Creating a Radar Threat Simulator and Receiver Calibrator with Precise Angle of Arrival

Application Note

Overview

For many types of multiple-input devices, precise testing requires accurate control over the amplitude and phase of multiple stimulus signals applied to the inputs of the unit under test (UUT). Examples include phased-array radar systems and multiple-input/multiple-output (MIMO) devices used in commercial communications and wireless networking. In these applications, precise control over amplitude and phase makes it possible to accurately simulate parameters such as the angles of arrival of incident signals.

This type of testing is useful in research, product development, design verification, manufacturing and calibration. In all cases, the test solution that provides flexible synchronization of test signals can help reduce test time. Shorter test times are especially beneficial in the manufacturing of complex devices that have many inputs.

This application brief focuses on a solution for radar testing and covers three key topics: the problem, the solution, and the associated results and benefits. The problem section covers the general and specific measurement challenges. The solution shown here is based on an actual system designed to test a four-port UUT. The results from this system provide significant benefits from technical and operational perspectives.

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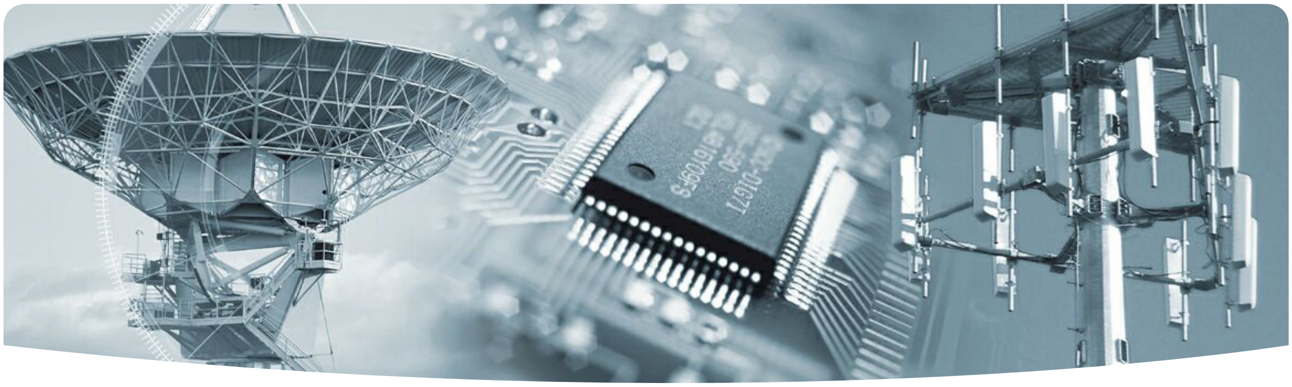


Problem

The testing of a multiple-input receiver presents one key challenge: providing the desired signal at the end of long test cables. Simulating this scenario presents two requirements. One is the ability to measure changes in phase and amplitude at the UUT, not at the test equipment. The other is the need to make real-time corrections to the amplitude and phase of each waveform. This level of control is needed to ensure proper alignment of the simulated incident signal in the presence of reflected signals from the inputs of the UUT.

In the specific case of the four-port radar receiver, the challenge was to create a system that could serve as both a threat simulator and a receiver calibrator. To thoroughly test the UUT, the system had to provide phase accuracy of less than 1 degree from 100 MHz to 20 GHz—and do so at the end of six-foot test cables. To support the intended usage model, the system had to meet two additional criteria: maintain its calibrated accuracy for at least 12 hours, and support hands-free calibration (i.e., no need to manually attach and detach calibration standards during a test).

Solution

Agilent's application engineering organization helped the customer create a system that met or exceeded the requirements outlined in the preceding section. As shown in Figure 1, the system has two major sections: coherent wideband stimulus and complex wideband modulated RF correction. The coherent stimulus section generates two sets of complex waveforms that simulate real-world signals. The complex modulated RF section provides 12-term error-corrected stimulus measurements at the UUT and provides feedback for correction of the RF and microwave signals.

Although it isn't shown, the system also includes a host PC running a test executive, which was written in C using LabWindows. The PC is linked to the LXI-compliant instruments through LAN connections and a router.

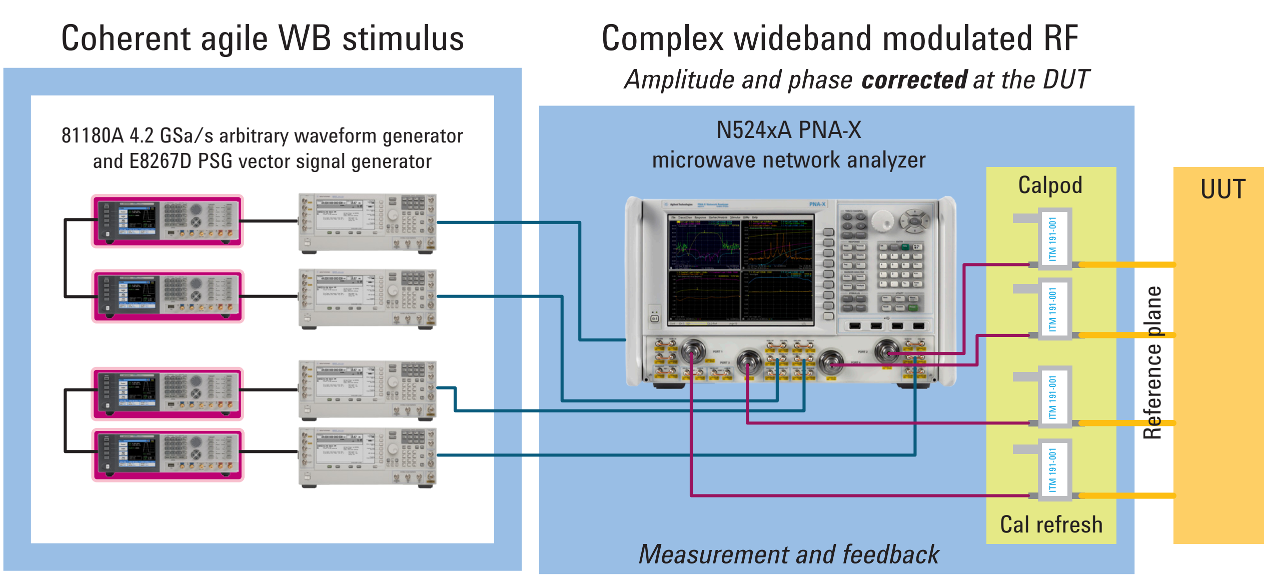


Figure 1. The threat simulator/receiver calibrator system has two major sections and includes nine instruments

Coherent wideband stimulus

Taking a closer look at Figure 1, the left-hand side includes two types of instruments, vector signal generators and arbitrary waveform generators (AWGs). Specifically, there are four Agilent E8267D PSG vector signal generators paired with four Agilent 81180A 4.2 GSa/s AWGs. For the E8267D PSG, the key specifications are phase accuracy of less than 1 degree and an amplitude imbalance of less than 0.1 dB. For the 81180A AWG, the key attributes are fast waveform switching and waveform resolution of less than 0.25 ns.

Each PSG/81180A pair outputs a complex waveform that simulates a combination of reference and offset signals. This is accomplished by defining two sets of complex waveforms in a two-channel 81180A and using those signals to drive the I and Q wideband modulation inputs of the vector signal generator.

To simulate angle of arrival, the AWGs are loaded with multiple copies of the reference signal. The memory for the reference channel is loaded with a single reference waveform. In contrast, the memory for the offset channel contains multiple copies of the reference signal, and each of these has a different phase offset (Figure 2). The test executive simply calls up and plays the desired phase sequence.

All of the individual waveforms were created using MATLAB from The MathWorks (Figure 3). The waveforms were based on examples published by Agilent.

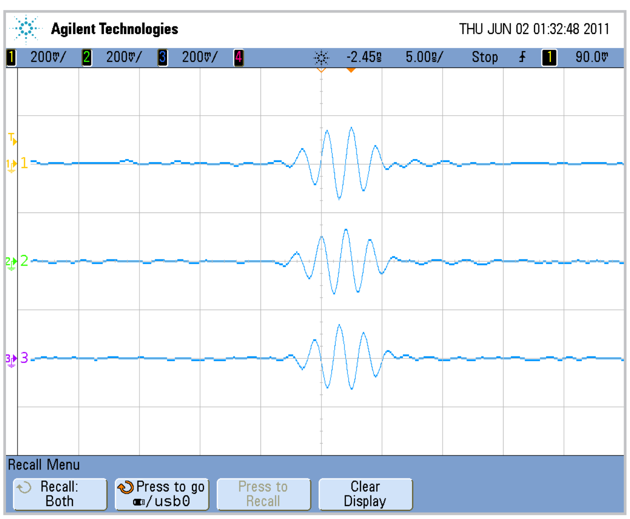


Figure 2. Referencing the centerline, these 8-ns raised-cosine pulses have precise offsets of 90 and 180 degrees

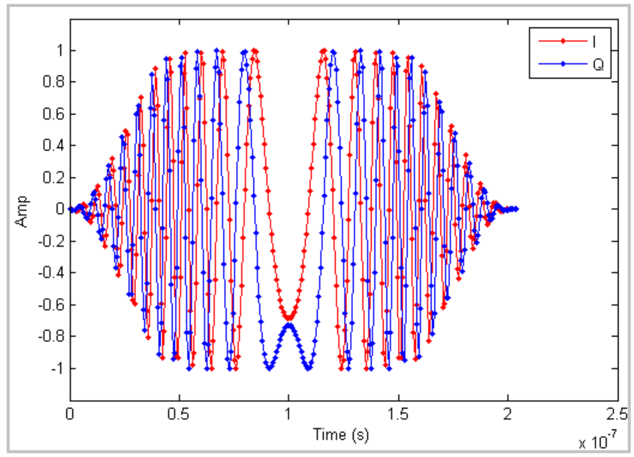


Figure 3. These 300 MHz I and Q chirps were created using MATLAB

Complex wideband modulated RF correction

On the right-hand side of Figure 1, an N524X PNA-X microwave network analyzer measures the vector sum of the incident and reflected waveforms at the inputs of the UUT. The network analyzer uses those measurement results to compensate for system drift and UUT mismatch with the test system. The UUT test cables are the largest contributor to system drift.

PNA-X calibration is maintained over time and temperature using the calibration pods shown in Figure 1. This capability is enabled by first performing a system calibration (after all cables have been connected) using Agilent electronic calibration (ECal) modules; the PNA-X controls the ECal modules through a USB connection. Because the cal pods are always in the signal path, the initial calibration captures their characteristics and uses those measurements as a baseline for calculating the corrections that will be applied whenever a refresh is performed. With this capability in place, the test executive can direct the PNA-X to refresh its calibration during the testing process without requiring a reconnection of the calibration devices.

This portion of the system delivers one of the key contributions: The system "knows" the actual phase and amplitude of the test signals at the inputs to the UUT. Previously, the reference point was the output of the signal generator; however, environmental changes can have a profound effect on cable length over the required range of test frequencies. The configuration used here accounts for changes between the paths and, through the test executive, commands the AWG to play a signal that provides the desired phase offset at the UUT.

1. *These can be downloaded as a Zip file. Please go to www.agilent.com and search on "MATLAB radar scripts".*

Results & benefits

The deployed system has met or exceeded expectations from both the technical and operational perspectives. On the technical side, there are five key accomplishments:

- Capable of producing virtually any known radar pulse
- Requires a single set of four connections per UUT
- Achieves accuracy of less than 1 degree at the UUT
- Provides milli-degree resolution
- Delivers on/off ratios of greater than 100 dB by using AWG markers to drive the PSG (Figure 4)

From an operational perspective, the system is providing three key benefits. The most striking change is set-up time, which has been reduced from days to minutes. The other two benefits are related: Operator effort is reduced thanks to hands-free calibration, and the cost of test is lower because tests can run autonomously under PC control.

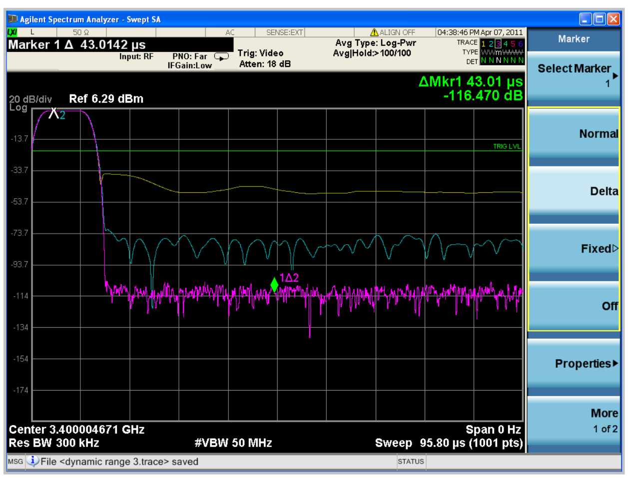


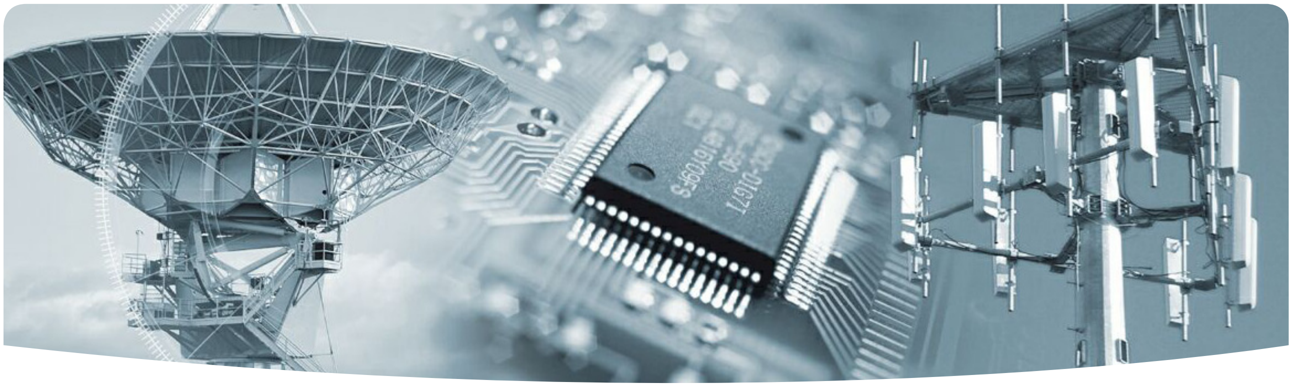
Figure 4. In this example, the system achieves a pulse on/off ratio of 116 dB (see delta marker readout at upper right of trace)

Conclusion

The approach described here was designed to test radar receivers. One of its key contributions is the ability to "know" the actual phase at the UUT and make changes on the fly. This enables precise receiver calibration and highly realistic threat simulations.

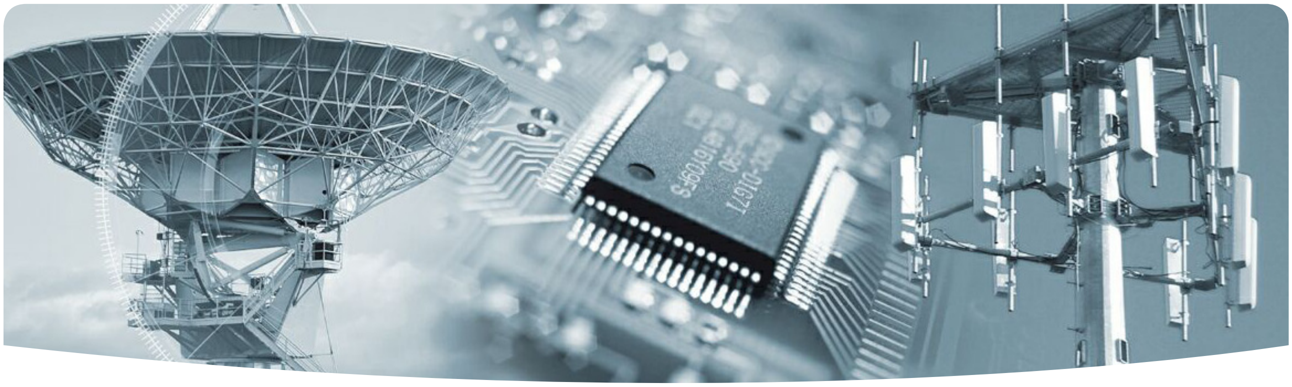
As a further extension, the system could be easily expanded to more than four ports using a PNA-X multiport test set. Models are available to support 6, 8, 10, 12, 14, 16, 20 or 22 ports. Custom and high-power test sets are also available.

With the versatility of the AWG, the system could be easily adapted to test other radar designs or other types of equipment such as MIMO communications or networking devices. For more challenging applications, a higher-performance AWG such as the 12 GSa/s Agilent M8190A could be used for "signal scenario generation" in the testing of aerospace, defense and commercial systems.



Related information

- *Agilent 81180A 4.2 GSa/s Arbitrary Waveform Generator Data Sheet*, publication 5990-5697EN
- *Agilent M8190A 12 GSa/s Arbitrary Waveform Generator Data Sheet*, publication 5990-7516EN
- *Agilent E8267D PSG Vector Signal Generator Data Sheet*, publication 5989-0697EN
- *Agilent PNA-X-Series Microwave Network Analyzers Brochure*, publication 5990-4592EN
- MATLAB information: Please visit **www.mathworks.com/products/matlab**



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