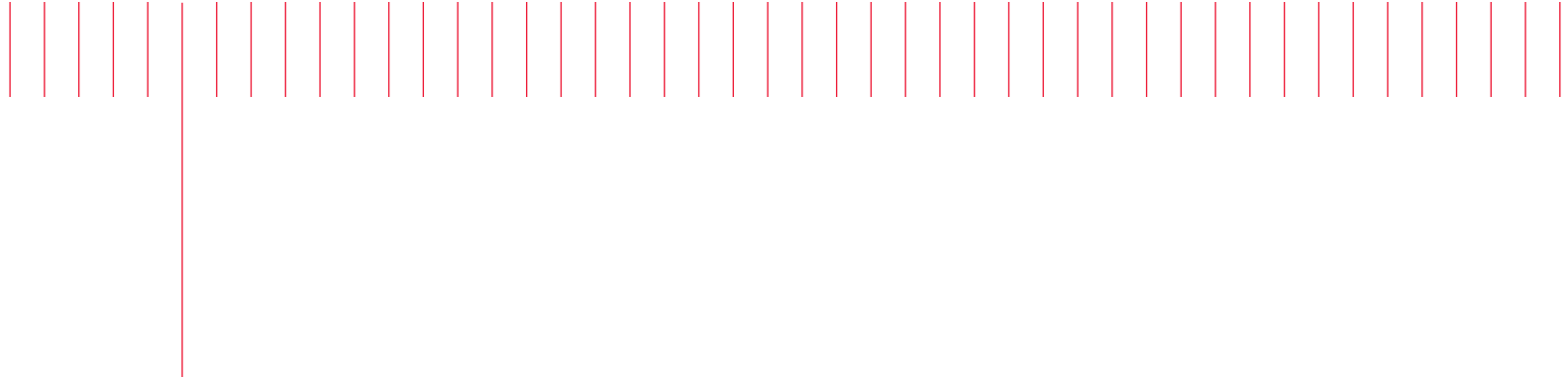# Keysight Technologies
Solutions for Creating Multi-Emitter Signal Scenarios with COTS Software and Instrumentation

Application Brief

Today's radar and electronic warfare (EW) systems face an increasingly cluttered spectral environment. As an example, the airwaves in an urban setting may include countless RF and microwave emitters—and therefore potential interferers—such as wireless communications infrastructure, wireless networking systems and civilian radars. Evaluating radar/EW hardware under a variety of highly realistic scenarios can help characterize system performance in the presence of multiple interference signals.

To test devices still in development, one possibility is to capture actual waveforms in the field and play them back in the lab environment. As a potentially more convenient alternative, a flexible software application such as Keysight Technologies, Inc. SystemVue can be used to create highly realistic multi-emitter test signals. These can be downloaded into a high-precision arbitrary waveform generator (AWG), which can play back complex signals for lab-based testing of a device under test (DUT).

With this combination of software and hardware, it's possible to alter an offending emitter's frequency, power or bandwidth—and this includes scalable emitters such as orthogonal frequency-division multiple-access (OFDMA) signals. One of the key enabling technologies is a feature called SignalCombiner within the Keysight SystemVue electronic system-level (ESL) software. This "combiner" component resamples multiple unrelated signals for interference studies, multi-standard radio (MSR) support, and more.

This note describes a key problem, and describes a commercial off-the-shelf (COTS) solution for signal generation and analysis. Two examples will be presented.Highlights include creation of multi-emitter test signals, demodulation for error vector magnitude (EVM) analysis, and creation of a 16-radar scenario.

Problem: Creating multi-emitter signals

Simulation sources have generally been used in ESL or electronic design automation (EDA) environments to design RF systems and circuits. Until recently, these have been used to design for a single format within categories such as wireless communications, wireless connectivity and radar.

In such cases the simulation time-step or sample rate is set to match the specific signal format of interest. For example, in an LTE simulation the sample rate might be set to oversample a 15.36 MHz signal by a factor of two (30.72 MHz) or four (61.44 MHz).

In simulation, using a single sample rate for a single signal is a relatively straight-forward process; however, today's real-world signal scenarios are much more complex. With most EDA or ESL tools, it can be quite challenging to combine multiple signal types that utilize different sample rates. As an example, imagine combining radar, LTE and

802.11ac wireless LAN (WLAN) signals. Achieving a common sample rate requires the cumbersome process of finding suitable up-sampling or down-sampling factors for each signal. This level of complexity presents a significant barrier to the creation of realistic scenarios that contain multiple emitters.

Solution: A COTS configuration

Recently, Keysight has overcome this barrier with advances in arbitrary resampling techniques. These capabilities enable resampling and combining of multiple signal types that have different bandwidths and signal types.

In SystemVue, the SignalCombiner feature enables the creation and combination of multi-emitter signals within the simulation environment. Through resampling, multiple emitters are combined into a single waveform that can be downloaded to a high-precision AWG such as the Keysight M8190A for playback (Figure 1). Because the M8190A delivers high resolution and wide bandwidth simultaneously, it is well suited to applications that require playback of complex, high-fidelity signals.

Emitter #1
Center frequency = Fc1
Bandwidth = BW 1
Sample rate = SR 1

Emitter #2
Center frequency = Fc2
Bandwidth = BW 2
Sample rate = SR 2

Emitter #N
Center frequency = FcN
Bandwidth = BW N
Sample rate = SR N

"Signal combiner" element

Multi-emitter output
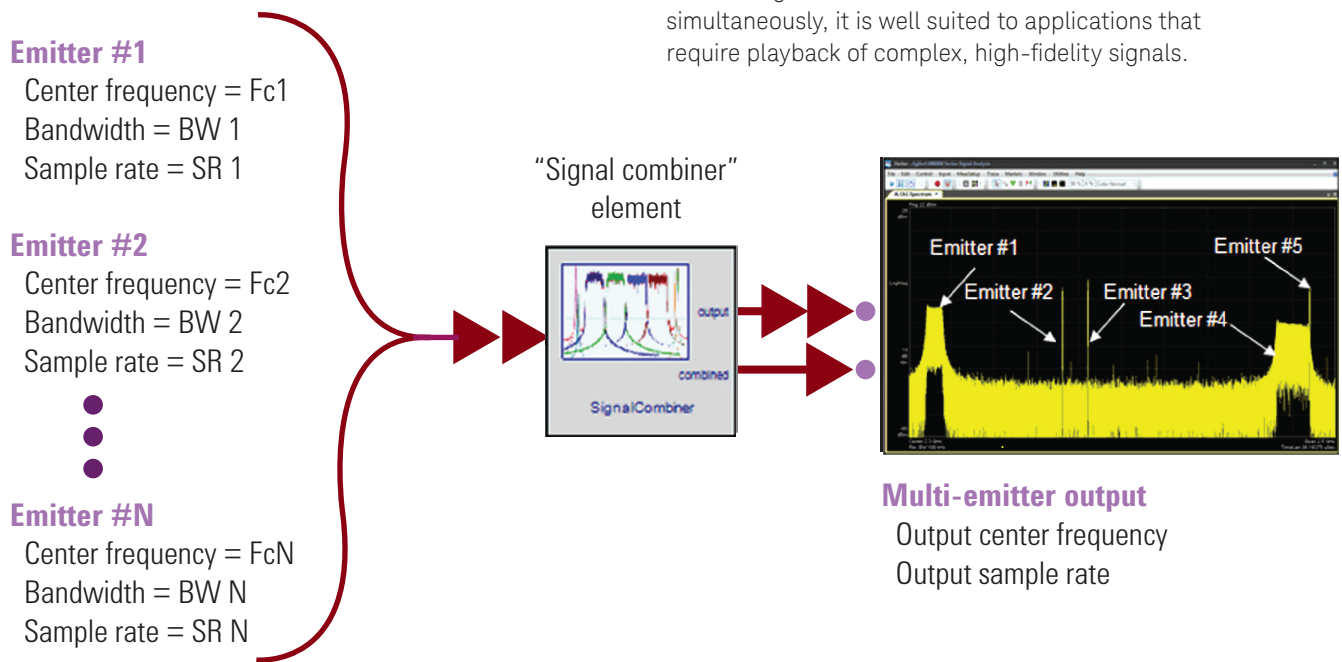Output center frequency
Output sample rate

Figure 1. SignalCombiner resamples multiple emitters and produces a single signal that can be used as a stimulus in device testing.

Figure 2 shows an annotated SystemVue screen. In this example, two radar signals are summed with multiple wireless signals: GSM, EDGE, LTE and WCDMA. Each signal has a unique center frequency, bandwidth and sample rate at the SignalCombiner input. To ensure compatibility with the M8190A in its 14-bit mode, the output sample rate was set to 8 GSa/s. The resulting multi-emitter waveform was then downloaded to the AWG.

Two notes are worth mentioning. First, the LTE and WCD-MA signals are available as SystemVue waveform libraries, which provide sources, receivers, channel modules and reference designs that comply with physical-layer standards. In contrast, GSM and EDGE are legacy signal types so file-based waveforms were used.[1] Second, the length of the combined waveform is limited by the available waveform memory, which is a maximum of 2 GSa per channel in the M8190A. This creates a tradeoff between sample rate and waveform playback time.

1. GSM and EDGE models were released along with version 2013.03 of SystemVue and are now available.
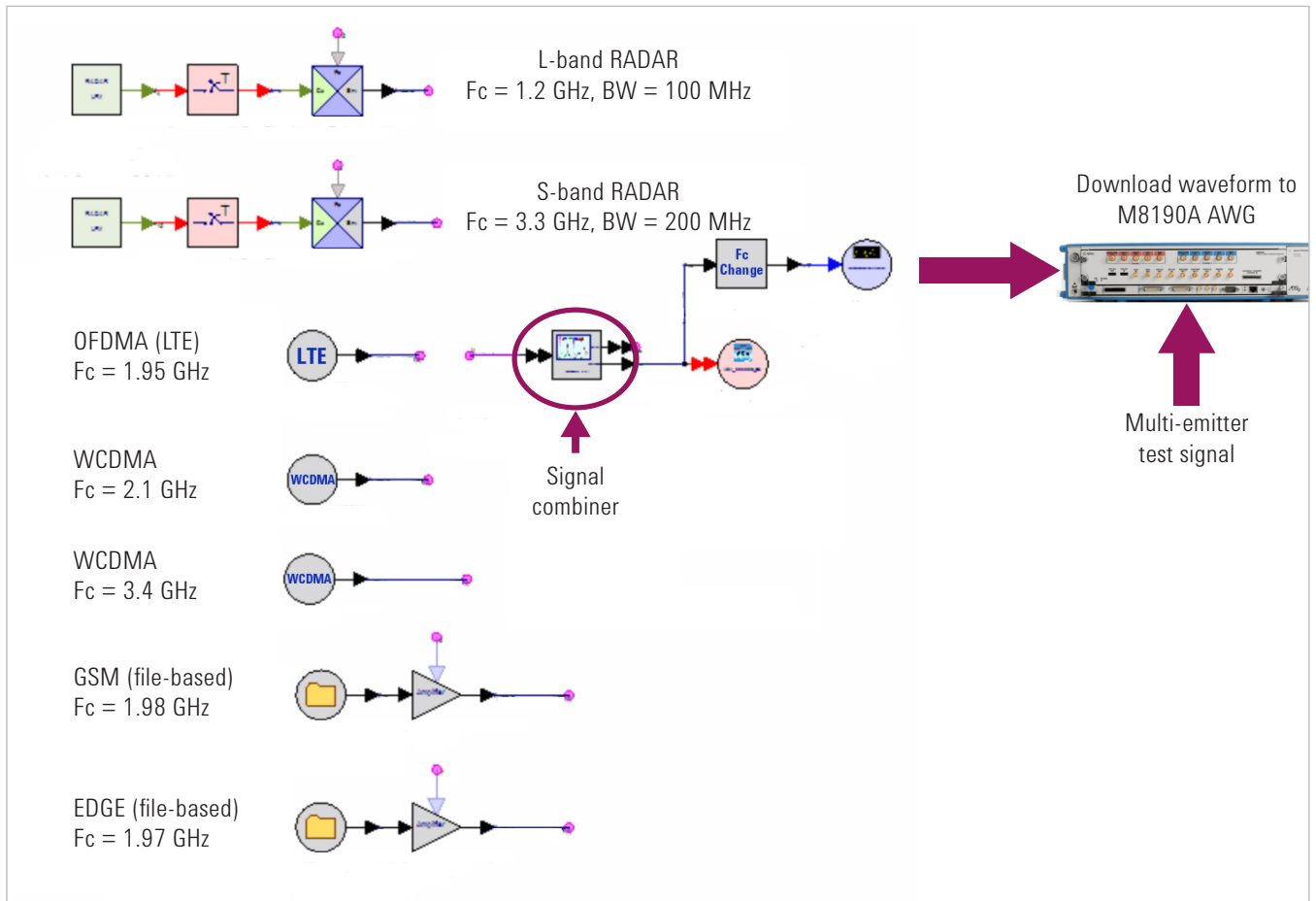

Figure 2. Within the SystemVue environment, multiple emitter types are processed by SignalCombiner before being downloaded to the M8190A AWG for playback.

The complete software and hardware configuration, as shown in Figure 3, contains the following elements:

– W1461BP SystemVue simulation environment provides SignalCombiner component and connectivity to equipment. Libraries for W1905 Radar, W1918 LTE-Advanced, W1916 3G, and other standards.
– M8190A: The AWG provides 12-bit resolution at 12 GSa/s and 14-bit resolution at 8 GSa/s. Its two output channels can be used to drive the wideband I and Q inputs of an E8267D PSG vector signal generator.
– E8267D with Option 016: The PSG vector signal generator can be used to modulate and upconvert I and Q baseband signals produced by the AWG. The maximum carrier frequency is 44 GHz.
– DSAX96204Q: This high-performance Infiniium oscilloscope provides 62 GHz bandwidth for analysis of ultra-wideband (UWB) signals.
– PXA: The signal analyzer provides frequency coverage from 3 Hz to a maximum of 50 GHz.
– 89600: Our industry-leading vector signal analysis (VSA) software supports more than 70 signal standards and modulation types. It provides analysis capabilities in the time, frequency and modulation domains.
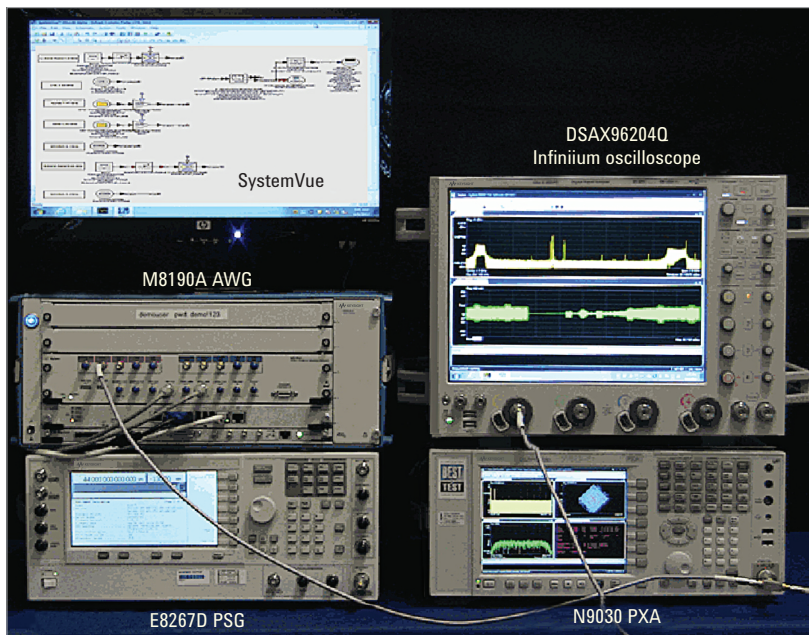

Figure 3. This combination of COTS hardware and software enables cost-effective creation and analysis of multi-emitter signal scenarios.

In the example configuration, the SystemVue ESL software is running on the AWG's embedded controller. The 89600 VSA software, which provides demodulation capabilities, is running inside the oscilloscope but could also run inside the PXA.

One note: Unlike expensive multi-bay test systems that produce signal scenarios in real time, the example configuration produces multi-emitter signals in what amounts to "batch mode." When SignalCombiner performs resampling to 8 GSa/s, signal creation can be time consuming, depending on the complexity, sample rate and total playback time.

When compared to real-time systems, the configuration shown here may provide a fraction of the capability but it still covers a significant number of the likely use cases for testing in R&D applications. In addition, the COTS configuration has a much total lower cost, making it possible to equip multiple designers or teams with individual systems, facilitating analysis of various scenarios prior to testing a device with the real-time system.

Deciding when to use an oscilloscope or a signal analyzer

Your analysis requirements will help you determine when to use an oscilloscope or a signal analyzer. The key factors are analysis bandwidth and the required number of measurement channels. Additional factors include dynamic range, spurious and error vector magnitude (EVM) measurements.

Currently, the highest-performance signal analyzers have a maximum analysis bandwidth of 160 MHz. Thus, if the required analysis bandwidth is 160 MHz or less, then either a signal analyzer or scope can be used. If a wider bandwidth is required, then a high-performance oscilloscope is the best choice.

If multiple phase-coherent channels are required, then an oscilloscope is the best choice. When one channel is enough, a standalone signal analyzer such as the PXA usually has an advantage in the other factors: dynamic range, spurious performance, and EVM performance and measurement speed.

Results, part 1: A multi-emitter environment with radar and comms signals

SystemVue, SignalCombiner and the M8190A were used to create a wideband multi-emitter signal. The signal was measured with a 62 GHz oscilloscope and analyzed with the 89600 VSA software, which was running inside the scope.

In Figure 4, the upper trace shows a frequency-domain view. From left to right, the frequency spectrum includes seven signals: L-band radar, LTE, EDGE, GSM, WCDMA, S-band radar, and WCDMA. The lower trace shows the composite time-domain waveform downloaded to the M8190A and captured with the scope.[2]

For wide-bandwidth analysis of radar signals, a DSAX96204Q with the 89600 VSA software enables analysis of the L, S, X, Ku and Ka bands. Although Figure 4 shows only L- and S-band signals, the suggested configuration has been used to create and analyze multiple radar emitters centered at 40 GHz and spanning 2 GHz.

Figure 5 shows error vector magnitude (EVM) demodulation of the GSM, EDGE, LTE and WCDMA emitters. For these measurements, a PXA signal analyzer was used to zoom in on each emitter for modulation-domain analysis. Each signal type was demodulated with the 89600 VSA software, which was running inside the PXA.
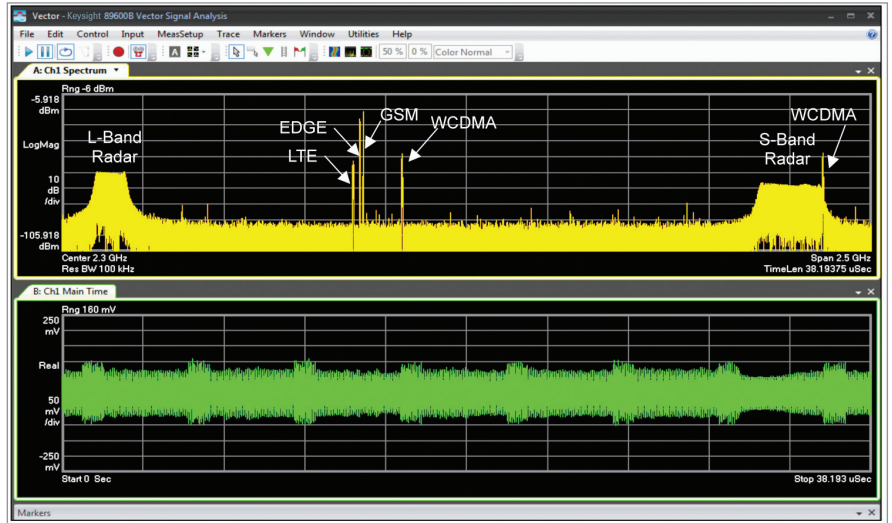

Figure 4. In the upper trace, a measurement made with a 62 GHz scope and VSA software reveals all seven emitters in the scenario created with SystemVue and SignalCombiner.
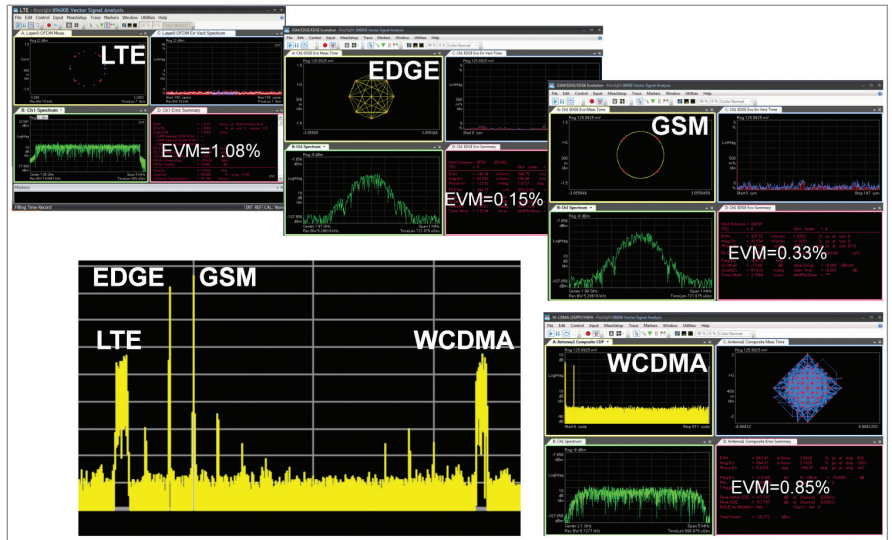

Figure 5. Demodulation with a PXA signal analyzer and the 89600 VSA software shows EVM values for the wireless communications signals: LTE (1.08%), EDGE (0.15%), GSM (0.33%) and WCDMA (0.85%).

2. The waveform downloaded to the M8190A was a real-signal representation of the combined envelope of the seven signals in the scenario.

Results, part 2: Creating a multi-emitter radar environment

The same system configuration can be used to create a scenario containing 16 radar signals. In this example, eight are Barker-coded and eight are LFM-chirped waveforms. For simplicity, all signals were set up with the same pulse width and pulse-repetition interval (PRI); however, these parameters could be easily changed. The individual carrier signals were spaced at 120-MHz intervals and each signal had an 80-MHz bandwidth.

Figure 6 shows the SystemVue environment used to create this scenario. SignalCombiner resampled and aligned all 16 waveforms, and the output sample rate was set to 8 GHz to match the 14-bit, 8-GSa/s mode of the M8190A.

Within SystemVue, an M8190A "two-channel sink" is used to download the simulated I and Q signals into the AWG. In this case the I and Q signals were fed into the wideband I/Q inputs (Options 016 and H18) of the PSG, which modulated the complex signals onto a 10-GHz carrier.

The signal was analyzed by connecting the output of the PSG to an oscilloscope running the 89600 VSA software. In Figure 7, the upper trace shows the frequency spectrum of the measured signal. All 16 signals are clearly visible:

- The eight Barker-coded signals produce distinct frequency spikes at approximately 9.12, 9.48, 9.72, 10.20, 10.56, 10.68 and 10.92 GHz.
- The LFM-chirp signals produce relatively flat shapes in the frequency spectrum. These are centered at approximately 9.24, 9.36, 9.60, 9.96, 10.08, 10.32, 10.44 and 10.80 GHz.
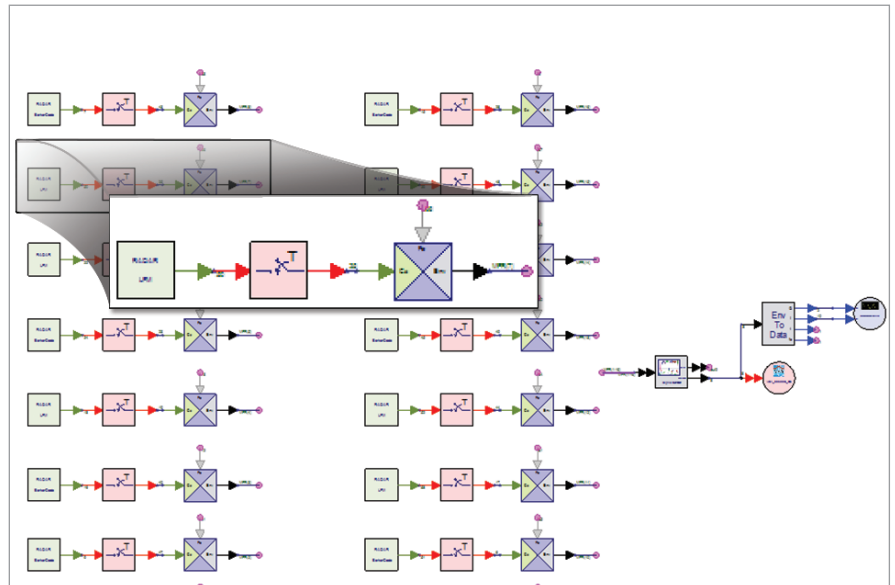

Figure 6. This example design simulation schematic illustrates the combination of multiple LFM and Barker-coded signals.
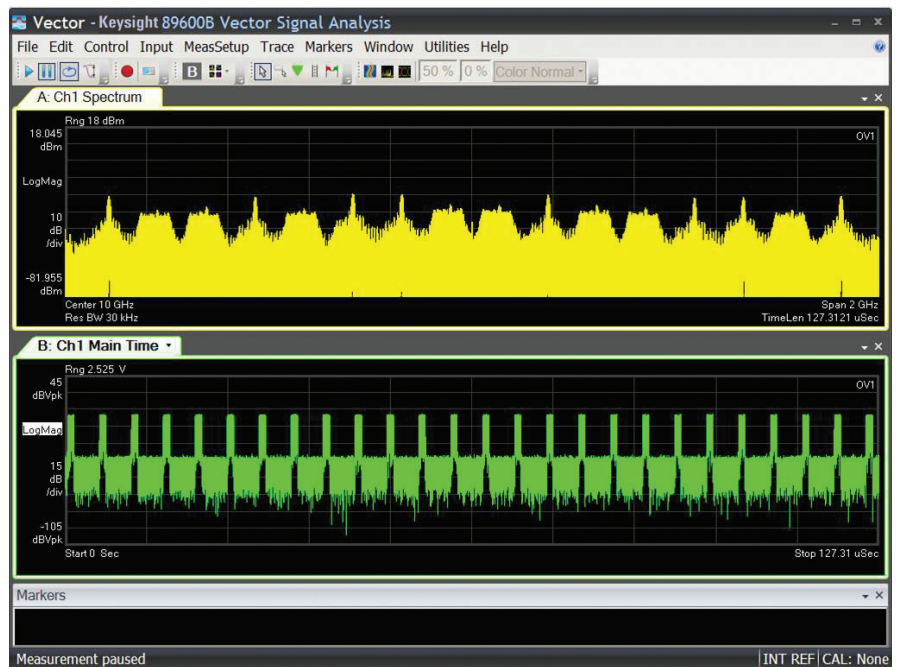

Figure 7. The upper trace is a frequency spectrum that reveals all 16 radar signals within a 2-GHz span.

This same approach can be used to create a 40-GHz test signal. As above, the AWG produces I and Q waveforms that are modulated onto a 40-GHz carrier using a PSG with wideband I/Q inputs.

Conclusion

The approach shown here can be used to create multi-emitter test signals with COTS ESL software, a wideband AWG and a vector signal generator with wideband I/Q inputs. Within the SystemVue ESL environment, Keysight's advances in arbitrary resampling technology—when combined with the signal fidelity provided by recent advances in AWG technology—simplify the generation of wideband multi-emitter signals. The flexibility of this approach enables detailed examination of coexisting emitters using the same test equipment.

The multi-emitter radar results shown here represent preliminary work-in-progress. However, early results show the potential for effective testing of R&D DUT hardware with multiple-emitter test signals. This approach has been used to generate multi-radar emitter waveforms at X-band and Ka-band across 2 GHz of bandwidth.

Although this is not a real-time capability, the flexibility gained by combining design simulation with COTS wideband test equipment is an efficient way to address emerging multi-emitter signal scenarios. With a modest array of equipment, the example configuration provides a cost-effective test solution for present and future multi-emitter applications in R&D.

Related literature

- *Keysight EEsof EDA SystemVue 2012 Technical Overview,* publication 5990-4731EN
  Note: The technical overview includes information about a variety of waveform libraries including radar (W1905), LTE (W1912), WLAN (W1917) and LTE-Advanced (W1918)
- *89600 VSA Software Product Brochure,* publication 5990-6553EN
- *M8190A Arbitrary Waveform Generator Data Sheet,* publication 5990-7516EN
- *E8267D PSG Vector Signal Generator Data Sheet,* publication 5989-0697EN
- *PSG Signal Generators Product Brochure,* publication 5989-1324EN
- *Infiniium 90000 Q-Series Oscilloscopes Data Sheet,* publication 5990-9712EN
- *Infiniium 90000 X-Series Oscilloscopes Data Sheet,* publication 5990-5271EN
- *N9030A PXA X-Series Signal Analyzer Product Brochure,* publication 5990-3951EN
- *X-Series Signal Analysis Product Brochure,* publication 5990-7998EN

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