelope.*

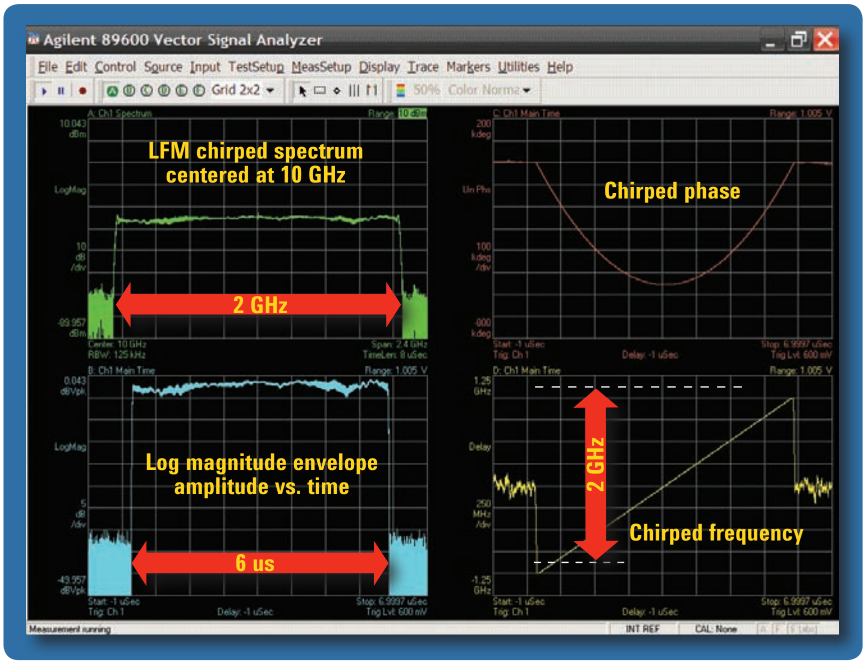


FIGURE 3: *Shown here is a wide-bandwidth LFM chirped Radar measurement using the VSA software on the 90000X oscilloscope.*

Example: Wideband 16QAM

In addition to Radar measurements, the same COTS test equipment can be used for a range of different applications, including wideband communications. Consider the example of a 1.76 GHz wide-bandwidth 16QAM signal. It is created and analyzed using the COTS test setup shown in Figure 1. MATLAB is used to generate a 16QAM waveform that is downloaded to the M8190A AWG. As shown in Figure 4, VSA software running on the oscilloscope is used to demodulate the 16QAM waveform.

Recall that EVM is an indicator for amplitude and phase distortion of a digitally modulated signal. In this case, the residual EVM is approximately 1.17%, which is quite good for a 1.76 GHz wide modulated waveform at X-band (10 GHz). In contrast, with existing equipment, the EVM that can be achieved at this data rate is typically only around 2 to 3 percent, which results in significantly higher measurement error and uncertainty.

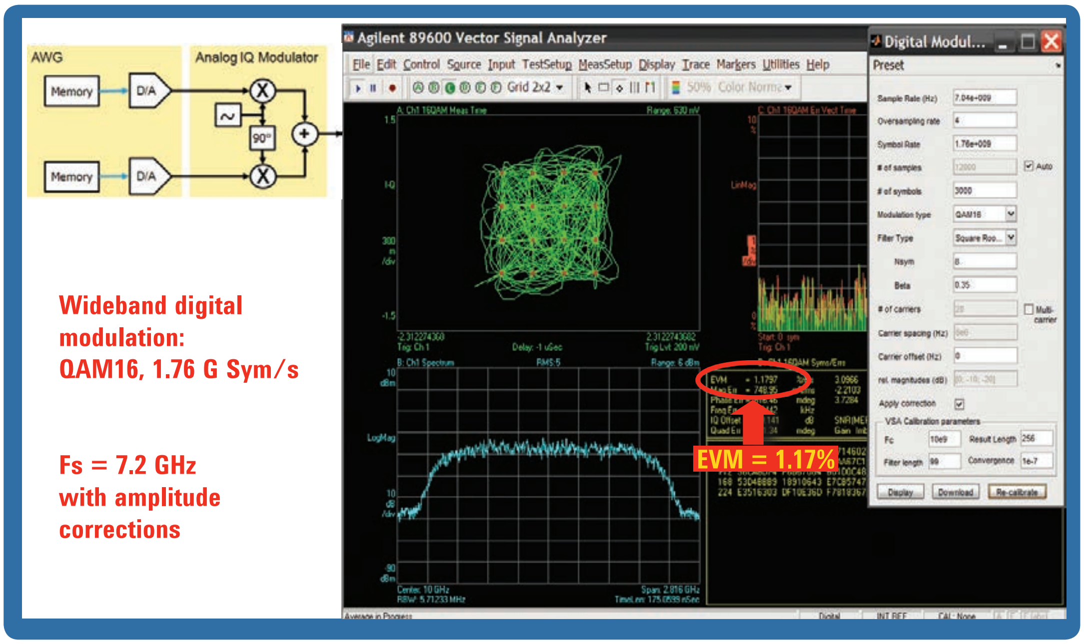


FIGURE 4: *The four quadrants of the VSA display show the constellation diagram (top, left), the 10 GHz X-band spectrum (bottom, left), the EVM versus time (top, right) and the EVM summary on the bottom right. In this example, the residual EVM performance is a combination of the AWG, PSG with wideband IQ inputs, and 32 GHz digital oscilloscope.*

Summary of results

Using external down-conversion hardware to measure wide-bandwidth Radar and Satcom transmitter performance can be a costly and time-consuming task. It may not be optimal in gaining visibility into the RF/microwave transmitter's true performance. Agilent's 90000 X-Series and 90000 Q-Series oscilloscopes provide RF engineers a viable alternative; a means of *directly measuring and analyzing the performance of RF/microwave transmitters* for Radar and Satcom applications. The oscilloscope can be combined with the M8190A AWG and PSG signal generator, which together can create and analyze physical test signals. Custom/proprietary signal waveforms can be generated using MATLAB and then downloaded to the M8190A AWG, combined with a PSG signal generator, to create the test signal. With these oscilloscopes, the transmitter's output can be measured using Agilent's VSA software, a MATLAB user-defined function or the oscilloscope's built-in time-domain analysis capabilities. With today's Radar and Satcom applications employing wider bandwidths and higher frequencies, direct and accurate measurement of the transmitter's output using the 90000 X-Series or 90000 Q-Series oscilloscope has become essential in gaining insight into the transmitter's true performance, saving time and helping to mitigate costly design re-work.

Related applications

- LTE MIMO Measurements, Physical Layer Modulation Analysis and Test

Related Agilent products

- DSOX93204A 32 GHz Digital Signal Oscilloscope with Options:
  - 02G, 2 Gpts/ch memory
  - 062, MATLAB Standard Digital Package
  - 010, User Defined Function
- DSOX96204Q 62 GHz Digital Signal Oscilloscope with Options:
  - 02G, 2 Gpts/ch memory
  - 062, MATLAB Standard Digital Package
  - 010, User Defined Function
- M8190A Arbitrary Waveform Generator
- 89601A/AN VSA Software with Options:
  - 200, Basic Vector Signal Analysis
  - 300, Hardware Connectivity
  - AYA, Vector Modulation Analysis
- E8267D PSG Vector Signal Generator with Options:
  - 520 or 532, Frequency range from 250 kHz to 20 GHz or 31.8 GHz
  - 016, Wideband differential external I/Q inputs
  - H18, Wideband modulation less than 3.2 GHz

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