SOLUTION
BRIEF

Satellite Data Link and Telemetry Validation Solutions

ni.com

SATELLITE DATALINK AND TELEMETRY VALIDATION SOLUTIONS

Explore NI's Solutions

The recent commercialization of low Earth orbit (LEO) and medium Earth orbit (MEO) has led to an introduction of modern satellite-based applications like non-terrestrial networks (NTN) and high-resolution remote sensing and imagery. The satellite constellations, ground equipment, and supporting launch vehicles developed to support these new services come with new communication and data link technologies that, in turn, include new challenge in design, system validation, and production test.

NI offers a broad range of hardware and software validation solutions to assist you in developing high-performance space communication systems.

Importance of SATCOM Data Link and Telemetry Test

The small-satellite constellations being deployed to facilitate new applications can range from one to several thousand in size, each rapidly orbiting the earth. This dynamic nature presents a challenge for communications and connectivity for both inter-satellite and ground station data links. In response, cutting-edge communication systems have been developed using modern electronically scanned array (ESA) antennas that can rapidly shift one or more beams without any mechanical movement. This allows for the telemetry, tracking, and control (TT&C) of multiple satellites at once while in the field of view of the array. More importantly, these ESA arrays are inherently modular and scalable allowing for ground terminals and payloads to be optimized for specific applications and missions. These data links are further supported via software defined radio (SDR) backends. These SDR implementations allow for adaptive and reconfigurable data links such as the Consultative Committee for Space Data Systems (CCSDS).

Customer Needs

01
Dynamic satellite constellations

02
Telemetry, tracking, and control of multiple satellites at once

03
Proliferation of software-defined radios

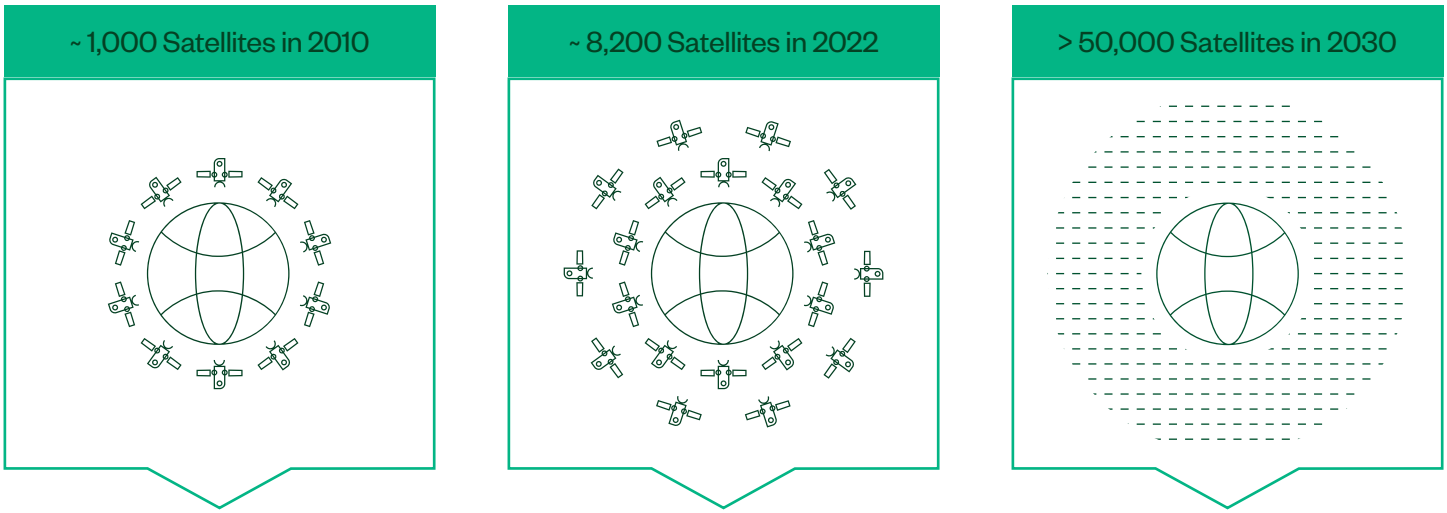


FIGURE 01
Evolution of Number of Satellites

NI Solutions for SATCOM Data Link and Telemetry Validation

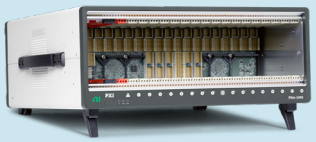
The NI solution for SATCOM and Telemetry systems validation consists of COTS modular hardware and flexible software tools to address RF signal fidelity, system level validation, and digital system test requirements. The solution is built on the PXIe modular test platform that can be customized to meet your specific IO performance requirements.

The NI Vector Signal Transceiver (VST) is the central RF technology for this solution. On its own, the VST can transmit and receive TT&C and SATCOM data link signals performing key signal fidelity measurements such as modulation accuracy, transmit power, and more. The VST can be augmented with a PXIe FlexRIO coprocessor with full-rate streaming to and from an open FPGA capable of hosting real-time, inline signal processing and channel models. With a coprocessor configuration, the VST is transformed into an RF channel emulator—unlocking the ability to do full system-level validation.

Digital system test is accomplished with the use of NI FlexRIO modules as well, yet with a digital front-end configuration. NI FlexRIO combines a large user-programmable FPGA with a serial or parallel digital IO to meet the system interfacing and IP protocol requirements of satellite payload subsystems test. With NI FlexRIO, engineers can import custom digital protocols to emulated digital interfaces without using custom hardware.

PXIe System Platform

- 3U Modular Instrumentation Chassis
- Expandable to 18 slots
- Data Transfer up to 24 GB/s
- Integrated Clocking/Triggers



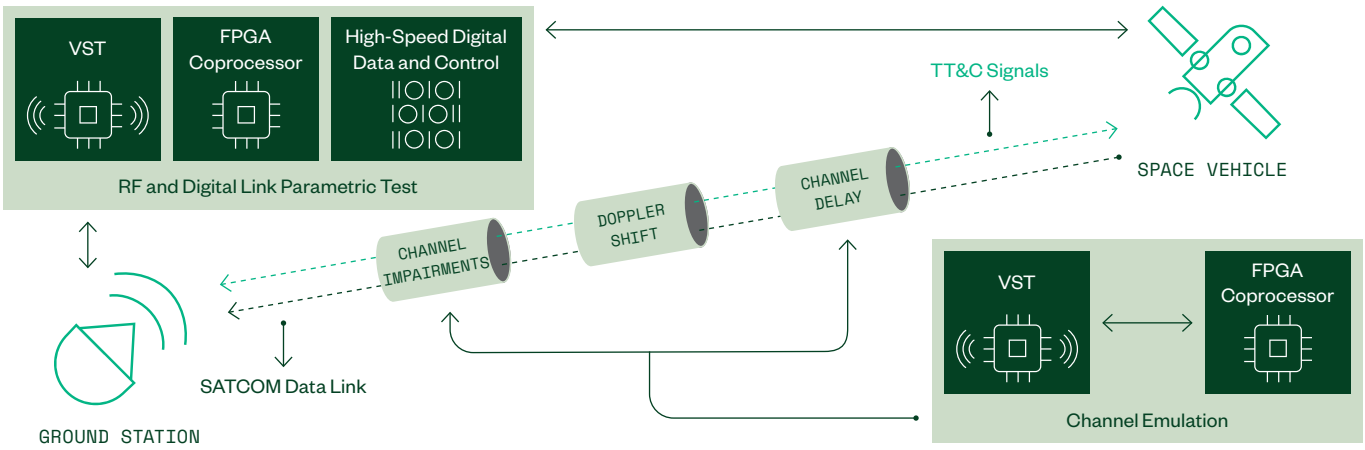


FIGURE 02
Common SATCOM and Telemetry Tests

Data Link and Telemetry Endpoint Emulation

Whether designing a radio for a ground station or a satellite payload, the design must be validated against expected common RF characteristics, such as noise and linearity, as well as the application specific performance, such as error vector magnitude (EVM) or bit error rate (BER). This leads to a unique blend of traditional RF parametric test instruments, including spectrum analyzer, signal generators, and VNAs, as well as application specific instruments such as telemetry receivers, emulators, or "Golden DUTs." The combination of all of these various test articles creates an often large and expensive test rack with complex software to automate and synchronize everything together. Over time, pieces of the test rack become expensive to maintain or obsolete due to outdated capabilities or expensive "upgrade fees." This is especially true when the protocol or modem IP requires customization or deviations from standard off-the-shelf definitions.

The NI data link offering looks to provide a consolidated, scalable solution to both the RF test need and the application specific endpoint emulation. By combining the versatility of the NI Vector Signal Transceiver (VST), a robust suite of measurement personalities within NI RFmx, and a customizable FPGA framework based on NI FlexRIO products—the NI data link offering allows for simultaneous RF parametric test and real-time hardware in the loop validation.

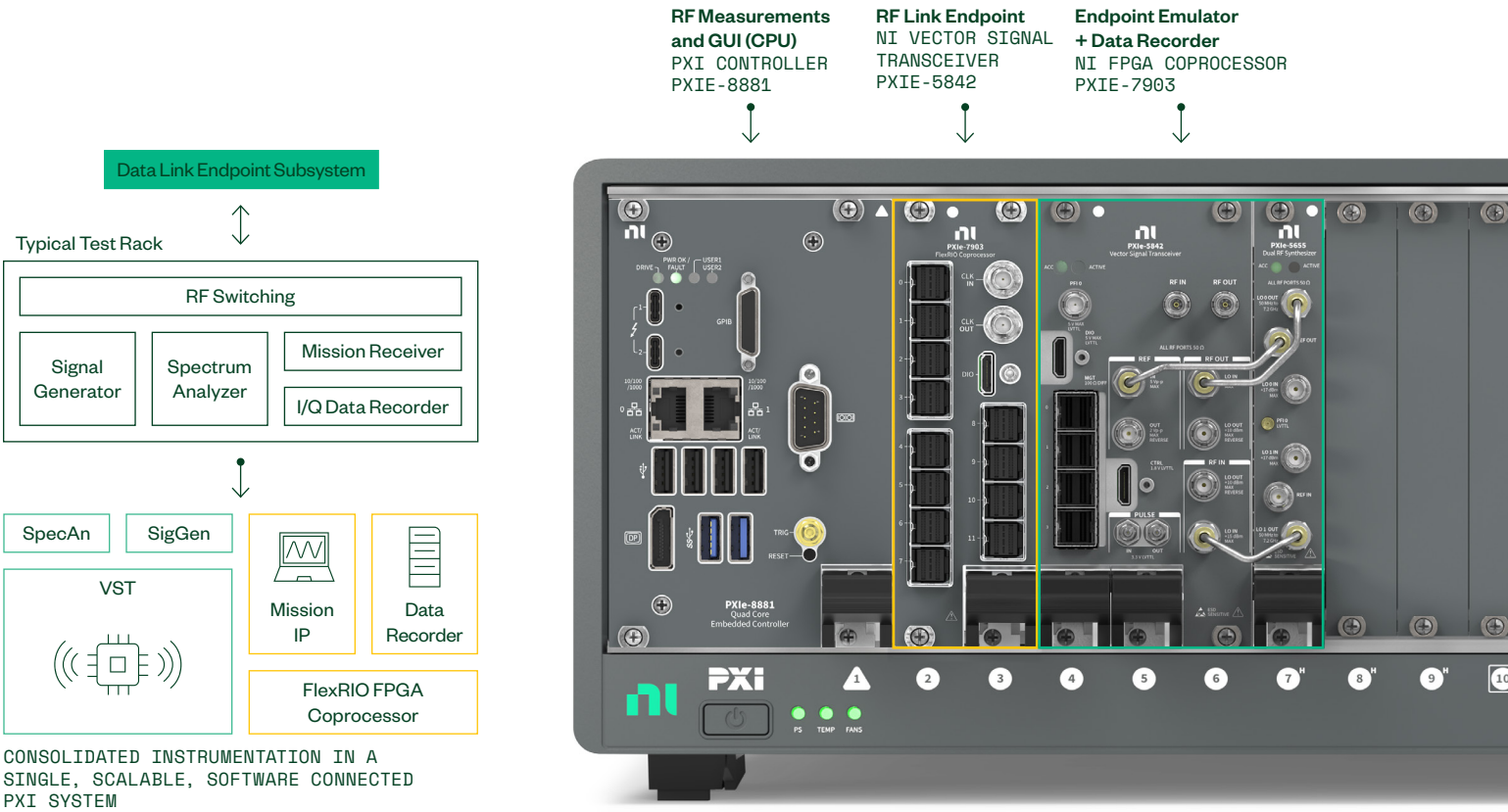


FIGURE 03

Satellite Link Emulator | Hardware Architecture

Satellite Link Emulation

Engineers building the next generation of satellite communication hardware must be able to emulate, design, and test real-life and challenging conditions prior to the satellite launch to model and evaluate system performance. To guarantee deterministic, repeatable results, it's more effective to combine model-based simulations with hardware-in-the-loop (HIL) testing. Our Satellite Link Emulation Application Example allows the satellite to interact with a simulated space environment in real time prior to launch.

Our satellite link emulation application example consists of a hardware layer, VST to interface with the system under test, and an FPGA hosting the channel parameters. An FPGA coprocessor can also accept integrating user code with VHDL for user defined models. The instruments are programmed using LabVIEW™ and LabVIEW FPGA via the instrument drivers that in conjunction with RFmx, a measurement library, allow the VST to operate as an instrument grade measurement device for testing the RF link performance. A user interface (UI) available in LabVIEW allows the user to configure the parameters, load custom profiles, or interface the UI with third-party simulation tools for scenario generation. In this reference system, satellite orbit simulation provided by STK software communicates the profile parameters to the LabVIEW interface via a Python plugin. Those parameters are then sent to the FPGA on the fly to be applied to the data stream.

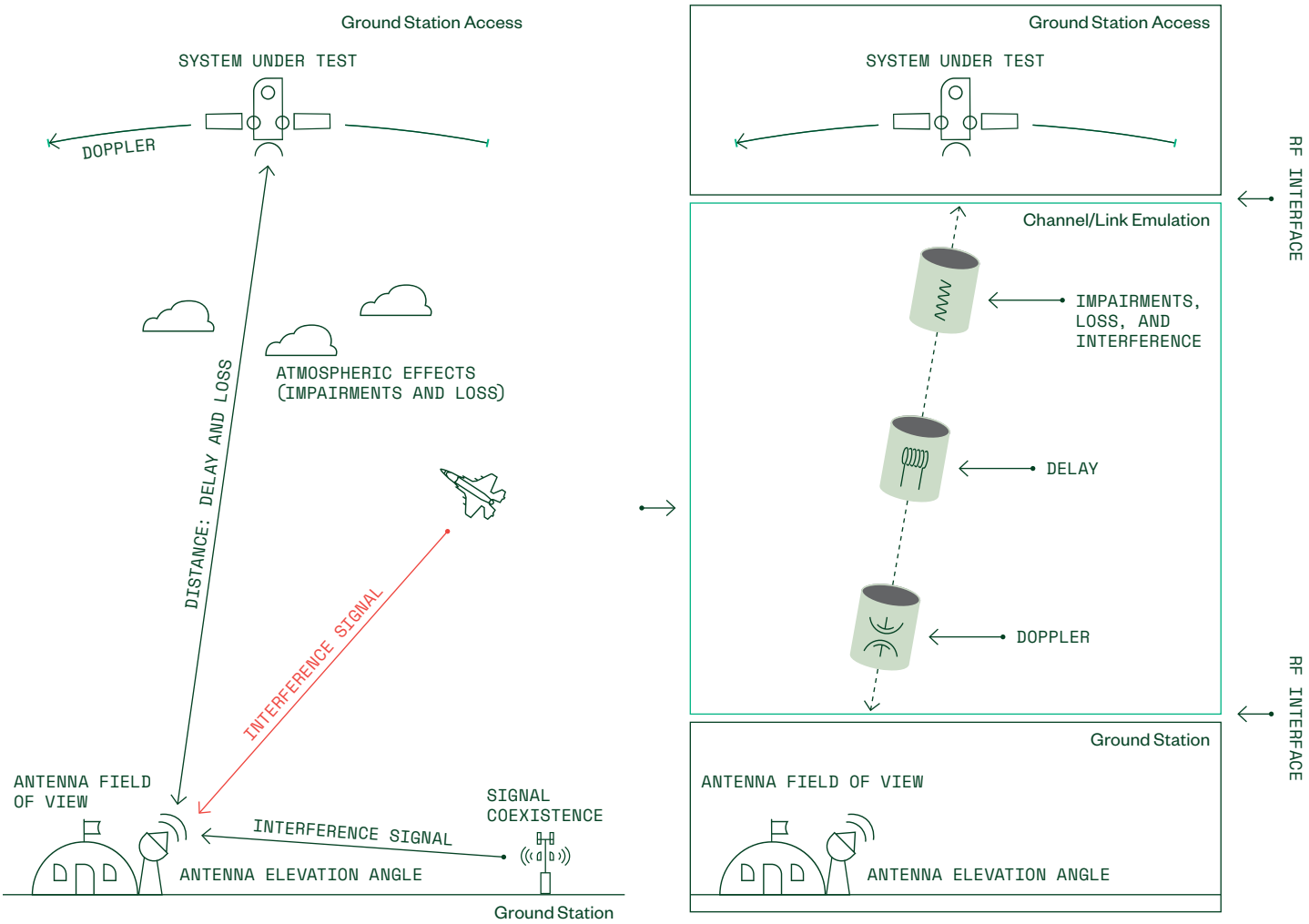


FIGURE 04

Application Challenge | Real-Time Hardware Emulation

SATCOM and Telemetry Validation Hardware and Software

VECTOR SIGNAL TRANSCEIVER

The PXI Vector Signal Transceiver (VST) combines a vector signal analyzer and vector signal generator with a user-programmable FPGA along with high-speed serial and parallel digital interfaces for real-time signal processing and control. With up to 2 GHz of instantaneous RF bandwidth, and frequency coverage from 9 KHz to 54 GHz, it's fully capable of covering all the key SATCOM frequency bands (L, S, C, X, Ku, and Ka). The NI VST is ideally suited for modulated signal generation and spectral analysis. The VST product line provides the high-performance measurements and the fast speed for automation in a small form factor. You can use VST instruments throughout the design cycle from design to validation to production test—minimizing measurement correlation errors and improving efficiency with test software reuse. The modular PXI platform allows users to configure systems with multiple VSTs to support multiple input, multiple output (MIMO) applications, including mmWave up to 1 GHz bandwidth up to 44 GHz frequency range, and simplifies synchronization between instruments thanks to shared timing and synchronization resources in the PXI chassis.

HIGH-SPEED SERIAL AND PXI FLEXRIO™ COPROCESSOR MODULES

High-Speed Serial Instruments are designed for engineers who need to validate, interface through, and test high-speed serial protocols. They consist of Xilinx Kintex-7, Virtex-7, and UltraScale+ FPGAs and are programmable in LabVIEW FPGA for maximum application-specific customization and reuse. These instruments take advantage of FPGA multigigabit transceivers (MGTs) to support line rates up to 28 Gbps and up to 24 TX and RX lanes. As part of the PXI platform, they benefit from PXI clocking, triggering, and high-speed data movement capabilities, including streaming to and from disk, as well as peer-to-peer (P2P) streaming at rates up to 3.2 GB/s.

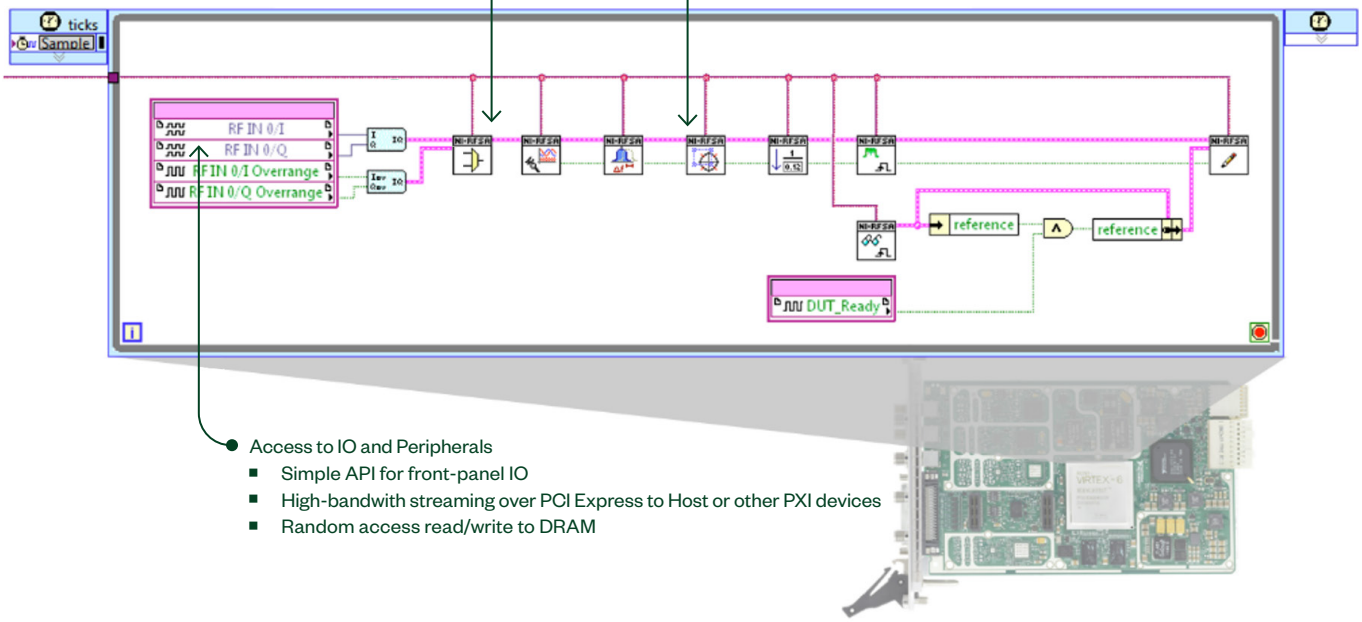
Mated with FlexRIO Coprocessor Modules feature high-performance FPGAs that add signal processing capability to PXI systems. These modules leverage the latest FPGAs from Xilinx, streaming technologies such as PCI Express, and NI Peer-to-Peer Streaming for high-bandwidth data communication with other modules over the backplane. When paired with another PXI device, such as a PXI Vector Signal Transceiver, PXI FlexRIO Coprocessor Modules provide the additional FPGA resources required to run complex algorithms in real time. Import your VHDL or Verilog channel model algorithms easily with LabVIEW FPGA Component Level IP Integration capabilities.

LABVIEW FPGA

LabVIEW FPGA is a software add-on for LabVIEW that you can use to more efficiently and effectively design FPGA-based systems through a highly integrated development environment, IP libraries, a high-fidelity simulator, and debugging features. You can create FPGA VIs that combine direct access to I/O with user-defined LabVIEW logic to define custom hardware for applications such as digital protocol communication, hardware-in-the-loop simulation, and rapid control prototyping. Though the LabVIEW FPGA Module contains many built-in signal processing routines, you can also integrate existing hardware description language (HDL) code as well as third-party IP.

Program with LabVIEW FPGA
- LabVIEW programming elements
- Develop, simulate, debug, compile, and deploy through LabVIEW
- Integrate external FPGA IP
- Higher-level language to abstract throusands of VHDL code lines

High-Performance Features
- High-throughput math functions
- Advanced timing control
- Access to optimized DSP cores



Access to IO and Peripherals
- Simple API for front-panel IO
- High-bandwith streaming over PCI Express to Host or other PXI devices
- Random access read/write to DRAM

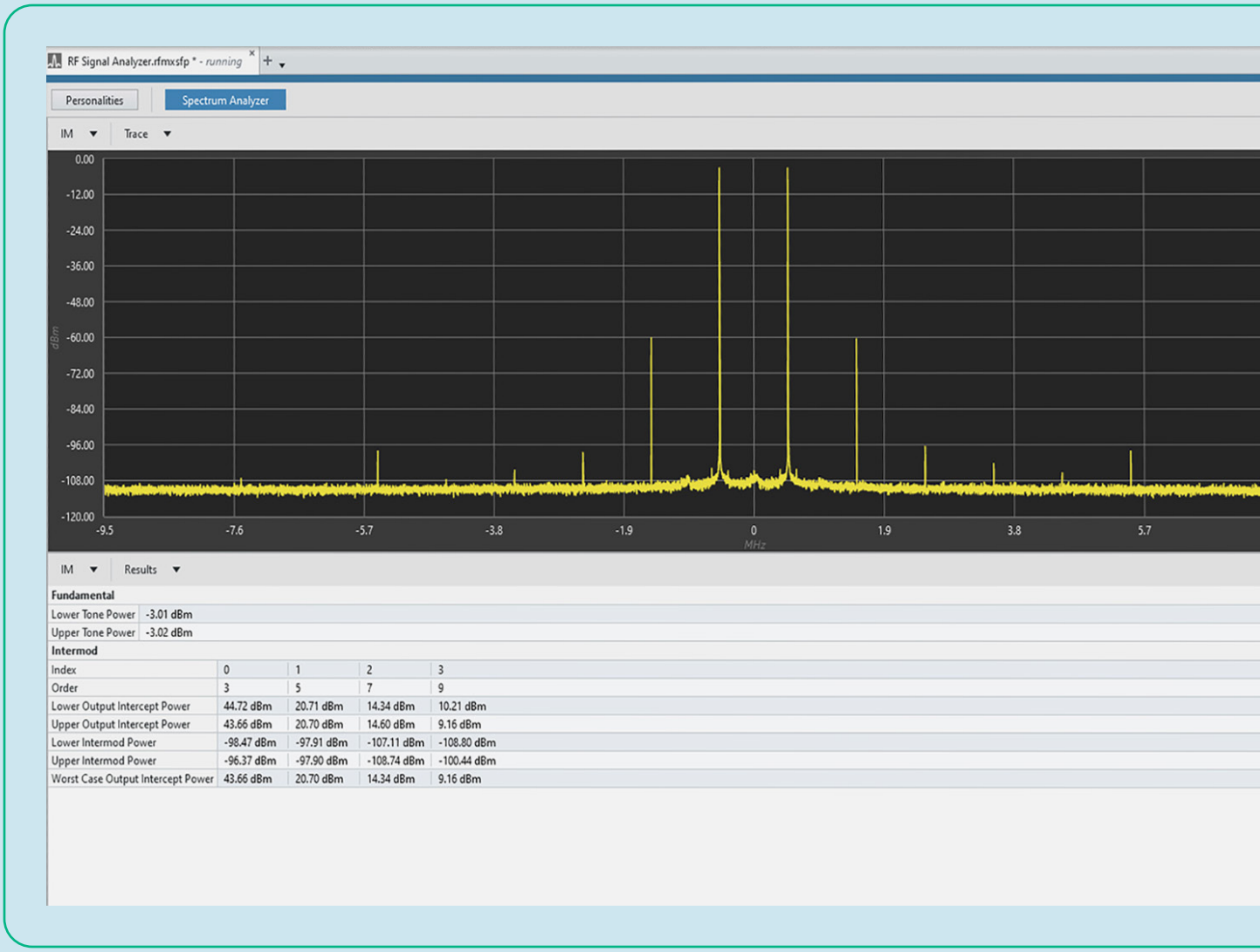


FIGURE 04

Use RFmx Soft Front Panels for Interactive Measurement and Debugging of Complex RF Signals

RFmx

RFmx is a set of interoperable software applications that optimize NI RF instrumentation for general-purpose, cellular, connectivity, and aerospace/defense test applications. RFmx streamlines test system development by accelerating setup, measurement, and performance. Soft front panels provide an intuitive interface for connecting to hardware, enabling users to efficiently perform measurements and debug automated tests. Composite measurement functionality and parallelized execution ensure maximum instrument utilization for test time reduction. You also can perform and debug measurements with interactive software front panels, create and playback open, unlocked waveforms with the included RFmx Waveform Creator, and speed up automated testing with the performance-optimized API. And with dedicated personalities for conventional spectrum analysis, modulated signals, and standard defined signals, RFmx is tailored to your application.

RFmx SpecAn

RFmx SpecAn is a measurement personality that extends the capability of NI RF instrumentation for spectrum analysis and device-specific characterization. This software enables you to analyze signals in the time, frequency, and power domains with measurements such as transmit power (TXP), adjacent channel power (ACP), and CCDF. You can characterize and correct for amplitude-amplitude/amplitude-phase distortion (AM-AM/PM) using built-in digital predistortion (DPD) models, or you can validate beamformer performance by capturing phase and amplitude versus time (PAvT).

RFmx Noise Figure

RFmx Noise Figure is application software that runs inside RFmx SpecAn. This software extends the capability of NI RF instrumentation and helps you measure noise figure, gain, and effective temperatures using the Y-factor and Cold Source methods. Additionally, you can use RFmx Noise Figure to improve measurement accuracy with built-in calibration procedures and decrease test time with integrated noise source control and multifrequency measurement optimization.

RFmx Phase Noise

RFmx Phase Noise is application software that runs inside RFmx SpecAn. This software extends the capability of NI RF instrumentation for phase noise analysis and helps you measure log plot, spot, and integrated phase noise with intelligent automatic range settings or manual configuration. You can enhance measurement performance with advanced techniques such as trace smoothing, spur removal, and instrument phase noise cancellation.

RFmx Demod

RFmx Demod is a measurement personality that extends the capability of NI RF instrumentation for analog and digital modulated signal analysis. This software enables you to analyze signals with a variety of modulation schemes including AM, FM, PM, ASK, FSK, MSK, PSK, and QAM with measurements such as analog distortion, frequency error, error vector magnitude (EVM), and demodulated bits. You can apply advanced signal processing to acquired signals with pulse shape filtering, equalization, synchronization, and impairment compensation.

NI Space Application Areas

Launch


Avionics HW Test


HIL and Integration and Test


TT&C, FTS, and RF Components


Launch Operations


Engine Test


Electronic Ground Support Equipment


Environmental, Structural, and Mechanical Test

Satellites


Avionics HW Test


HIL and Integration and Test


TT&C, FTS, and RF Components


Power Systems Tests


EOIR, SAR, and Comms Payloads


Electronic Ground Support Equipment


Environmental, Structural, and Mechanical Test

Enterprise Test, Data, and Systems Management Software

NI Services and Support

NI offers a variety of solution integration options customized to your application-specific requirements. You can use your own internal integration teams for full system control or leverage the expertise of our worldwide network of Alliance Partners to obtain a turnkey system.

Contact your account manager or call or email us to learn more about how NI can help you increase product quality and accelerate test timelines at (888) 280-7645 or info@ni.com.

NI Services and Support

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- Turnkey Solution Delivery and Support
- Repair and Calibration
- Global Support
- Prototyping and Feasibility Analysis
- Training and Certification

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