





# NCS TITAN

The most powerful GNSS Simulator available

- Scalability 
- Fidelity 
- Reliability 
- Usability 
- Extendability 
- Flexibility 
- Upgradability 

# NCS TITAN GNSS Simulator



## Features

### Signal Capabilities

- Support of all global (GNSS) and regional satellite navigation systems (RNSS) as well as satellite based augmentation systems (SBAS)
- 32 - 256 signal channels (up to 8 RFSIM signal generation engines)
- Each RFSIM module is divided into 4 signal banks of 8 signal channels each (32 channels total)
- Each signal bank with its 8 channels is fully configurable in terms of frequency and signal modulation
- Each signal channel has additional 4 multipath channels
- In-field extension of signal capability and GNSS functionality by software license
- On-the-fly re-configuration of constellation and signal configurations
- All GNSS constellation types and all frequencies (up to 16 with 16 SVs each) brought into a single chassis
- Multi-RF output options available, with up to 4 independent RF outputs per chassis
- RF switch matrix allows the user to assign each signal bank of 8 channels to any RF output

### Connectivity

- Remote control capability via Ethernet interface
- 1 PPS in & out
- 10 MHz reference in & out
- External trigger input
- External interference signal input

### System Setup

The NCS TITAN GNSS Simulator is a powerful high-end satellite navigation testing and R&D solution. It is fully capable of multi-constellation, multi-frequency simulations for a wide range of GNSS applications. The NCS TITAN GNSS simulator consists of the NCS Control Center simulation software (on MS Windows® 10 and Linux OS) and the TITAN RF signal generation unit.



NCS - Control Center simulation software



TITAN - RF signal generation unit

### System Support for all GNSS Signals

The NCS TITAN GNSS Simulator is the leading solution providing all signals for GPS, GLONASS, Galileo, BeiDou, IRNSS, QZSS, SBAS and beyond in one box. All signals are available using a flexible licensing scheme.

System	Frequency Band	Signal(s)
GPS	L1	C/A Code, P-Code, L1C, M-Noise
	L2	C/A Code, P-Code, L2C, M-Noise
	L5	I, Q
Galileo	E1	OS Data/Pilot, PRS Noise
	E5	E5a Data/Pilot + E5b Data/Pilot, AltBOC
	E6	CS Data/Pilot (unencrypted), PRS Noise
GLONASS	L1	Standard and high accuracy
	L2	Standard and high accuracy
	L3	L3 (with release 2.2)
BeiDou	B1	B1-I
	B2	B2-I
	B3	B3-I / B3-Q (with release 2.2)
IRNSS	L5	SPS, RS-Noise
	S-Band	SPS, RS-Noise
QZSS	L1	C/A Code, L1C
	L2	L2C
	L5	I, Q
	L6	L62 (with release 2.1)
SBAS (WAAS, EGNOS, MSAS, GAGAN, SDCM)	L1	C/A Code
	L5	I, Q (with release 2.1)

### NCS Control Center Simulation Software

The user friendly NCS Control Center simulation software provides the user with full control over all aspects of the test scenario configuration, interactive control, monitoring and data logging. The rich and easy to use Control Center software is the result of IFEN listening and implementing changes requested by multiple customers from a wide variety of applications. This is an ongoing process and IFEN continues to enhance the software as customer needs evolve.

A very comprehensive set of simulation parameters can be modified by the user to build up the desired scenario. Various graphical widgets are used to visualize the simulated data in a very clear way. The NCS Control Center allows the user to log a variability of simulated parameters in real-time to corresponding files. The host computer as a dual-boot system enables the customer to select MS Windows or Linux as the preferred operating system.

For Hardware-In-The-Loop (HIL) testing with integrated vehicle motion simulators, user trajectories (user position and attitude plus their derivations) can be streamed in real-time asynchronous at any rate up to 1.000 Hz into the simulator via Ethernet using UDP datagrams.

The Remote Control capability allows the user to load, modify, start and control scenarios from a remote PC via a simple TCP/IP client (e.g. Telnet, Hyperterm) or by using a scripting language with TCP/IP module (e.g. Perl, Python). The Remote Control capability allows for full featured batch processing of several scenarios and above all, an enhanced interactive control of the generated signals.

The design of the NCS GNSS simulator allows the user to easily enhance system capabilities by SW licensing to cover changing user needs. This enables the customer a cost-efficient selection of the needed signals, without limitation of the signal license to the number of applied generation modules.

- Additional GNSS signals at any time by easy SW licensing
- One signal license can be applied to all modules/signal banks/channels

### TITAN RF Signal Generation Unit

The design of the TITAN GNSS RF signal generator allows the user to enhance system capabilities by easy HW plug-in on-site to match changing user needs or new test specifications, without the need to return the equipment.

- On-site addition of RFSIM modules with 32 channels each (up to 8 modules, 256 channels per TITAN signal generation unit)
- On-site addition of RF signal combiner (up to a maximum of 4 RF combiner)
- Integrated noise generator by on-site exchange of RF combiner modules



Rear View

RFSIM plug-in module

## Features

### User/Antenna Configs

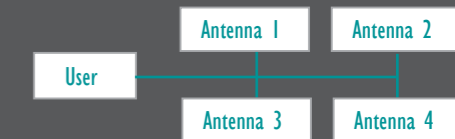
- 1 user | 1 antenna (baseline)



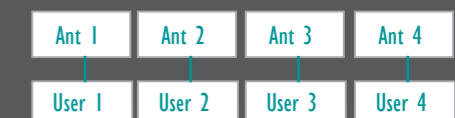
- 1 user | 2 antenna (dual)



- 1 user | 4 antenna (quad)

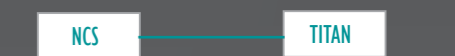


- 4 user / 1 antenna per user



### SW/HW Configurations

- 1 NCS | 1 TITAN (baseline)



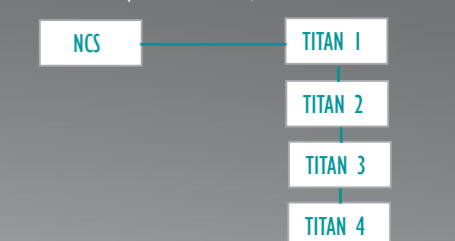
- 1 NCS | 2 TITAN (up to 8 RF-out)



- 1 NCS | 3 TITAN (up to 12 RF-out)



- 1 NCS | 4 TITAN (up to 16 RF-out)





## Features

### RF Signal Combiner

- Up to 4 RF signal combiner modules
- With optional noise generators
- Support of external IF signals

### RF-Output 1

Ext. Interference-Input 1

### RF-Output 2

Ext. Interference-Input 2

### RF-Output 3

Ext. Interference-Input 3

### RF-Output 4

Ext. Interference-Input 4

The 4 physical RF-Outputs at the front side



# TITAN Signal Generator

## ▶ Leading Signal Generation Flexibility

The core flexibility of the TITAN signal generator is the capability of the (up to 32) RF signal banks to simulate any GNSS signal, selectable by the user. Every RF signal bank output can be routed to the selectable RF signal combiner 1 to 4.

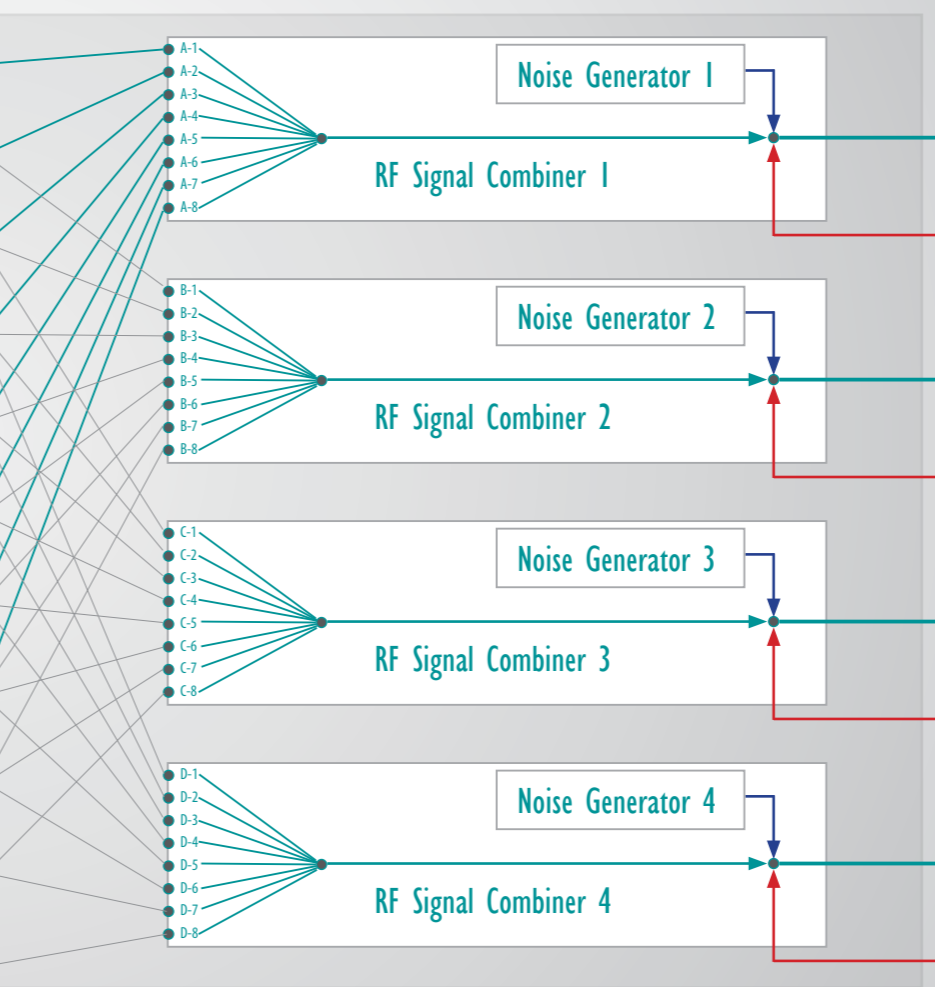


Example configuration of RFSIM modules with up to 32 RF-out signals

## ▶ Leading RF-Signal Combination Flexibility

The TITAN may be equipped with up to 4 RF signal combiner modules, each connected to one of the the 4 pre-installed physical RF-outputs. Every RF signal combiner is linked to all RFSIM modules, thus enabling free assignment of signals of each of the 32 signal banks to each final RF-output (1 - 4) according to the user configuration, offering maximum configuration flexibility to the user.

The RF signal combiner also considers additional signal input from the optional noise generator (per RF combiner). Furthermore, also an external interference signal (one per signal combiner) may be added to the RF signal combiner.



Up to 4 RF signal combiner (and optional noise generator) in one TITAN

## ▶ Typical Multi-RF Configuration Example for CRPA Application

RFSIM 1	GPS L1 (16 channels)	GPS L5 (16 channels)	RF-Combiner 1
RFSIM 2	Galileo E1 (16 chann.)	Galileo E5ab (16 chann.)	
RFSIM 3	GPS L1 (16 channels)	GPS L5 (16 channels)	RF-Combiner 2
RFSIM 4	Galileo E1 (16 chann.)	Galileo E5ab (16 chann.)	
RFSIM 5	GPS L1 (16 channels)	GPS L5 (16 channels)	RF-Combiner 3
RFSIM 6	Galileo E1 (16 chann.)	Galileo E5ab (16 chann.)	
RFSIM 7	GPS L1 (16 channels)	GPS L5 (16 channels)	RF-Combiner 4
RFSIM 8	Galileo E1 (16 channels)	Galileo E5ab (16 chann.)	



Up to 8 RFSIM signal generation modules

- RFSIM Module 1
- RFSIM Module 2
- RFSIM Module 3
- RFSIM Module 4
- RFSIM Module 5
- RFSIM Module 6
- RFSIM Module 7
- RFSIM Module 8

Sample configuration with all existing GNSS systems in one TITAN

## Features

### RFSIM Signal Modules

- 1 - 8 RFSIM plug-in signal generation modules
- Every RFSIM module is grouped into 4 RF signal banks, with 8 channels per RF signal bank (up to 32 signal banks)
- Free assignment of GNSS signals (frequency & modulation) to RF signal banks

## ▶ Leading Signal Channels Scalability

The TITAN signal generator may be fitted with up to 8 RFSIM signal generation modules, providing then up to 32 signal banks with overall 256 primary channels and 1.024 multipath channels in one TITAN. This scalability of signal channels, multipath channels and unlimited assignment of GNSS signals to RF signal banks is unique and provides the user with a competitive advantage in device and application testing using the NCS TITAN.

The above signal assignment is just an example configuration, demonstrating that the NCS TITAN GNSS simulator is the one and only signal simulator, capable to **simulate all GNSS systems in one box!**



# NCS Control Center

## Features

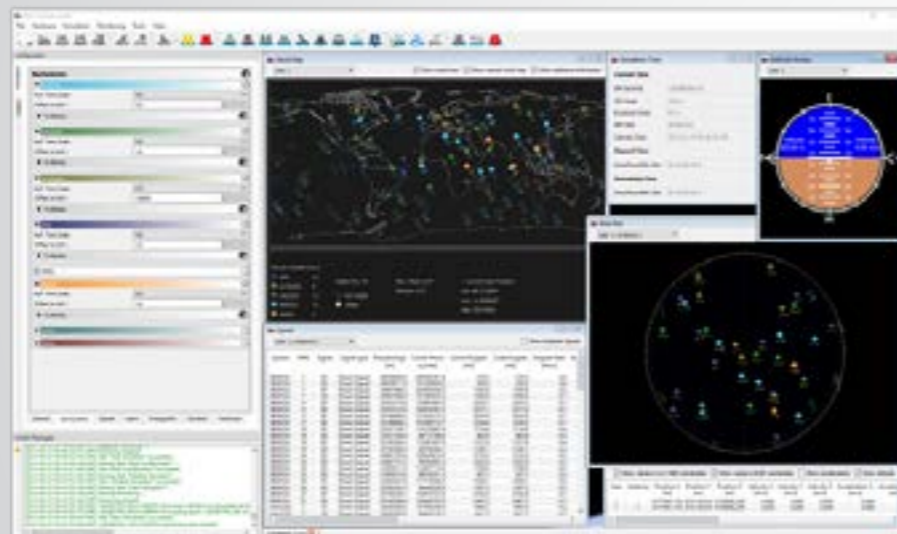
### Simulation Capabilities

- Satellite orbits and clock simulation for all existing and coming GNSS systems
- Different signals per GNSS constellation batch (e.g. IIR-M, IIF...)
- Ionosphere and troposphere effects
- Different user types (vehicle, aircraft, space vehicle, ...) supported
- 6D-trajectories from static ground to dynamic space user (pre-defined, from file, via editor or remote motion data)
- Simulation of multi-user and multi-antenna configurations
- Simulation of transmit and receive antenna characteristics
- Simulation of LNA (in active antenna) effect on C/N0 using optional noise generator for realistic C/N0 generation
- Full control of signal power level (automatic or manual)
- Different satellite simulation selection strategies available
- User selectable assignment of simulated signals to HW signal banks, providing full signal and simulation flexibility
- Selectable logging of all simulated outputs (true values and broadcast values) for later performance comparison analysis with the receiver

### ► Full GNSS Simulation Configuration & Control Flexibility

The powerful and easy to use NCS Control Center GNSS simulation software offers the user with full control over all aspects of the test scenario configuration, interactive control, monitoring and data logging. This capability allows a wide range of GNSS testing to be conducted, for any customer application, with the same hardware ensuring maximum utility for the investment.

Within the 'Simulation' configuration view, all aspects of the simulated GNSS systems and signal, the propagation path effects, the local user environment and the user dynamics can be configured. The assignment of the simulated GNSS signals to available hardware resources (signal banks) is an important topic in the configuration, offering full flexibility to the customer in assigning the number of channels to one signal (8-channels, 16-, 24-, ...).



Screenshot of the NCS Control Center software

### ► Comprehensive GNSS Simulation Data logging

Within the 'Logging' configuration view, all output data can be individually selected by the user to log to files for later analysis comparison. These logged files can also be edited to introduce artificial errors for later simulation input in the next simulation run. Core output data are satellite position and clock, signal broadcast data, propagation data, multipath data, observations and user PVT.



Logging of GNSS simulation data using 'Logging tab (at left side)

### ► Leading GNSS Satellites Constellation Simulation Capability

The simulated GNSS satellites (GPS, GLONASS, ...) can be individually configured for complete constellation or individual satellites. The constellations can be either generated internally by a constellation generator or imported from external files in various formats (e.g. YUMA, GLONASS legacy, RINEX, SP3(C)).



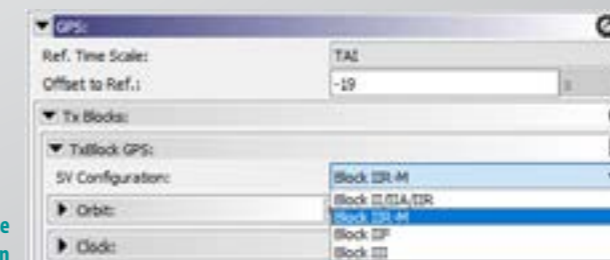
"NavSystems" tab satellite settings

The possibility to generate orbit and clock parameters from external files enables to simulate residual satellite clock errors. It is possible to distinguish between simulated true satellite orbits and broadcast satellite orbits.

### ► Advanced GNSS Mixed Signal Simulation Capability

With the increased complexity of GNSS satellites in orbit (with different signal capabilities, depending on the production batch), the capability to assign different signals to the same GNSS constellation becomes increasingly important, enabling to test GNSS receivers under complex GNSS constellation/signal conditions.

For GPS it is possible to select different production batches (e.g. IIR, IIR-M, IIF, III) with different signal designs. This enables to simulate complex signals scenarios within the same GNSS system, but transmitting different signals.



Assigning a GPS block signal type to part of the GPS constellation

## Features

### Usability

- Advanced graphical user interface (GUI) for scenario definition, simulation configuration and control
- Easy modification of variables
- Full constellation, user and vehicle motion control

### Signal Licensing

- Licensing of additional signals on-the-fly within a day
- One signal license can be applied to as many signal banks as selected by the user
- New signal licenses will be added as new ICDs are introduced

### Extended Simulation

- Support of Differential GNSS (DGNSS) test scenarios, including generation of DGNSS correction data in RTCM format.
- Real-time external user trajectory streaming for Hardware-In-The-Loop (HIL) applications
- Enhanced simulation capabilities for space applications and very high signal dynamics for simulation of spinning vehicles / objects to support aerospace and defense applications
- Optional IMU/Sensor Emulation Package (SEP)



## Features

### Threat Event Simulation

- Configure errors in the broadcast messages
- Simulate specific system events (leap seconds, week rollover...)
- Add pseudorange ramps and jumps
- Add modeled noise to ionosphere and troposphere delay
- Simulate excessive ionosphere errors through different scintillation models
- Model local user environment effects with a large range of multipath models (from simple power attenuation to deterministic path delay to complex ITU standardized statistical and combined deterministic/statistic driven models)
- Model excessive broadband interference (whole RF-spectrum) using the optionally (recommended) integrated noise generator
- Simulate ICAO defined EWF (Evil Waveforms)
- Simulate signal distortions from satellite hardware by flexible parameter configuration
- Insert any type of interference/jamming signals generated by an external device through the 'external interference input' interface into the RF output signal
- Simulate simple to complex (using also the flexible secondary channels) spoofing attacks for advanced threat scenarios

### ► Simulation of Ionosphere, Troposphere and Scintillation Effects

Propagation effects through the ionosphere are either simulated according to the Klobuchar model, the 3D TEC model NeQuick, the IONEX model, the SBAS and NavIC-IRNSS iono grid model, spacecraft ionosphere model or by data imported from RINEX files. The NCS Control Center software allows the user to distinguish between simulated ionospheric influences and broadcast ionospheric data.

Scintillation scenarios are simulated by using the Cornell model or the GISM. The ionospheric scintillation influences can either be simulated for Lines-of-Sight (LoS) or for a spot area around a dedicated point location.

The NCS Control Center software supports also the modeling of ionospheric and tropospheric delay noise, which is added to the modeled ionospheric or tropospheric delays. For the ionospheric and tropospheric delay noise modeling for a single LoS and for the grid spatial correlation, the noise on range (one-sigma), noise on phase (one-sigma), noise on Doppler (one-sigma) and the correlation time parameters can be selected.

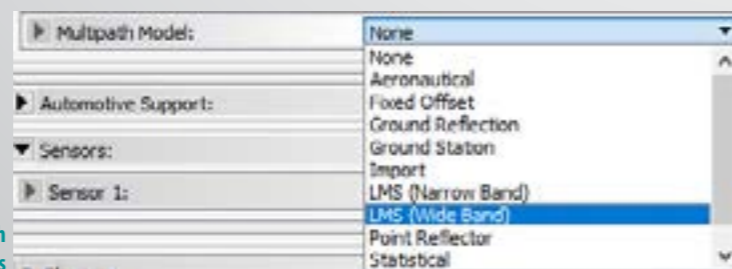


Configuration of Cornell scintillation model

### ► Simulation of Multipath Effects

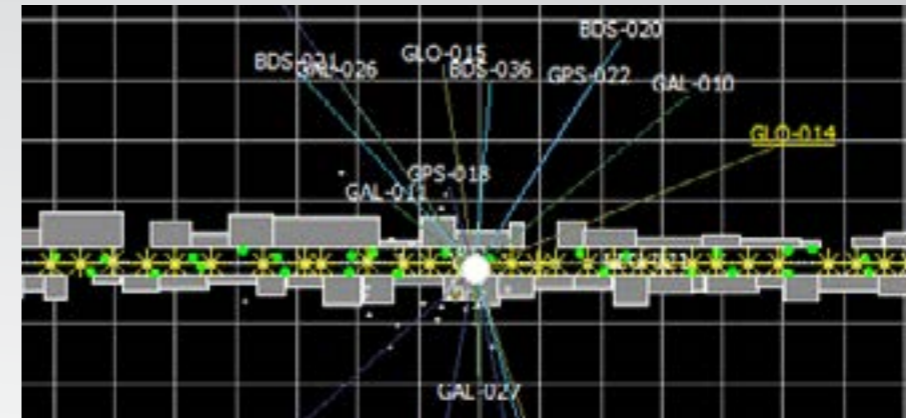
Multipath is the most important receiver local environment driven error contribution. The NCS Control Center software provides a wide range of multipath models, from simple single reflection models to advanced statistical and combined statistical/deterministic models, including the ITU based Aeronautical Mobile Propagation data multipath model and the Land Mobile Propagation data multipath model (both, the Narrow-Band and Wide-Band LMS model). This enables to test the impact of multipath concerning C/N degradation and LoS path delay on the receiver performance.

Multipath effects are simulated by using the dedicated multipath channels supported by each primary channel, in order to guarantee a very high level of fidelity and smooth changes to the relevant parameters like Doppler shift, path delay and power loss between the different epochs.



Selectable multipath models

The following screenshot shows the LMS wide-band model simulation, providing evidence of the local simulated environment (height of buildings, street width, trees), with the dynamic user driving along the street.



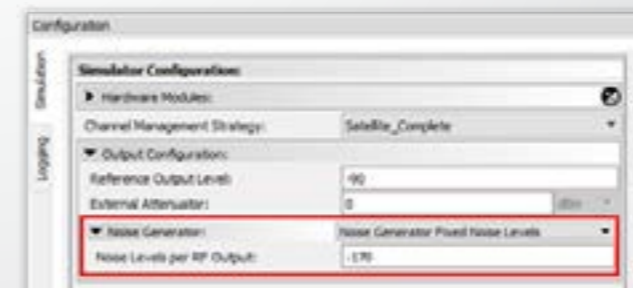
Screenshot of LMS wide-band model simulation visualization

### ► Simulation of C/N0 of Active Antenna with LNA

Many GNSS receivers use active antennas, which include a low noise amplifier (LNA), typically providing a gain of 20 to 52dB. The LNA increases the received power level, but also increases the noise power density. Generating a controlled Carrier-to-Noise (C/N0) ratio is very important, as the C/N0 ratio is one of the core parameters when evaluating receiver performance. As there is no antenna between a signal generator and a receiver, antenna/LNA have also to be modeled.

The received signal power can be modeled by the antenna gain pattern (using the integrated editor or reading from file) and by increasing the signal power level. The signal power depends on the configured satellite transmitted EIRP value or the received signal power value in the 'Power Level' control according to the LNA gain.

The NCS TITAN GNSS simulator can be equipped with an optionally available internal noise generator, which allows configuration of a noise floor and – in conjunction with the definition of signal power levels – the generation of signals with dedicated, controlled C/N0.



Using fixed noise levels for the configuration of the internal noise generator

The noise figure may be defined and remain constant for the simulation run, or varying noise influences may be read from a file.

### ► Simulation of Interference, Jamming, Spoofing and Evil Waveforms

Furthermore, as the noise generator can generate noise with a power density of up to -110 dB/Hz over the entire RF bandwidth, also strong broadband interference can be simulated. Stronger interference/jamming signals generated externally can be inserted into the generated signal, using the external interference input.

Due to the high flexibility of the simulator the generation of spoofing signals is also possible, which can be merged into one signal. The flexible secondary channels (generally used for multipath) can also be used to generate advanced multi-level spoofing scenarios. Due to the multiple RF-outputs, even spoofing scenarios for CRPA multi-antenna systems can be generated.

Finally, the simulator also supports the generation of evil waveforms and other signal distortions (user definable by parameter selection).

## Coming Features Simulation

- Adding support of latest and coming ICD changes and updates
- Ray-tracing based multipath
- Enhanced sensor fusion
- Addition of coming navigation data and signal authentication
- Integrated support to external interference simulators

## Signal Generation

- More channels ...
- New modulations, multiplexing ...
- Plug-in interference modules

## Usability

- Enhanced configurability
- Enhanced real-time visualization
- Simulation dashboard
- Additional editing tools



## Applications

Discover the perfect test solution for all GNSS applications. The innovative multi-constellation/multi-frequency simulation capability in combination with the Multi-RF output option sets new standards in the field of GNSS simulation.

## Extensions

If your application requires an advanced test setup, select the available extensions or ask for your specific customization.

### Dual-RF Output Applications

- **Antenna Diversity**  
Two antennas of the same type but with different orientation at the same receiver.
- **Heading Determination**  
Two antennas with the same orientation at one receiver.
- **Differential GNSS**  
Static reference receiver and mobile rover.
- **Dual Tracking**  
Two antennas with different gain patterns optimised for special visibility at the same receiver.

### Multi-RF Output Applications

- **Attitude Determination**  
3 or 4 antenna based attitude determination.
- **Formation Flying**  
Spacecraft formation flying with up to 4 spacecrafts.
- **Radio Occultation (RO) and Precise Orbit Determination (POD)**  
3 antenna approach with Dual-Frequency and Multi-GNSS capability. 1 zenith antenna for POD, 1 velocity-direction antenna and 1 anti-velocity antenna for RO.
- **CRPA Applications**  
Test your steered antenna beam array applications with 4 antennas for multipath mitigation, interference suppression, anti-spoofing and more. You need more than 4 antennas for your sophisticated CRPA application? Ask us for a solution.

## Applications and Extensions

### ► The Solution for all GNSS Applications



### ► IMU/Sensor Emulation Package (SEP) Extension

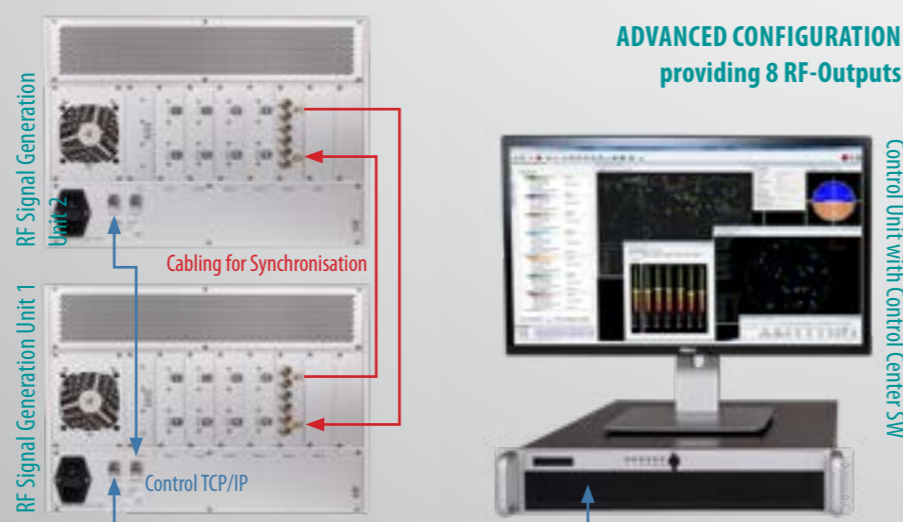
The real-time IMU/Sensor Emulation Package enhances the NCS TITAN with emulation capability of Inertial Measurement Units (IMU) and inertial sensors, such as micro electro-mechanical system (MEMS) sensors, and of other common aiding sensors, enabling full testing of sensor fusion algorithms of the receiver under test.

### ► Automotive Test Platform (ATP) Extension

The Automotive Test Platform provides a complete solution to test integrated vehicle navigation systems, which combine GNSS with emulated vehicle sensor data (e.g. wheel ticks), CAN-bus data and a rate table (2-D rotations). Future "Emergency Call" (eCall) and Advanced Driver Assistance Systems (ADAS) for the automotive sector can be tested based on this platform in a simple way.

### ► Advanced Multi-RF CRPA or Multi-Receiver Applications

For applications which require more than 4 RF-outputs (e.g. CRPA testing), signal generator units may be combined and synchronized, offering unlimited scalability. The example below shows a configuration with 8 RF-outputs. But also 12 or even 16 RF-outputs (simulated antennas) are possible. Ask us for a specific configuration.



## Key Specification

Parameter / Notes	Detail / Value
<b>Channels, Modules, Signal Banks and Frequencies</b>	
Signal channels per signal generator unit	Up to 256 (grouped in up to 8 modules)
Signal channels per signal generator module	32 channels (grouped into 4 signal banks)
Signal channels per signal bank	8 (and multipath channels)
Signal generator modules per signal generator unit	Up to 8 RFSIM modules
Signal banks per signal generator module	4 (with modulation & frequency selectable)
Multipath channels per signal generator unit	Up to 1.024
Multipath channels per signal channel	4
Frequencies generated simultaneously per signal generator unit	Up to 32 (signal banks with frequencies ranging from 1 GHz to 2,6 GHz)
<b>Power Levels</b>	
RF Signal Power	-90 dBm to -177 dBm
Dynamic Range	87 dB
Resolution	0.1 dB
Linearity (over total Dynamic Range)	<0.1 dB
Absolute Accuracy	±0.3 dB
Run-to-Run Repeatability	±0.1 dB
<b>Signal Accuracy</b>	
Simulation (Iteration) Rate	250 Hz (up to 1.000 Hz optionally)
Hardware Update Rate	> 200 MHz
Pseudorange Accuracy	< 0.1 mm RMS
Pseudorange Rate Accuracy	< 0.1 mm/s RMS
Pseudorange Uncertainty (due to Interchannel Bias)	0 mm RMS
Deltarange Accuracy	< ±0.5 mm RMS
<b>Internal Noise Generator (optional)</b>	
Noise Level	-170 dBm/Hz to -110 dBm/Hz
Resolution	0.1 dB
Accuracy	± 0.1 dB
Bandwidth	500 MHz in L-Band, 100 MHz in S-Band
<b>Signal Dynamics</b>	
Max. Velocity (LoS)	± 1,460,000 m/s
Max. Acceleration (LOS)	± 667,000 m/s <sup>2</sup>
Max. Jerk (LoS)	± 6,600,000 m/s <sup>3</sup>
Angular Rates (indicative) (at 1.5 m lever arm) (at 0.5 m lever arm)	> 15π rad/s > 60π rad/s
<b>Spectral Purity</b>	
Harmonics	< -40 dBc
In-band Spurious (relative value) (absolute value)	< -70 dBc ≤ -190 dBW
Phase Noise	< 0.005 rad RMS
Frequency stability	< ± 5 * 10 <sup>-10</sup>
<b>Inter-Carrier Phase Coherence</b>	
Inter-Carrier Bias	< ± 1.0 ns
Carrier Phase Coherence (@ Rf Output)	< 0.5°

Contact your local IFEN sales representative for expert advice regarding the optimum simulator configuration to meet your current and future needs



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