



Intersatellites Channel Emulator

Technical Specifications

- The Intersatellites Channel Emulator is a very accurate Channel Emulator with RF (or low IF) input and RF (or low IF) output with an excess Bandwidth of 100MHz capable of emulating any type of Inter-Satellite Link (ISL) for Telecom or Navigation application. The instrument emulates in real time, together with channel propagation effects, several Payload On Board degradation effects and it has been used on the Market to Test ISL between MEO to MEO SVs and LEO to LEO SVs. Being driven by the SV Ephemeris files, any sort of SV (LEO, MEO, GEO, IGSO etc.) could be modeled generating mixed SV to SV configurations.
- The Channel Emulator although is driven by a signal processing data path engine, is fully transparent to the signal Modulation so any type of modulated signal, compatible with the I/O bandwidth requirements, can be passed through and interfaced at RF signal level.
- The Satellite Channel Emulator controls the channel dynamic parameters (Delay, Doppler and Attenuation) being driven by a couple of very accurate Orbital Propagators developed by Space Technology which embeds:
 - Non Spherical Gravity Field of Earth (standard JGM-3 with $N=M=20$).
 - Third-Body Forces: (Sun, Moon and other Planets)
 - Solar Radiation Pressure
 - Atmospheric Drag
- Alternatively for Navigation applications, the Channel Emulator dynamic can be driven also by the SVs Ephemeris parameters set with (real) and without (ideal) corrections.
- The unit is assembled in a 19" 2U (55 cm. of depth) case as reported below in Figure 1 (Front Panel) and Figure 2 (Rear Panel)



Figure 1

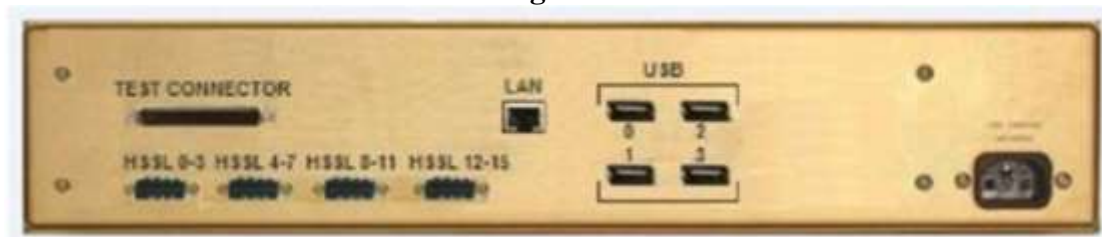


Figure 2

- The Satellite Channel emulator embeds the following On Board effects:
 - On Board Power Amplifier memory-less nonlinear amplitude (AM-AM) and phase (AM-PM) distortions

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- On Board Antenna Radiation Diagram
 - User configure Phase Noise IIR emulator when used with IF interface
 - Atmospheric Fading
 - Ionosphere Delay (Klobuchar and soon Nequick2) (where appropriate)
 - Troposphere Delay and Attenuation (where appropriate)
 - Pre-HPA 64 FIR taps complex Filter
 - Post-HPA 64 FIR taps complex Filter
 - Programmable frequency offset
- The Channel Emulator can embed inside, when ordered with such option a local PC I5 INTEL Core Mother Board 8Gbytes RAM e HD 500Gbytes (LAN, USB 3.0, USB 2.0, VGA or HDMI external interfaces) to run the SW Graphical User Interface. Alternatively it can be configured and monitored through a standard Windows OS PC using a single USB 2.0 link and the SW Driver provided by Space Technology.
 - The Channel Emulator provides as accessories (i.e. ordered as options) the Channel Input Signal and Output Signal Recorder and as additional option also a Channel Input Signal Player. Such options allow from a controlling PC the Recording and Playing of Base Band samples up to max symbol rate of 75Mbauds (I and Q, 8 bits per components)

Some of the Channel Emulator effects are reported below as tested in real time by standard instrumentation (Vector Signal Analyzers and Spectrum Analyzers). In particular below in Figure 3 are reported the On Board Antenna (left) and the Doppler effects (right) on the symbol Scattering Diagram.



Figure 3

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Figure 4

Figure 4 reports a single NLOS Multi Path ray test for an 8PSK Modulated signal, while in Figure 5 the AM-AM distortion for a GALILEO E5 AltBOC modulated signal is reported.

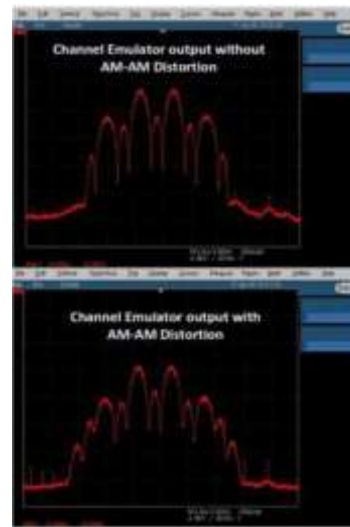


Figure 5

Finally Figure 6 reports on the left side the accuracy of the Space Technology Orbital Propagator based on JGM-3 N=M=20 Non Spherical Gravity Field of Earth Model compared to a third party N=M=360 EGM96 modeler of the same Non Spherical Gravity effect.

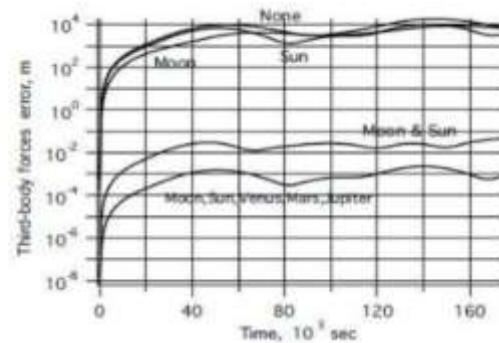
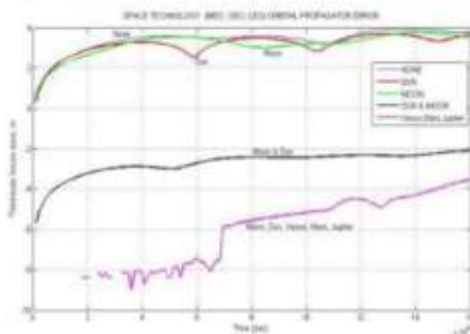


Figure 6

The Channel Emulator HW processing crate is built around a single Space Technology proprietary Software Defined Radio Board (16 cm by 10 cm form factor), whose picture is reported below in Figure 7.

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Figure 7

The baseline configuration of the Intersatellites Channel Emulator product is single Antenna feed RF I/O. The RF up and down converters can be ordered from L band to Ka Band and are custom manufactured by DIGIMIMIC (www.digimimic.com) pending RF performance and RF I/O interface electrical specifications feasibility.

In particular in the L band from 1.7GHz to 2.2GHz, the Channel Emulator could be ordered also with a very convenient and compact 8 feeds Beam Forming RF front end option. Such configuration is implemented using the couple of RF up and down converter Boards developed by DIGIMIMIC in a very compact 3U form factor as reported below in Figure 8. Using that Channel Emulator BFN RF configuration is possible to emulate and test a Space Diversity Antenna without having designed the actual RF BFN Front Ends in the Modulator and Demodulator units under test.

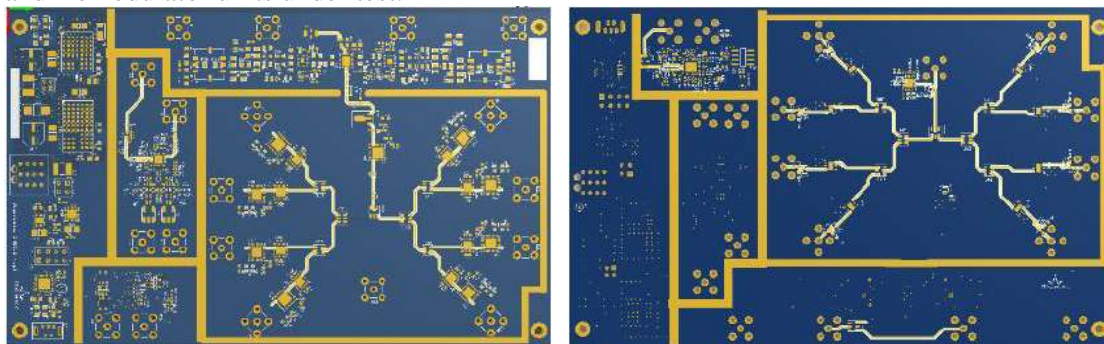


Figure 8

While the single feed RF I/O can be factory customized to any RF from Ka band down to L band, the BFN option of the Satellite channel emulator at the moment is available only in L band with the following specifications:

Up Converter Section (left side of Figure 8)

- 8 Beam Forming Nodes

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- 360°, 6 bits phase control for each of the 8 paths
- 31.75 dB Attenuation with 0.25 dB steps of control
- Output frequency range 1.7GHz to 2.2GHz @125MHz of bandwidth
- Maximum output power: -8dBm for each BF node

The equivalent Down Converter Section of the L band RF BFN FE (right side of Figure 8)

- 8 Beam Forming Nodes
- 360°, 6 bits phase control for each of the 8 paths
- 31.75 dB Attenuation with 0.25 dB steps of control
- Input frequency range 1.7GHz to 2.2GHz @125MHz of bandwidth
- Input power range: -9dBm fto -55 dBm or each BF node
- Noise Figure < 4 dB (@RFIN < -20dBm)

The Channel Emulator with Beam Forming option can be configured to have Beam Forming only on the RF input side or only on the RF output side or both.

The BFN Amplitude and Phase weight coefficients can be updated externally by the User application via a USB 2.0 or a USB 3.0 fast link depending from the Coefficient rate of updating, or they can be preloaded, at test session configuration time, in a file to be played at a given rate directly by the Channel Emulator at run time.

Instead when one of the section of the emulated link is a Ground receiver, its cinematic model (so one SV and a Ground receiver with a given cinematic) can be uploaded using a file containing the ECEF X,Y and Z directions receiver position and velocity coordinates sampled with a time stamp @100Hz. Such file could be either pre-loaded by the Channel Emulator GUI SW or updated externally at run time, using a User SW application communicating with the Channel Emulator via a USB 2.0 link, which should guarantee a 100Hz sustained rate during the test session.

The Channel Emulator embeds a state of art very low phase noise 10.23MHz OCXO reference oscillator (see Fig. 9 right side) that allows the instrumental RF Front End even to Ka band not to limit the overall Phase Noise performances of the Test Bed where the Channel Emulator is going to be used. A cheaper but yet low phase noise OCXO Option is available (see Fig. 9 left side).

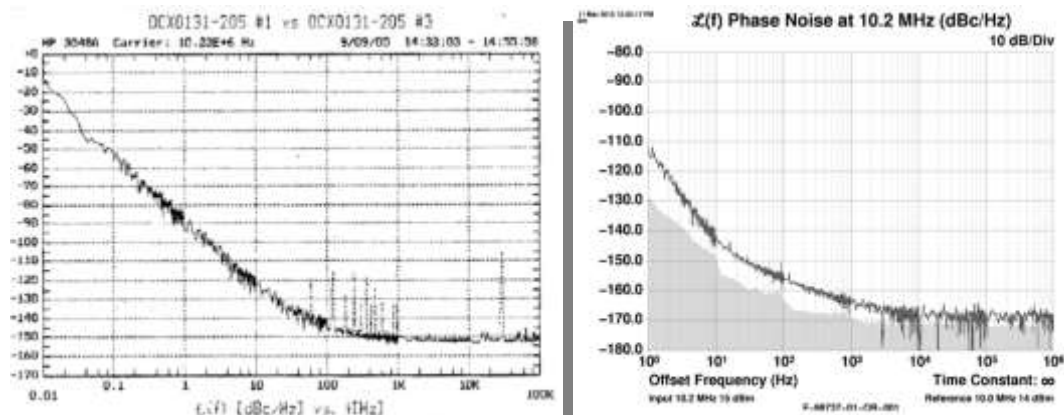


Figure 9

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The Channel Emulator can be configured through GUI to operate:

- either at IF analog level
- or at RF level (in the band domain up to Ka Band. RF central value to be selected at PO time)

When the Channel Emulator is used to operate with IF interface, the User can configure through Graphical User Interface, the coefficients of three IIR Filters and the gain of a white noise generator, all the four sub-units being cascaded and aimed at generating, when properly combined, any arbitrary Phase Noise Mask starting from the 10.23MHz OCXO Phase Noise performances reported in Figure 9.

When operated the Channel Emulator is used with its RF interface, the Phase Noise SW model should be disabled through the GUI.

The Channel Emulator is equipped with DRAM memory modules aimed at modeling any SV to SV or SV to Ground delay from a minimum of 10 ms to 250 ms.

The Channel Emulator has been tested up to the following maximum Doppler and Delay rates:

- Max Doppler Rate: $\pm 1.420\text{KHz/sec}$
- Max Delay Rate: $\pm 83\text{ us/sec}$ respectively
- Standard Delay Range: 10ms to 250 ms (expandable with more DRAM module options)

The Channel Emulator accuracy in modeling the MEO to MEO SVs relative dynamic has been tested using a GALILEO L1 Signal Generator and a Real Time GNSS receiver operating with Delta Code Phase Pseudorange (PR) readings @10Hz (including an RF L band Front End). The GNSS Test Receiver PR readings (i.e. the one coming from the HW GNSS Receiver in real time as 32 bits fixed point values) have been compared, in ideal conditions, with the IEEE Floating Point format of the real GALILEO MEO to MEO dynamic profile controlling the Channel Emulator with the Test Bench reported in Figure 10.

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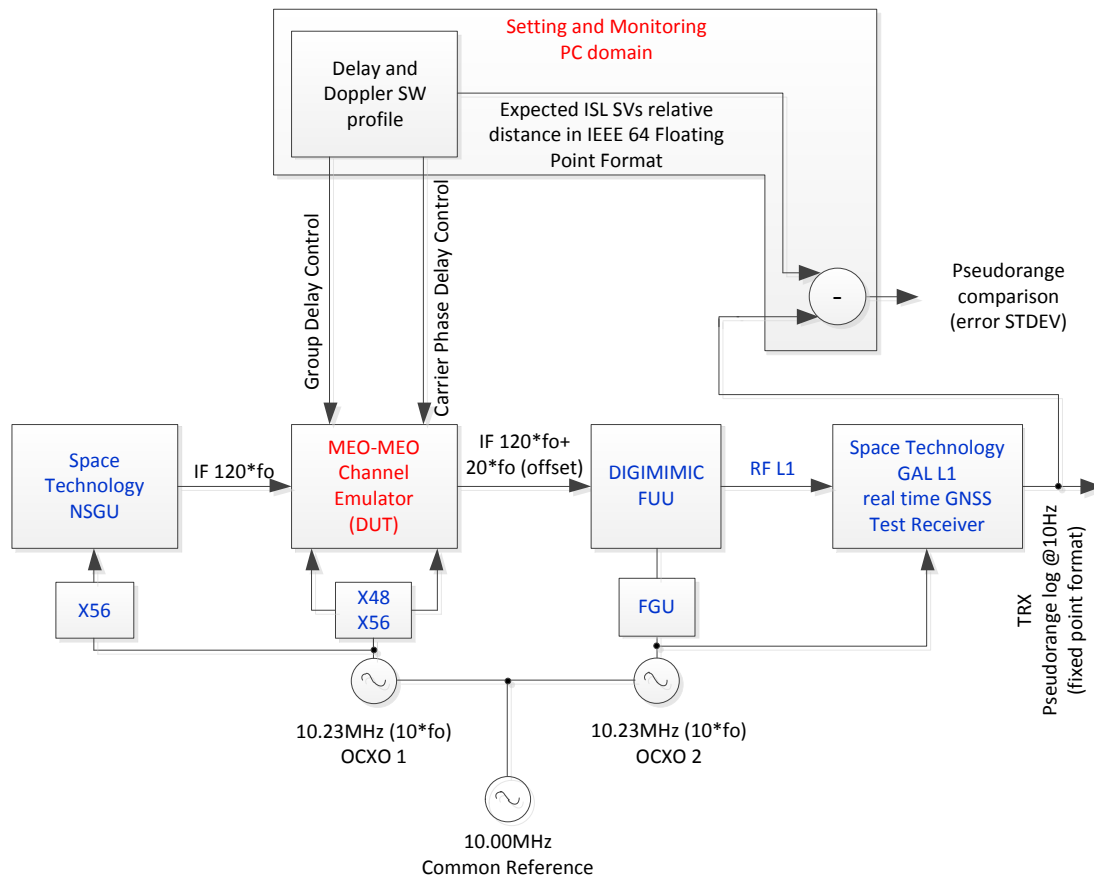


Figure 10

In such a case the 1σ STDEV error (estimated over 6 hours testing time) between the SW model and the CE HW PR readings, including the DLL and PLL implementation losses of the real time GNSS Test Receiver, as reported in the legend of Figure 11, was 35 ps !.

For User convenience, during any test session, the Intersatellites Channel Emulator can be driven not only through the SVs Ephemeris file Mode, but also via a Stress Test Mode where the Delay and Doppler profile are configured via GUI as sinusoidal functions whose Delay and Doppler excursion ranges, their period of variation (Doppler rate and Delay rate) as well as their initial phases can be User specified, up to the maximum excursion values for the Delay, Doppler Rate and Delay Rate ranges, reported above.

Finally the Channel Emulator is capable, when operated at IF, to generate also the wideband (100MHz) White Gaussian Thermal Noise. The Gaussian Noise and the Phase Noise Generators are uncorrelated with repetition period greater than 2 days.

The Channel Emulator can be operated, when in Ephemeris mode, enabling the C/N0 variation due to satellite propagation or disabling it.

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When configured to operate in Stress Test Mode, also the C/N0 variation could be forced to be a sinusoidal function, yet controlled by the User, via the SW GUI setting.

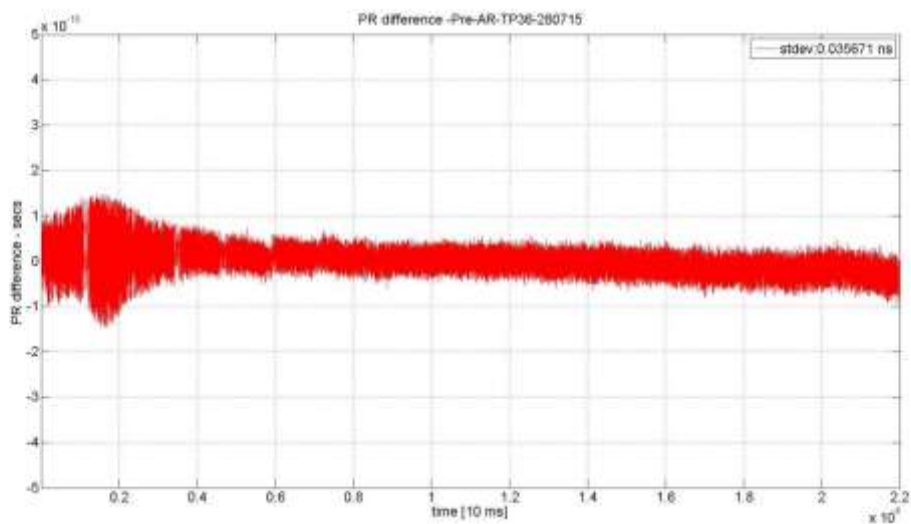


Figure 11

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