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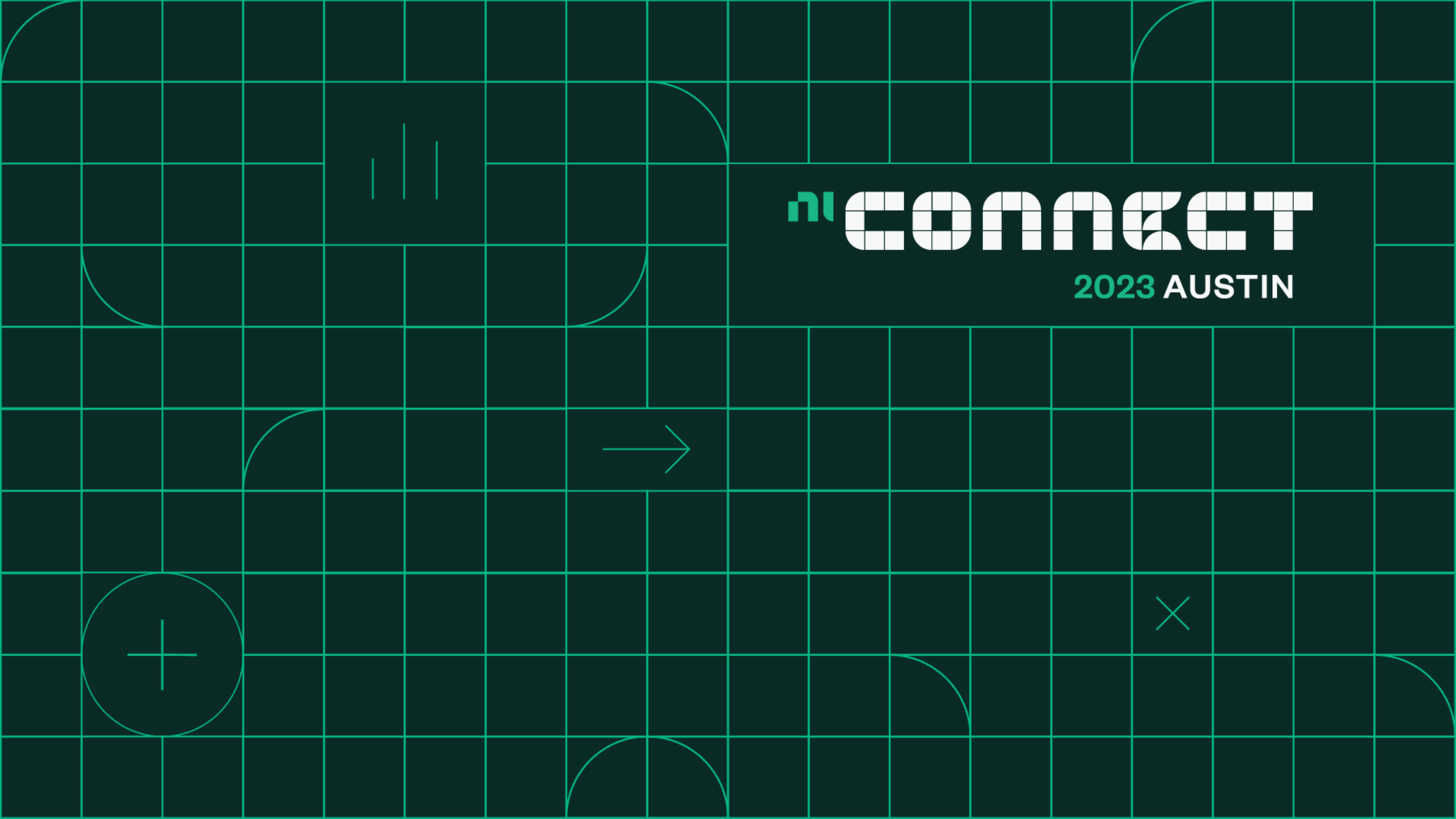

CONNECT
2023 AUSTIN

Characterizing Digital T/R Modules and AESA Systems

Tim Sileo

Principal Applications Engineer

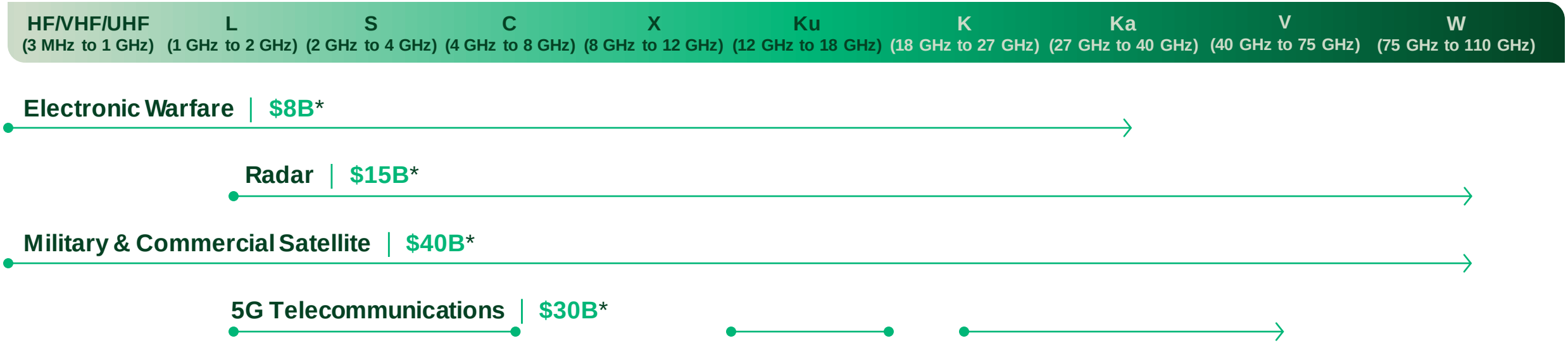
- The Digital AESA
  - Technology and Market Trends
  - Next Gen Digital AESAs
  - Defining the Digital + RF Test Challenge
- The NI Solution Digital + RF Test
  - Scalable High Speed Digital Interfacing
  - Wideband RF Stimulus and Response
  - A system level, NI solution
- Conclusion, Demo, and Q&A

The Digital AESA

Technology and Market Trends

Market Trends and Momentum

*Forecasted In 2020



Example Market Drivers

Continued investment in 5th generation and exploration of 6th generation fighters

- Multi-functional RF Systems (Radar + EW + Communications)

High resolution SAR payloads for terrestrial imaging and monitoring

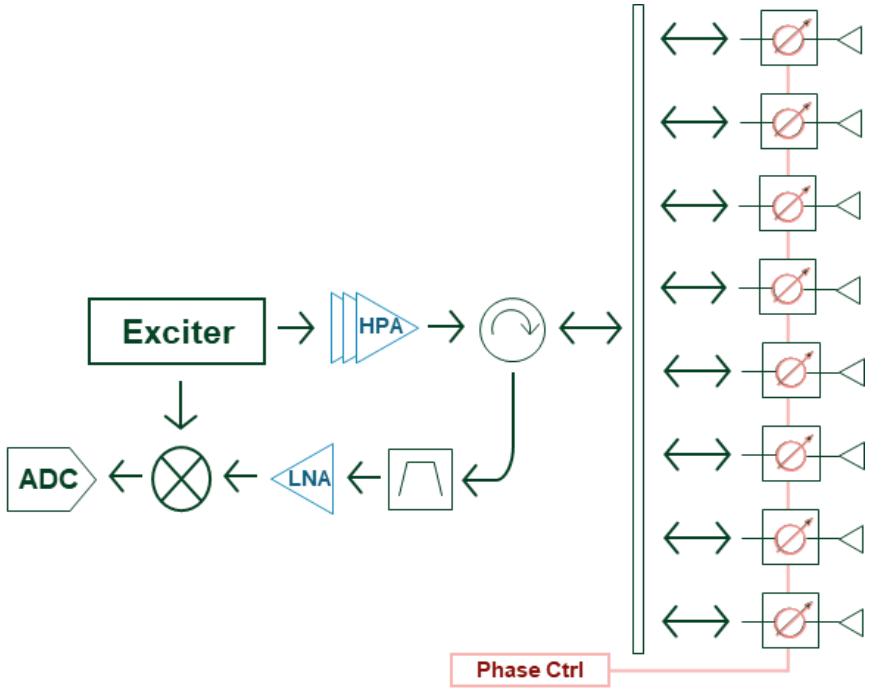
High throughput communications and convergence of Satcom and 5G

Hypersonic Intelligent weapons and next generation UAVs

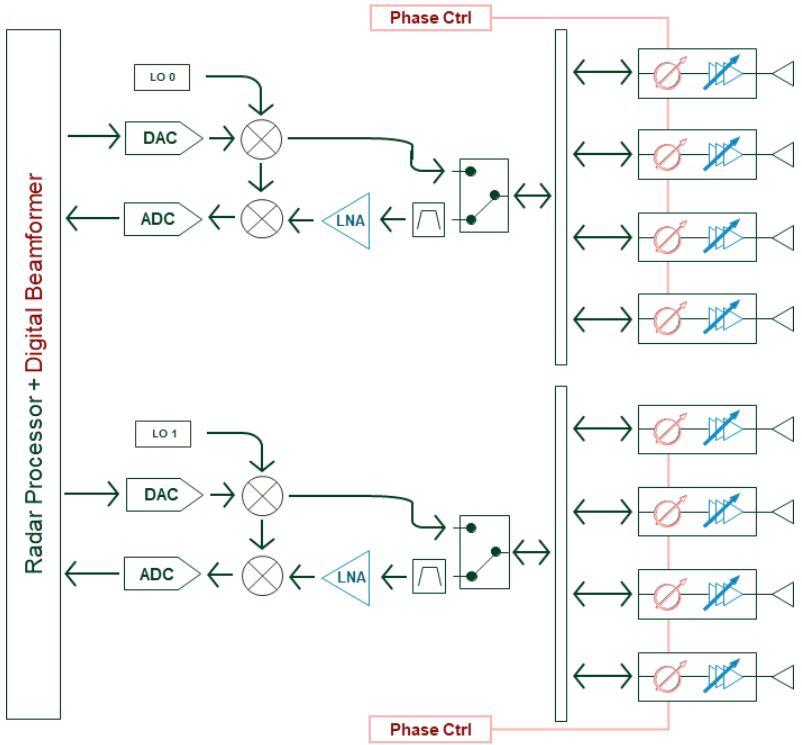
Cognitive Electronic Warfare systems

The Active Electronically Scanned Arrays (AESA)

Passive Electronically Scanned Array (**PESA**)



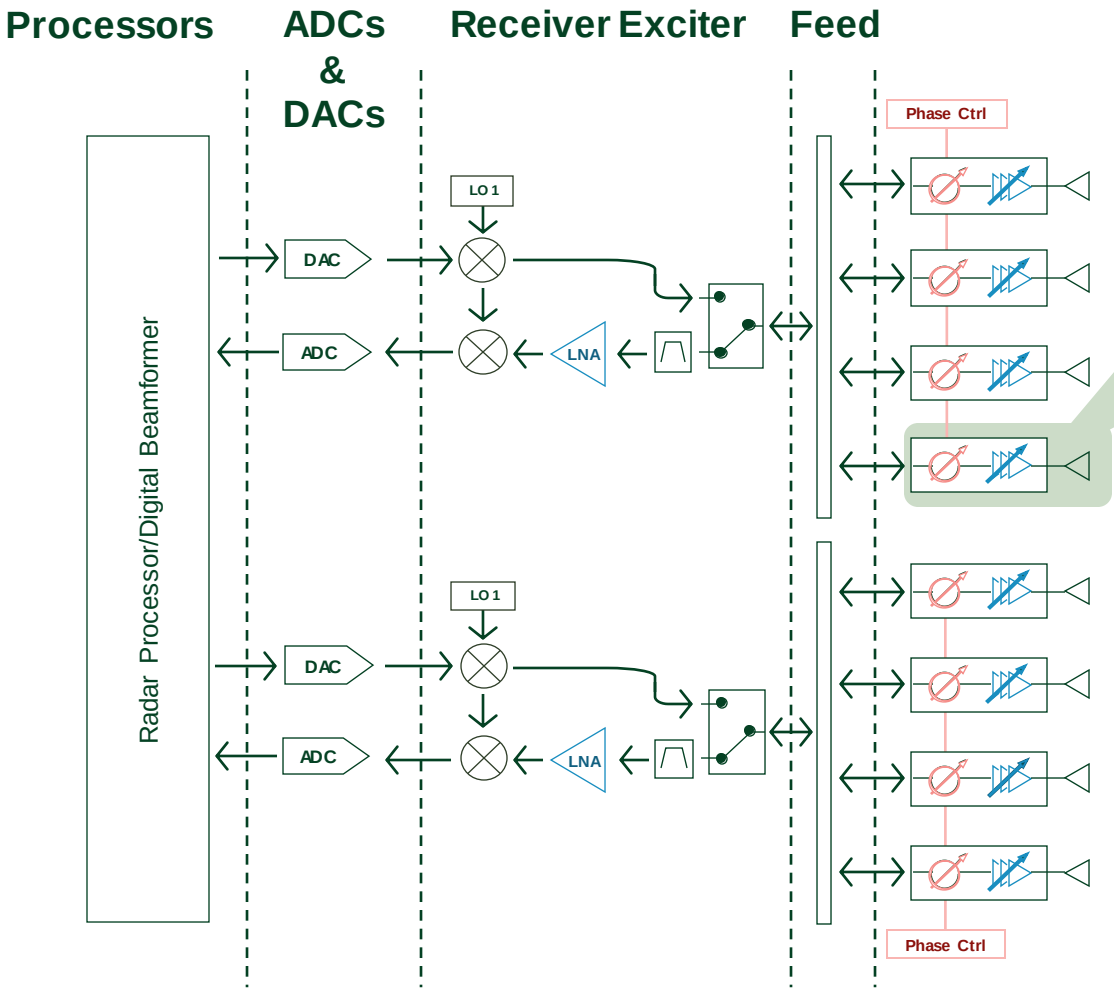
Active Electronically Scanned Array (**AESA**)



- Single Receiver/Exciter
- Per Element Phase Control for Beam Scanning
- Number of Elements Limited by centralized Gain

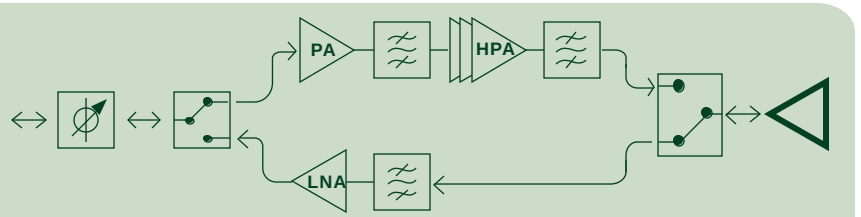
- Distributed Gain per Element -> Active T/R Modules
- Flexible Sub-Arrays allow for multiple beams
  - Varied frequencies and signal profiles

Testing AESA Components and Modules



Historical Test Boundaries Maintained – RF components and modules, Low frequency Data Converters, and Digital Processors

RF Transmit Receive (T/R) Module



Testing of AESA components and modules largely consists of traditional RF parametric measurements due to distributed architecture, including:

Common:

- S-Parameters

T/R Modules

- Relative Phase (Phase Shifter)
- Noise Figure
- Compression

Receiver/Exciter

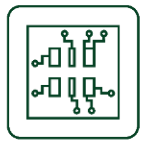
- Conversion Gain
- Phase Noise

ADCs & DACs

- SNR / SFDR
- Group Delay

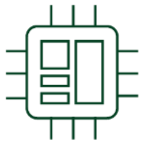
Technology Shifts and Application Evolution

Key technology shifts are leading to new mission capabilities along with new test challenges



GaN Revolution

Lower Energy Loss
Higher Voltages
More Power Per Area



Increased Integration

Integrated Digital to RF
Built in DSP
Antenna in Package

Wideband Data Converters

Increasing Bandwidths
Software Defined
Multi-Function

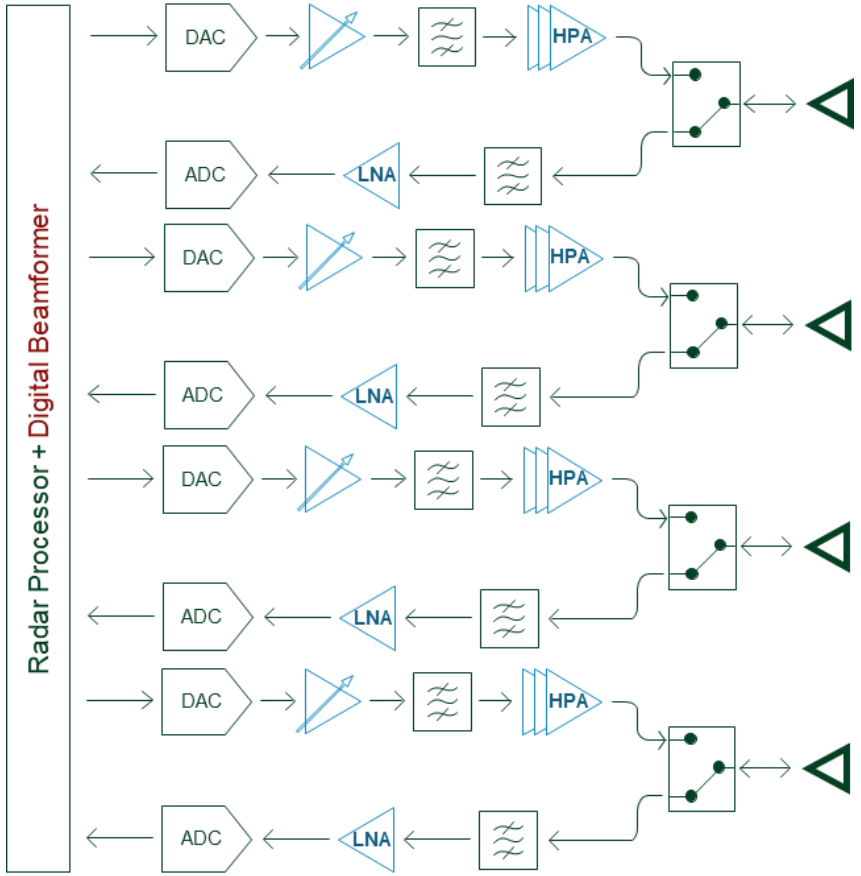
Modular, Multi-Element Antennas

1000’s of Active Elements
Multiple Beams
Increased Signal Fidelity

Looking Forward | The Next Generation **Digital** AESA

A True “RF to Bits” Architecture

- Wideband RF Data Converters allow for direct synthesis and acquisition of signals at mission frequencies
  - Digital and Analog BW rapidly scaling from low frequency to X-band without needing an up- or down-converter
- Simplified RF frontends and antenna integration allows for increased density and capability, per antenna element
- Robust Channel Synchronization and Coherency
- True Digital Beamforming and Multi-Frequency Functionality
- Software Defined Multi-Mode and Multi-Functional Operation
- Integrated High-Speed Data Transfer (i.e JESD204C, 100Gb Ethernet)



The Digital AESA

Defining the RF + Digital Test Challenge

Fully Digital T/R Modules

Common Test Challenges

Increased sampling rates and real-time processing

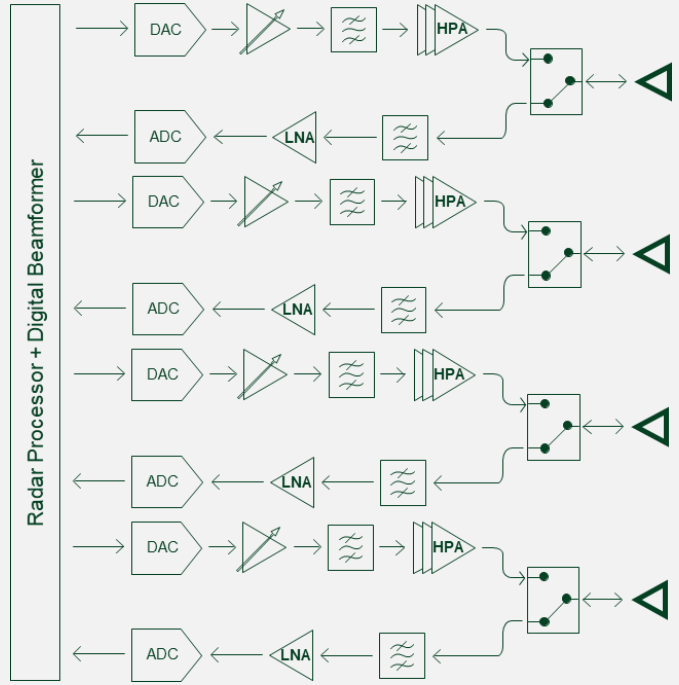
Multichannel synchronization and alignment

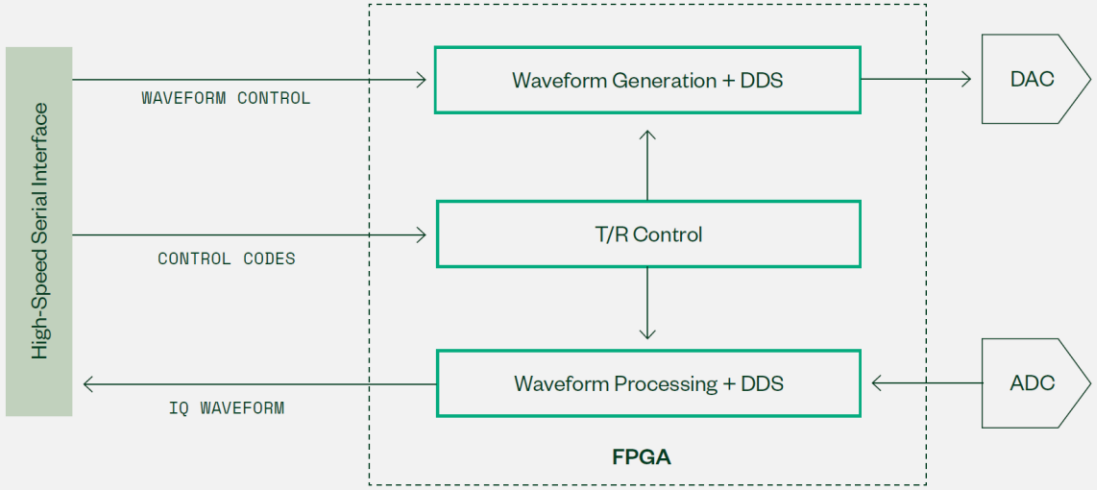
Calibration and de-embedding of DUT characteristics

Changes in measurement scope

Diversity of operational and functional test scenarios

RF connectivity limitations

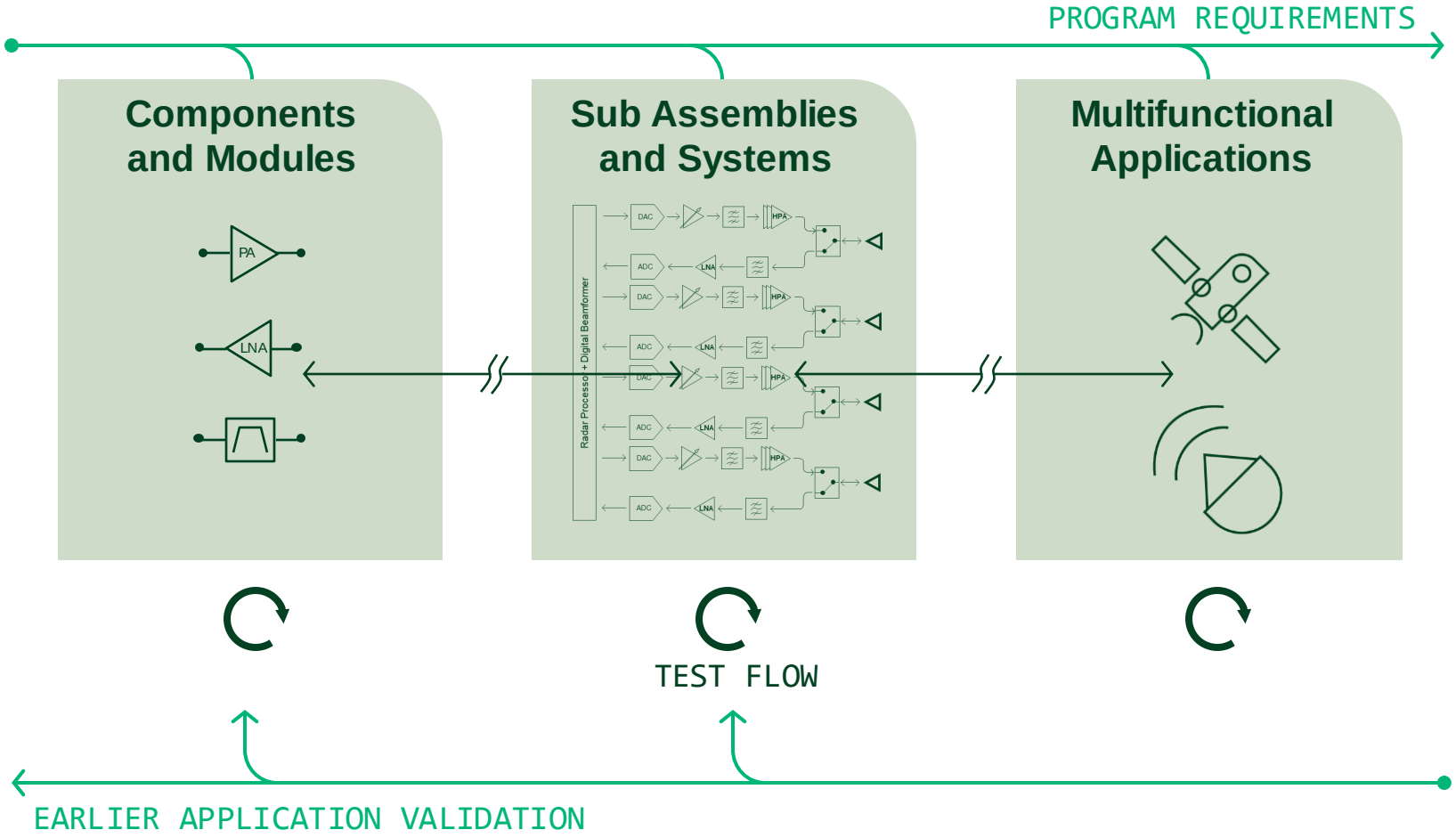




DIGITAL PATH OF A DIGITAL T/R MODULE

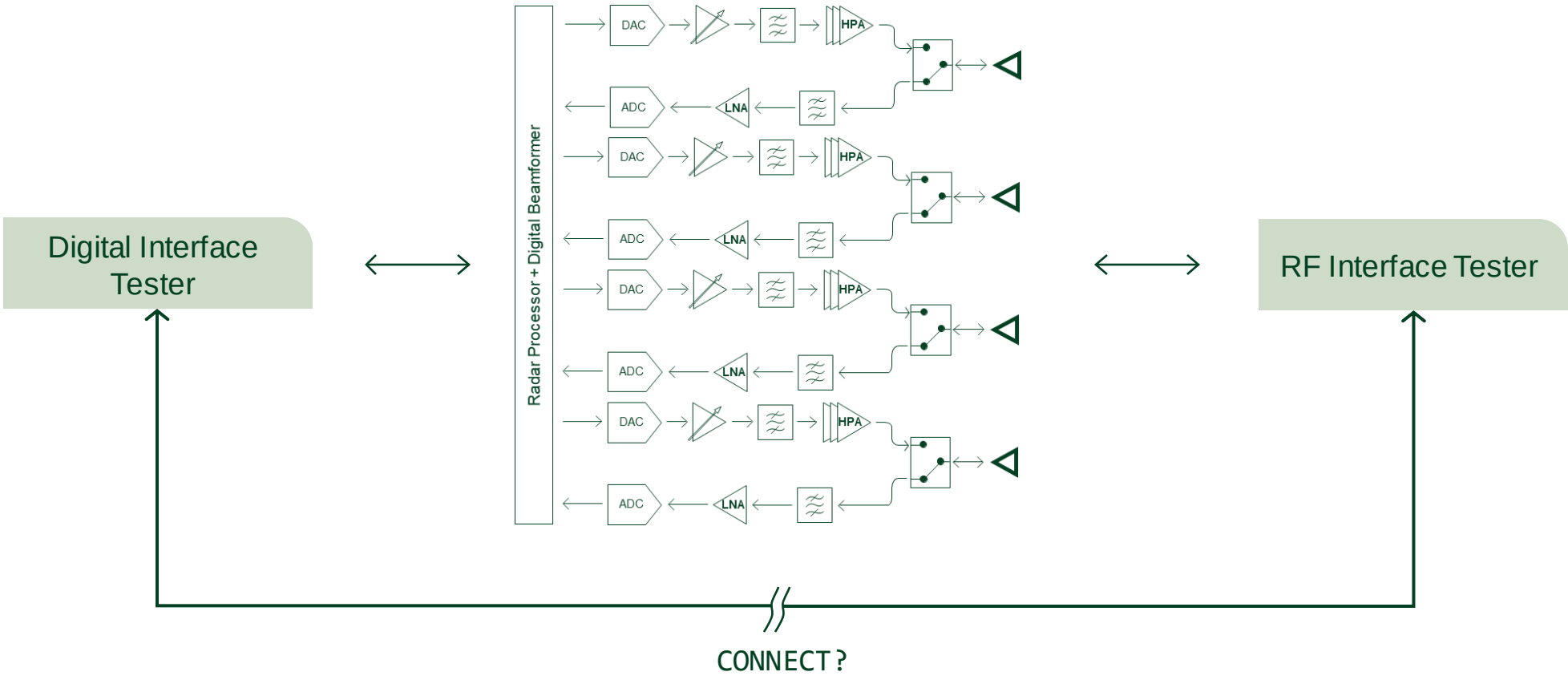
Connecting Parametric Test with System Validation

Key Test Challenge: Enable application specific validation earlier in the design and integration cycles to catch flaws sooner and reduce time to market



Digital Integration and the Need for Mixed I/O Test

Key Test Challenge: Provide robust and abstractable mixed I/O interfaces that can scale and adapt to evolving DUT needs while easily integrating I/O such as highspeed serial interfaces with RF instrumentation in order test functionality in an optimized and synchronous manner.



The NI Solution for RF + Digital Test

Scalable High Speed Digital Interfacing

Digital AESA - Digital Interfaces

Key Test Challenge: Provide robust and abstractable mixed I/O interfaces that can scale and adapt to evolving DUT needs while easily integrating I/O such as highspeed serial interfaces with RF instrumentation in order test functionality in an optimized and synchronous manner.

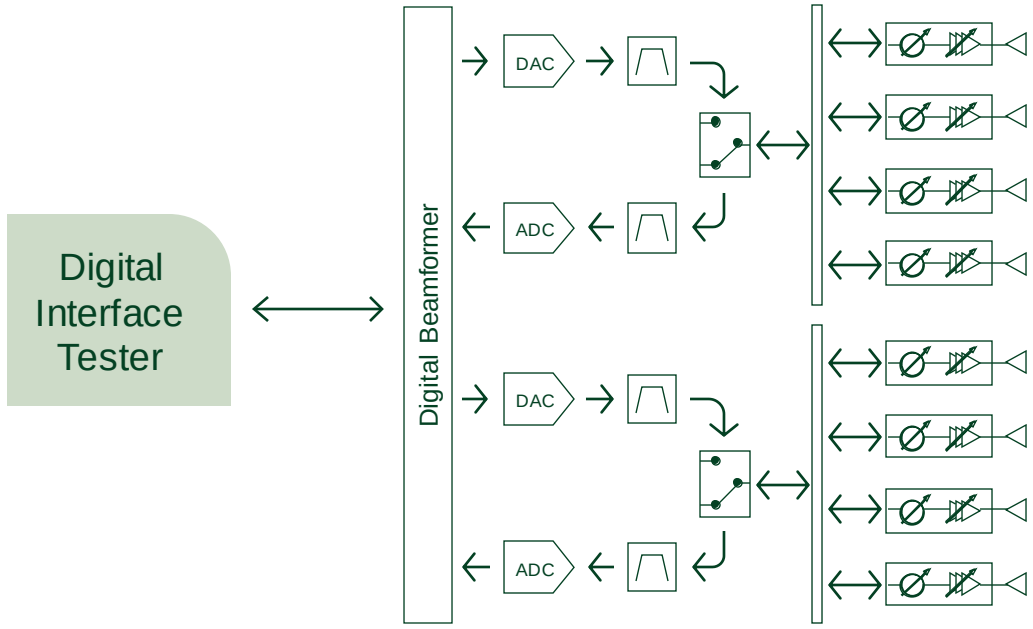
Common Technical Challenges

High Speed Serial (HSS) Interfacing Pushing Throughput Limits

Number of Links based on Array Size

Custom/Proprietary Protocols for Digital Interface

Command and Control DIO Synchronization (Embedded in HSS or Separate DIO)



2-Slot FlexRIO Coprocessor

PXIe-7903

Features

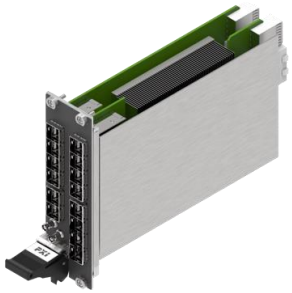
- 12 MiniSAS zHD Connectors
- 28.2 Gbps Line Rate, 48 TX/RX
- External Clock Input/Output
- Xilinx Virtex UltraScale+ FPGA, VU11P
- DRAM: ~25GB/s / Bank; 2 Banks of 10GB
- PCI Express Gen 3x8

Target Applications

- Real-time Spectrum Analysis
- Comms Algorithm Prototyping
- Beamforming RF Signals
- Spectral Stitching RF Instruments

Scalable Digital Interfacing with NI FlexRIO

High Speed Serial Product Table Link



Specification	NI PXIe-6593	NI PXIe-6594	PXIe-7903
Line Rates	500 Mbps – 16.3 Gbps	500 Mbps – 28.2 Gbps	Up to 28.2 Gbps
Channels	8 RX/TX (GTH)	8 RX/TX (GTY)	48 MGTs (GTYs)
User Programmable FPGA	Kintex Ultrascale (KU040 or KU060)	Kintex Ultrascale + (KU15P)	Virtex Ultrascale+ (VU11P)
DRAM	4 GB	8 GB	16 GB
Host Streaming Bandwidth	7 GB/s	7 GB/s	7 GB/s
Connector	QSFP28	QSFP28	12x miniSAS zHD
Cabling Options	Copper or Optical	Copper or Optical	Copper or Optical (TBD)
Aux DIO	8 GPIO, 4 GTH (RX/TX)	8 GPIO, 4 GTY (RX/TX)	12 GPIO (MiniHDMI)
Relevant Protocols	JESD204B, 10/40 GbE, Aurora, Custom	JESD204B/C, 10/25/40/100 GbE, Aurora, Custom	100 GbE, Aurora 64b66b

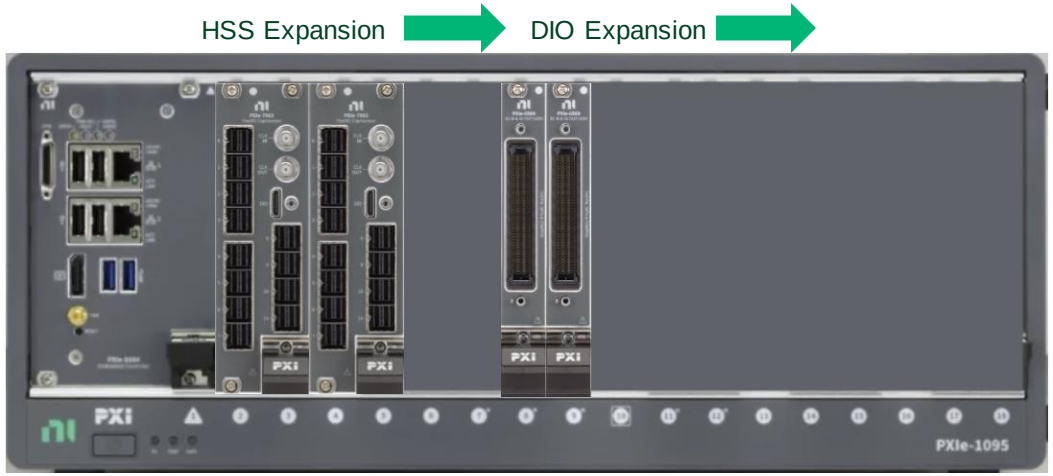
Digital AESA Digital Interfaces

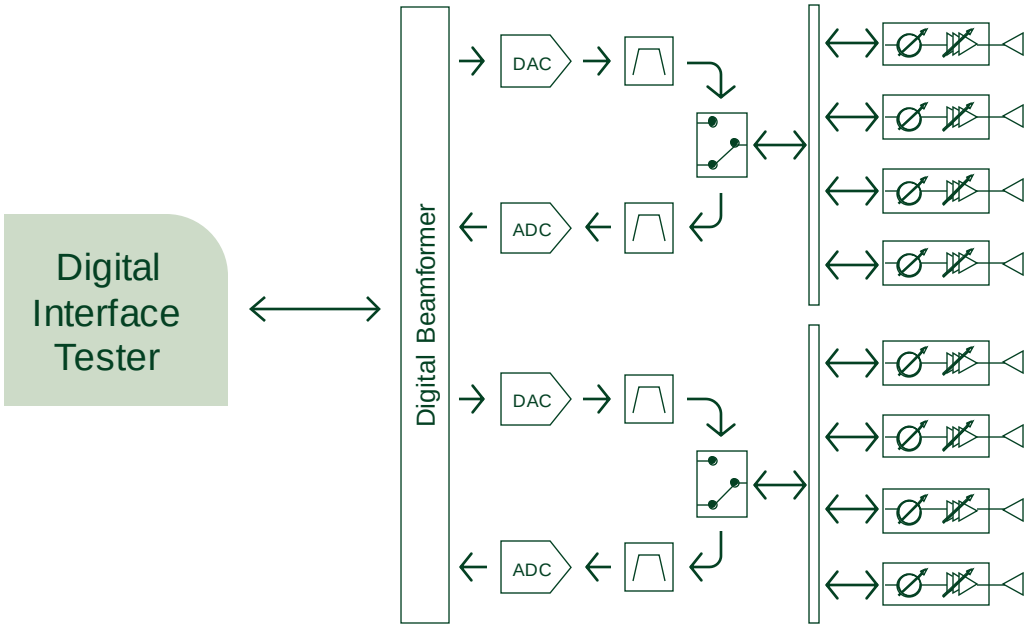
Key Test Challenge: Provide robust and abstractable mixed I/O interfaces that can scale and adapt to evolving DUT needs while easily integrating I/O such as highspeed serial interfaces with RF instrumentation in order test functionality in an optimized and synchronous manner.

The NI Approach

PXI Platform

- Expandability
- Synchronization
- High Throughput
- Customizable FPGA Functionality



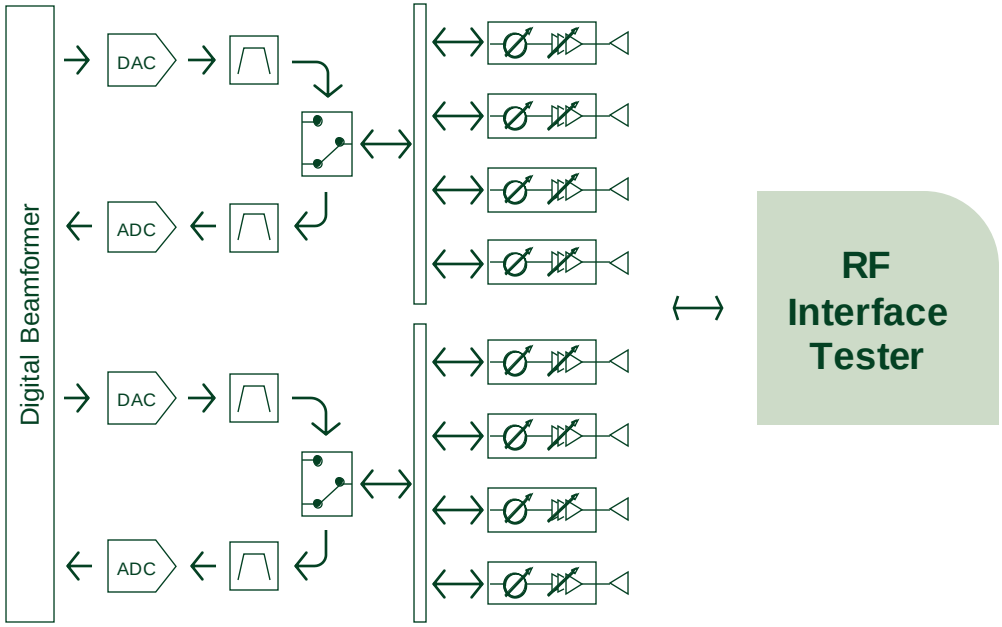


The NI Solution for RF + Digital Test

Wideband RF Stimulus and Response

Digital AESA - RF Interfacing & Measurements

Key Test Challenge: Provide robust and abstractable mixed I/O interfaces that can scale and adapt to evolving DUT needs while easily integrating I/O such as highspeed serial interfaces with RF instrumentation in order test functionality in an optimized and synchronous manner.



RF Interface Tester

Common Technical Challenges

High Number of RF Channels and Need for Decreased Test Times

Time/Phase Synchronization Between RF Channels

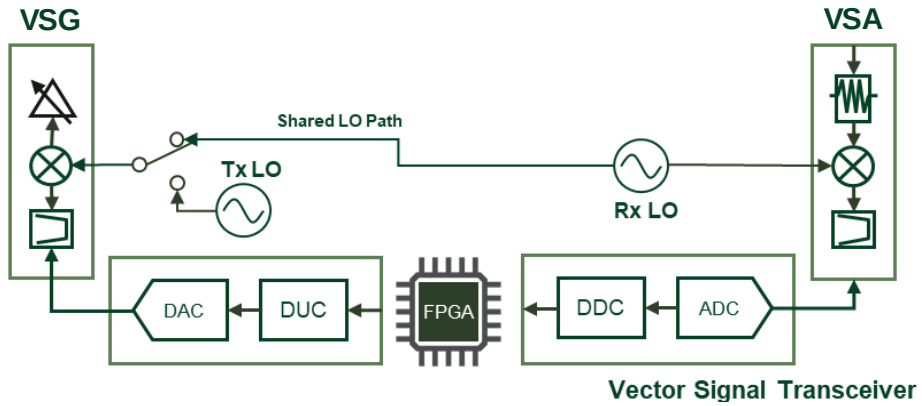
Synchronization with Digital Links

Frequency Coverage for High BW ADC/DAC's

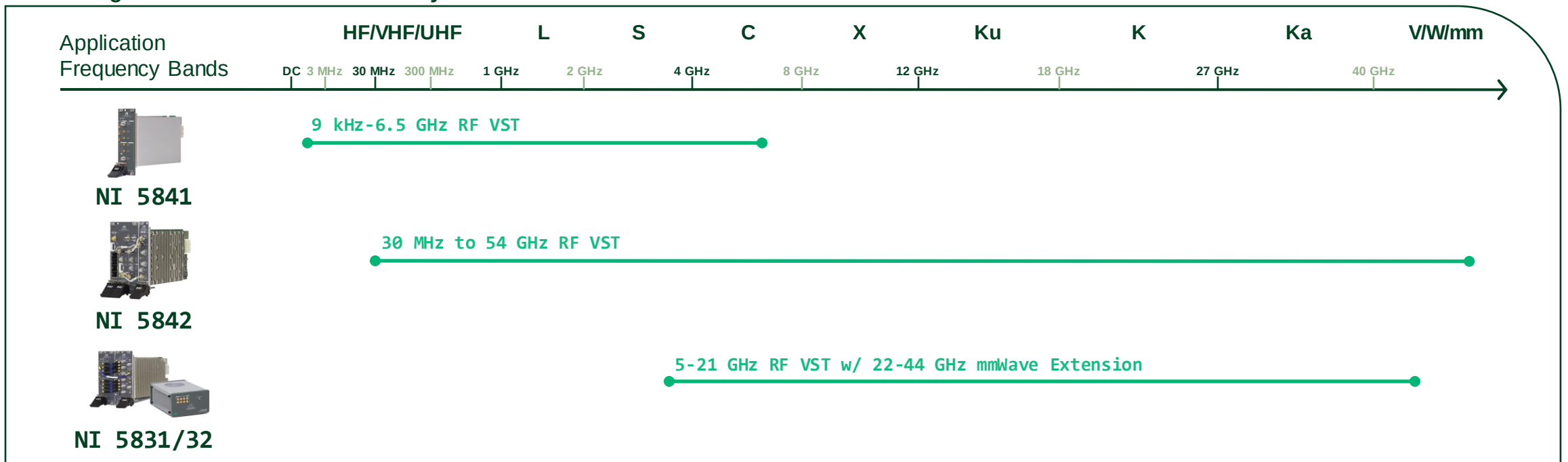
Vector Signal Transceiver

Integrated, instrument grade VSA and VSG with up to 2 GHz of instantaneous bandwidth
Support Onboard and External LO's for phase noise optimization
Multi-Channel Synchronization (< 1nsec) and Phase Coherent LOs
Easy SW and HW integration with mixed I/O and PXI
Optimized for automated characterization and production
Customizable firmware for deploying application IP or test speed optimization

- Onboard, open FPGA
- Full rate peer to peer streaming to FPGA coprocessors



Vector Signal Transceiver Product Family



PXIe-5842 26.5 GHz VST

- Expand Capabilities with Flexible Licensing/Upgrade Options
- Expand Functionality with additional HW
  - mmWave extension up to 54GHz
- Common SW tools to PXIe-583x and PXIe-5841
- Full IBW I/Q Data movement supported via integrated High-Speed MGT interfaces and PXI ecosystem – including the new NI 7903 FPGA Co-Processor

Parameter	Instrument Capability
Frequency Range	30 MHz – 23 GHz (Q4 2022) 30 MHz – 26.5 GHz (H2 2023)*
Bandwidth	Up to 2 GHz
RF IN / OUT Flatness (2GHz)	< ±0.45 dB typ. / < ±0.4 dB typ.
RF IN / OUT Absolute Accuracy	< ±0.4 dB typ.
Max Unleveled Tx Power	+20 dBm typ. (<18 GHz)

***Upgrade from 23 GHz HW to 26.5 GHz HW requires a paid upgrade service**

PXIe-5842 VST

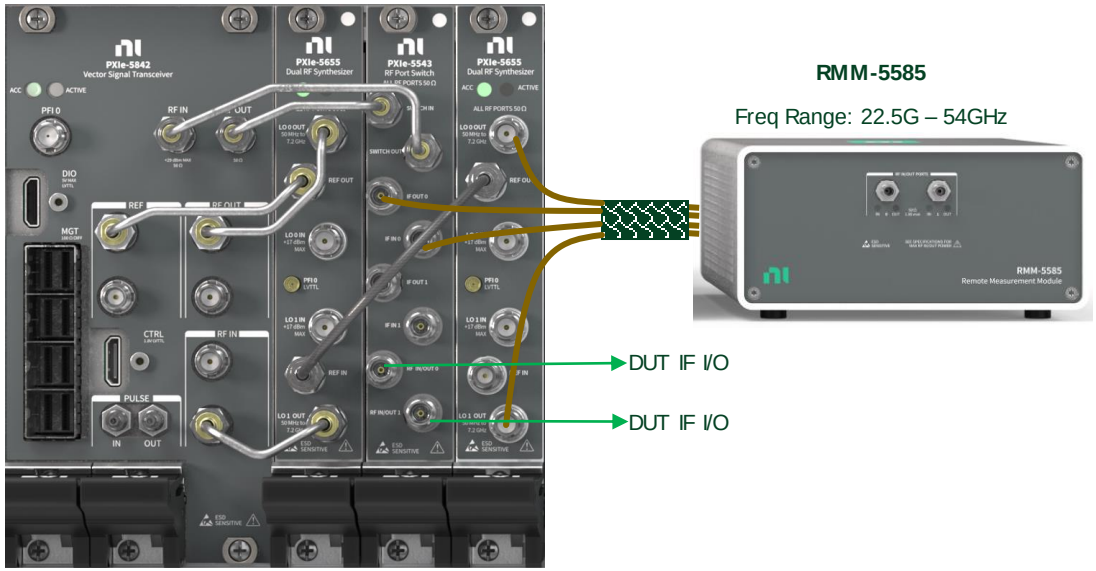
PXIe-5842 with 54GHz Freq Extension | High Level Overview

Key Features

- Extended, Wideband coverage for mmWave Applications such as 5G, Satcom, Radar, and EW
- 2x Bidirectional RF ports for both mmWave and IF DUT connections
- Simultaneous operation of RF Tx & Rx ports on a single RMM-5585
- Independent frequency tuning of RF Tx & Rx ports on RMM-5585

Parameter	Instrument Capability
Frequency Range	22.5GHz – 54 GHz (RMM-5585 RF IN/OUT) 100 MHz – 23 GHz (PXIe-5543 RF IN/OUT)
Bandwidth	2 GHz
RMM RF IN/OUT Flatness (2GHz BW)	1.2 dB (39GHz)
RMM RF IN/OUT Absolute Accuracy	± 1.0 dB (39GHz)
RMM RF OUT Max Power	28 GHz: +13 dBm
5G NR,100MHz EVM	Better than -43 dB @ 47GHz

PXIe-5842 VST with 54 GHz Freq Extension



26.5 GHz Vector Signal Analyzer

High Dynamic Range

- Superheterodyne Architecture with Image Rejection and Signal Conditioning

Wide Instantaneous Bandwidth

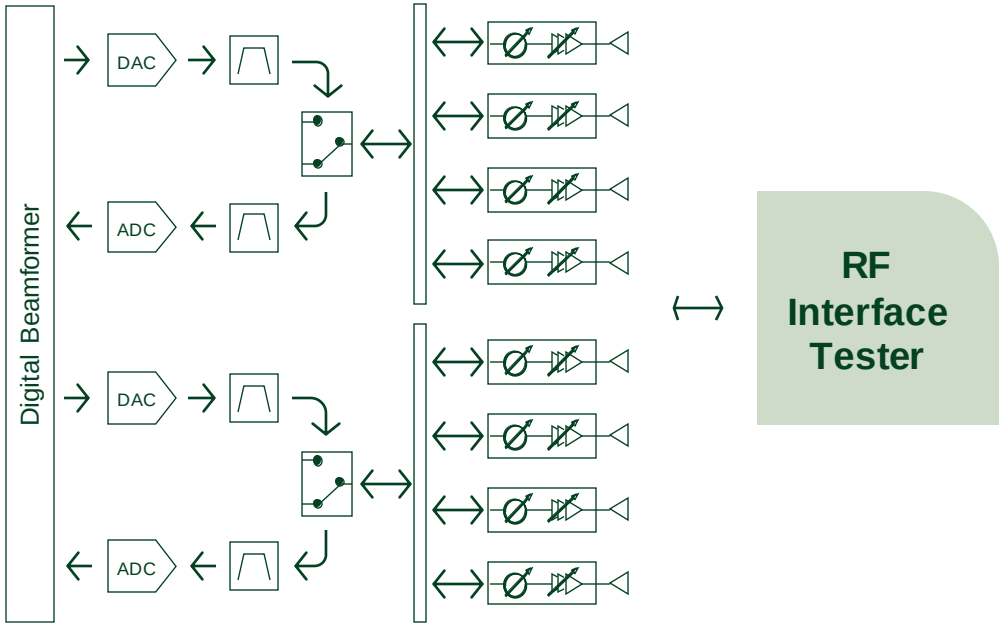
Optimized Phase Noise

PXIe-5668 Specifications

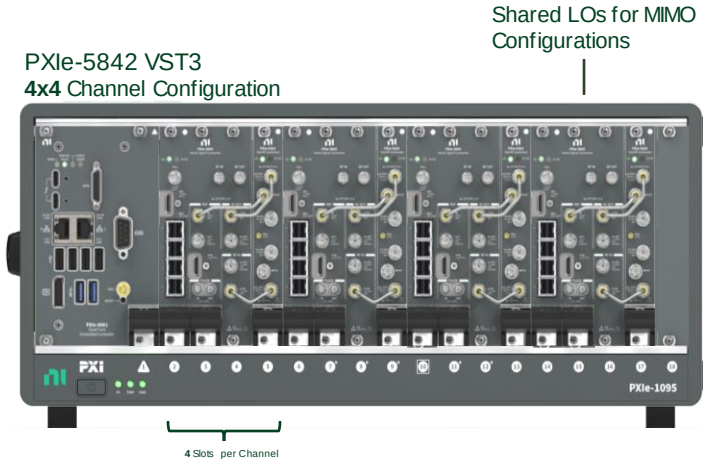
	Without NI 5698 Pre-amplifier	With NI 5698 Pre-amplifier
Frequency Range	20 Hz to 26.5 GHz	
Analysis BW	320 MHz below 3.6 GHz 765 MHz above 3.6 GHz	
Phase Noise	-129 dBc/Hz @ 1 GHz (Typ, @10kHz offset) - 120 dBc/Hz @ 8 GHz (Typ, @10kHz offset)	
RMS Noise Floor (Nominal)	< -157 dBm/Hz (1 GHz) < -150 dBm/Hz (26 GHz)	< -170 dBm/Hz (1 GHz) < -157 dBm/Hz (26 GHz)
TOI	> +19 dBm (20 Hz to 26 GHz)	> -13 dBm (1 GHz) > -13 dBm (1 GHz)
Non-Input Related Spurs	< -115 dBm (1 GHz) < -105 dBm (26 GHz)	< -131 dBm (1 GHz) < -115 dBm (26 GHz)
No. of Slots	7	8

Digital AESA RF Measurements

Key Test Challenge: Provide robust and abstractable mixed I/O interfaces that can scale and adapt to evolving DUT needs while easily integrating I/O such as highspeed serial interfaces with RF instrumentation in order test functionality in an optimized and synchronous manner.



RF Interface Tester



The NI Approach

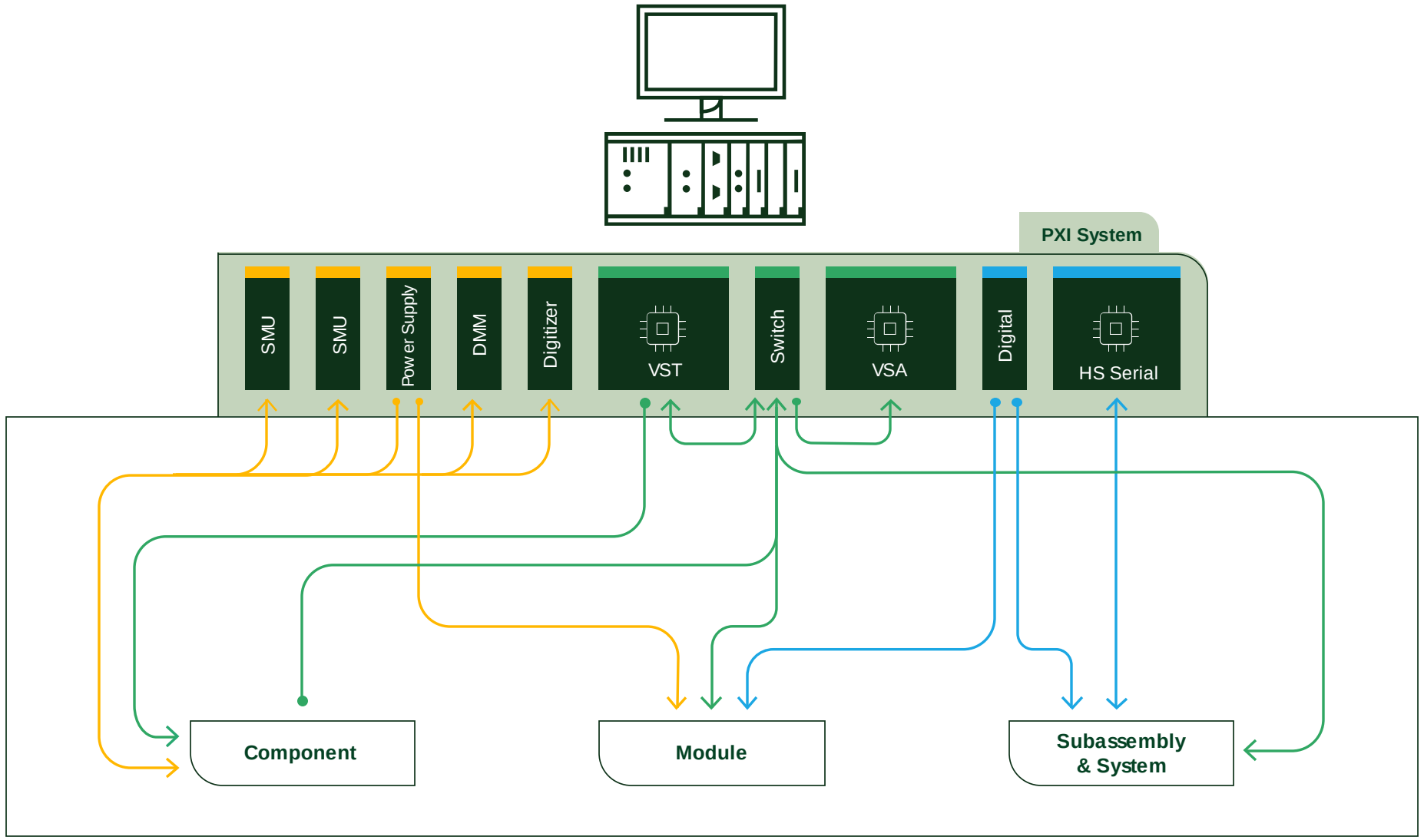
High Performance, Multi-Channel RF Instrumentation

- Optimized for Wideband Measurements
- Expandable to multiple synchronized, phase-coherent channels
- Synchronization across PXI to Mixed I/O interfaces
- Scalable Measurements and Application IP
  - Traditional Host Based Data Processing and Customizable FPGAs for Real-Time HIL needs

The NI Solution for RF + Digital Test

A system level, NI Solution

Modular Automated Test Bench



Modular Automated Test Bench

Digital Control & Highspeed Data

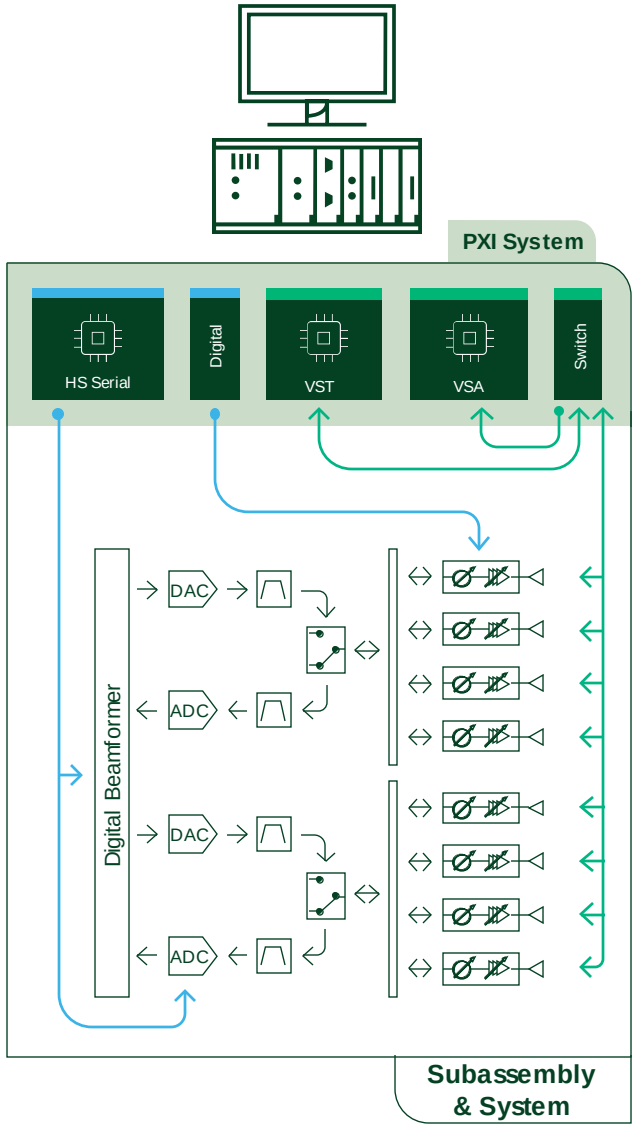
Digital Control
- LVDS, TTL Control

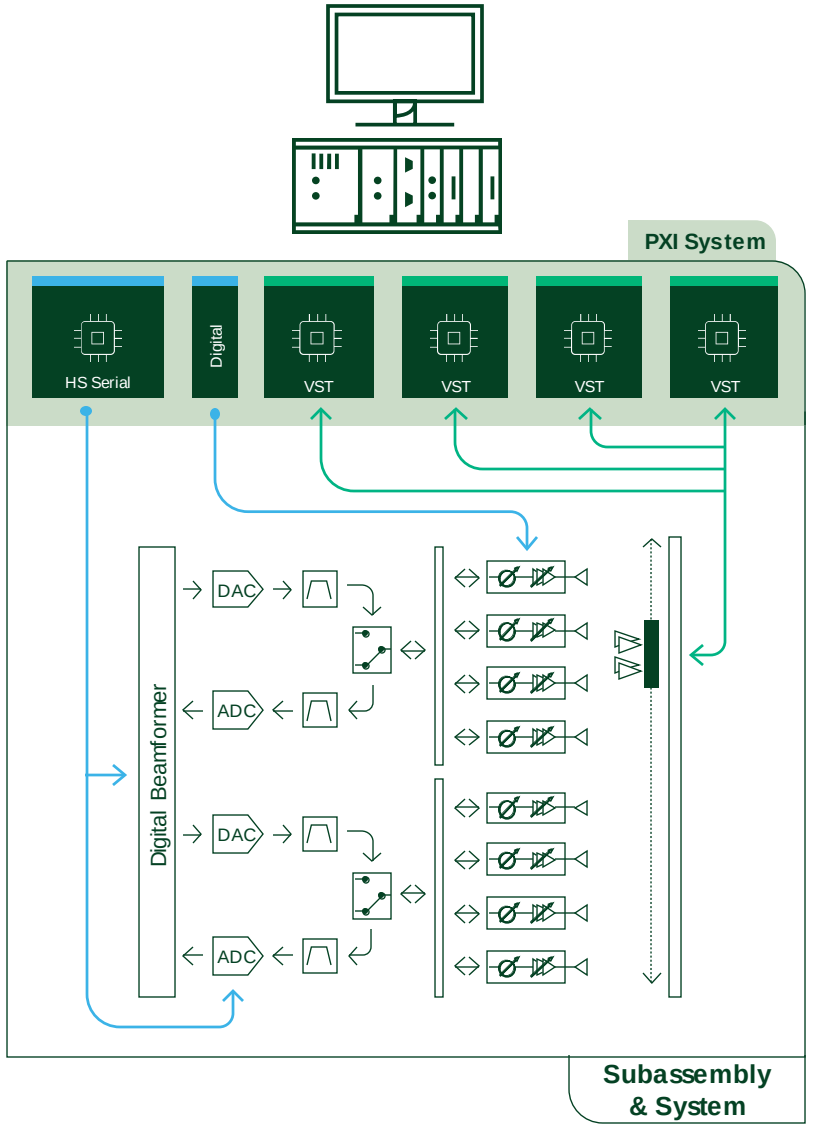
Pattern Based Digital
- 100 MVectors/s
- PPMU, Voltage and Current

Highspeed Digital Transceivers
- Up to 12.5 Gbps
- 24 TX and RX lanes

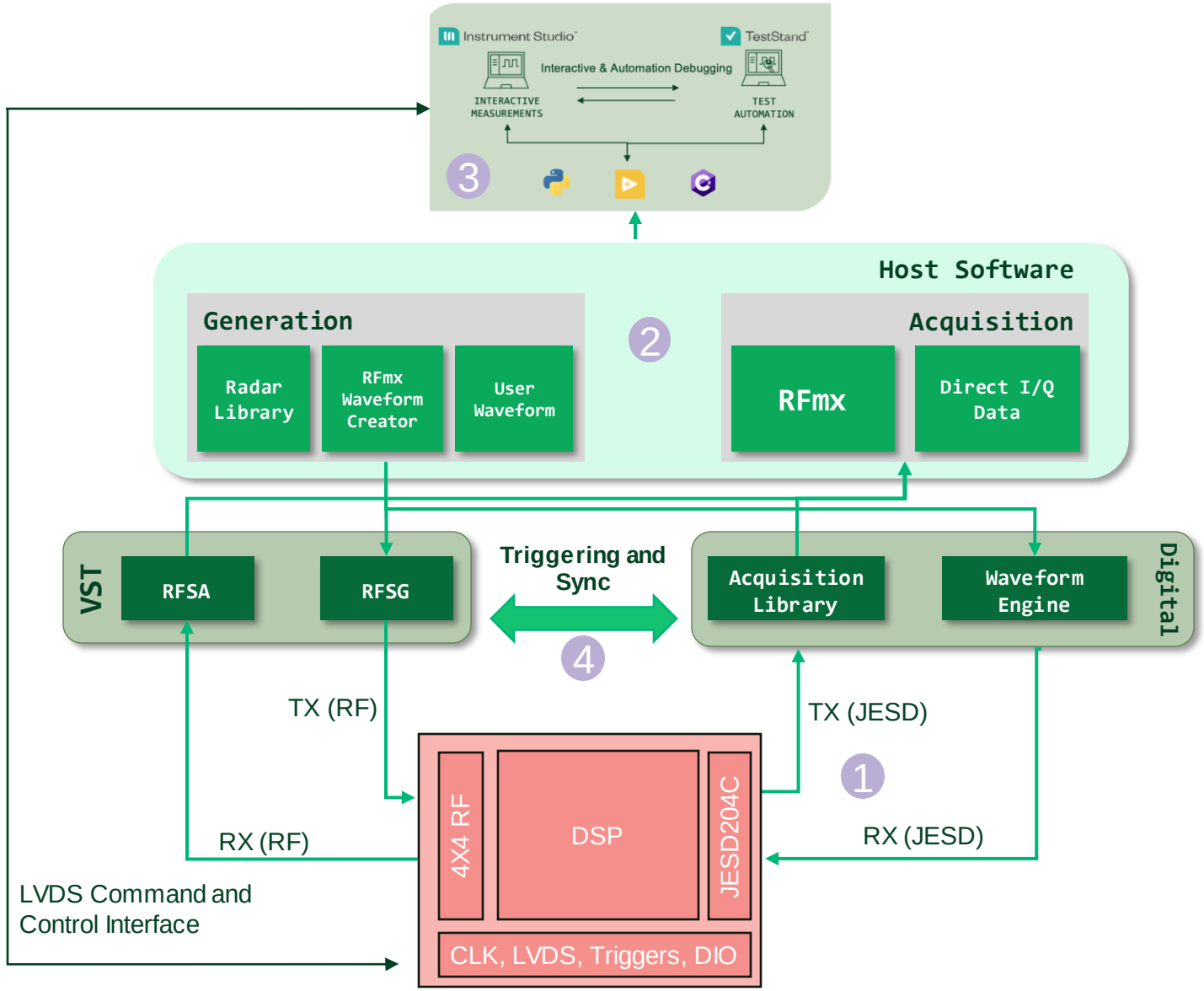
RF Stimulus and Response

- Vector Signal Analyzers, Generators, and Transceivers
- Up to 1 GHz of Instantaneous BW
- Software Defined with Open FPGA
- < 100psec synchronization with phase coherency





Electronically Scanned Array Characterization (ESAC) Offering for "RF to Bits" Validation



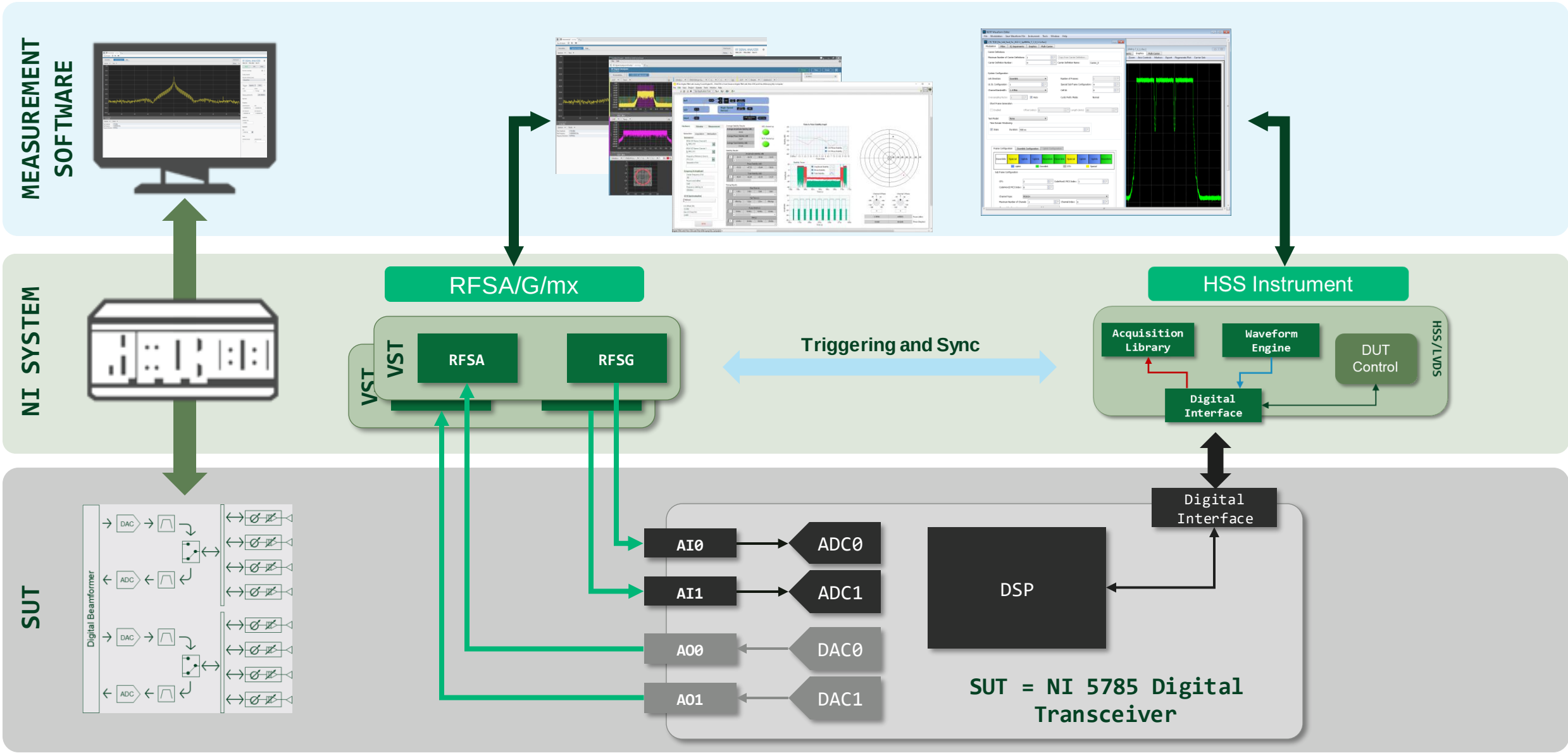
NI Provided Elements:

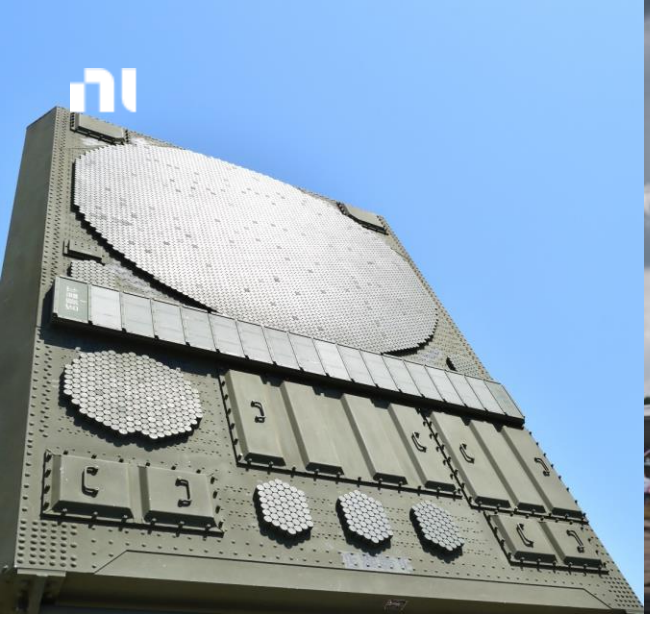
1. Industry Standard and Customizable Digital Interfacing
   - JESD204A/B/C, Aurora, 100Gb Ethernet, Proprietary
2. Integration of RF/Digital for standard measurement libraries
   - RFmx SpecAn, Phase Noise, Noise Figure
   - RFmx Pulse
   - Application Specific Measurements and Custom IP
3. Interactive Workflows supported by NI InstrumentStudio and NI TestStand
4. Synchronization between RF & Digital interfaces for coherent measurements (future)
5. Expansive Capabilities via PXI Ecosystem
   - Multi-Channel Synchronization, I/Q Data Movement, Real-Time FPGA based Processing, Record & Playback

Value Statements:

1. Minimize time to first measurement
2. Provide maximum measurement flexibility
3. Minimize integration issues
4. Implement software architecture that will scale throughout lifecycle

NI Digital TRM Characterization – Demonstration Overview






Today's Active Electronically Scanned Array (AESA) systems are becoming increasingly more capable due to market and technology trends such as

- Advances in GaN based RF components and Wide Bandwidth Data Converters
- High Density and Scalable Array Architectures
- Full Integration of Digital and RF Domains – True "RF to Bits

The Digital AESA creates a unique test challenge for traditional RF centric measurement solutions and workflows based on the mixed domain interfaces, diversified mission and application space, and sheer amount of data generated.

NI approaches this challenge with the strengths of the PXI ecosystem and high-performance software tools that scale to higher RF channel counts, wider digital data pipes, and complex measurement science needs.

- See it in action in the Aerospace and Defense Experience Lounge, or contact your NI representative for more information!

connect

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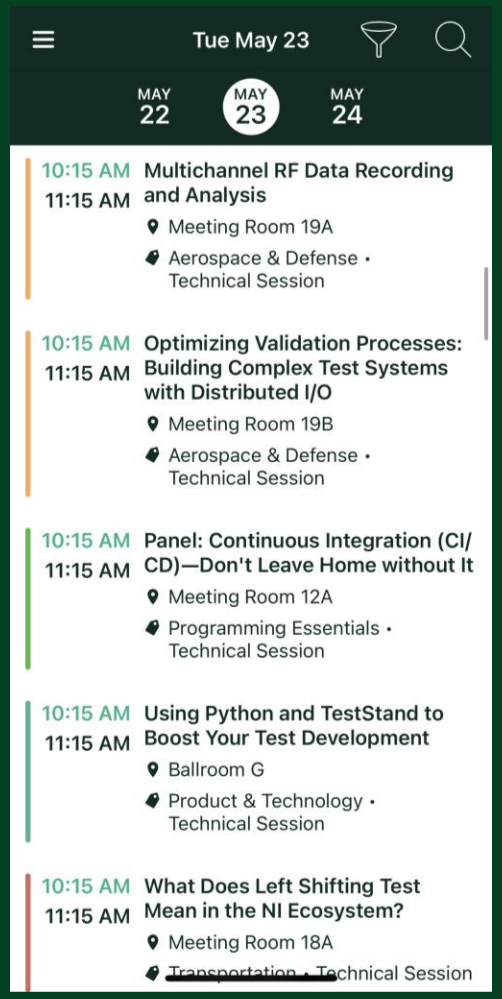
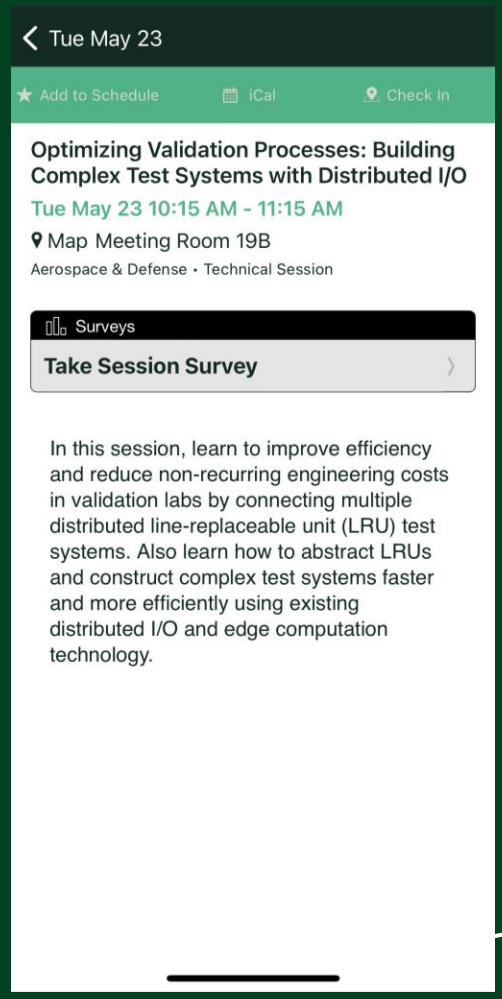
Quick 2 Question Survey

In the mobile app, click into the session you would like to provide feedback for





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