Solutions for

Ultra-Wideband Radar System Design

Integrating Design with Ultra-Wideband Test for Flexible Radar Verification

Application Note

Overview

Ultra wideband (UWB) Radar has become increasingly popular in both commercial and defense industries. UWB Radars (whether impulse, LFM, noise, or OFDM-based) are defined as having a bandwidth of greater than 0.5 GHz, or more than 20% of their center frequency, and are regulated by FCC rules that allow UWB technology to coexist with existing radio services without causing interference. They offer several advantages, including high accuracy for target detection, good precision for penetrating radars, and low cost for combining radar and communication systems. UWB Radars can pass through walls and other obstacles for geolocation/positioning, and can support multipath immunity and frequency diversity with minimal hardware modifications.

Modern UWB Radar systems often operate in environments that are unpredictable, with interference, jamming and other “real world” performance limitations. Therefore, during system development, it is critical for engineers to understand how their actual hardware will perform in these environments.

Problem

Effective Radar system design requires comprehensive system validation, a time-consuming and expensive process often necessitating costly facilities and complex measurement systems. Radar algorithms, such as target recognition and countermeasures, need to be validated early enough to change the signal processing hardware design. Hardware receivers must also be tested with realistic threats and jamming scenarios. Together, these often require outdoor ranges, chambers and real-time hardware simulators costing tens of thousands of dollars per hour.

Unlike communication system designers, UWB Radar system designers face a number of unique challenges, beyond sheer bandwidth. Impulse radar signals, for example, can change shape during propagation (e.g., non-sinusoidal waveforms), while for noise-like radars, just figuring out how to model the noise in the waveform can be challenging. With Linear FM systems, generating UWB signals with Doppler frequency offsets, target echoes and clutter to perform receiver verification can be challenging. As a result, designing and testing UWB Radar systems requires a variety of signal sources, target environment setups and measurements. Carefully designed and optimized waveforms are absolutely essential to ensure excellent real-world performance.

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Solution

To successfully develop UWB Radar systems, today's system engineers require a more flexible, lower cost means of validation with stimulus/response equipment that is specifically geared toward UWB. That R&D test bed starts with Electronic Design Automation (EDA) software to model a working reference design. The reference design is used to generate test vectors, as well as process received signals that are captured from live measurements, and organize a "model-based design flow." The test bed also includes a UWB signal generator with a wideband arbitrary waveform generator (AWG) to render simulated signals, including realistic threats and jamming scenarios, for testing UWB hardware receivers. Finally, the UWB test bed should include a wide-bandwidth oscilloscope for waveform capture.

An additional role of the EDA software is to surround the raw Radar design and test equipment with the environmental, baseband and RF modeling required to close a round-trip signal processing loop in order to perform early simulation-based verification. As hardware becomes available, the software continues to connect directly into the physical hardware measurement. By leveraging the design tools into verification, a consistent approach is maintained throughout the research and development process, saving time, promoting re-use, and making optimum use of the capital equipment assets.

Agilent Technologies provides a prime example of just such a test system. As shown in Figure 1, the system starts with the SystemVue simulation and modeling environment, which is used with Agilent's 81180A wideband AWG (upper left), the N8267D PSG vector signal generator (lower right) and the 32 GHz Infiniium 90000 X-Series oscilloscope (lower left). Together, these components allow engineers to carefully design and optimize the UWB signals that are so critical to the design, verification and test of UWB Radar systems.

The test bed shown in Figure 1 supports investigations of UWB architectures, as well as direct connection to test equipment for verification. It can be used to model, encode and download UWB test signals and also post-process received signals. The wide-bandwidth 90000 X-Series oscilloscope allows RF engineers to measure and analyze UWB Radar transmitter outputs using up to 32 GHz of true analog bandwidth, without the need for external down-conversion. This direct approach reduces hardware calibration, system impairments, and measurement system complexity and uncertainty.

Agilent's E8267D PSG microwave vector signal generator features wideband baseband IQ inputs. When combined with a wideband AWG, such as the 81180A, M9330A or the new M8190A, the PSG provides the flexibility necessary to create microwave and millimeter-wave signals for UWB Radar scenarios, as well as component validation.

With this test system, SystemVue generates and downloads different UWB Radar test vectors to the wideband AWG to create the necessary baseband signals. The output differential IQ signals of the AWG are then modulated by the PSG to create an X, Ku or Ka band test signal, to be used directly as an input to a device under test (DUT) for Radar component test. Next, the output of the DUT is captured using the Infiniium 90000 X-Series oscilloscope where Radar measurements can be made (Figure 2). Signals can be analyzed inside the Infiniium oscilloscope using the Oscilloscope Signal Analyzer (OSA) or Vector Signal Analysis (VSA) software. For further analysis and signal processing, measured signals up to 32 GHz wide can be brought back to SystemVue with the help of the 89600B VSA software, to close a unique "round trip" signal processing loop (Figure 2).

Because of the versatility of this UWB test bed, it can be used for both validation and troubleshooting of UWB transmitters and UWB receivers.

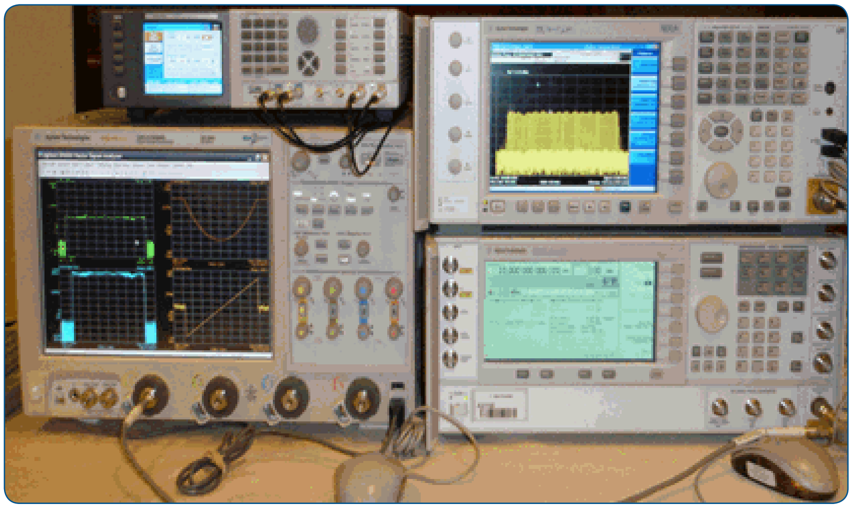


FIGURE 1. With SystemVue integrating this UWB test platform with a working Radar reference design, engineers can precisely generate and measure UWB waveforms for any point in a UWB system architecture, and perform closed-loop stimulus/response measurements that reduce the need for expensive ranges, chambers and hardware simulators in early R&D.

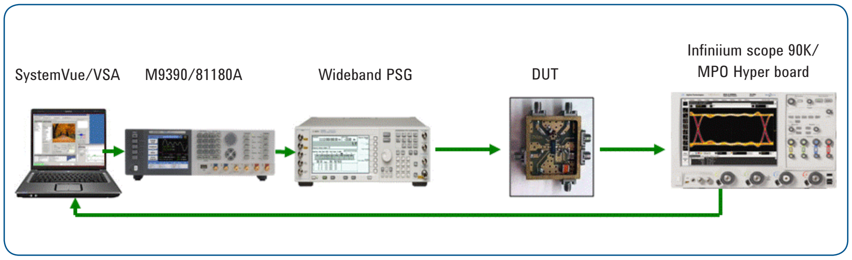


FIGURE 2. SystemVue, in combination with best-in-class AWG and oscilloscope test families, provides a closed-loop, stimulus/response modeling and verification platform up to 32 GHz wide. It enables a versatile and cost-effective UWB system-level approach in R&D.

UWB Waveform Creation

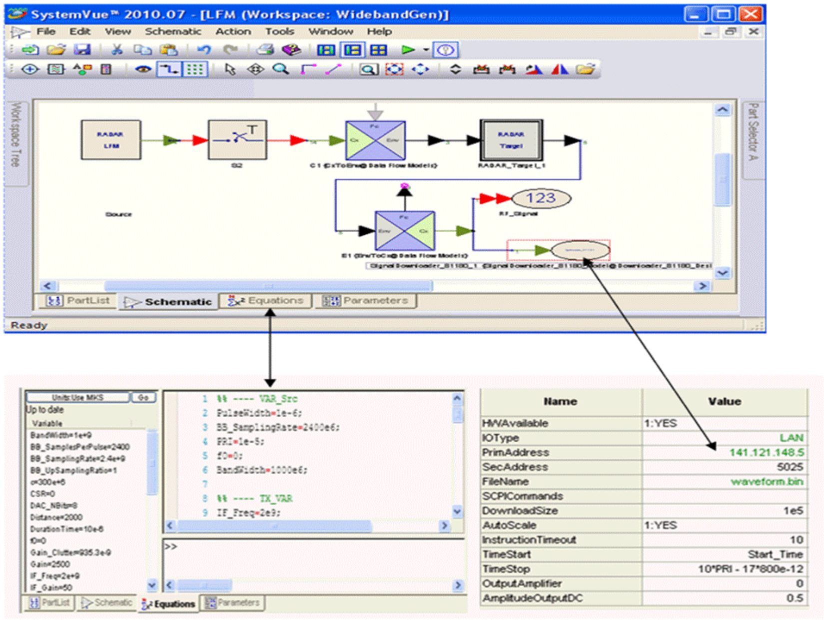
Carefully designed and optimized waveforms can be created using SystemVue running within the Infiniium 90000 X-Series oscilloscope, or on an external PC. SystemVue plays a critical role in UWB waveform creation by providing a workspace with open, parameterized signal processing diagrams for LFM, pulse, and noise UWB Radar signal generation. Transmitter signals can be generated for Linear and Nonlinear FM pulses and coded signals; sort pulse signals with Gaussian windowing; and noise UWB Radar. Radar target return signals with Radar cross-section (RCS), clutter, jamming, and interferers can also be generated.

Before downloading to test equipment, the simulated waveforms can be verified in SystemVue for conformance to both frequency- and time-domain specifications. SystemVue also enables engineers to incorporate their own custom signal processing intellectual property (IP) and create custom signals that integrate C++ dynamic link libraries, MATLAB models, VHDL, and test vector data files.

Example: LFM UWB Transmitter/Receiver Signals

To better understand how easily UWB Radar transmitter and receiver signals can be generated and measured, consider the example of LFM UWB transmitter/receiver signals. Using the test platform shown in Figure 2, a LFM UWB transmitter signal is created with 1 GHz bandwidth, 1 microsecond of pulse-width and a 10 microsecond repetition interval. It is generated using SystemVue with the 81180 AWG, the PSG and the 90000 X-Series oscilloscope (Figure 3).

The LFM UWB transmitter signal is then measured using VSA software with a pre-stored configuration file. The results are shown in Figure 4.



```
%% ---- VAR_Src
PulseWidth=1e-6;
BB_SamplingRate=2400e6;
PRI=1e-5;
f0=0;
BandWidth=1000e6;

%% ---- TX_VAR
IF_Freq=2e9;
```

```
>>
```

Name	Value
HWAvailable	1:YES
IOType	LAN
PrimAddress	141.121.148.5
SecAddress	5025
FileName	waveform.bin
SCPICommands	
DownloadSize	1e5
AutoScale	1:YES
InstructionTimeout	10
TimeStart	Start_Time
TimeStop	10*PRI - 17*800e-12
OutputAmplifier	0
AmplitudeOutputDC	0.5

FIGURE 3. An LFM design in SystemVue (upper image) is used to generate a UWB signal. The final block in the system-level schematic captures the simulation result and downloads the waveform data into the 81180A AWG using the parameters shown (lower right). Then, the 81180 (not shown) repeats the generated signal for hardware testing.

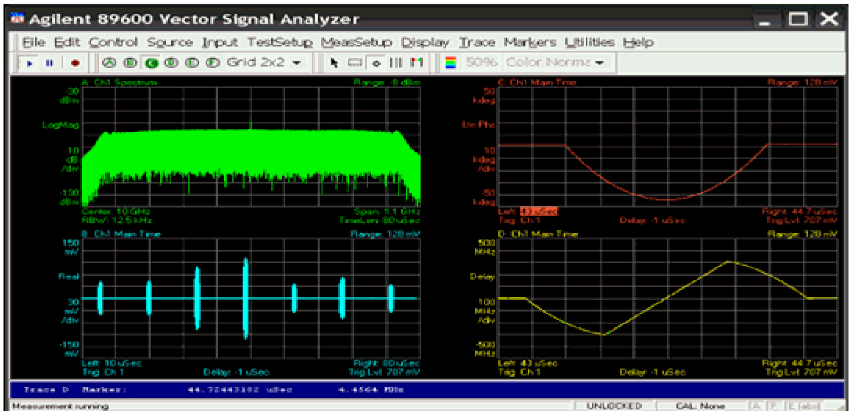


FIGURE 4. Shown here is a 1-GHz LFM UWB signal. The upper left image shows the 1-GHz wide Radar spectrum centered at 10 GHz, while the log magnitude envelope versus time is shown just below it. The signal phase is shown on the upper right graph. The 1 GHz-wide LFM chirp is displayed on the lower right graph.

For receiver component test, the same equipment is used to create a LFM UWB receiver signal for a target with a 100 meter range and a 20 m/s velocity. The 89600B VSA software is used to capture the LFM UWB receiver signal. The VSA measurement is configured using a stored "setup" file which is quickly recalled at the simulation runtime.

Note that for either impulse or OFDM type transmitter signals, the impulse or OFDM UWB source objects must first be activated in the SystemVue simulation to generate the respective UWB signals. Like the LFM UWB signals, these alternate types of UWB signals can be measured using the VSA software.

Summary of Results

Designing, verifying and testing UWB Radar systems requires precisely controllable UWB signals. Unfortunately, generating and measuring the required UWB Radar signals is no easy task. Agilent's SystemVue with a wideband AWG and the PSG signal generator provide a "simulatable" UWB Radar reference design and working waveforms that engineers can use to test and troubleshoot UWB Radar transmitter and receivers, thus reducing development effort. When Agilent's 90000 X-Series oscilloscope is added, Radar transmitter and receiver measurements can also be performed, completing a full "round-trip" signal processing path for Radar architecture validation up to 32 GHz wide. Together these instruments create an interactive UWB test system that can be used to optimize UWB system architectures conveniently and cost-effectively, as well as to verify individual RF and baseband components over challenging bandwidths and signal conditions.

For more information, go to:

- www.agilent.com/find/eesof-systemvue-Radar-library
- www.agilent.com/find/oscilloscopes
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Related Applications

- Electronic warfare and electronic intelligence
- Satellite communications
- Military communications and proprietary backhaul
- Emerging communications systems (e.g., LTE-Advanced, 802.11ac and 802.11ad (60 GHz))

Related Agilent Products

- W1461BP SystemVue Communications Architect
- W1905EP Radar Model Library
- E8267D PSG Vector Signal Generator with wideband I/Q inputs
- 90000 and 90000 X-Series Infiniium Series oscilloscopes
- 81180, M9330A and M8190 wideband AWG families
- 89600B VSA software

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