From ORU to Sky : Prot ORU, X420 and NTN

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Speaker

Dr. Bharat Agarwal is a 6G Wireless Applications Engineer at NI (Emerson), working on practical 5G-Advanced and 6G systems with a focus on mmWave/Sub-THz, AI/ML-assisted PHY/MAC, beam management, ISAC, and XR streaming. He has led real-time SDR demonstrations on open-source platforms (OAI, srsRAN, ns-3), contributed to EU Horizon Europe projects, and bridges AI-driven wireless research with real-world RF implementations.

USRP X420

NI Ettus USRP X420

Wide BW, LO Sharing and High Freq. Coverage for FR3, Ku and X Bands

Fig1. NI Ettus USRP X420

Why Choose the NI Ettus USRP X420?

- Prototype Radar, satellite Communications, or NTN for 6G Freq. Up to 20 GHz.
- Create multi channel phase coherent systems with built in LO sharing capabilities and <1 degree RMS
- Process data in real time with a large on board programmable FPGA
- Sync. Multiple radios with a built in GPSDO or 10 MHz and PPS inputs
- The open source UHD driver lets you choose the software that works best for you.

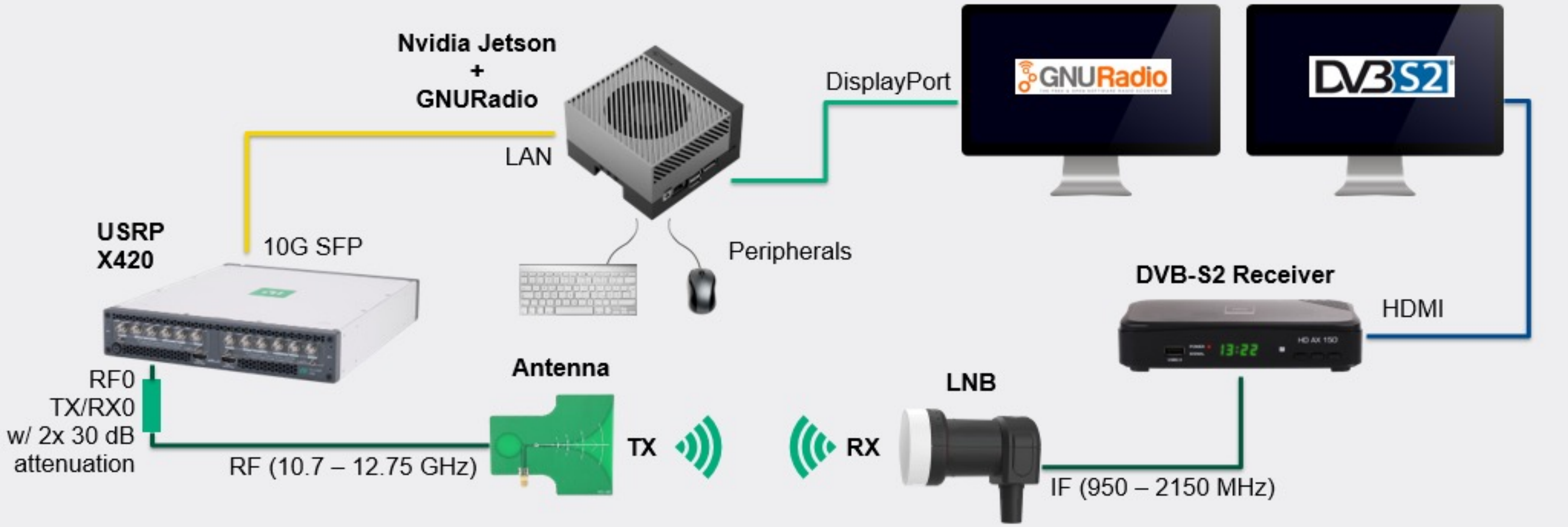
Technical Specifications

PARAMETERS	NI ETTUS USRP X410
Frequency Range	10 MHz to 20 GHz
Bandwidth	Up tp 1GHz per channel
Number of Channel	2 TX (via TX/RX Port) and 2 RX (via TX/RX or RX2 port)
Sync	Onboard GPSDO, 10 MHz and PPS Ref., Trigger In/Out Interface, LO In and Lo Out
Control	2 HDMI GPIO Interfaces, Type C USB Port (Serial Console, JTAG)
FPGA	AMD Zynq Ultrascale+ RFSOC ZU28DR
Interface	Dual 100 GbE or Quad 10 GbE via QSFP28, 1GbE via RJ45

Software Specifications

PARAMETERS	NI ETTUS USRP X410
Development Tools	UHD, RFNoC, GNURadio, Python, C/C++, LabView
SW Compatibility	UHD Driver (Open Source)

X420 DVB-S2 Transmission – Block Diagram



ProtO-RU

ProtO-RU

Foundation

srsRAN Radio Unit Emulator (Base Platform)

Extended with three new capabilities to become a fully complaint O-RU

Open Fronthaul (OFH)
Packet processing support for O-RAN fronthaul interface compliance

Low-PHY Processing
Physical layer signal processing functions for the radio chain

UHD-Based Radio
Integration with USRP hardware drivers (UHD)for RF I/O

ProtO-RU — fully compliant, software-based O-RAN O-RU
Runs on general-purpose processors (GPP) + SDR as RF frontend — no dedicated accelerators

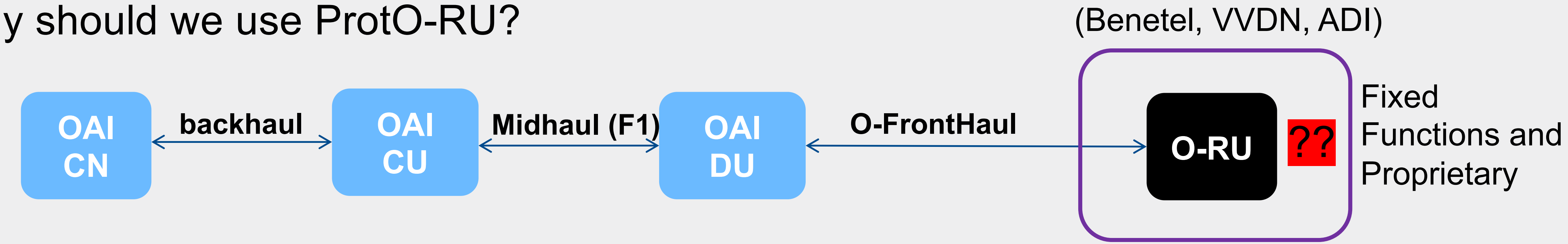
General-Purpose Processor
Standard CPU/server hardware runs entire O-RU software stack

Software-Defined Radio
Acts as RF frontend(e.g. USRP via UHD)

USE CASES ENABLED
Rapid prototyping · Algorithm development · Performance evaluation · O-RAN experimentation · AI/ML integration · Custom instrumentation & debugging→ Faster iteration than FPGA/ASIC O-RUs — ideal for academic research, PoCs, and early-stage O-RAN innovation

ProtO-RU (Contd...)

Why should we use ProtO-RU?



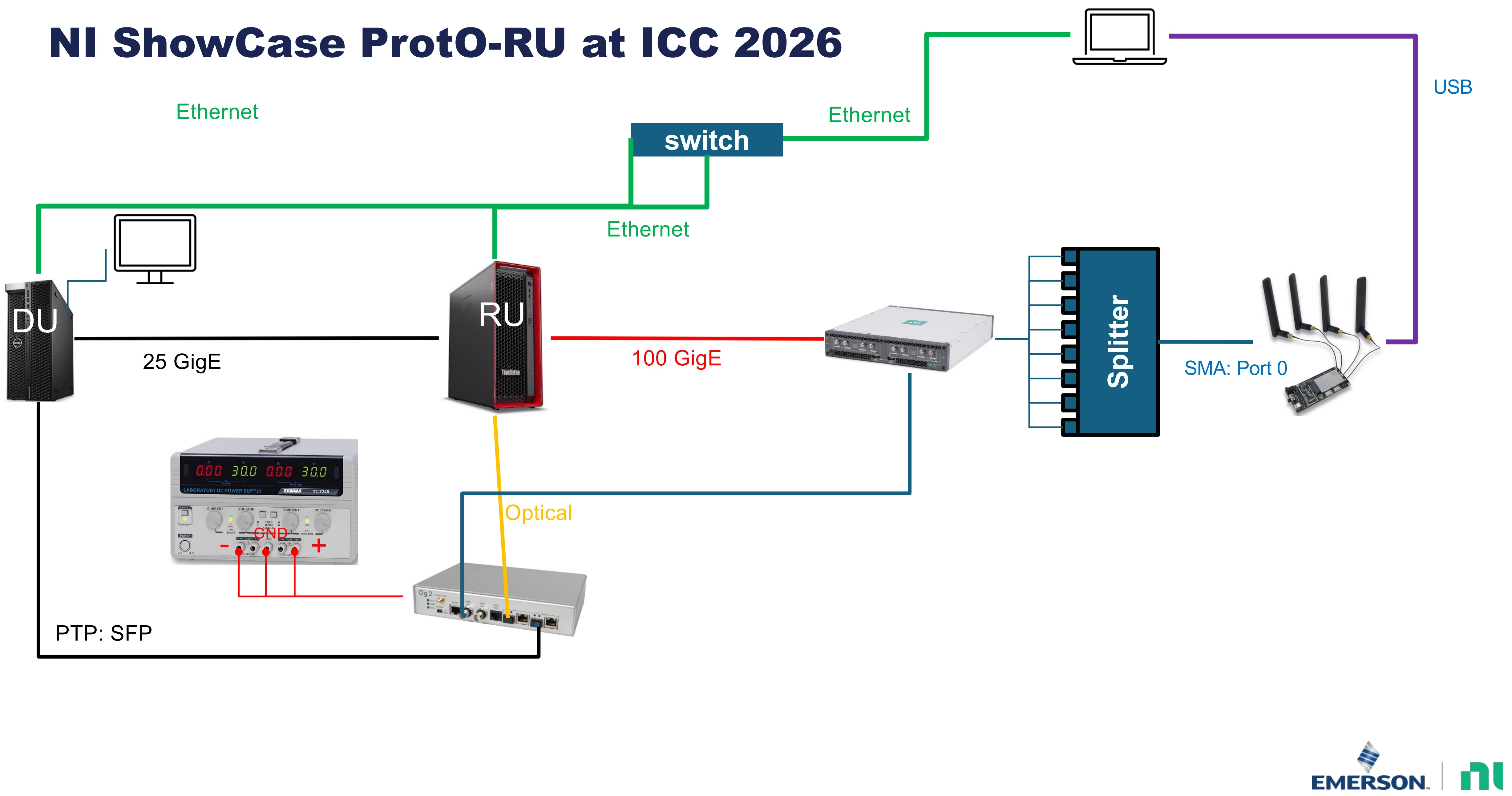
Parameter	Commercial ORU	ProtO-RU
Usage	Commercial Deployment	Research Prototyping
Duplexing Mode	TDD or FDD	Support Different Duplexing Mode
Frequency Bands	Limited Range	Support Different Freq. Range
AI/ML Driven Research	Limited	ML-driven Low PHY Processing
OFH Protocol Design	Cannot extend OFH Protocol	Explorations of new OFH protocol designs such as multipoint routing
Timings	Standardized	Limitations (High E2E RTT), along with ODU and ORU timing windows

ProtO-RU (Contd..)

Latency Breakdown –Where the Delay comes From

1. **Largest Contributor: Contributor 1 — srsRAN hardcoded rx-to-tx offset:** srsRAN's low PHY hardcodes rx_to_tx_max_delay = 1.0008 ms (3 slots at 30 kHz SCS). Downlink IQ samples must be ready in the Resource Grid (RG) pool at least 3 slots before transmission. This is not configurable without patching srsRAN source code.
2. **Significant Contributor: Contributor 2 — OFH processing time:** IQ data extraction and decompression at the OFH layer takes 1–2 slots empirically. Using the upper bound pushes to approximately 5 slots total. This is a software CPU overhead — FPGAs/ASICs handle this in nanoseconds.
3. **Moderate Contributor: Contributor 3 — Low PHY uplink processing :** OFDM demodulation and cyclic prefix removal on the CPU takes 1–2 slots, driving to exceed 2 slots.
4. **Structural Contributor: Root cause — CPU vs FPGA/ASIC** Commercial O-RUs (Benetel RAN550, etc.) use FPGAs or ASICs for low PHY and OFH processing, achieving sub-slot latency. ProtO-RU runs entirely on general-purpose CPUs (Intel Xeon / Core i7), making the delay fundamentally higher and non-deterministic under load.

NI ShowCase ProtO-RU at ICC 2026



NI Channel Emulator

Channel Emulator System Software (CHESS)

- **Real-Time Channel Emulation:** CHESS uses high-performance hardware, FPGA-based processing, and software IP to emulate complex RF channel conditions in real time.
- **VST and FPGA Integration:** A **Vector Signal Transceiver (VST)** interfaces with the system under test, while the FPGA dynamically applies channel parameters directly to the live RF data stream.
- **Easy Configuration via InstrumentStudio:** The **NI InstrumentStudio™ plug-in** enables engineers to configure channel settings, load custom channel profiles, and integrate with third-party simulation tools for scenario generation.
- **Support for Advanced RF Testing:** CHESS can be combined with other NI solutions to perform **end-to-end link emulation, advanced RF environment simulation, and validation of data link receivers and recorders**.
- **FPGA Customization with DLTF:** By using the **NI Data Link Test Framework (DLTF)** as an add-on, engineers can deploy their own signal processing models directly onto the FPGA coprocessor for enhanced flexibility and customization.

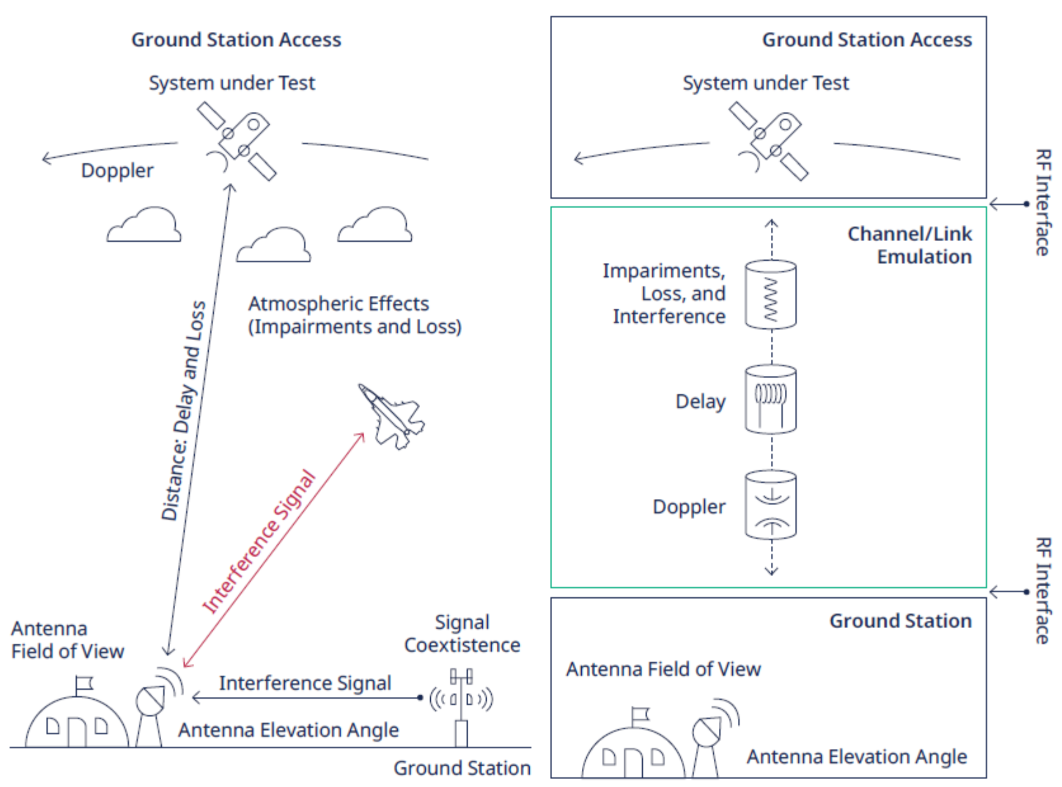


Fig.2. Examples of Real-World Signal Impairments for Ground, Air, and Orbital Communication Links

CHESS (Contd..)

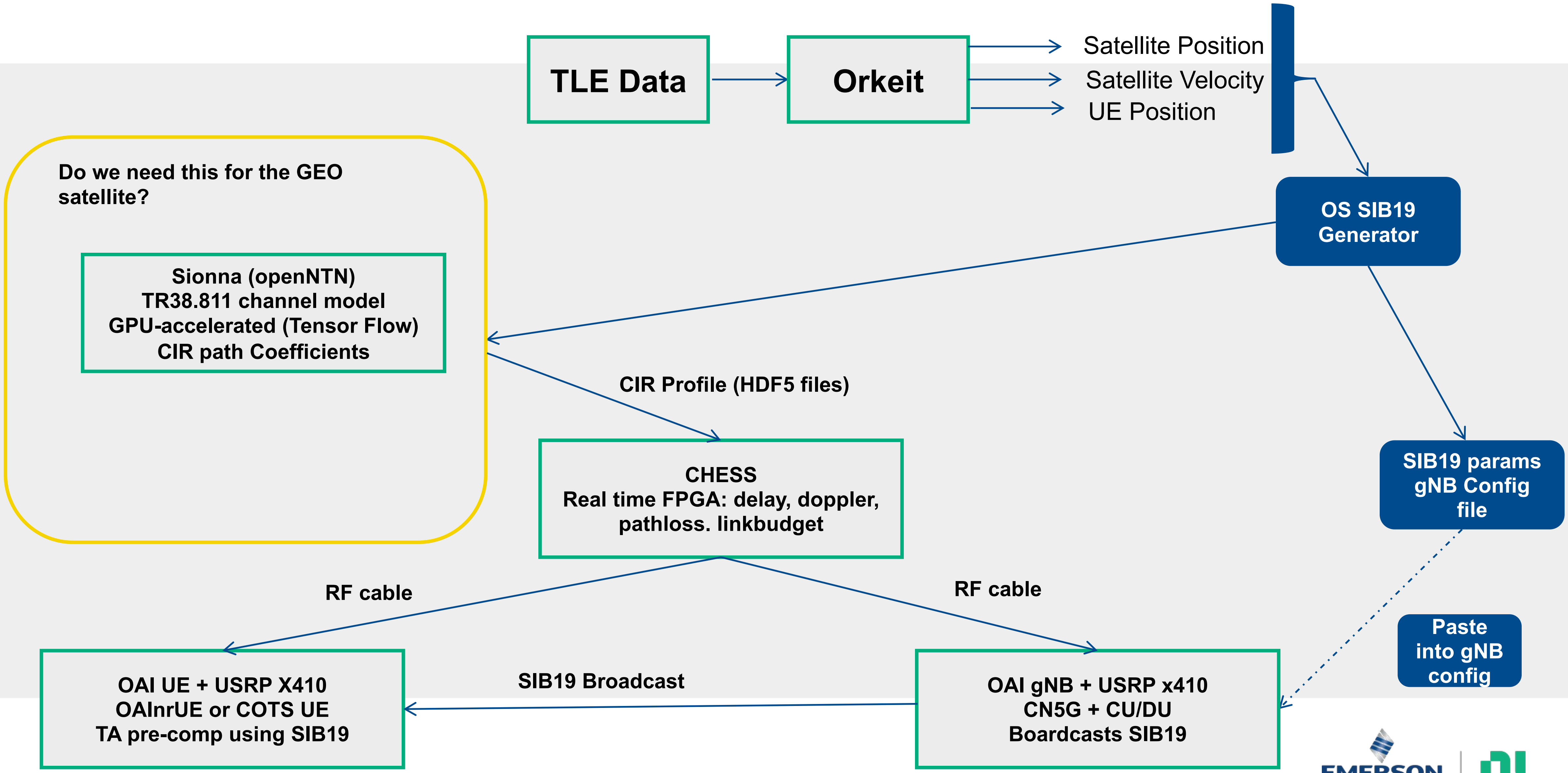
- **Test Against Real-Word Scenarios**

1. **Simplified Aerospace and Satellite Testing:** CHESS enables rapid creation of realistic aerospace, space, and satellite communication test scenarios using custom IP and third-party plug-ins.
2. **Open gRPC-Based Interface:** It provides a modern **gRPC interface** that allows easy integration with external applications and simulation environments.
3. **Cross-Platform Compatibility:** CHESS supports interoperability across different operating systems, programming languages, and software toolchains.
4. **Integration of Custom Models:** Engineers can seamlessly incorporate customer-specific channel models, mission profiles, and proprietary algorithms into the emulation workflow.
5. **Direct Connectivity to Simulation Tools:** Native integration with tools such as Ansys STK enables the generation of highly realistic, mission-oriented channel conditions with minimal development effort.

CHESS Key Features

Feature	Value
Frequency Range	30 MHz to 26.5 GHz
Channel IBW	2 GHz
Number of RF Channels	Up to 4 Channels (with Specified Multichannel Performance) Additional Channels Possible in Extended Multichannel PXI Systems
RF System Compensation	Included Compensation Routines Channel Compensation: Delay Measurement and Channel Equalization Multichannel: Time Alignment (NI-TClk) Phase Coherent Calibration Wideband Magnitude and Phase Alignment
Number of Digital Channels	Up to 2 Digital Channels per RF Port Reconfigurable Channel Assignments
Channel Parameters	Gain (Path Loss), Delay (Range), Frequency Shift (Doppler), Additive AWGN, Fading (32 Taps, Rice/Rayleigh), Interference, Linear Distortion (32-Tap Filter)
Channel Parameter Configuration	Static (Interactive), List Mode (Interpolated), Streaming (Interpolated)
Update Trigger Mode	External Digital and Software Trigger
Graphical User Interface	Standalone Application Software GUI Integrated within Instrument Studio
Programming Software	gRPC Enabled API

Potential E2E Architecture for Integration of Sionna, X410, OAI and CHESS



Thank You!!!
Obrigado

- Questions???

Performance Comparison

DU	RU SW	RU RF	UE	BW (MHz)	MIMO	Throughput (Downlink)	Stability	
SRS		B210	SRS	20	1x1	-	Not working	SRS UE discontinued
SRS		B210	Commercial	20	1x1	-	> 30 min	
SRS		B210	OAI	20	1x1	-	> 30 min	
SRS		X410	Commercial	20	1x1	-	> 30 min	
SRS		X410	Commercial	100	1x1	-	working	
SRS		X410	Commercial	100	2x2	-	working	
SRS		X410	Commercial	100	4x4	-	Not working	Lots of late / underflow This becomes a UHD streaming issue
SRS	ProtO-RU	B210	Commercial	20	1x1	50.6 Mbit/s	> 30 min	
SRS	ProtO-RU	B210	Commercial	40	1x1	103 Mbit/s	> 30 min	
SRS	ProtO-RU	B210	Commercial	20	2x2	49.4 Mbit/s	> 30 min	
SRS	ProtO-RU	X410	Commercial	20	1x1	53 Mbit/s	> 30 min	
SRS	ProtO-RU	X410	Commercial	20	2x2	-	> 30 min	
SRS	ProtO-RU	X410	Commercial	20	4x4	-	working	
SRS	ProtO-RU	X410	Commercial	40	1x1	110 Mbit/s	> 30 min	
SRS	ProtO-RU	X410	Commercial	40	2x2	-	working	
SRS	ProtO-RU	X410	Commercial	40	4x4	-	working	
SRS	ProtO-RU	X410	Commercial	100	1x1	330 Mbit/s	working	
SRS	ProtO-RU	X410	Commercial	100	2x2	-	working	
SRS	ProtO-RU	X410	Commercial	100	4x4	-	Not working	Lots of late / underflow This becomes a UHD streaming issue