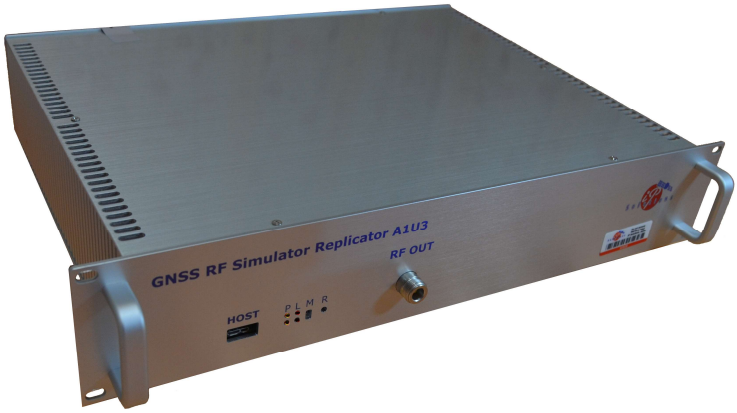
GNSS Simulation Solutions 2023



The Replicator A1-R4-Q8-U3 simulator.

Since 2007, IP Solutions has been committed to the research, development, and refinement of GNSS solutions. Our particular expertise in ionospheric scintillation monitoring has driven us to present novel models and approaches to simulation, a testament to which are our numerous publications and articles, including two textbooks on GNSS published with Cambridge University Press. Our simulator solutions represent the result of seven years of collaboration with the Japan Aerospace Exploration Agency (JAXA), offering high signal quality and industry-leading accuracy at reasonable prices. Custom models and signals can be implemented through ANSI C Model API and Signal API.

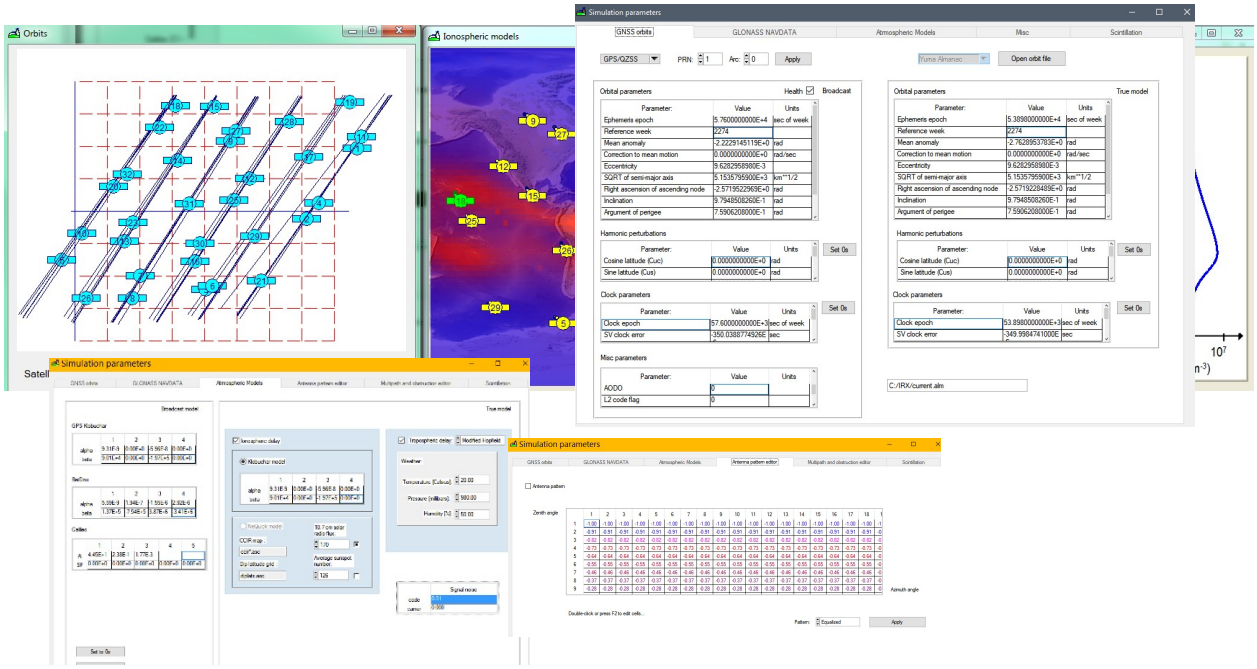
The ReGen control software features

- Position, Start Time, Duration, Static Position or Dynamic Trajectory
- Simulated scenario CSV files with information on satellite navigation data, position, true range, atmospheric errors.
- Signal propagation models (true and broadcast) for ionosphere and troposphere (Klobuchar, Saastamoinen, Hopfield, Black model, etc.).
- Step, Ramp, Acceleration of Pseudorange and Carrier Phase Errors.
- All orbital parameters for broadcast and true ephemerides (including Cuc, Cus, Cic, Cis, Crc, Crs). Input from Yuma, GUI or RINEX (optional).
- Navigation message parameters and bits editing.
- User trajectory input.
- Spoofing simulation.
- Power level control.
- Cut-off antenna elevation angle (including negative)
  - user defined
  - based on Earth tangent
  - Based on local horizon

Contact: ***info@ip-solutions.jp*** **www.ip-solutions.jp**
Level 9, Ariake Frontier Building Tower B, 3-7-26 Ariake, Koto-ku, Tokyo 135-0063 Japan *Tel: +81-3-5530-8667*

ReGen advanced features (professional version and optional items)

- Receiver antenna pattern editor.
- Satellite antenna pattern editor.
- Obstruction editor.
- Single channel simulator: allows to switch off code, carrier and data, set a Doppler profile.
- HIL support.
- Trajectory simulator for land vehicle, aircraft, satellite 6-DOF movement.
- INS simulator.
- Satellite clock degradation models.
- SBAS, NavIC grid model.
- Additional tropospheric and ionospheric models including user defined.
- Extensions of Atmospheric models for LEO and GEO satellites
- Multipath simulation
    - Scenario defined attenuation, Doppler, range and phase shifts for two multipath channels for each GNSS channel.
    - Ground reflection model
    - Statistical model
- Advanced ionosphere simulation:
    - NeQuick model, ionospheric gradient error editor,
    - scintillation simulation, ionospheric bubble simulation
    - fault scenarios (RTCA LAAS ICD and FAA CAT-1 LAAS spec).

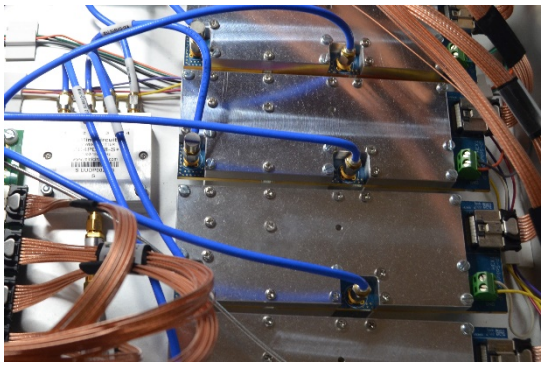


The ReGen Pro screenshot showing satellite orbital deployment, NeQuick ionospheric model, vertical TEC distribution, atmospheric parameter models, orbital parameter editor and antenna pattern editor.

Contact: ***info@ip-solutions.jp*** **www.ip-solutions.jp**
Level 9, Ariake Frontier Building Tower B, 3-7-26 Ariake, Koto-ku, Tokyo 135-0063 Japan *Tel: +81-3-5530-8667*

Hardware

The Replicator and Simceiver™ simulator solutions offer a range of configurable options, providing a balance of cost-effectiveness and performance to meet your testing needs. We also provide testing solutions where live satellite signals are recorded and played back.



Replicator RF cards .

The Replicator is a high-end simulator model. It houses up to 6 RF cards, which are set to specific central frequencies through the GUI.

The Ninja model provides up to 8 RF outputs for CRPA

CRPA Ninja A6-R4-Q8-U3 Simulator

Simceiver™ A1-R2-Q3-U2 mid-level simulator

The Simceiver™ model is an economical, compact, mid-level multi-frequency simulator.

Interface Capabilities

Each simulator model is equipped with a multifaceted interface that includes the following signal and control options:

- One Pulse Per Second (1PPS) Input and Output
- Reference Clock Input and Output
- Trigger Input/Output Capability

This architecture ensures a seamless and efficient interaction between the simulator and any externally connected systems, facilitating time synchronization, reference clocking, and external triggering functions.

Standard Interface for Ninja and Replicator models

Certain models are available with an optional digital programmable interface offering enhanced customization and control capabilities.

Record and playback solution

The Streamer playback software for Simceiver allows the playback of pre-recorded GNSS signals. Recorders are sold separately. The ReGen-S software enables the Simceiver to generate GNSS signals.

GNSS signal recorder PORTOS A1-R4-L-U2 (supports four frequencies).

Contact: ***info@ip-solutions.jp*** **www.ip-solutions.jp**
Level 9, Ariake Frontier Building Tower B, 3-7-26 Ariake, Koto-ku, Tokyo 135-0063 Japan *Tel: +81-3-5530-8667*

Simulator model *(examples, more available)*	*RF outputs (Ax-) AxD- differential*	*RF cards (Rx-) RxW-AltBOC*	*Signal resolution (Qx-) (the higher, the better)*	*Interface*	*Features*
Simceiver A1-R2-Q4-U2	*1*	*2*	*4 (2 for playback)*	*USB-2*	*Playback*
Replicator A1-R2-Q8-U2	*1*	*2*	*8*	*USB-2*	*Mid level*
Replicator A1-R4-Q14-U3	*1*	*4*	*14*	*USB-3*	*Standard*
Replicator A2D-R4W-Q14-U3	*2 differential*	*4 wideband*	*14*	*USB-3*	*Differential*
Ninja A6D-R6-Q14-U3	*6 CRPA*	*6*	*14*	*USB-3*	*CRPA*

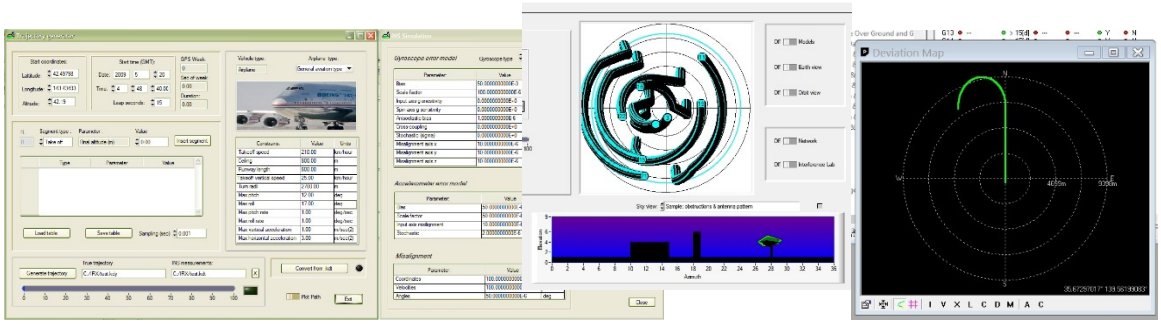
Simulator hardware models

ReGen version	
-S or -R	*Controls Simceiver or Replicator models.*
-Pro	*Professional version*
-D	*Differential. Support two independent vehicle movements on two RF outputs*
-CRPA	*Supports CRPA simulation*

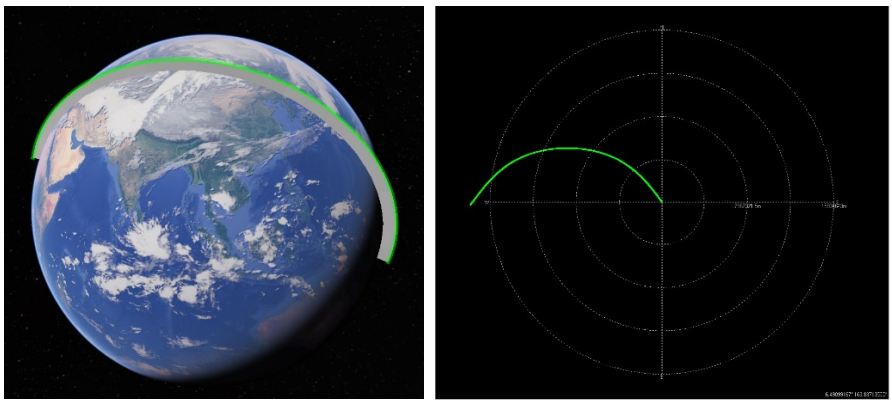
Simulator control software versions

ReGen dynamic user simulation

ReGen™ supports dynamic trajectory for a single vehicle or for two vehicles (ReGen-D). It can work with user-defined trajectory. Additionally, our Trajectory Generator software is also available to generate trajectories for ground vehicles, aircraft, and satellites, along with corresponding INS data using user-defined gyroscope and accelerometer models.



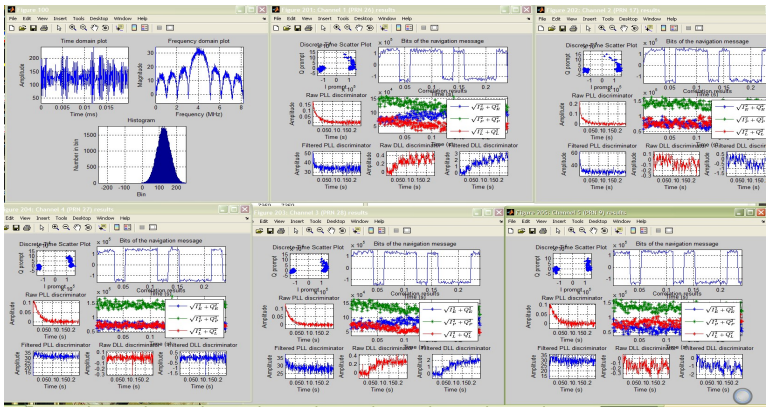
INS and trajectory generator add-on to ReGen. ReGen Skyview plot for simulated circling flight vehicle and uBlox deviation map with position estimate .



The ReGen™ simulates GNSS signals for a LEO satellite (the data are courtesy by ESA project team).

Contact: ***info@ip-solutions.jp*** **www.ip-solutions.jp**
Level 9, Ariake Frontier Building Tower B, 3-7-26 Ariake, Koto-ku, Tokyo 135-0063 Japan *Tel: +81-3-5530-8667*

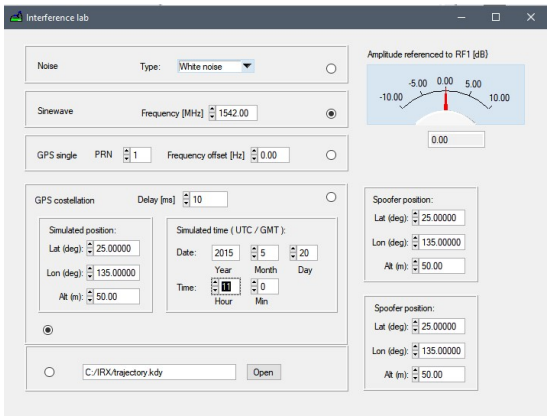
ReGen digitized IF simulation



MATLAB receiver from Kai Borre working with a GPS signal simulated by ReGen.

ReGen™ also allows for the generation of a simulated digitized IF (DIF) signal similar to one recorded from live satellites. The signal can be played back by specific simulator models using optional Streamer software.

Spoofing simulation



Various options are available to support spoofing simulation. The standard ReGen version includes a Model API, which allows for the simulation of a simple user-defined scenario for RAIM testing. An example of such a scenario is provided with the Model API. The Model API is provided with a ready-to-run Microsoft Visual Studio Project.

Additionally, a Spoofing Simulator add-on is available with the following features:

- Spoofer simulation with access to constellation parameters similar to the "true" constellation.
- Static or dynamic spoofer position.
- Interference simulation as noise, sine wave, or GNSS signal.
- Simulation of true and false NAVDATA.
- Simulation of true and false error budgets.
- Spoofer antenna pattern model.
- Simulated time sync error.
- Simulated false vehicle position (trajectory).
- Simulated spoofer location or trajectory with spoofer-receiver profile.

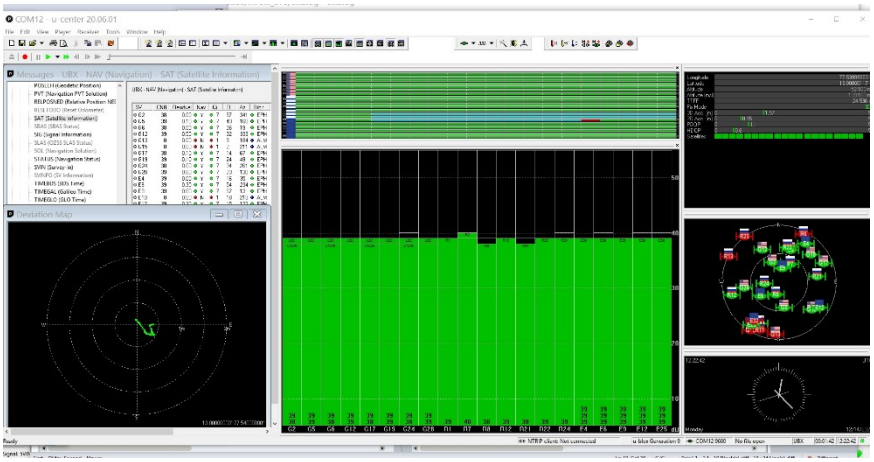
Support and Warranty

Our dedication to our clients extends beyond delivering products. We provide extensive post-sales support and a comprehensive warranty on our GNSS RF Simulator and recorder products. We also provide our customers with customized updates.

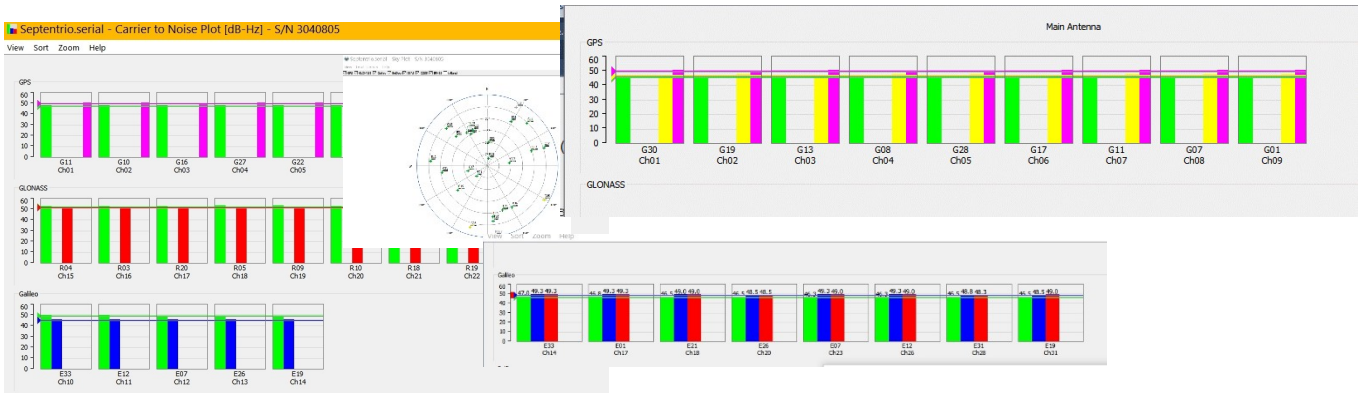
Contact: ***info@ip-solutions.jp*** **www.ip-solutions.jp**
Level 9, Ariake Frontier Building Tower B, 3-7-26 Ariake, Koto-ku, Tokyo 135-0063 Japan *Tel: +81-3-5530-8667*

Compatibility with COTS receivers and receivers under development

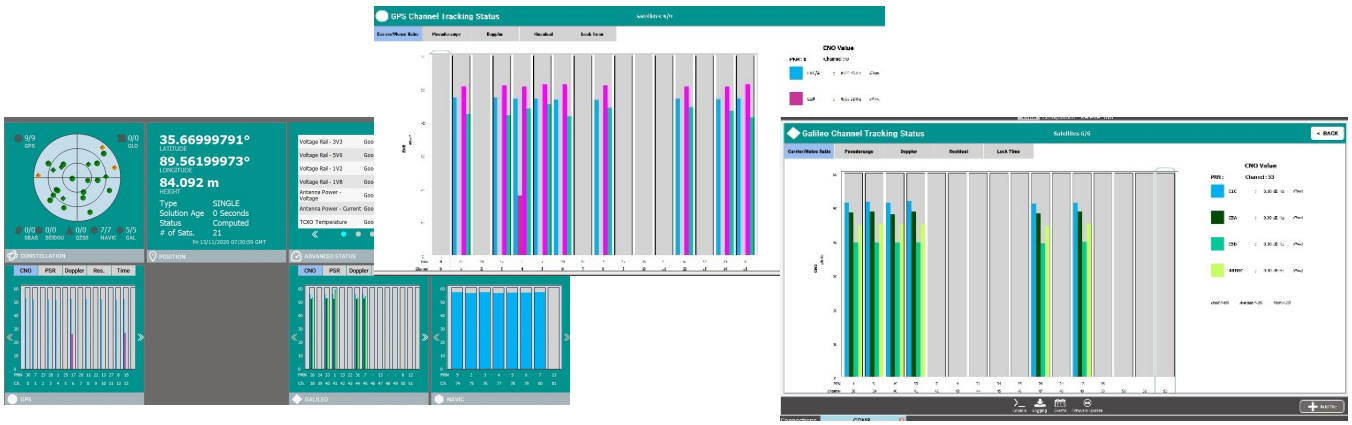
Our GNSS RF Simulator delivers high-fidelity performance when interfacing with a variety of COTS receivers. Successful test scenarios have been conducted with receivers such as uBlox 9, Novatel OEM7, Septentrio, Trimble, AllyStar, with the simulator effectively provided dual and triple frequency signals. Notably, with the support from our simulator, high-end receivers can demonstrate decimetre-level accuracy.



uBlox 9 working with the Replicator A1-R4-Q8-U3 dual frequency GPS, GLONASS and Galileo simulated signals. The scatter plot is usually within 50 cm from true position.



Septentrio receiver with dual and triple frequency GPS, GLONASS and Galileo simulated by the Replicator A1-R4-Q8-U3. It usually demonstrates (under normal simulation conditions) deviation within 50 centimetres from true position in horizontal plane and 2 meters in vertical .



Novatel OEM7 working with the Replicator A1-R4-Q8-U3 dual/triple frequency GPS, Galileo, NavIC and GLONASS simulated signals.

Contact: ***info@ip-solutions.jp*** **www.ip-solutions.jp**
Level 9, Ariake Frontier Building Tower B, 3-7-26 Ariake, Koto-ku, Tokyo 135-0063 Japan *Tel: +81-3-5530-8667*

Simulator specification

1	Parameter	
	Signals (including optional)	GPS L1C/A, L1C, L2C, L5, BeiDou B1I, B1C, B2a, B2b, B2I, B3I, Galileo E1, E5A, E5B, E6, QZSS L1C/A, L1C, L2C, LEX, NAVIC L5, S, GLONASS L1OF, L2OF, L1OC, L2OC, L3OC, SBAS and user defined signals.
	Frequency	In accordance with ICDs
	Number of RF outputs	1,2,4 or 6
	Number of channels per RF output	For system with single RF output: 72 . For system with two RF outputs: 144 (72 per RF output)
	Number of satellite channels	14 satellite signals can be simulated for each GNSS constellation and 5 for SBAS on each frequency. For example, 47 channels for L5 GPS L5 + Galileo E5 + NavIC L5 + SBAS L5
2	Power control	
	Range	25 dB [1,3] ; 45 dB (from -30dB to +15dB) [2]
	Linearity	0.5 dB [2]
	Resolution	1 dB [1,3] ; 0.1 dB [2]
	Accuracy	±0.5 dB [1,2,3]
	Run to run repeatability	±0.2 dB [2]
3	Signal quality	
	Spurious	≤-40dBc [2]
	Harmonics	≤-40dBc [2]
	Single side band phase noise	0.02 Rad RMS [2]
	Jitter	≤ ± 0.1 nano sec [2]
4	Connectors	
	RF OUT	N female [1,2] ,SMA [3] , DC block . 50 ohm
	1 PPS IN	BNC female[1,2] , SMA [3]
	1 PPS OUT	BNC female[1,2] , SMA [3]
	Trigger	BNC female[1,2] , SMA [3]
	External clock IN	BNC female [1,2] , SMA [3]
	External clock OUT	BNC female [1,2] , SMA [3]
	USB control	USB-3 [1,2] , USB-2 [3]
	Power	5 or 12 V DC , 4 W . AC/DC adapter is included.
5	Accuracy	
	Code phase	< ±1 cm RMS [1,3] ; < ±1 mm RMS[2]
	Carrier phase	< ±1 mm RMS [1,3] ; < ±0.1 mm RMS[2]
	Bias between RF channels	< ±2 ns[1,3] ;< ±0.5 ns[2]
	Inter carrier bias	< ±5 nanosec RMS[2]
	Inter channel bias	< ±0.5 nanosec RMS[2]
6	User dynamics	
	Update rate	100 Hz [1,2,3] ; 1,000 Hz [2]
	Maximum Altitude	As required by trajectory (LEO, GEO supported) [1,2,3] , up to 76,000 km [2]
	Maximum Velocity	As required by trajectory (LEO supported) [1,2,3] , up to 20 km/s [2]
	Maximum Acceleration	As required by trajectory(LEO supported) [1,2,3] , up to 25g[2]

Contact: ***info@ip-solutions.jp*** **www.ip-solutions.jp**
Level 9, Ariake Frontier Building Tower B, 3-7-26 Ariake, Koto-ku, Tokyo 135-0063 Japan *Tel: +81-3-5530-8667*

	Maximum Jerk	As required by trajectory(LEO supported) [1,2,3] , up to 25g/s [2]
	Angular velocity	As required by trajectory(LEO supported) [1,2,3] ,up to 2π rad/s at 1.5m lever arm [2]
	Maximum duration	12 hours [1,3] ; 240 hours [2]
	Antenna position offset	6-DOF (Linear in vehicle frame and angular in roll, yaw, pitch)
	Antenna elevation cut-off angle	User or geometry specified (including negative)
	Control software	ReGen [1,2,3] , Streamer [3] (for playback)
7	Time base	
	Clock type	OCXO
	Aging	±0.1 ppb /day
	Stability	±0.1 ppb [1,2] , ±5 ppb [3]
8	Environmental (for indoor use only)	
	Safety and EMC	Built in compliance with CE requirements in electrical, mechanical, chemical safety and EMI
	Operating temperature	+10°C to +40°C.
	Operating humidity	40 to 90% RH (non-condensing)
	Storage temperature	-10°C to +50°C.
	Storage humidity	20 to 90% RH (non-condensing)
	Dimensions	Rack-mount , 19 inches, 2U [1,2] .
	Weight (approx.)	~1 kg [3] ; ~10 kg [1,2]

[1]Replicator -Q8, [2]Replicator -Q14, [3]Simceiver -Q4

Contact: ***info@ip-solutions.jp*** **www.ip-solutions.jp**
Level 9, Ariake Frontier Building Tower B, 3-7-26 Ariake, Koto-ku, Tokyo 135-0063 Japan Tel: +81-3-5530-8667