BROCHURE

PNT X CRPA Test System

Dedicated wavefront
anti-jam antenna test solution

Spirent Federal Systems

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1. Introduction

CRPAs and other adaptive antenna systems need to be thoroughly tested, particularly if they are to be used in safety and mission-critical contexts. Comprehensively exercising the positioning precision, anti-jam and anti-spoof capabilities of CRPAs requires precision GNSS signal generation, reliable phase alignment, conducted and over-the-air capability, and the high level of realism required for testing to be realistic and representative. From the advent of adaptive antennas, Spirent technology has been trusted by the leading developers and integrators, and the PNT X simulation system is the latest in this line of unrivaled technological excellence.

2. Key capabilities

Powered by SimGEN® scenario creation and simulation control software and using the latest state-of-the-art PCIe Gen 3-based architecture designed specifically for GNSS signal simulation, the PNT X produces a comprehensive range of emulated RF signals with industry-leading ICD compliance, flexibility, fidelity, performance, and reliability.

PNT X is an integrated solution and is designed to support unique wavefront simulation requirements.

GNSS signals

- Full application of existing capabilities of PNT X as per reference a).
- Generation of **all known GNSS signals**, including L and S band and encrypted signals, supported by a continuous program of development to ensure compliance to the latest versions of Signal-in-Space ICDs.
- **Regional Military Protection:** First-to-market solution for GPS RMP. Enhanced M-Code modeling allows for on-the-fly generation of RMP and non-RMP signals on the same SDR - without need for pre-recorded datasets.
- Support for **16+ antenna elements**, each outputting multiple inter-carrier phase-aligned multi-frequency, multi-GNSS, plus spoofing and interference/jamming signals.
- Simultaneous simulation of **thousands of independent signals**

Custom signals

- **Flexible signal modification** including non-SIS ICD internally generated codes, variable chipping rates and code sequencing, modulation types, shaping and filtering.
- **Navigation data injection** - I/Q input of external waverforms available, blended with internally generated GNSS signals.
- **I/Q spatial awareness** - a patented solution that superimposes scenario-specific signal effects such as power levels and Doppler offsets onto external I/Q data

Interference and Spoofing

- **>130 dB** Jammer to GNSS nominal signal ratio.
- **140 dB of continuous dynamic range** to support full range of interference signal power
- Generation of a **wide range of multiple interference/jammer signals**, including **custom waveforms** with variable bandwidth.
- Simulation of **multiple spoofers/repeaters** allowing a range of PVT corruptions such as trajectory and navigation data spoofing using comprehensive controls via SimGEN.

Enhanced realism & Other sensors

- Unique approach to simulating **real-time multipath and obscuration effects** based on an embedded synthetic 3D environment and an advanced signal propagation model.
- Configurable simulation iteration rate - up to **2000 Hz**.
- Optional mode of operation for fast spinning vehicles that increases the update rate of the system to **100 kHz along the spinning axis**
- **EGI/IMU signal simulation** through the SimINERTIAL™ add-on module for Spirent's SimGEN control software to characterize the performance of a CRPA-based GNSS/Inertial solution.

Secure By Design

- Security is a core element of design, with CAT I and CAT II STIG requirements
- TPM 2.0 (ISO/IEC 11889) chip in the motherboard future-proofing the system for more demanding requirements
- Self-encrypting SSDs available for an extra layer of protection

3. System Architecture

Testing adaptive antennas demands high levels of integrity. To deliver this, it is essential for test systems to employ tightly integrated hardware and software architecture that is designed and optimized for purpose.

Unlike other platforms, PNT X was designed and built using bespoke hardware and decades of experience to deliver on the unique requirements of GNSS testing. This means that users can push the system to the limits of its capability without ever worrying that the signal generation performance will be compromised. Ultimately, this dedicated approach helps you to develop products that are ready to succeed in the real world by ensuring the performance of your device is never masked by the performance of the test instrument.

System hardware components

The overall system comprises several key hardware components depicted in Figure 1. The number of signal generators or I/Q streaming servers varies depending on user application and testing needs. All the equipment is self-contained in a 19" rack cabinet solution.

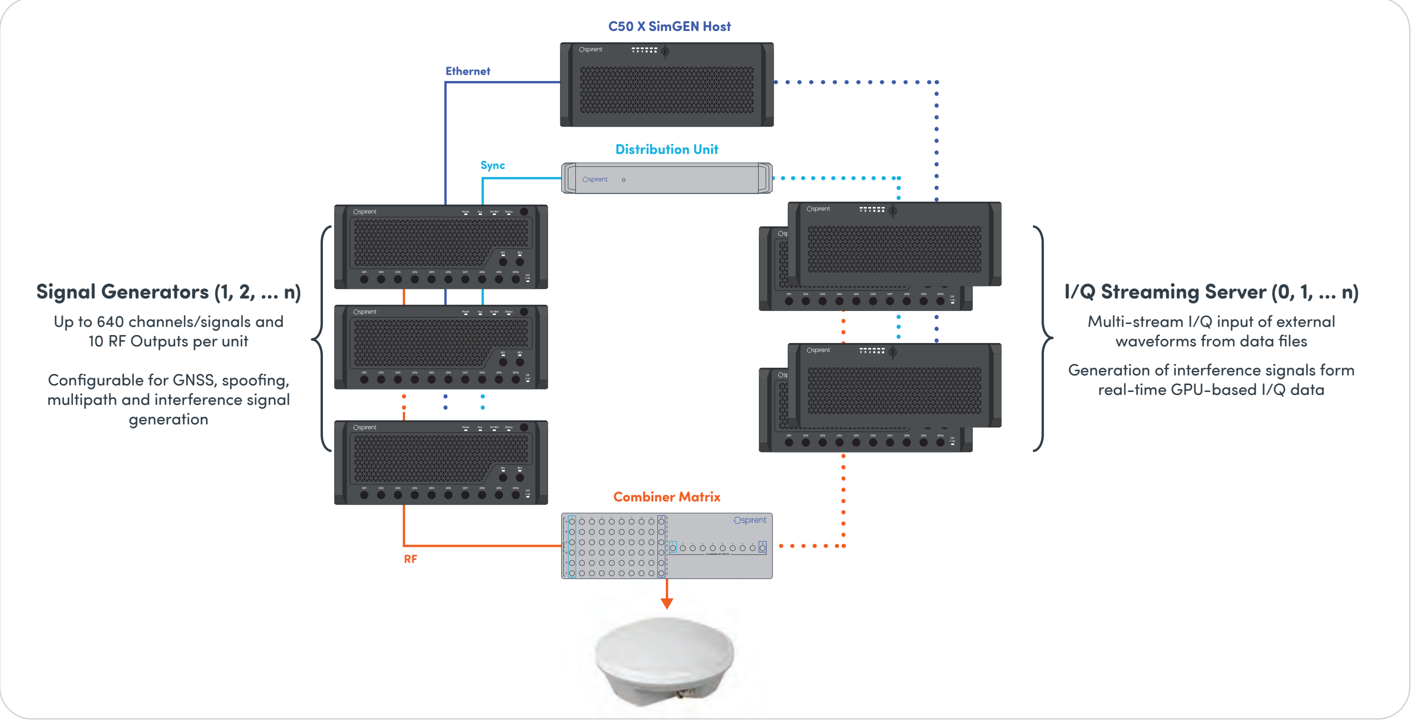


Figure 1: Multi-element system configuration diagram

C50 X – Host controller

This is the system orchestrator, running SimGEN Scenario Generation and Control Software. The host controller allows the user to define all scenario conditions and control the simulation at runtime from a Spirent proprietary design multi-processor/core system, installed with Spirent's mixed Operating System (OS) environment (Linux and Windows 10 Professional for Embedded Systems ESD [Virtualization Only]).

Distribution Unit

The distribution unit provides a timing source of 10 MHz from the reference oscillator and 1 PPS output from the first PNT X across the rest of the system.

PNT X – RF signal generator

The overall system includes one or more RF signal generators, each with its own dedicated embedded controller running the simulation engine, and each providing up to 10 individual and 2 composite RF outputs.

The PNT X simulation system employs a highly digital and flexible hardware architecture that is used to generate GNSS signals, interference waveforms and spoofer/repeater signals at multiple frequencies.

The configuration of generated signals (depending on type) can be changed 'on-the-fly' between different scenarios and from run-to-run. Multiple signal generators can be combined, depending on the combination of signals that need to be generated simultaneously.

I/Q Streaming Servers

Spirent's GPU-based SimIQ product, which adopts the InfiniBand networking standard, coupled with the flexibility, high-fidelity RF and very high power of PNT X further adds to the scalable nature of the system.

In real-time and under the direct control of SimGEN, SimIQ can read in user defined I/Q files and apply all spatial, motion, environmental and antenna effects. Alternatively, under the direct control of SimGEN, SimIQ can generate GTx signal directly from the standard library of supported signals types.

RF signal combiner matrix

The combiner matrix blends all the RF signals generated and allows users to combine more than 16 antenna elements to match their CRPA antenna design.

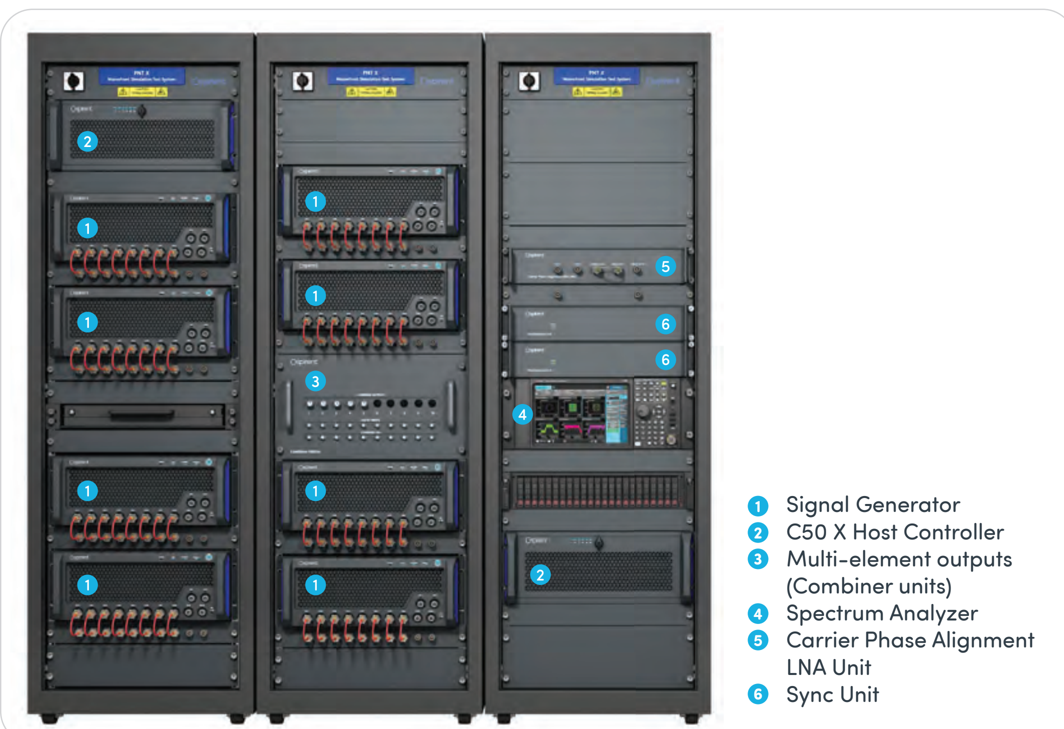


Figure 2: Example of a multi-element, multi-GNSS + jam + spoof simulation system

SimGEN software

The user interacts with a single instance of Spirent's SimGEN software application running on the C50 X SimGEN Host.

In addition to automatically calculating a vast array of data necessary to generate GNSS constellation and other signals, SimGEN (see reference b) provides the user with an extensive set of features that can be used to configure and define the required test scenario. This includes interactive controls for adjusting scenario parameters either before the scenario run or in real-time, as well as display, logging and streaming of every parameter associated with the scenario at configurable rates up to 2000 Hz.

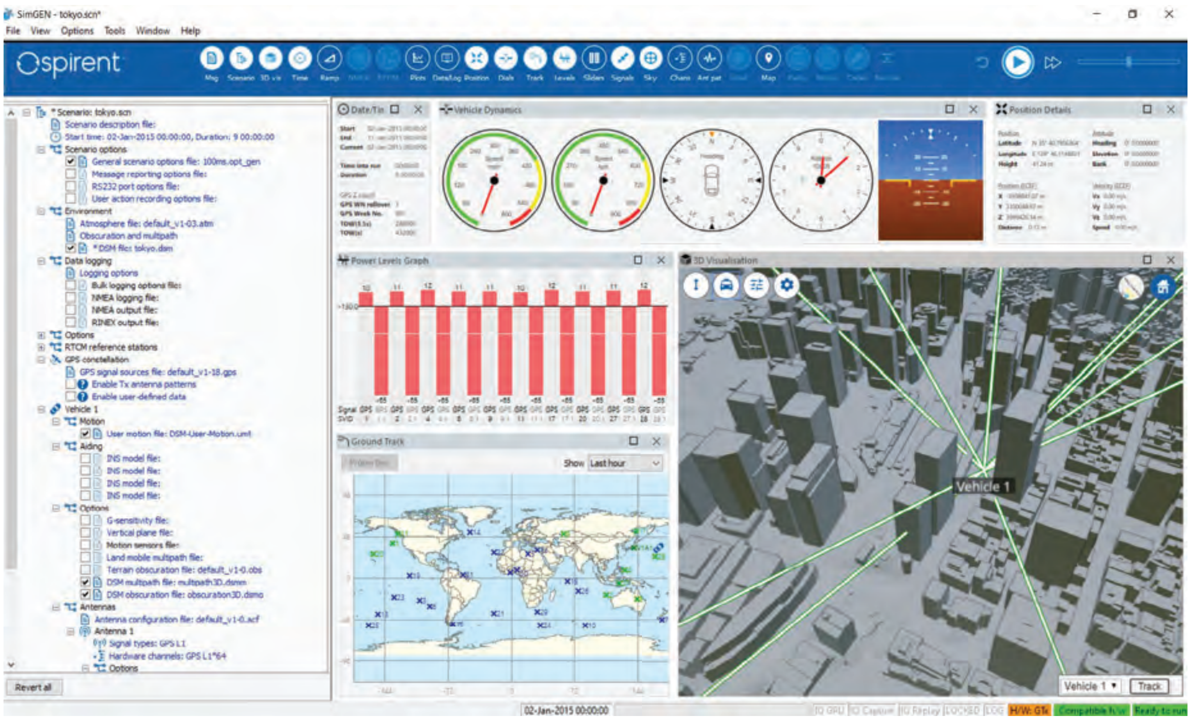


Figure 3: SimGEN scenario definition and simulation control software GUI

Precise Signal Definition

- Fully automatic and propagated generation of satellite orbital data, ephemerides and almanac, as well as capability to closely align simulated signals to live-sky (see MS3121).
- Multiple mechanisms for applying declared and undeclared errors and modifications to navigation data, satellite clocks and orbits.
- Independent satellite signal power, pseudorange , modulation and code control.
- DGPS corrections.
- Leap-second and week roll-over event testing.

Advanced Simulation of Signal Impairments and Threats

- Terrain modeling features for real-time obscuration and multipath calculations based on a 3D scene.
- Simulation of ionospheric and tropospheric effects, including ionospheric scintillation.
- Coherent and non-coherent interference and noise modeling.
- Multi-copy constellations and spoofing capabilities.

Configurable Vehicle and Antenna Models

- Built-in, customizable dynamics models for aircraft, spacecraft, LEO satellites, marine vessels and land vehicles.
- Reception and satellite transmit antenna gain, phase and polarization pattern control.
- Application of antenna lever arm effects – including fast-spinning vehicles.
- Consideration of clock g-sensitivity.

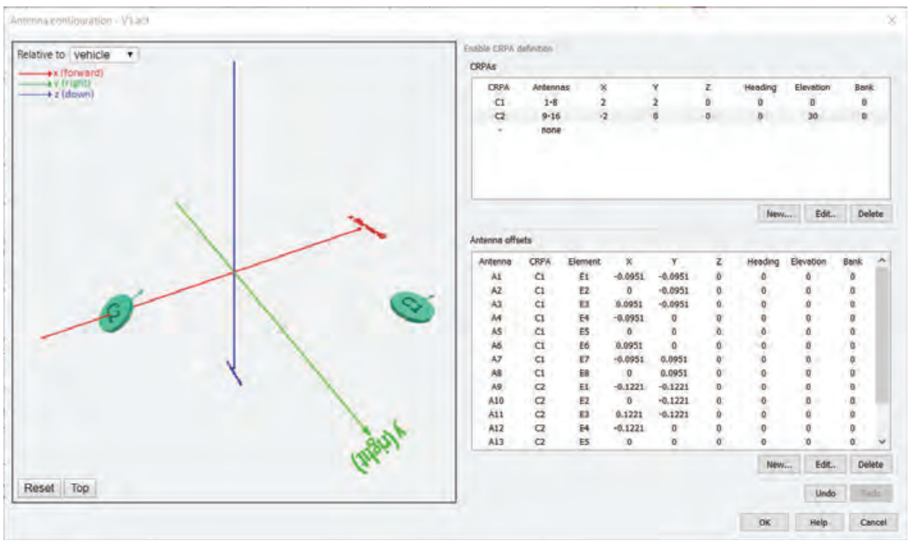
Real-Time and Post-Processing Tools

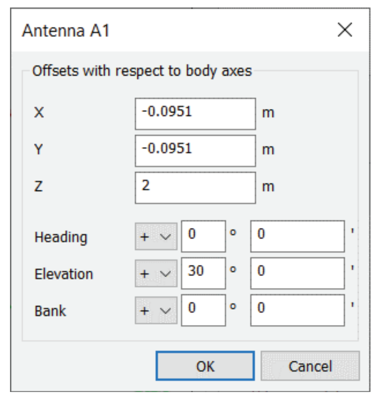
- Data logging and streaming of signal, time, control, vehicle and trajectory data over a variety of interfaces.
- Built-in gRPC schema to support external applications written in different programming languages (e.g., Python, C++, Java).

CRPA definition tool

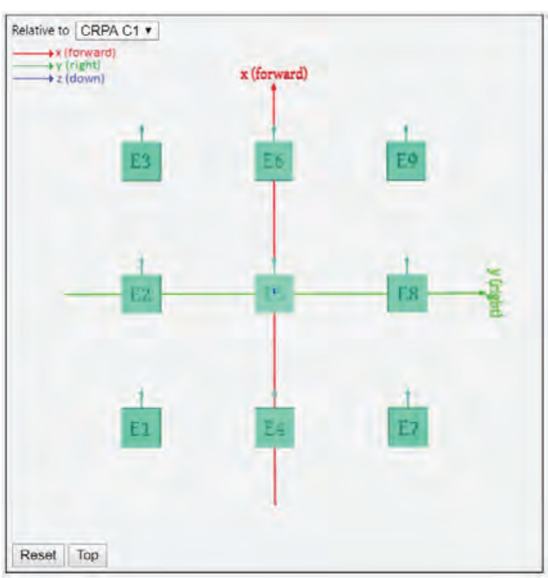
A key feature of SimGEN for CRPA testing is the antenna configuration tool. This accurately recreates and represents the position and orientation of the antennas with respect to the vehicle in the scenario. Users can:

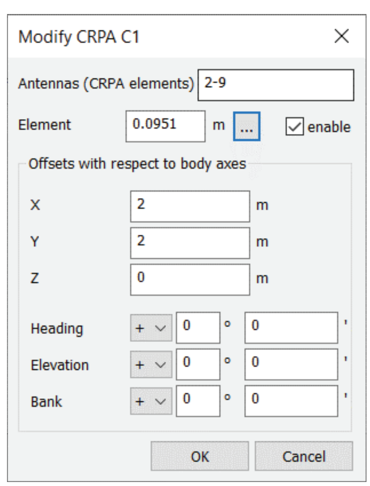
- Visualize the active configuration on a 3D plot
- Edit parameters such as
  - Antenna offsets
  - Heading
  - Elevation
  - Bank angles
- Easily create, edit, or delete antennas
- Share configurations across SimGEN scenarios





For CRPA definition, users can – in just two steps – create antenna arrays and uniformly space the individual elements based on half-wavelengths or precise distances. Parameters such as power level can be modified in-run for the whole CRPA antenna using the standard SimGEN Power Adjustment sliders.





System Calibration

PNT X employs high-quality electronics. Together with a highly digital architecture, this means precise alignment is simplified. Built-in calibrator circuitry greatly aids the alignment process and ensures real-time alignment remains in spec. In addition to the routine annual power and reference clock alignments, the two principal alignments concern delay and phase.

Delay alignment

As part of the production calibration of the system, Spirent Federal will perform a proprietary multi-output delay alignment procedure. This procedure will ensure alignment of the modulation for non-CW signal types. Spirent Federal also supplies a customer-facing procedure, an automated utility, and a phase-stable RF cable for this delay alignment process to be performed by the customer at their own facility – without the need for any additional test equipment.

Inter-antenna carrier phase alignment

As part of the production calibration of the system, Spirent Federal will perform a proprietary multi-output carrier phase alignment procedure. This procedure will ensure the specified inter-antenna carrier phase alignment performance is met. Spirent Federal also supplies a customer-facing procedure, automated utility, and an accompanying alignment kit for this carrier phase alignment process to be performed by the customer at their own facility.

4. Interference Testing

The primary function of CRPAs is to provide uninterrupted positioning in interference environments. To develop and qualify this capability, developers need to be able to test devices against a comprehensive range of threats. Thanks to its flexible and scalable architecture, PNT X allows the generation of thousands of simultaneous interference signals from hundreds of transmitters using the same scenario file.

Embedded Interference

Embedded Interference is an established feature enhancement of SimGEN. Configuration of transmitters includes:

- Position mode setting—orbital, absolute position (ECEF) or relative to vehicle supported.
- Grouping to form the transmitters into a single source enabling simulation of complex interference sources.
- Interactive map allowing placement of transmitters.
- Matched Spectrum controls in the GUI editor.

Complex scenarios simulating vehicle(s) in a field of multiple interference transmitters can be configured easily. Figure 4 shows multiple CRPA-enabled vehicles maneuvering around a field of 128 multi-frequency interference transmitters.

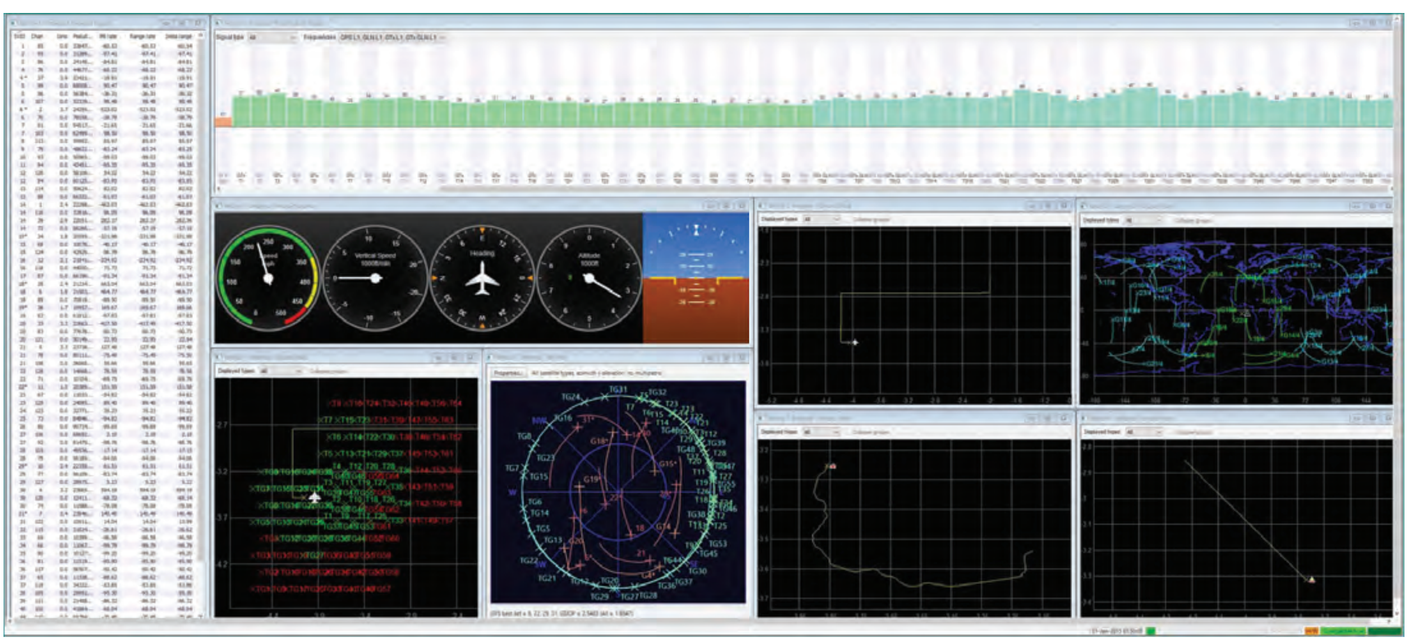


Figure 4: Multi-vehicle, multi-interference scenario

In addition to the characteristics outlined above, for each of the transmitters, users can control the following signal properties:

- L-band frequency and frequency offset.
- Signal type selection (e.g., CW, BPSK, CW Pulse, FM, PM, AM, Wideband AWGN up to 90 MHz, BOC, Chirp, Matched Spectrum etc.).
- Power level as an offset from L-Band (dB) or absolute (dBm).
- Pulse rate and duty cycles.
- Specific signal properties according to the signal type selection (e.g., 3 dB bandwidth for AWGN).

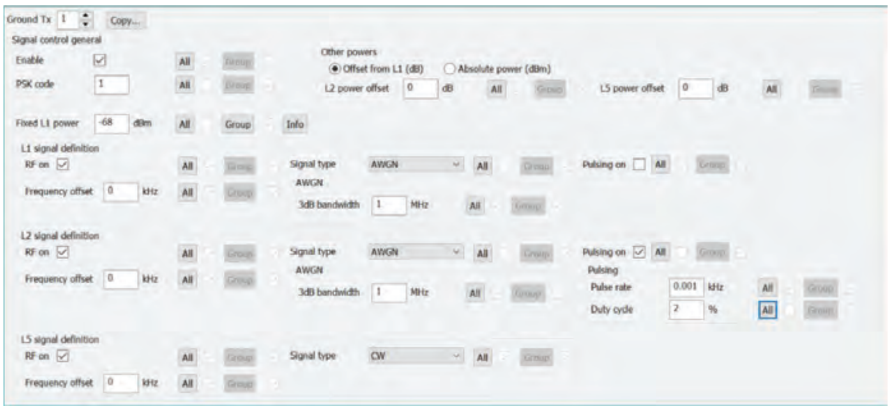


Figure 5: Interference Configuration window

I/Q Streaming With Spatial Awareness

Depending upon your exact test requirements, Spirent supports different **user defined I/Q file streaming and real-time generation options, with realistic signal effects automatically applied**. When determining the appropriate solution, a number of factors must be considered:

- Number of concurrent interference sources.
- Required maximum J/S and dynamic range.
- Interference signal bandwidth and sample rate.
- File sizes and bit depths.
- GPU Server/Raid Array selection.
- Latency and SIR requirements.

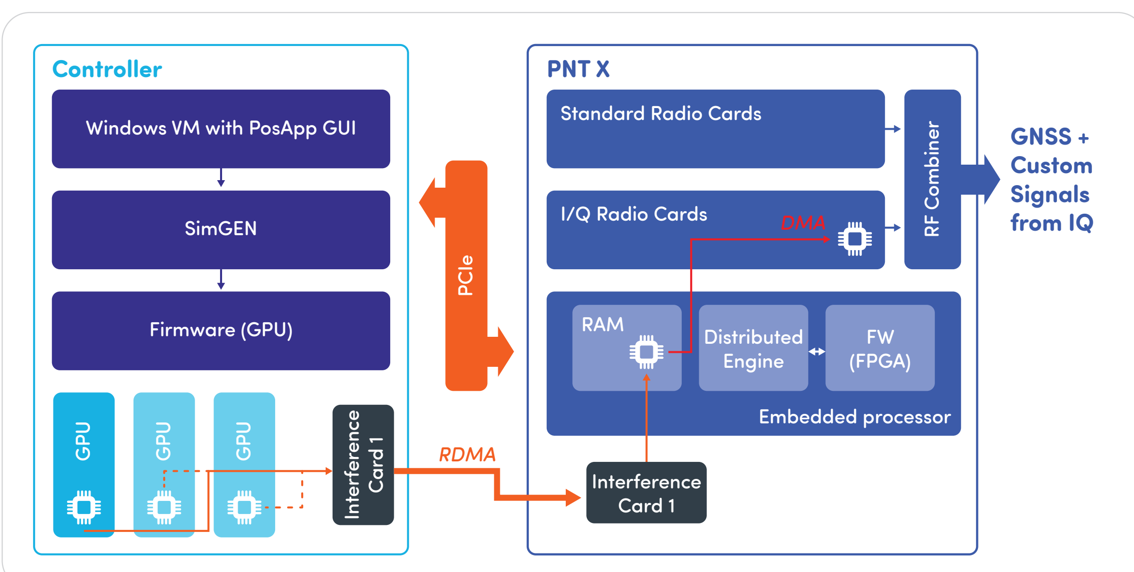


Figure 6: SimIQ principle

5. Spoofing Testing

Spoofing attacks have become significantly more common in recent years, and all safety- and mission-critical systems must be protected against them. The advanced capabilities of PNT X enable users to build advanced and varied spoofing scenarios with a unique level of control and coherence.

An integrated spoofing solution

For added realism, independent and uncorrelated noise patterns for each spoofer are supported with a fixed 90 MHz (3 dB bandwidth) noise source to simulate the unique wideband thermal noise of each transmitter.

SimGEN allows you to define and configure using the same scenario file:

- A vehicle instance representing the "truth" or "target" vehicle location/trajectory; and
- N vehicle(s) representing "false" or "spoof" vehicle locations/trajectories.

The composite signal associated to all the vehicles in the scenario is provided at a single RF output, for connection to a single DUT. In this way, from a test scenario perspective, 'truth' and 'spoof' signals are all treated as signal types received by the target vehicle (see Figure 7).

Figure 7: Vehicle antenna signal types selection

Spoofers can be easily added to the scenario (see Figure 8), alongside standard GNSS constellation and vehicle groups.

- Each "*Spoofer transmitters*" definition file specifies 1 spoofer transmitter:
    a. Location: static or dynamic.
    b. Signal level: fixed or modeled.
- Each "*Spoof GPS constellation*" can be unique and allows full configuration of the constellation parameters.
- Each "*Spoof vehicle*" can be unique and supports SimGEN's built-in vehicle models, user motion files and real-time remote motion input.

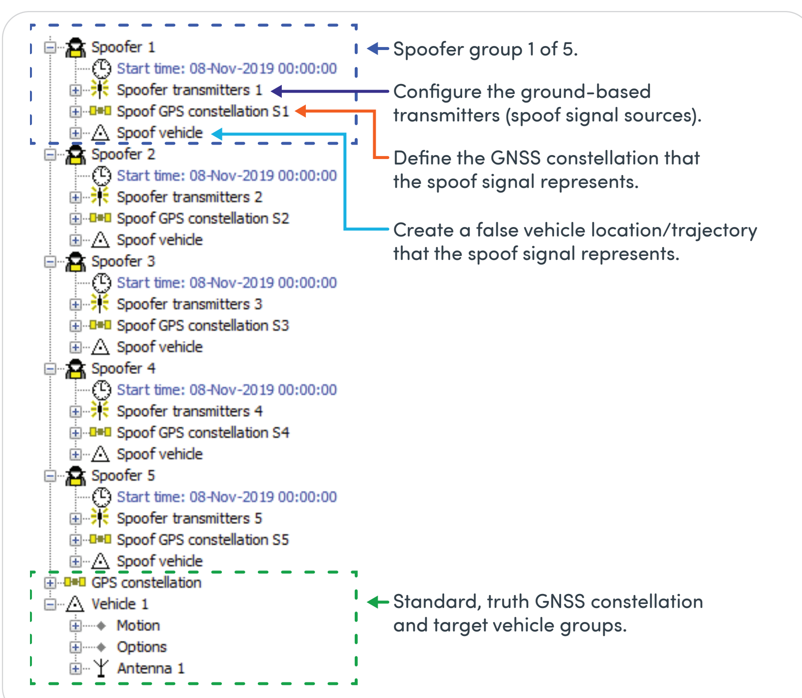


Figure 8: Scenario tree – truth and spoofer definitions

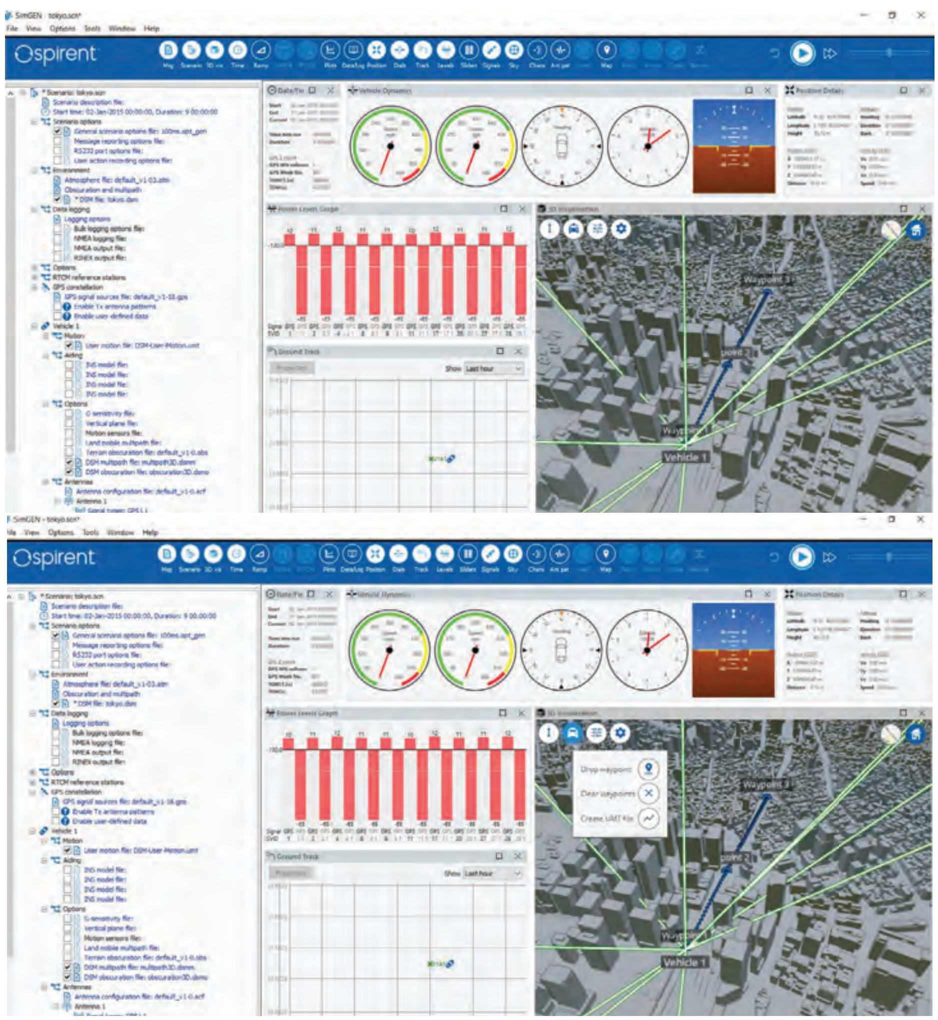
6. Modeling and Control

Realism is the core component of all GNSS testing. Without realism, testing is not representative of real-world conditions, and products and systems under development could not be relied on to transfer performance into production. From generating signals from first principles through to advanced environment modeling, PNT X delivers the most realistic GNSS signal environment available for testers.

Terrain Modeling

PNT X delivers a unique approach to simulating real-time multipath and obscuration effects based on an embedded synthetic environment and an advanced RF propagation model. This model relies on a 3D scene, which is used to generate multipath effects (reflection and diffraction) and obscuration signatures relative to the location of the receiver's antenna. This intuitive 3D visualization simplifies the configuration of complex settings. It also allows the inclusion of elements like jammers, spoofers, and repeaters. Furthermore, users can generate trajectories directly over the 3D scene with an easy-to-use, built-in tool, combining to create a comprehensive, fully customizable and user-friendly solution for advanced scenario modeling.

3D scenes can be easily imported by the user or Spirent Federal, using open-format terrain models such as DTED, to ensure the missions simulated are representative of the real-world application.



This 3D realism is applicable to any signals generated within the system, including all GNSS constellations and frequencies, jamming, spoofing, LEO and I/Q defined transmitters extensible to multi-vehicle, multi-antenna scenarios for ultra-realistic CRPA testing.

SimINERTIAL

Our Inertial simulation tools enable users of embedded GPS/inertial systems (EGIs), individually coupled GNSS/INS systems (IGIs) or standalone IMUs to simulate coherent GNSS and sensor measurements to evaluate the positioning algorithms. Modeling physical sensors using accurate error parameters in our simulation environment enables users to tune integrations and algorithms prior to deployment.

Coupled with Spirent's PNT X, and powered by SimGEN, our inertial simulation tools provide real-time emulation of raw measurements that can be fed into filters within the positioning engine. SimINERTIAL provides support for a variety of data interfaces, formats, and sensors, including accelerometers, gyroscopes, magnetometers,
compasses, and barometers (through SimBARO™).

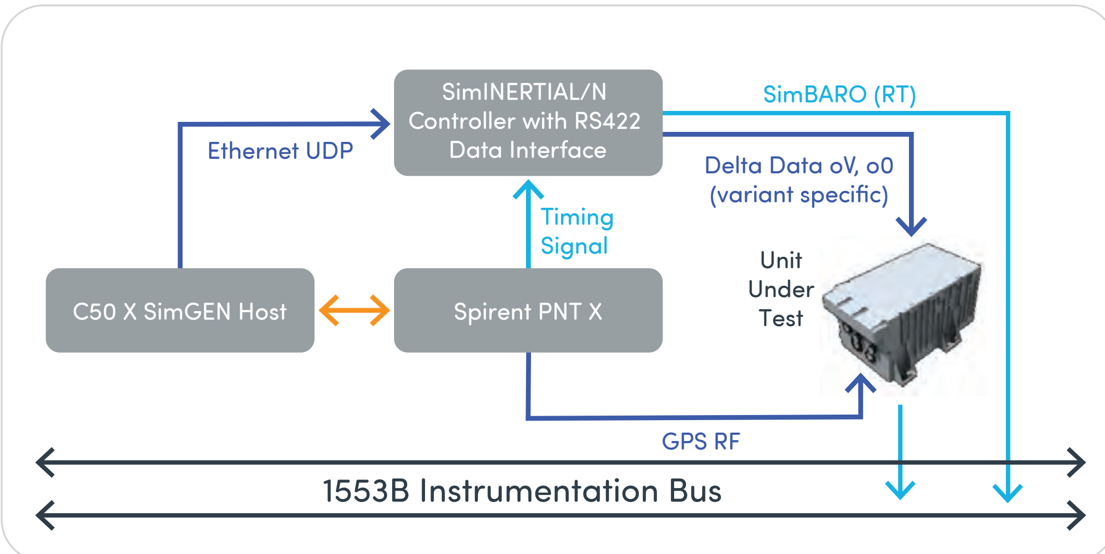


Figure 9: SimINERTIAL Typical Configuration

SimREMOTE

A powerful capability of PNT X is SimREMOTE, which allows the user direct control of all the functions available via the SimGEN GUI plus full 6DOF trajectory delivery. SimREMOTE performs three main functions:

- Simulation control: such as selecting scenarios, start/stop and run-time control.
- Signal modification: finite manipulation of signal phase, delay and Doppler plus enabling/disabling of codes/data.
- Trajectory delivery: 6DOF trajectory delivery in real-time of from a file up to 2000 Hz update rate.

gRPC

A gRPC schema is provided to automatically generate idiomatic clients for SimGEN service in a variety of languages and platforms, including C++, Java and Python.

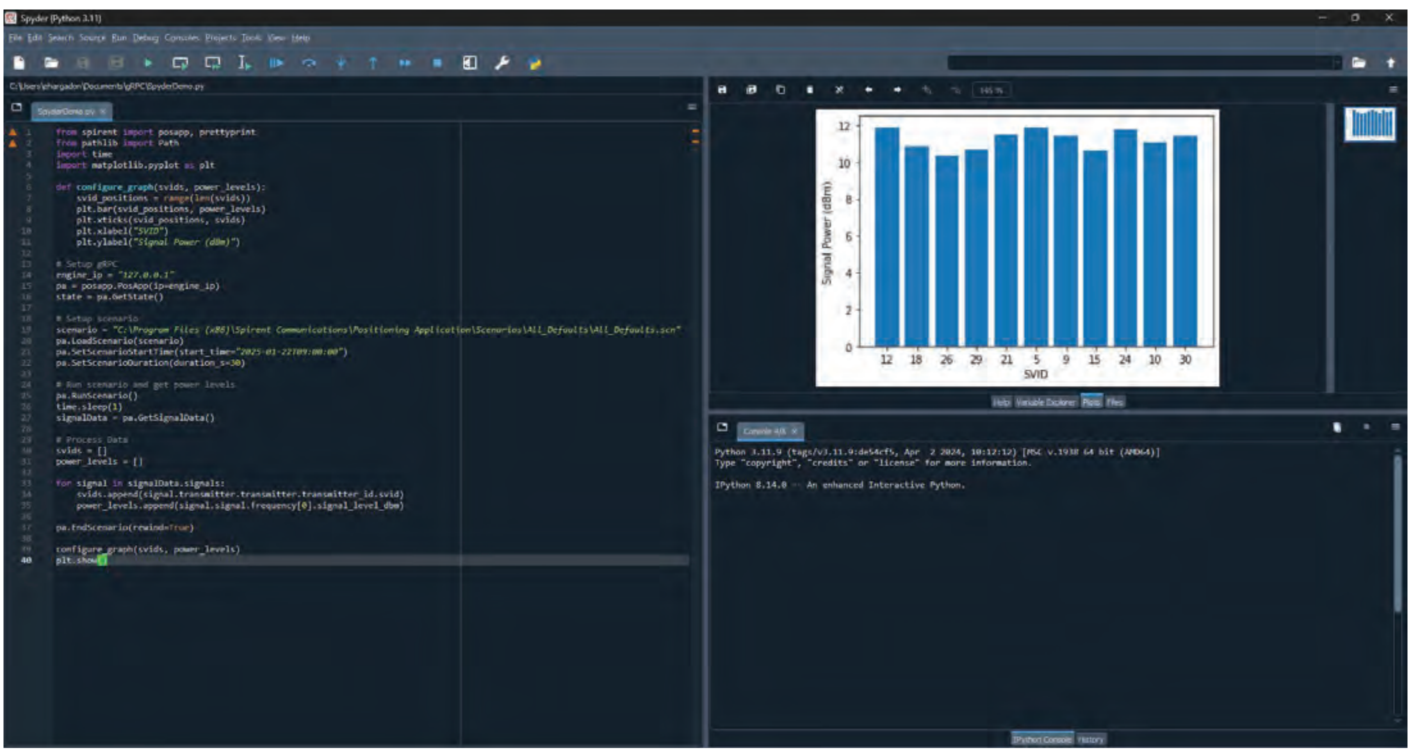
Python Integrated Development Environment (IDE)

SimGEN installation also comes by default with Spyder, an open-source Python development environment. Combined with pre-loaded gRPC schema, users can now write their own scripts, applications, and software add-ons in order to schedule tests, control the scenario execution, and manage simulation data.

- Post-process SimGEN logging data using Python libraries.
- Accelerate the development of simulation software tools.
- Define self-explanatory test flows and share results with Jupiter Notebooks.

All commands are time-stamped, and multiple commands can be scheduled for the same timestamp. For further information, see reference c).

Open-source API is available to support third-party applications written in programming languages such as Python and C++.



7. Professional Services

Spirent Federal has a dedicated team capable of delivering a range of Professional Services. More specific to CRPA projects, these can be listed as:

Installation and configuration

Help ensures you quickly maximize return on your investment. Let the experts get your simulation system integrated, configured, and validated in your test set-ups, saving time, money, and mishaps.

Embedded engineer for all your GNSS requirements

For complex systems such as these, there is the possibility to make use of a Spirent Federal professional services consultant for a set period of time who will be able to provide ongoing consultancy, running test and implementing test procedures, ad-hoc training, and support. With the rest of Spirent Federal resources to call upon, the savings in terms of time and cost will certainly be evident.

Scenario creation and Test Methodology

Spirent Federal consultancy on test methodologies for your testing requirements (including requirements analysis), along with scenario design and verification will ensure your test campaign gives you actionable results.

Factory Acceptance Test (FAT)

FAT is regularly undertaken by Spirent Federal. Spirent FAT concentrates on key performance aspects of the delivered system and any newly introduced 'tailored' elements only. Standard COTS capabilities are not covered as part of the FAT.

Spirent Federal supplies a draft FAT document ahead of the scheduled testing for review and agreement with the customer. Once the document has been agreed, it is formally issued and then forms a contractual document.

Customer Acceptance Test (CAT)

After the system has been received at the customer site, Spirent Federal shall conduct a CAT. The CAT involves system installation and confirmation that the equipment is in a correct working order.

Spirent Federal produces a draft CAT document, based on the approved FAT, ahead of the scheduled system delivery, for review and agreement with the customer. Once the document has been agreed, it is formally issued and then forms a contractual document.

Training

Training can be delivered by Spirent Federal, which could be very useful following successful completion of a CAT or even on existing CRPA systems. It can involve classroom style training / presentation sessions as well as 'hands-on' demonstrations with the purchased system (where appropriate and travel is possible). Alternatively, remote sessions can also be used as a means of delivering the training.

8. Product Specification

Table 1: GNSS signal capability summary

Parameter	Qualifier	Value
Signal sources	At each element, per centre frequency	Configuration dependant
Nominal carrier frequencies	GPS L1, Galileo E1, BeiDou B1c, SBAS L1	1.57542 GHz
	GPS L2	1.2276 GHz
	GPS L5, BeiDou B2a, NavIC L5, SBAS L5	1.17645 GHz
	Galileo E5	1.191795 GHz
	Galileo E6	1.27875 GHz
	GLONASS L1	1.602 GHz (F0)
	GLONASS L2	1.246 GHz (F0)
	BeiDou B1I	1.561098 GHz
	BeiDou B2I, BeiDou B2b	1.20714 GHz
	BeiDou B3I	1.26852 GHz
Ranging Code Signals	GPS L1	C/A, L1c, P, Pseudo Y, M Noise, **Y**[1], **AES-M**[2], **MNSA**[3], **SDS-M-Code, RMP**
	GPS L2	C/A, L2c, P, Pseudo Y, M Noise, **Y**[1], **AES-M**[2], **MNSA**[3], **SDS-M-Code, RMP**
	GPS L5	I, Q
	Galileo E1	OS Data/Pilot, PRS Noise, **PRS**[4], OSNMA
	Galileo E5	E5a-IQ, E5b-IQ
	Galileo E6	CS/HAS Data/Pilot (without encryption), PRS Noise, CAS, **CS/HAS Data/Pilot** (with encryption), **PRS**[4]
	GLONASS L1	C/A, P
	GLONASS L2	C/A, P
	BeiDou B1	B1I, B1C
	BeiDou B2	B2I, B2a, B2b
	BeiDou B3	B3I
	QZSS L1	C/A, L1c Data/Pilot, S
	QZSS L2	L2c
	QZSS L5	L5I, L5Q
	QZSS L6	L61, L62
	NavIC L5	C/A, S
	NavIC S	
	SBAS L1	C/A
	SBAS L5	I
RF signal level GPS, at Combiner Matrix output ports	L1C/A	-130 dBm
	L1c (pilot)	-128.25 dBm
	L1c (data), L1P	-133 dBm
	L1 AES-M	-128.5 dBm
	L2c, L2P	-136 dBm
	L2 AES-M	-132.5 dBm
RF signal level Galileo, at Combiner Matrix output ports	E1-A	-125.5 dBm
	E1-A PRS Noise	-125.5 dBm
	E1-B, E1-C	-127.0 dBm
	E6-A	-125.5 dBm
	E6-A PRS Noise	-125.5 dBm
	E6-B, E6C	-128.0 dBm
	E5a-I + E5a-Q + E5b-I + E5b-Q	-122.0 dBm

1 Y-code via SimSAAS upgrade package (export controlled)
2 AES-M code via SimMCODE upgrade package (export controlled)
3 MNSA via SimMNSA upgrade package (export controlled)
4 PRS vis PRS[WARE] 3rd party upgrade package from LZE GMBH

Parameter	Qualifier	Value
RF signal level Glonass, at Combiner Matrix output ports	C/A P C/A P	-131 dBm -131 dBm -137 dBm -137 dBm
RF signal level BeiDou, at Combiner Matrix output ports	B1I B1C B2I B2A B2B B3I	-133 dBm -130 dBm -133 dBm -127 dBm -131 dBm -133 dBm
RF signal level QZSS, at Combiner Matrix output ports	C/A code S L1c Data + Pilot L2c I + Q L61/L62	-128.5 dBm -131 dBm -127 dBm -130 dBm -124.9 dBm -126.82 dBm
RF signal level NavIC, at Combiner Matrix output ports	C/A S	-130 dBm -130 dBm
RF level control	Range Resolution Linearity (+20 to -30) (-30.1 to -40)	+20 to -40 dB 0.1 dB <0.1 dB <0.2 dB\
Limit of signal dynamics	Relative velocity[5] Relative acceleration[6] Relative jerk Angular rates (indicative)[7] at 1.5m lever arm at 0.05m lever arm	120,000 m/s 192,600 m/s^2 890,400 m/s^3 >15π rad/s >60π rad/s
Signal Accuracy	Pseudo-range accuracy[8] Pseudo-range uncertainty due to Inter-channel bias[9] Delta-range accuracy Inter-carrier Bias[10]	0.3 mm (RMS) 0 mm (RMS) ±0.1 mm (RMS) < ±2 ns
Signal Purity	Unmodulated in-band spurious[11] Harmonics Phase noise[12] (single side band) PNT X MS	≤ -182 dBm ≤ -40 dBc ≤ 0.005 rad (RMS) -182 dBw
Configurable Iteration Rate	GNSS chassis internal controller Spoofer/Repeater chassis internal controller C50r SimGEN Host C50 X	2000 Hz 1000 Hz 100 Hz 10 Hz (at least)

5 For 6-DOF data externally supplied via SimREMOTE or from data file
6 When operating at ≥250Hz SIR
7 Please refer to reference i) for more details
8 For signal acceleration <450m/s2, jerk <500m/s3, 1000Hz SIR
9 Single radio card, supporting up to 32 channels. When the same signal is generated across multiple radio cards the inter radio card bias uncertainty is ±230ps (±69mm)
10 Between any RF carrier
11 Measured at designated RF output port with interference source disconnected. For relative velocities <50,000m/s and signal bandwidths = GPS: L1/L2 ±20.5MHz; GLO (relative to channel f0): L1/L2 ±20MHz; GAL: E1±20MHz; BD: B1±20.5MHz
12 Value is typical, integrated over a 1Hz to 10kHz bandwidth. Worst case <0.01 rads (RMS)

Table 2: Interference signal capability summary[13]

Parameter	Qualifier	Value
Signal sources	At each element, per centre frequency	Configuration dependant
Nominal centre frequencies	L-band, S-BAND	As per Table 1
Carrier frequency offset	Independent for each source Range Resolution	 ± 25 MHz 0.5 kHz
Total RF signal power	Single CW interference signal per radio card[14] Multiple CW interference signals per radio card[15]	+2 dBm -7 dBm
Radio card attenuator	Attenuation[16] Resolution	0 to 60 dB 1 dB
Signal purity[17]	At each supported centre frequency Unmodulated in-band spurious Modulated in-band spurious	 ≤ -60 dBm < 40 dBc
Inter-antenna carrier phase alignment	Total variance[18] Run to run variance	± 5 degrees ± 1 degree
Configurable Iteration Rate	Interference chassis internal controller C50 X SimGEN Host	2000 Hz 1000 Hz 100 Hz 10 Hz (at least)

Table 3: Embedded Interference Option – Signal Performance

Parameter	Qualifier	Value
Frequency bands	L1	1.57542 GHz
	L2	1.2276 GHz
	L5	1.17645 GHz
	L6	1.27875 GHz
Carrier frequency offset	Independent for each source[19]	
	Range	± 25 MHz
	Resolution	0.5 kHz
Signal Purity	Unmodulated in-band spurious	≤ -60 dBm
	Modulated in-band spurious	< 40 dBc
BPSK	Narrowband main lobe width	0.1023 MHz
	Broadband main lobe width	20.46 MHz
CW Pulse	Pulse width	1 to 10000 μs
	Pulse repetition interval range	50 to 10000 μs
	Pulse repetition interval resolution	50 μs
	Rise time (10% to 90%)	100 ns (max)
	On/Off ratio	30 dB
AWGN	3 dB Variable Bandwidth	From 0.1 to 90 MHz[20]
	Bandwidth Resolution	0.01 MHz
	Bandwidth accuracy	±5%
FM CW	FM deviation	±15 MHz
	FM rate	0.005 to 10 kHz
	FM rate step size	0.005 kHz
	Modulating Waveform	Triangular, sine, chirp

13 Additional interference types available such as BOC and Chirp
14 Fixed attenuator set to +5dB
15 Incoherent signals. Fixed attenuator set to +5dB
16 Default +5dB attenuator setting used for calibration and system characterisation
17 Each radio card, measured at designated RF output port
18 Includes equipment being power cycled. Temperature variation since last alignment, ambient ±2oC
19 In addition to Doppler caused by vehicle motion. Applies to all signal types.
20 Number of channels per SDR card is limited to 32 for 90 MHz AWGN signal generation

Table 3: Embedded Interference Option – Signal Performance (cont'd)

Parameter	Qualifier	Value
Chirp	Deviation	±0.01 to ±15 MHz
	Sweep Rate	±0.005 to 50 kHz
	Modulation Type	Sawtooth
AM	Modulation depth	10 to 90%
	Modulation depth step size	10%
	AM rate	0.5 to 10 kHz
	Modulating Waveform	Sinusoidal
PM	Modulation deviation	±0 to ±5 rad
	PM rate	0.5 to 10 kHz
	Modulating Waveform	Sinusoidal
Comb	Waveforms	CW, FM, AM, PM[21]
	Tone waveform frequency offset resolution	0.5 kHz[22]
RF Signal Level	Single signal	-47 dBm (max)
	Multiple signals	-72 dBm (max)
	Minimum level per signal	-117 dBm
	Linearity, per signal, >-97 dBm	<0.1 dB
	Linearity: per signal, > –107 dBm	<0.2 dB
	Linearity: per signal, > –117 dBm	<0.5 dB

Table 4: Other Features

Parameter	Qualifier	Value
Terrain Modelling	3D Maps	San Francisco, Tokyo, Paris, London, White Sands, Shanghai, Fort Huachuca, Cape Pendleton, Cape Canaveral, Fort Moore[23]
3D Multipath	Max. Simulation Iteration Rates (SIR)	100 Hz
	No. of Multipath per LoS	1–8[24]
	3D Format Supported	DTED (0,2) for a DTM (Digital Terrain Model). GeoTiff + ESRI shapefile, for any 3D building environment.
FLEX	Carriers	L1, L2, L5, E1, E5, E6, B1, B2, QZL1, S[25]
	Codes	Two or three user-definable signals per SV
	Code Assignment	+I, -I, +Q, -Q
	Code Definition	User-definable memory codes (primary and secondary for each Flex signal)
	Base Chip Rate	1.023
	Chip Rate Multiplier	1, 2, 2.5, 3, 4, 5, 6, 7, 8, 9, 10
	BOC Rates Multiplier	Integer multiple of Base Chip Rate
	Nominal Signal Level	-123 to -133
	Nav Message	Standard for constellation
LEO Orbital Models	Max. number of satellites	500

21 Single signal per SDR card (CW, FM, PM, Chirp), -49dBm (BPSK, pulsed CW), -53dBm (AM), -60dBm (AWGN)
22 Per signal, up to 16 signals of AWGN on the same radio card – other signal types can be up to 3dB higher
23 The approximated size of each 3D map is 100 sqkm.
24 User can define the number of multipath signals per LoS
25 Galileo E5 AltBOC signal structure is not supported

Reference documents

For more information on the PNT X and additional products and services, see:

Reference	Title	Notes
a)	PNT X Datasheet Specification	
b)	SimGEN Software Suite Datasheet Specification	
c)	SimREMOTE Interface Upgrade Options Datasheet Specification	
d)	SimMCODE Upgrade for PNT X Product Specification	[FOUO]
e)	SimSAAS Upgrade for PNT X Product Specification	Spirent Federal document
f)	SimMNSA Upgrade for PNT X Product Specification	Spirent Federal document
g)	3rd Party PRS simulation add-on for PNT X	https://prs-ware.de/

Glossary of terms

Term	Definition
6DOF	Six Degrees Of Freedom – movement
AWGN	Additive White Gaussian Noise
BFEA	Blue Force Electronic Attack
CAT	Customer Acceptance Test
DofA	Direction Of Arrival
DUT	Device Under Test
FAT	Factory Acceptance Test
FOUO	For Official Use Only
GNSS	Global Navigation Satellite System (GPS / GLONASS / Galileo / IRNSS / BeiDou)
IDE	Integrated Development Environment
ISG	Interference Signal Generator
J/S	Jammer-to-Signal
OTA	Over-The-Air
PRS	Galileo Public Regulated Service
RF	Radio Frequency
SP	Spoofer/Repeater
SV	Satellite Vehicle

Environmental Social & Governance (ESG)

Spirent's Positioning Technology business unit has been committed to ESG good practice and improvement since achieving ISO14001:2015 Environmental Managemental System certification in 2004.

ESG is a priority for Spirent across all aspects of our business, from sustainable buildings and sustainable product design to sustainable supply chain, manufacturing and shipping/export processes. As is best practice, we follow a continuous improvement process in respect of ESG.

Many of Spirent's test solutions rely on physical test equipment used in situ by our customers. We are working to reduce the lifecycle impacts of our products, and the environments in which they are used, in a number of ways:

- Designing for environment and end of life, including compliance with all legal requirements;
- Reducing the size, weight, noise and power use of our products;
- Visualization and the development of Test-as-a-Service via PNT Professional Services;
- Improving utilization and automation; and
- In-field servicing and upgrades.

We use formal sustainability metrics in the product development process.

For more specific information on how ESG applies to our PNT test solutions, please contact your Spirent representative. For more information on Spirent initiatives, visit https://corporate.spirent.com/sustainability.

Ordering Information

Available to Order from Spirent Federal Systems

- info@spirentfederal.com
- 801-785-1448

PNT X CRPA Test System Part Numbers

- Due to PNT X's flexibility and wide range of use cases, there are many options to fit your test needs.
- Please contact us to determine which options will work best for you.

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Spirent Communications (LSE: SPT) is a global leader with deep expertise and decades of experience in testing, assurance, analytics and security, serving developers, service providers, and enterprise networks. We help bring clarity to increasingly complex technological and business challenges. Spirent's customers have made a promise to their customers to deliver superior performance. Spirent assures that those promises are fulfilled.

About Spirent Federal Systems

Spirent Federal Systems provides the world's leading PNT test solutions to the US Government and contractors to enable resilient PNT under any conditions and outpace evolving navigation warfare threats. As a US proxy company, Spirent Federal enhances Spirent's commercial offerings with classified and other sensitive military signal emulation capabilities. For more information visit **spirentfederal.com**.

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