Keysight Technologies
W1905 Radar Model Library

Offering the Fastest Path from Radar/EW Design to Verification and Test

Data Sheet

KEYSIGHT TECHNOLOGIES

Introduction

Offering the Fastest Path from Radar/EW Design to Verification and Test
The W1905 Radar Model Library is a simulation reference library for designing and testing Radar and electronic warfare (EW) systems. It is available as an option to the SystemVue system-level modeling software.

Modern Radar and EW systems are incredibly complex. They employ complicated architectures with state-of-the-art technology from multiple engineering domains and are installed on a diverse array of platforms such as airplanes, satellites and ships to track, detect and identify a variety of potential targets. Additionally, they must work in a host of operational environments that can include interference, jamming/deception clutters and different target radar cross sections.

To save development time and reduce cost, the SystemVue Radar Library provides 92 highly-parameterized simulation blocks and 93 higher-level reference design workspaces to create working Radar/EW system scenarios. These scenarios can include Radar and EW signal generation and processing, as well as environmental effects like clutter, jamming, interference, targets, and simulated platform and target hardware specific parameters. The ability to simulate not only a Radar/EW system concept, but the full deployment environment enables unprecedented development speed and provides rapid prototyping capabilities for any Radar/EW system development.

While the W1905 Radar Model Library is primarily structured for direct modeling and simulation of a conceptual Radar/EW system and its operational environment, it also can be used to design, verify and test development hardware. The W1905 block set and its example workspaces serve as algorithmic and architectural reference designs to verify Radar/EW performances under different signal conditions and environment scenarios. By accounting for a diverse set of environmental effects, while maintaining an open modeling environment (.m, C++, VHDL, test equipment), the Radar system designer can explore Radar/EW architectures with high confidence, rapidly test and prototype development hardware, and simulate operational results in multiple concept operations, without requiring expensive outdoor range testing or hardware simulators.

Key Benefits

- Accelerates the Radar/EW modeling process using a model-based platform and multi-format IP integration
- Reduces integration risk for RF-DSP architectures with earlier cross-domain analysis and verification
- Validates algorithms and systems under realistic, complex scenarios
- Saves time by starting from validated templates and block-level reference designs
- Generates wideband Radar/ EW waveforms and scenarios using wideband test and measurement equipment, directly from simulations
- Leverages user’s existing IP and test assets throughout the process

New Simulation Approach

The "scenario framework" simulation technique can model any system, from stationary monostatic ground-based systems to more complex multistatic and phased-array systems, including Multiple-Input Multiple-Output (MIMO) Radar.

- The modeling framework supports motion of the Radar transmit and receive platforms, as well as multiple targets, in an earth-centered inertial (ECI) frame
- Multiple antenna arrays can be setup in the framework for different systems
- Sophisticated Radar/EW scenarios, together with complex target modelling, are supported

A simulation example using the scenario framework is shown in Figure 1 and continued on page 11.

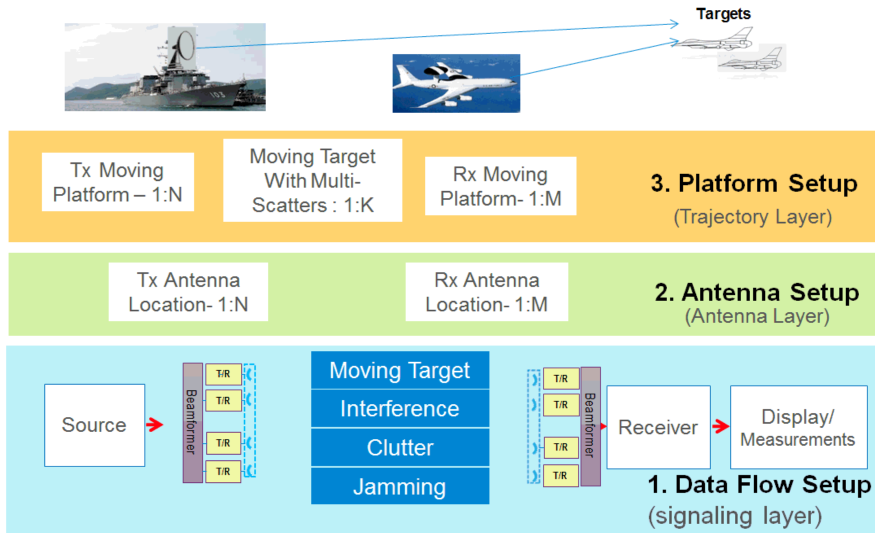

Figure 1. Shown here is a block diagram for the scenario framework simulation—a new simulation technique. Three layers are included.

Trajectory layer (shaded light green) – locates all transmitters, receivers and targets in 3D position, velocity and acceleration spaces.

Antenna layer (shaded yellow) – tracks rotational attitude (pitch, yaw, roll) and beamforming directions for antennas and phased arrays. Phased arrays are true arrays.

Signal layer (shaded green) – traditional baseband signal processing paths, which can include MATLAB, C++, HDL, and RF models, as well as W1905 blocks and instrument links.

Who should buy the W1905 Radar Model Library?

- Radar system designers in military, regulatory, commercial, avionics, automotive, medical, research, academic, and consulting applications
- EW system designers who want to use the W1905 library as a working reference to model unfriendly Radar topologies for jamming and countermeasure scenarios
- System test engineers who want to generate complex waveforms and analyze performance for Radar/EW systems

Supported Applications

The W1905 Radar Model Library includes over 90 examples that can be used as design templates and reference designs. Instead of starting from scratch, users can modify these block-level systems to reflect their algorithms, environments and measurements.

Applications for the W1905 library

- Create proposals and assess feasibility quickly
- Accurate Radar system architecture and scenario analysis
- Algorithmic reference and test vector generation for baseband DSP hardware design
- Precisely-degraded baseband/RF signal generation for receiver testing
- Radar/EW test signal generation, processing and analysis
- Include realistic RF effects, clutter, RCS, and directly-measured target returned waveforms
- Leverage existing math, HDL, and C++ algorithms
- Continue into hardware test using the same SystemVue environment and IP
- Reduce the need for expensive chambers, hardware emulators, faders, and field testing in the early phases of design
- Reduce NRE and scripting with regression suites of simulated scenarios
- Save time by verifying algorithms prior to targeted FPGA/ASIC implementation
- Minimize project costs with easily reconfigured Keysight simulation tools and test equipment

Modeling

Over 90 models are included in the W1905 library. Key models are listed in Table 1.

OS and Simulators	Models	Supported Operations
Source	CW pulse, LFM, NLFM, FMCW, binary phase coded (Barker), poly phase coded (ZCCode, Frank), Poly-Time, FSK HP, arbitrary PRN	DDS, UWB, SFR, SAR, phased array, MIMO
RF Behavior	Tx and Rx front-end, PA, LNA, filters	DUC, DDC, ADC, DAC, T/R modules
Antenna	Antenna Tx and Rx	Phased-array antenna, Tx and Rx
Environments	Clutters, jamming, interference	Moving target, multi-scattering RCS An optional link to the STK software from Analytical Graphics, Inc. (AGI) is also available.
EW	Detection, EP, ES, EA	Receiver, DOA, dynamic signal generation, DRFM
Signal Processing	Pulse compression, detection and tracking, CFAR, MTI, MTD	STAP, SF processing, beamforming, adaptive phased -array receiving
Measurements	Waveform, spectrum, group delay	Imaging display, detection rate, false alarm rate, range & velocity estimation, antenna pattern 2D & 3D
Moving Platform		Moving platform Tx & Rx
Systems	CW pulse, pulse Doppler, UWB FMCW, SFR, SAR	Phased array, MIMO

Table 1. The W1905 Radar Model Library provides a wealth of models, processing blocks and measurements to characterize common Radar architectures.

Radar and EW systems are designed using reference models from the W1905 library (Table 1), as well as the user's own Intellectual Property (IP). Existing models in floating point C++, MATLAB, and VHDL/Verilog formats can also be combined with graphical signal processing blocks and block-level RF subnetworks using the user-friendly System-Vue GUI. This allows components created by different people to be integrated and tested at the system level to validate performance continuously throughout the development process.

Source Models

- Basic waveforms include CW pulse, LFM, NLFM, FMCW, binary phase coded (Barker), poly phase coded (ZCCode, Frank), PolyTime, FSK, and arbitrary PRN
- Generated dynamic pulse with run-time parameters for EW or Radar
- Supports advanced systems for UWB, SAR, SFR, phased array, and MIMO
- Supports Electronic Attack (EA), Electronic Warfare Support (ES) and Electronic Protection (EP) for test purposes

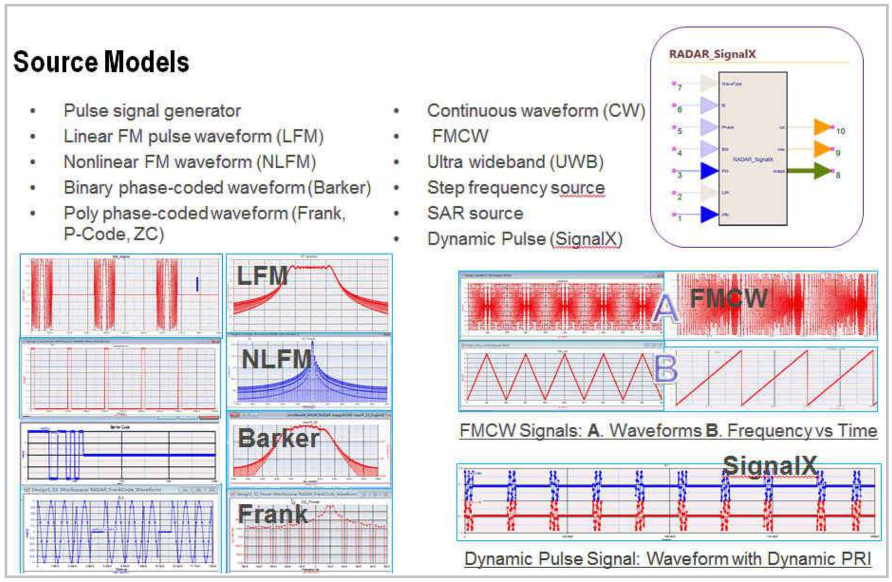

Figure 2. The “SignalX” model allows dynamic pulse offsets and jitter to be coded into Radar signals, essential for realistic system evaluation in crowded signaling environments.

Target Model

- Key parameters include
- Target location (LLA), initial range, speed, and acceleration
- SCR-type, for single point and multi scatters
- Radiation patterns, specified as either uniform, cosine, parabolic, triangle, circular, CosineSquared, pedestal, or Taylor, or a user-defined pattern imported from a pre-simulated result from EMPro or some other electromagnetic software

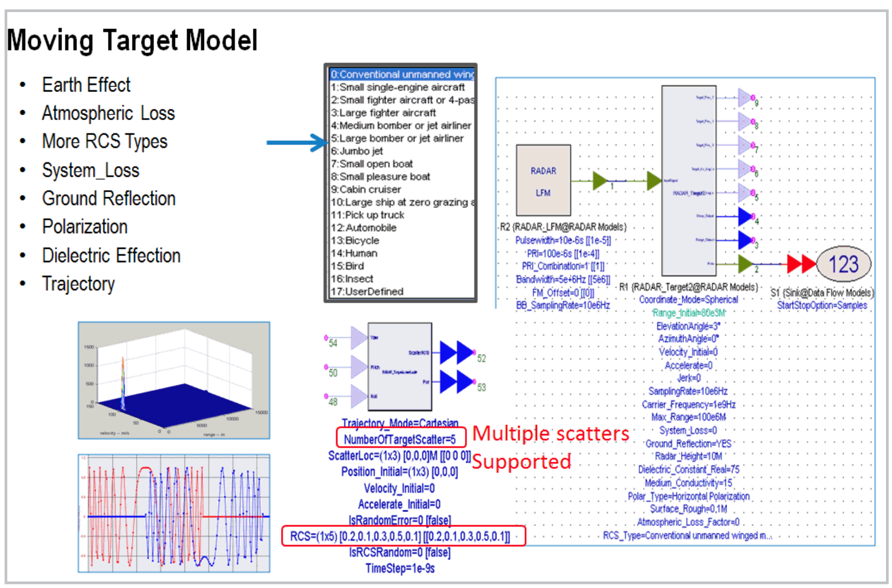

Figure 3. Creating reference signals with multiple RCS targets and scatterers is helpful for both simulation and waveform generation for test and measurement applications.

Antenna Models, Tx and Rx

Modes

- Search and tracking
- Support for moving target scenarios

Antenna patterns

- Pre-defined: uniform, cosine, parabolic, triangle, circular, CosineSquarePedestal, and Taylor.
- User defined: AntennaPatternArray parameter is used for importing from 3D electromagnetic software, such as EMPro

Scan patterns

- Circular, bi-directional sector scan, uni-directional sector scan, bi-directional raster, uni-directional raster.

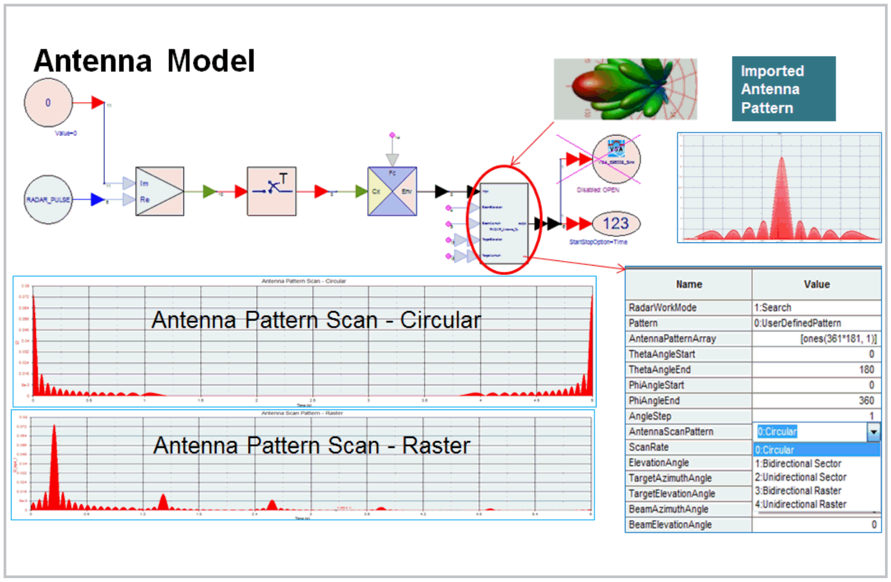

Figure 4. Antenna simulation models that scan a 3D environment in common patterns are useful for modeling coverage, detection margins and latencies in search, tracking and imaging modes of operation.

Phased-Array Models, Tx and Rx

Modes

- Linear array
- 2D Planar array

Array antenna pattern

- User-defined pattern: AntennaPatternArray parameter allows the user to specify arbitrary geometry of antenna units using the AntennaPatternArray in the UserDefinedPattern.
- Calculated patterns supports uniform, cosine, parabolic, triangle, circular, CosineSquarePedestal, and Taylor.

Moving target scenario: Supported by the PhiAngleStart and PhiAngleEnd for the scope of the azimuth angle

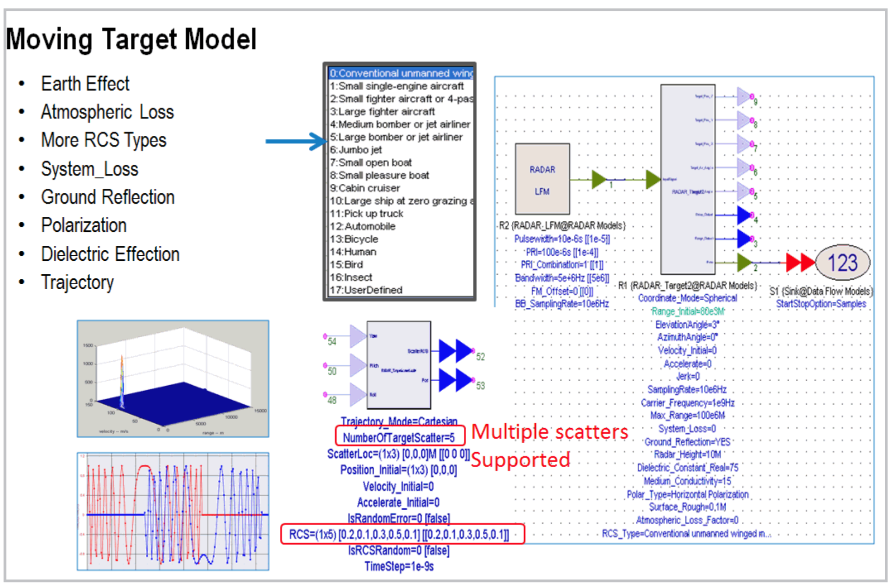

Figure 5. The phased-array antenna simulation model allows beamforming and statistical effects to be modeled at the system-level in a dynamically moving environment, affecting overall signal, sidelobe, clutter, and jammer levels during the simulation. This model influences system-level results, such as Probability of Detection (Pd).

Adaptive Digital Beam-forming

In the model, the digital beamforming architecture enables the use of a number of array signal processing techniques listed below to enhance Radar performance.

- Digital re-steering of beams on receive for improved search occupancy
- Adaptive cancellation for jammer and electromagnetic interference (EMI) mitigation
- High-resolution angle estimation of both targets and jammers for improved metric accuracy

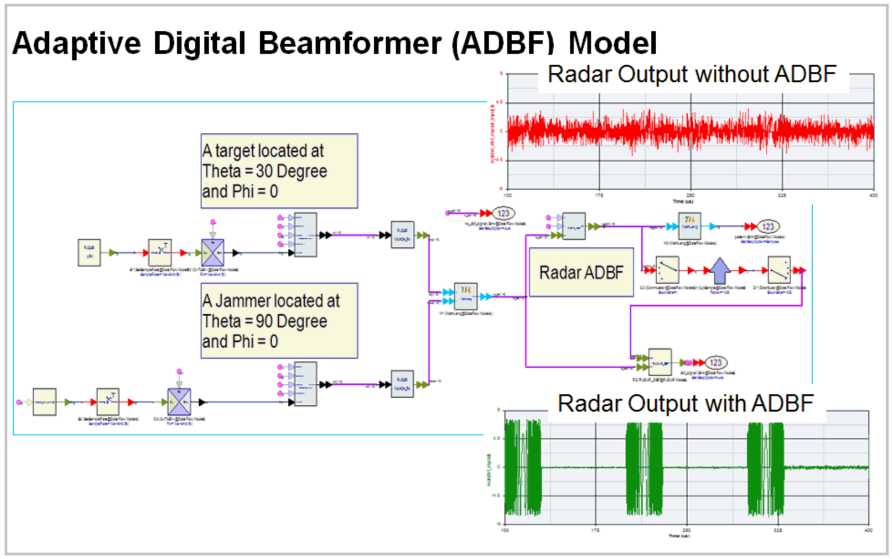

Figure 6. The Adaptive Digital Beamformer simulation model accounts for the dynamic behavior of phased arrays, such as the ability to modify the shape of the beam in order to null sources of interference and jamming coming from specific angular directions.

Modeling Clutter

- Models coherent or non-coherent correlated clutter
- Supports Rayleigh, Log Normal, Weibull, and K probability distribution functions; K-clutter is often used for sea-surfaces
- Gaussian, Cauchy and all pole PSD

Clutter Model

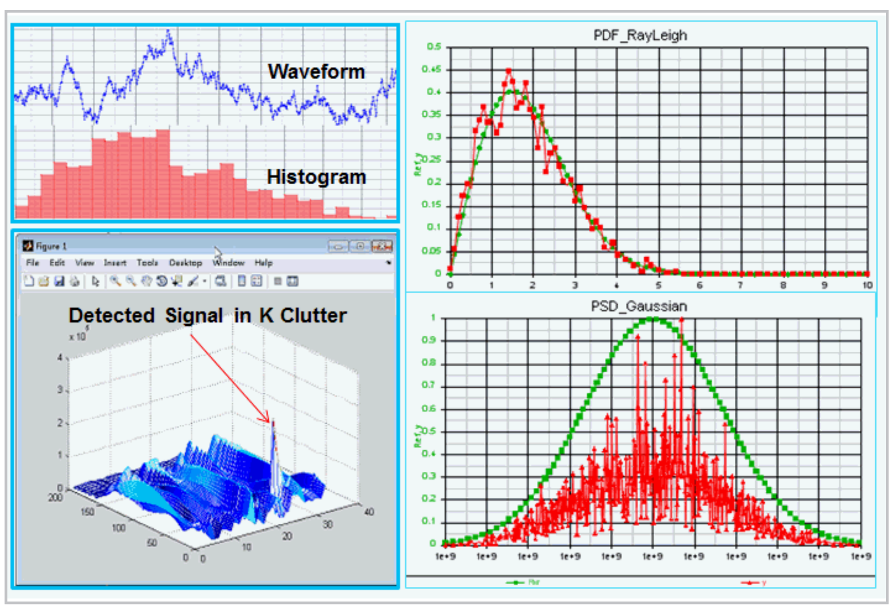

Figure 7. A target detection application example is shown here. The Radar signal processing detects the moving target successfully, even though the target echo is covered by strong K clutter.

Radar Measurements

- Basic measurements: waveform, spectrum and SNR
- Advanced measurements Detection probability, false alarm probability
- Parameter estimation for range, velocity and acceleration
- Antenna pattern measurements
- 3D Plot in the Range-Doppler plane

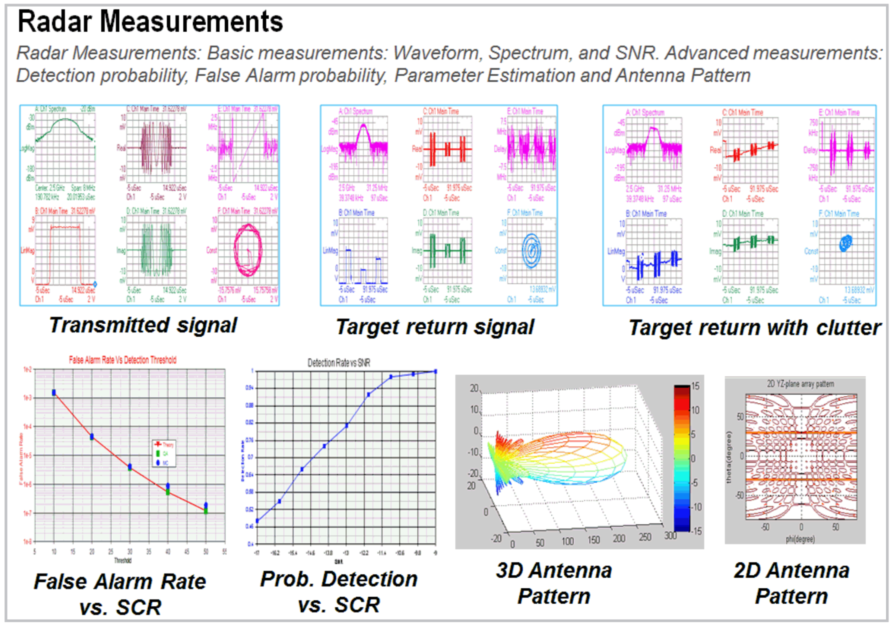

Figure 8. The W1905 library provides algorithms for common measurements, such as false alarm rate versus signal/clutter ratio, and integrates well with MATLAB from MathWorks, and Keysight's 89600 VSA software.

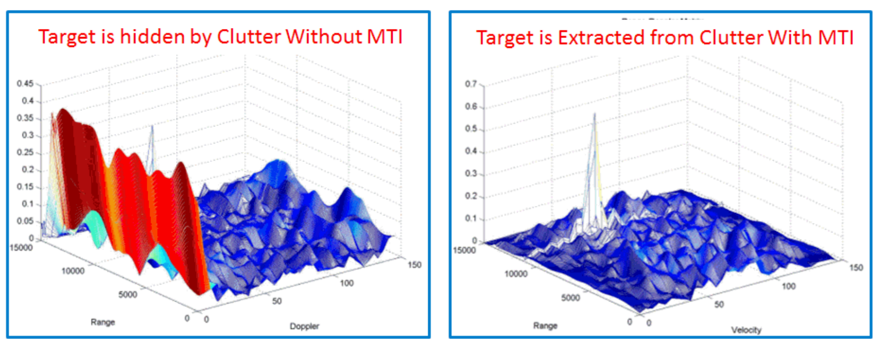

Figure 9. The effect of clutter can be seen in these plots of range bins, with and without Moving Target Indicator (MTI) processing.

Simulation and Application Examples

SystemVue is a simulation platform for users to model, design and verify a variety of Radar/EW systems, together with their external environments. Typical applications of SystemVue simulations are listed on Page 2. Using customers' models and built-in models, different Radar/EW systems can be constructed and simulated.

Typical Radar/EW technologies supported by the W1905 library:

- Continuous-Wave (CW) Radar modeling and simulation
- Frequency Modulated Continuous-Wave (FMCW) Radars, widely used in automotive applications
- Pulsed Radar simulation
- Pulsed-Doppler (PD) Radar architectures, for airborne and ground and sea environments applications
- Ultra-Wideband (UWB) Radars, and wideband receivers
- Synthetic Aperture Radars (SAR) for raster imaging and mapping
- Stepped-Frequency Radars (SFR) for ground- and wall-penetrating applications
- Phased-array and Digital Array Radars (DAR) for passive or active arrays
- MIMO Radars for increased range resolution and robustness
- Multistatic Radar simulation and capability

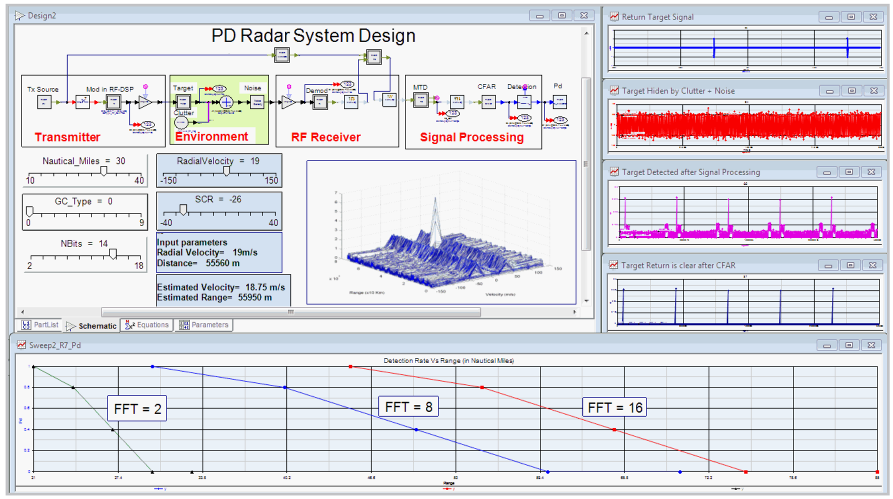

Figure 10. This pulsed Doppler application example profiles the Pd versus target range (a measure of sensitivity), for three values of Fast Fourier Transform (FFT) bin size.

Example: Pulse Doppler Radar

- Transmitter, detection environments, RF receiver, signal Processor and performance measurements are included in the design.
- It can be used as a template for both RF and DSP algorithm designs.
- First, the waveform analysis can be accomplished as shown in the waveform plots; the target return, received signal, detected target after PD signal processing, and CFAR outputs are displayed.
- Also, the 3D plot in the Range-Doppler plane is provided to analyze the signal processing algorithm.
- System performance can be measured by detection rate. Three curves profile the probability of detection rate versus the range under different signal processor FFT sizes.

Example: Synthetic Aperture Radar (SAR)

- In X-band with center frequency of 10 GHz, bandwidth of 24.13 MHz and 1.667 msec RPI.
- The SAR test signal is constructed. A SAR receiver with multi-dimensional signal processing is also provided.
- As can be seen, with the signal processing, target hidden in clutter can be detected.

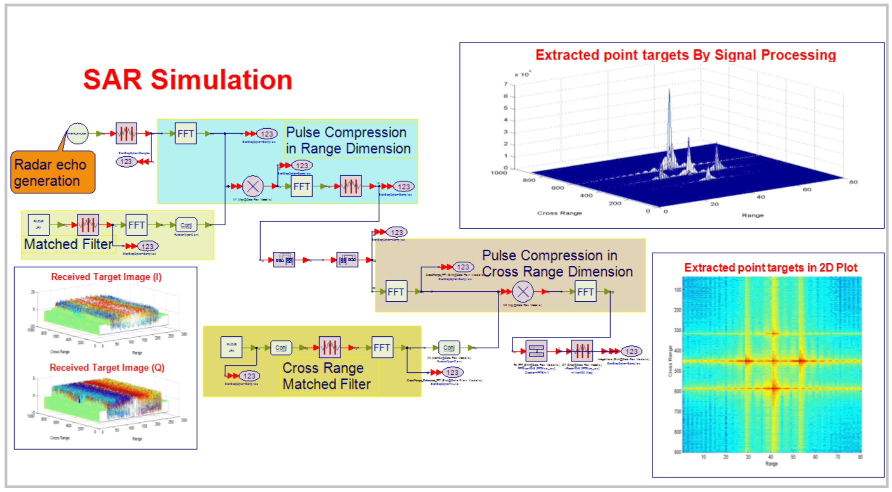

Figure 11. This SAR example shows the effect of 2-dimensional pulse compression to reveal targets previously hidden by clutter.

Example: Automotive Radar (FMCW)

- SystemVue supports an automotive Radar architecture including FM source, target, receiver, signal processing, and measurements.
- It can be used as a template of automotive Radar design. Users can replace models in the design with their own IP in MATLAB code or C code.
- Transmission measurements include waveform, spectrum and group delay to show the curve of frequency versus time.
- A 3D plot in the Range-Doppler plane is provided for convenient analysis of the signal processing algorithm.
- Range and velocity estimations are directly displayed to give users an indication of the quality of their designs.

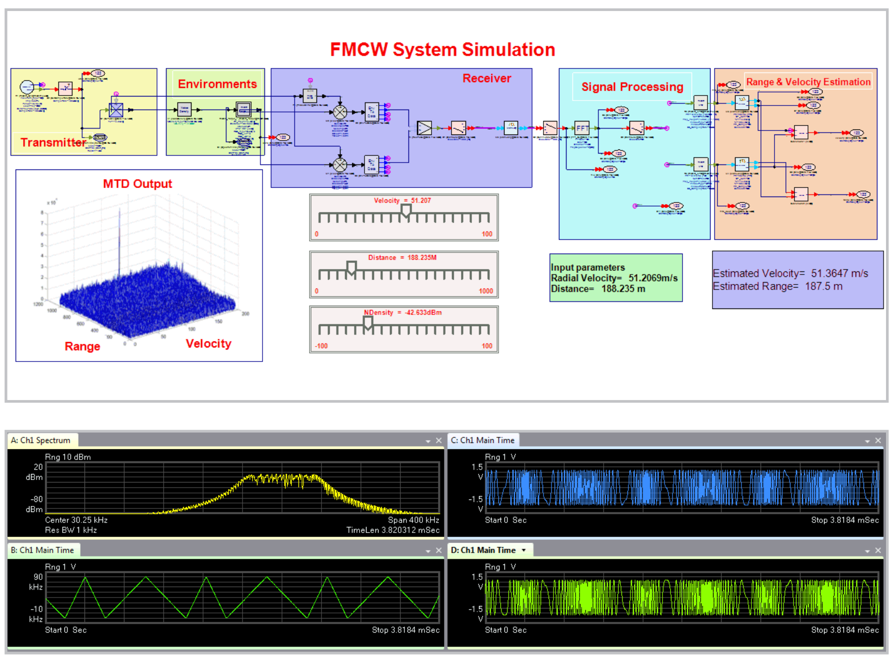

Figure 12. SystemVue provides FMCW support for automotive applications, and can also model system with array antennas. In this image, the FMCW waveforms are visualized using the Keysight 89600 VSA software, which can be used on SystemVue simulations, as well as test signals.

Example: RF-DSP Co-Validation

Looking left to right in Figure 13, the Linear-Frequency-Modulated (LFM) pulse is generated and then upconverted by a RF transceiver architecture toward a target at a range of 2000 m and speed of 100 m/s. The RF transceiver is characterized by an in-platform RF system simulator that accounts for nonlinear analog effects, and then included automatically at run-time at the system level. Radar clutter is considered. The echoes returning from the target are detected by the additional Radar signal processing in the receiver (lower right on the schematic). Finally, the Pd rate is measured to indicate system performance.

A reference design like this can be quickly and easily reused as a template for other system designs. Users would simply replace the models with either their own RF architectures or baseband DSP algorithms, and re-test.

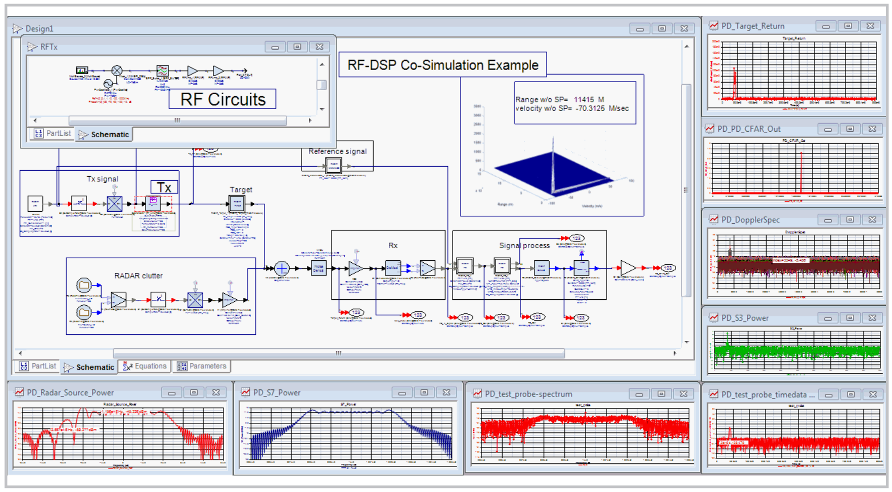

Figure 13. This example shows the validation of a RF-DSP co-architecture across the two domains.

Scenario Framework for Moving Platform Modeling

Modeling moving airborne, space-borne and ship-borne platforms and targets

The W1905 Radar Model Library provides a schematic-based framework for modeling Radar/EW scenarios in a 3-dimensional coordinate system. This allows the user to define the positions, velocities, rotations, and beamforming directions of each transmitter, receiver and targets in the system. Multiple objects are rendered as either "arrays" of data, or "buses" of schematic wires, making scaling to multiple objects straightforward.

From this additional inertial information, SystemVue derives secondary quantities such as delay, Doppler shift and reflection amplitude (accounting for beam direction and sidelobe levels), and then modifies the signal processing layer signals as required. This "framework" is essential for modeling even basic performance for moving Radar platforms, including airplanes, ships and satellites, and is fully scriptable.

While other software applications are available to render some of this spatial information more visually, SystemVue provides a single, in-platform cockpit and API to offer essential 3D modeling for reasonable numbers of objects. This allow users to build multistatic, moving scenarios, with active signal processing, with a minimum of overhead and software licenses. SystemVue's W1905 library offers this 3D scenario modeling, while still retaining polymorphic modeling interfaces to C++, .m, and HDL, as well as links to superior RF modeling, test equipment and a whole-platform API for regression harnesses. For ultimate 3D modeling, SystemVue can optionally link to external software, such as STK from Analytical Graphics, Inc. featured on page 15.

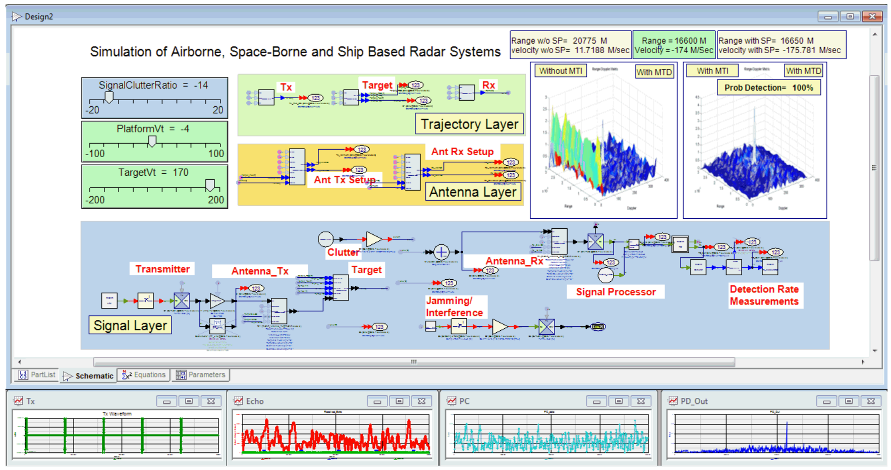

Figure 14. This example shows 3D scenario modeling using modeling layers for trajectory, beamforming and signal processing.

Modeling layers shown in Figure 14

1. **Trajectory layer** (shaded light green) – locates all transmitters, receivers and targets in 3D position, velocity, and acceleration spaces
2. **Antenna layer** (shaded yellow) – tracks rotational attitude (pitch, yaw, roll) and beamforming directions for antennas and phased arrays; phased arrays are true arrays.
3. **Signal layer** (shaded green) – traditional baseband signal processing paths, which can include MATLAB, C++, HDL, and RF models, as well as W1905 blocks and instrument links.

Advantages of SystemVue for Instrument Co-ordination

Integrated environment

- Different instruments
- DUT
- Test environments, clutters, interferences, target, RCS

RF Architecture consideration

- Complex HPA with nonlinearity
- Low noise PA
- Phase and frequency errors and additive and phase noise

Complex waveform

- Waveforms required by new standard
- Radar, EW
- MilCom, SatCom

System performance

- False alarm rate, detection rate
- Parameter estimation for range and velocity

Integration and controlling for System test

- Custom waveforms
- Advanced measurements
- Automated test

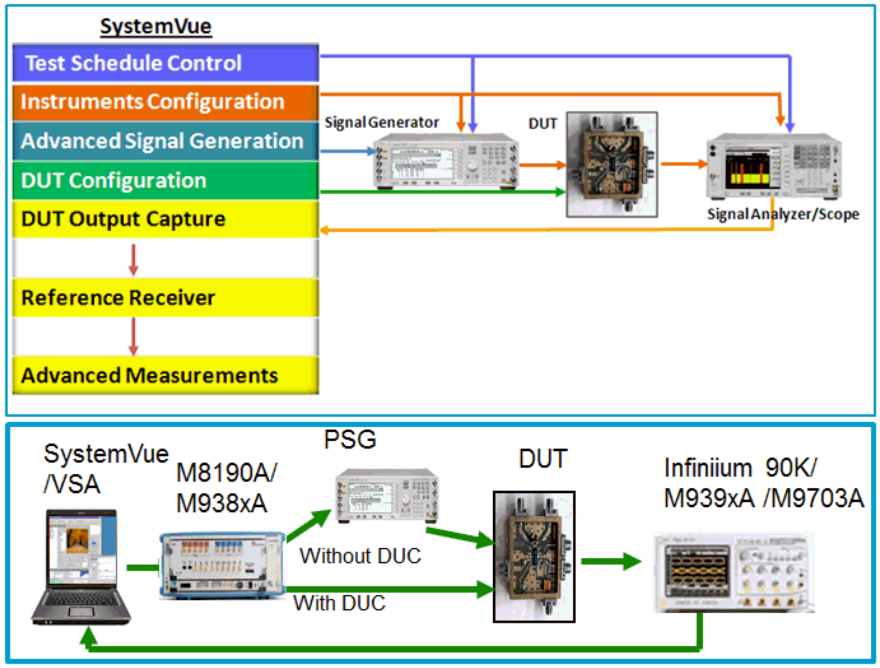

Figure 15. SystemVue is used as core software in a hardware test system

The same signals present in SystemVue simulations can be sent to, or captured from, the user's preferred test and measurement signal generation and digitizer platforms. This interaction quickly creates flexible application waveforms for test and measurement, and brings measured waveforms into the simulation environment, to validate DSP algorithms under conditions in the field. SystemVue also provides additional scripting through integration with Keysight's Command Expert software.

SystemVue can be controlled from external applications, such as C#, Microsoft Excel and Visual Basic, MATLAB, and LabVIEW. These allow standalone applications to harness the power of SystemVue into regression suites and test executives that automate routine verification tasks.

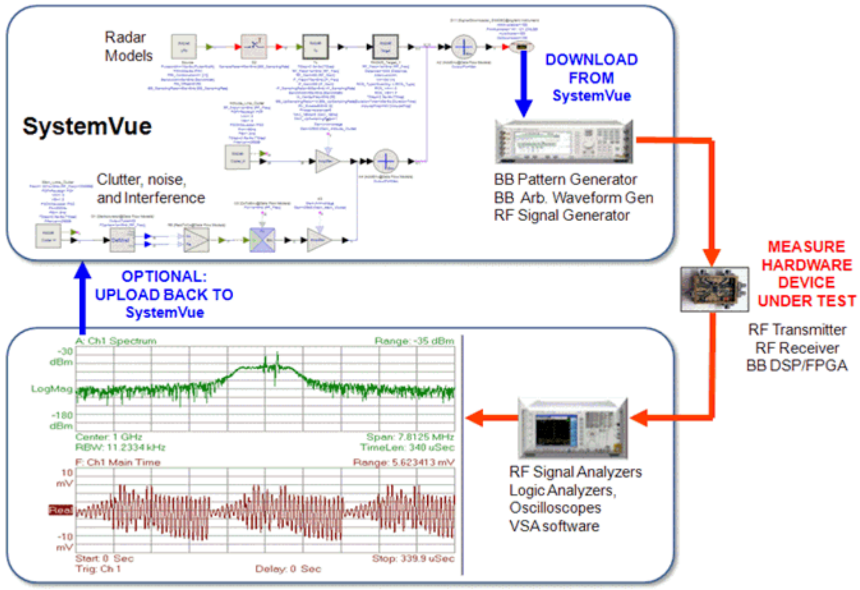

Figure 16. The same signals present in simulations can be sent to, or captured from, the user's preferred test and measurement signal generation and digitizer platforms.

Using the W1905 Library for Test and Measurement Applications

- Radar/EW signals can be generated in SystemVue simulation and then downloaded to arbitrary waveform generators (such as the M8190A), as well as a modulated RF vector signal generator (e.g., the N5182B and M9381A)
- Measured raw waveforms from Keysight's signal analyzer and digitizer (the M9307A, 90 Series and PXA) can be linked back to SystemVue for further analysis and advanced receiver measurements

Platform for EW Development

System analysis

- Algorithm development baseband and RF design
- Test integration

Versatile EW Test Signal Generation

- Waveform Sequence Composer
- Easy to use
- Long AWG waveforms
- Signal combiner
- Channelization source

Typical EA, EP and ES Applications

- Radar warning receiver
- Angle of direction
- DRFM for jammers

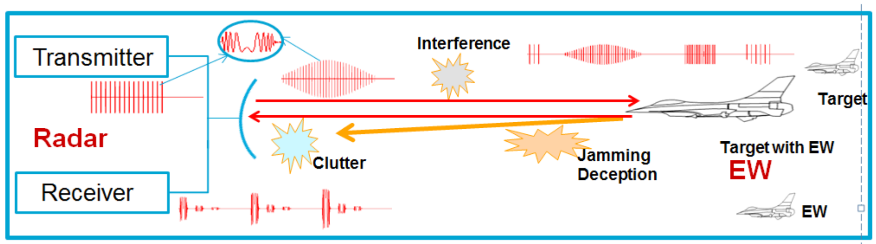

Figure 17. SystemVue's simulation infrastructure for modeling Radar system architectures can also be leveraged to model other components of Electronic Warfare scenarios, including EA, EP and ES applications.

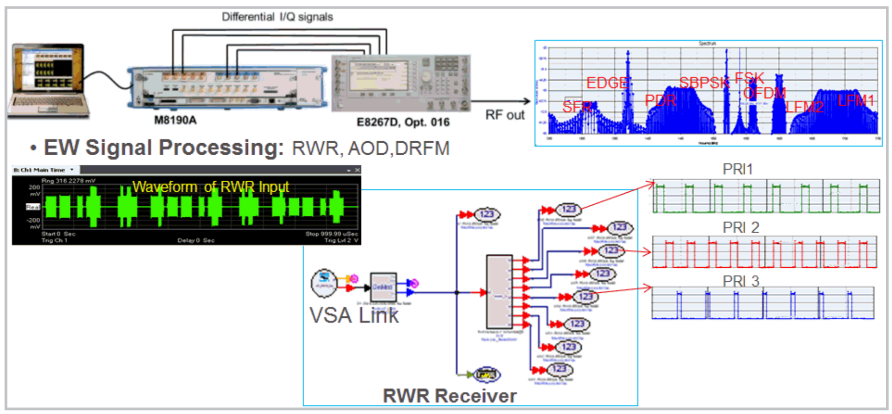

Figure 18. SystemVue's ability to create multi-GHz composite multi-emitter signals is essential for validating both algorithms and hardware designs. Upper: SystemVue creates a multi-emitter signal to download to test equipment signal generation, to test for detection by a Radar warning receiver. Lower: A captured signal is brought into SystemVue for testing RWR algorithms, which separate an unknown composite signal into three underlying Radar signals with different pulse repetition intervals (PRI).

The Digital RF Memory (DRFM) application example in Figure 19 shows how the effect of jamming on Radar receiver performance can be modeled quickly.

- In the upper left corner, a Radar transmitter transmits LFM pulses to illuminate targets.
- In the EW system (top), a DRFM algorithm is used with Range Gate Pull Off (RGPO). The EW system receives the Radar signal, down-converts it, and samples it through an ADC. The sampled Radar signal is then processed to modify the magnitude, phase and carrier frequency, and re-transmitted as a deceptive signal that is coherent with the original Radar signal.
- At the Radar receiver, the target return has now been jammed by the EW system. Additional signal processing can be used in the Radar receiver to detect and circumvent the deception from the DRFM. But, since the deception is coherent with the original Radar transmission signal, the unmodified Radar now fails to detect the target correctly.
- SystemVue as an EDA platform is used to design the desired algorithms and hardware, whether they are Radars or their countermeasures. The “other” functional components in the scenario need to be modeled also. The W1905 Radar Model Library can save time and NRE when modeling these other components.

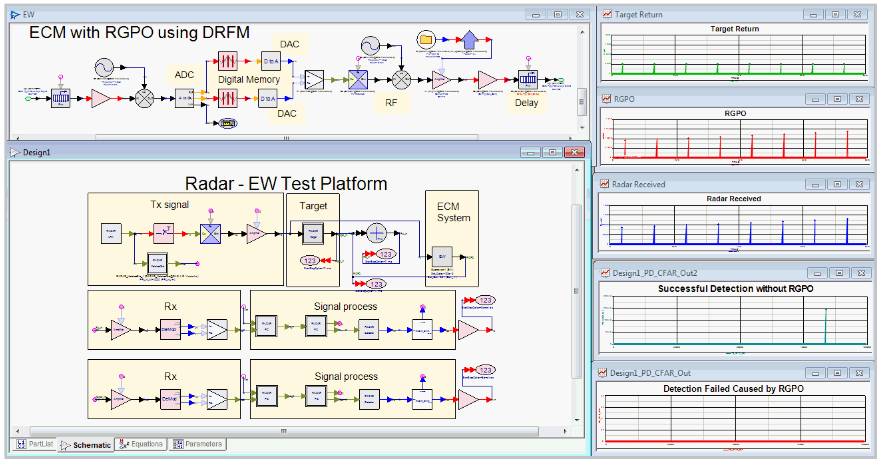

Figure 19. Shown here is an example of EA and Electronic Countermeasures (ECM) with a DRFM test platform.

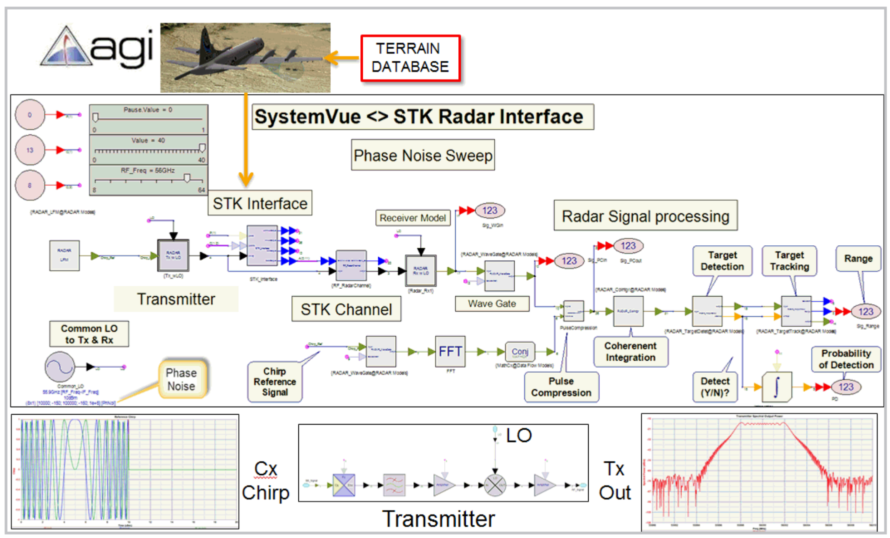

Figure 20. For advanced scenario modeling for Radar, satcomm, and terrestrial links, SystemVue can be integrated with STK from Analytical Graphics, Inc. (AGI).

In the example in Figure 20, parameters such as fading, delay and Doppler shift from a virtual flight scenario over a 3D terrain database are passed from the AGI STK 10 software into the fading, target and clutter models of the SystemVue W1905 library. SystemVue is then scripted to render the actual RF signal at any point along the virtual mission to Keysight instruments, in order to provide far less expensive “virtual flight testing” in an R&D environment. Learn more in application note 5991-1254EN.

Conclusion

The SystemVue W1905 Radar Model Library provides modern Radar/EW system designers with highly parameterized simulation blocks and high-level reference design workspaces they can use to create working Radar/EW system scenarios. Such functionality saves engineers development time, reduces cost, enables unprecedented development speed, and provides rapid prototyping capabilities for any Radar/EW system development.

For more information about SystemVue, please visit:

Product information
http://www.keysight.com/find/eesof-systemvue

Product Configurations
http://www.keysight.com/find/eesof-systemvue-configs

Request a 30-day Evaluation
http://www.keysight.com/find/eesof-systemvue-evaluation

Downloads
http://www.keysight.com/find/eesof-systemvue-latest-downloads

Helpful Videos
http://www.keysight.com/find/eesof-systemvue-videos

Technical Support Forum
http://www.keysight.com/find/eesof-systemvue-forum

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at:
www.keysight.com/find/contactus

Americas

Canada	(877) 894 4414
Brazil	55 11 3351 7010
Mexico	001 800 254 2440
United States	(800) 829 4444

Asia Pacific

Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 112 929
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Other AP Countries	(65) 6375 8100

Europe & Middle East

Austria	0800 001122
Belgium	0800 58580
Finland	0800 523252
France	0805 980333
Germany	0800 6270999
Ireland	1800 832700
Israel	1 809 343051
Italy	800 599100
Luxembourg	+32 800 58580
Netherlands	0800 0233200
Russia	8800 5009286
Spain	800 000154
Sweden	0200 882255
Switzerland	0800 805353
	Opt. 1 (DE)
	Opt. 2 (FR)
	Opt. 3 (IT)
United Kingdom	0800 0260637

For other unlisted countries:
www.keysight.com/find/contactus
(BP-09-23-14)

KEYSIGHT TECHNOLOGIES

Published in USA, October 7, 2014
5990-6347EN
www.keysight.com