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Phase Aligned Multi-Channel RF in Aerospace and Defense

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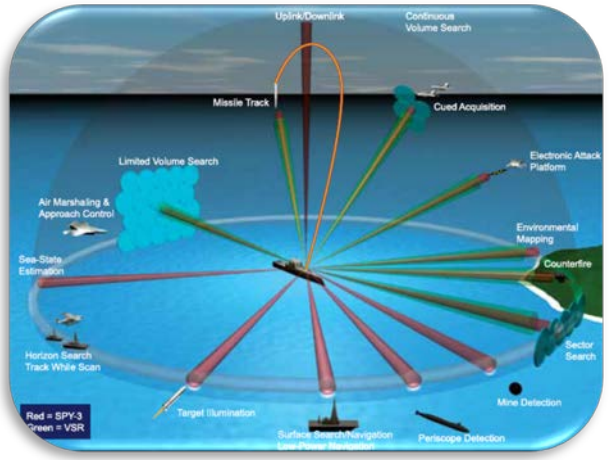
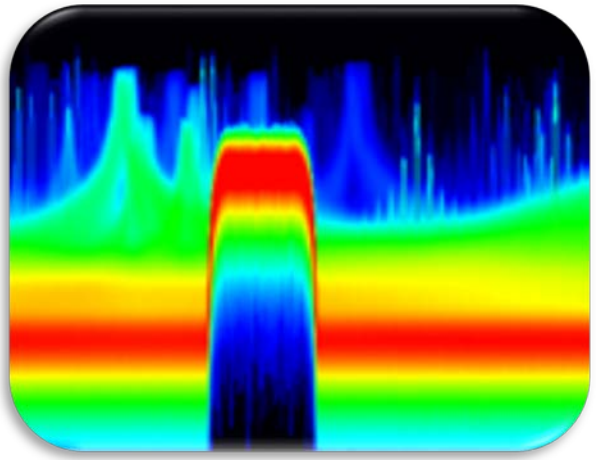
Phase Aligned Multi-Channel RF, a Key Attribute of Several Aero/Defense Applications



Radar

Electronic Warfare (EW)



Signal Intelligence (SIGINT)

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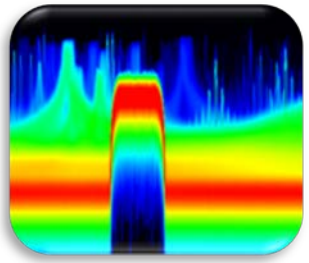
Engineering Challenges - Summary

Radar

EW

SIGINT



Enabling Technology

- Wide-band Receivers and Transmitters
- Multi-channel Phase Coherency
- Real-Time Signal Processing
- High bandwidth, low latency I/O

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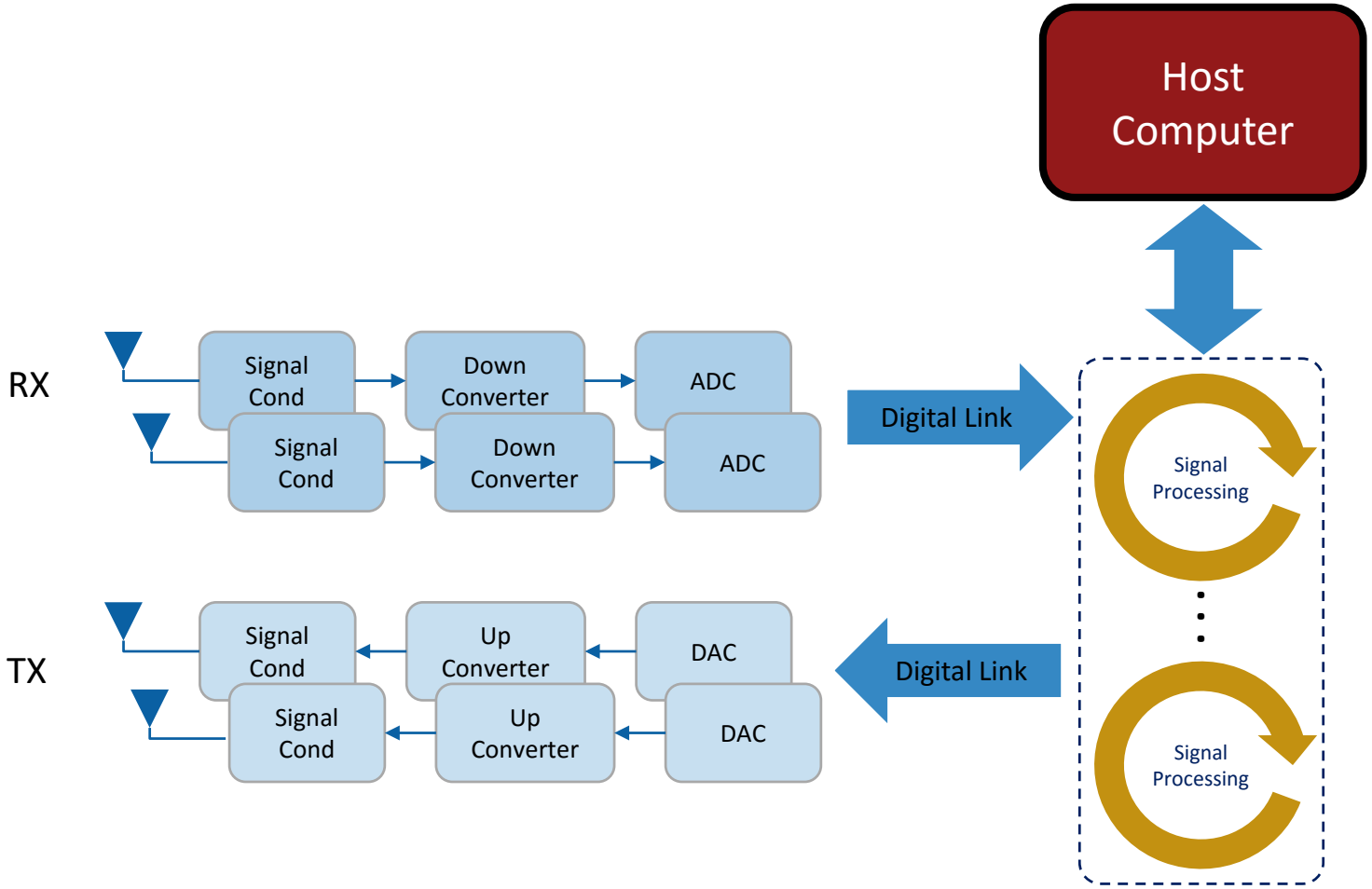
Example Requirements

- Sample 4 channels @ 1GHz bandwidth
- 12b Rx
- 14b Tx
- <1us latency
- All antenna data must be available to each processing node (MIMO applications)
- Fast time to market
  - Productive software design environment
  - Available IP

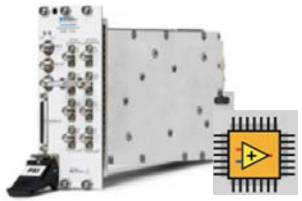
Architecture & System Blocks



- RF
- Timing
  - Phase alignment, Synchronization, Clocking
- Processing
  - Very high throughput digital signal processing engine
- I/O
  - High Bandwidth
  - Low latency
- Memory access

RF Choices

VST1



PXIe-5646R

- 65MHz to 6GHz
- 200 MHz bandwidth
- -161dBm/Hz avg noise floor
- 112 dBc/Hz phase noise (10kHz offset)
- 380us tuning time

VSG

PXIe-5673E

- 85 MHz to 6.6 GHz frequency range
- More than 100 MHz of RF bandwidth
- Up to +10 dBm RF power
- -112 dBc/Hz phase noise at 10 kHz (1 GHz)

VSA

PXIe-5668R

- 20 Hz to 14 GHz or 26.5 GHz
- 765 MHz of bandwidth
- -165 dBm/Hz average noise floor at 1 GHz
- -129 dBc/Hz phase noise at 10 kHz offset (800 MHz center frequency)

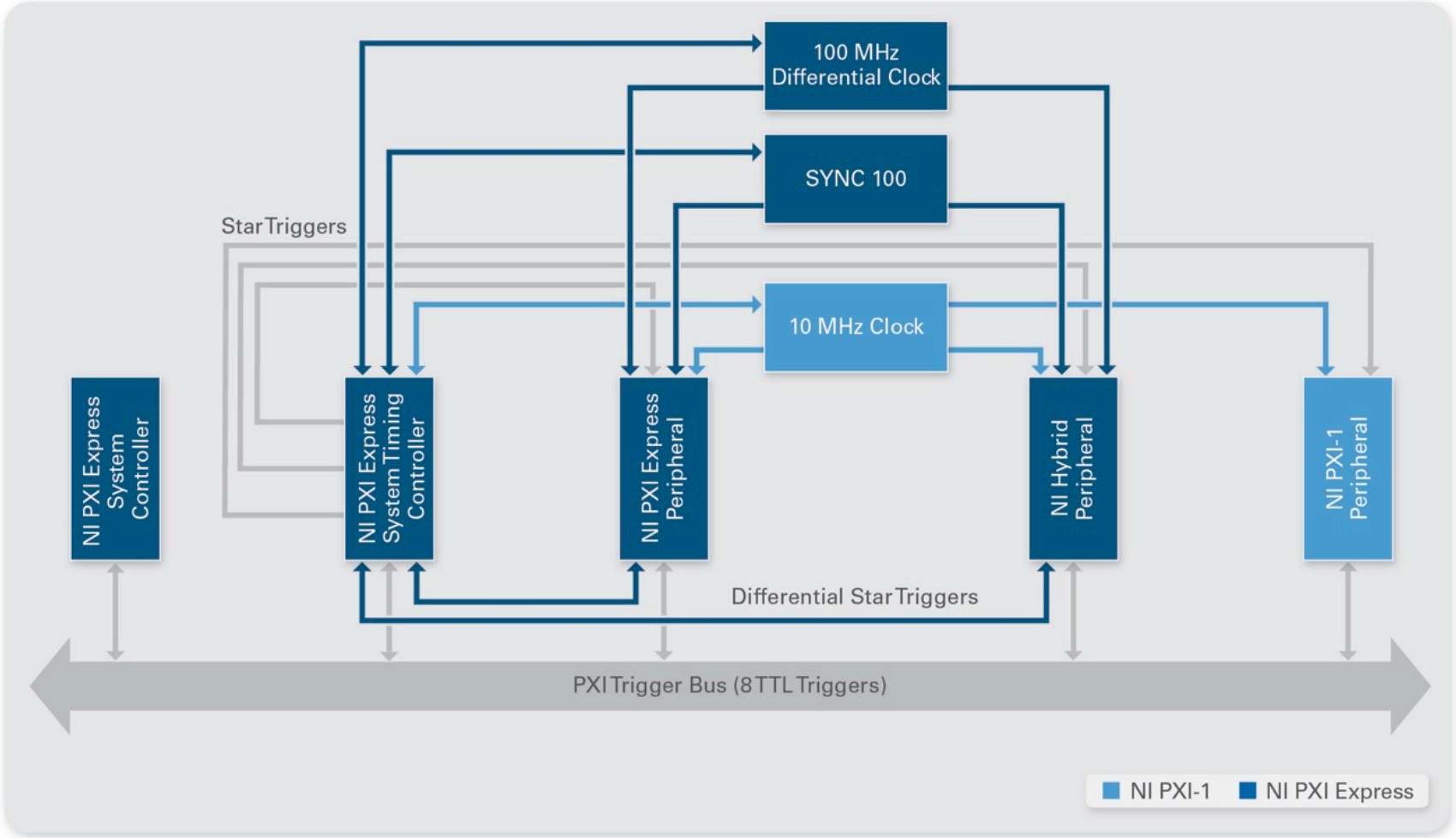
VST2

PXIe-5840

- 9 KHz to 6.5 GHz
- 1 GHz of bandwidth
- EVM -45dB @ 5.8GHz
- 200us tuning time
- 2 PXI slots

IEEE	HF		VHF		UHF		L	S		C		X	Ku		K	Ka		V		W	mm
NATO	A			B		C	D	E	F	G	H	I	J			K		L		M	LIDAR
Frequency	3-30 MHz		30-300 MHz		300-1000 MHz		1-2 GHz	2-4 GHz		4-8 GHz		8-12 GHz	12-18 GHz		18-27 GHz	27-40 GHz		40-75 GHz		75-110 GHz	110-300 GHz

Timing – PXIe Provides Necessary Phase Alignment



- Flexible triggering
  - Bus
  - Star
  - Differential Star w/ optional differential clock
- Phase alignment
  - ~1ps ch to ch phase
- Generate 100MHz from 10MHz

- PXI is an open standard
  - >50 association members

Processing Choices

PXIe-7902

- PXIe form factor
- 1x V7-485T
- 24x 12Gb serial lanes
- DSP slices: 2,800
- Memory: 2GB
- LabVIEW FPGA

ATCA-3671

- ATCA form factor
- 4x V7-690T
- 128x 10Gb serial lanes
- DSP slices: 14,400
- Memory: 64GB
- LabVIEW FPGA or Traditional (MATLAB/VHDL/Vivado)

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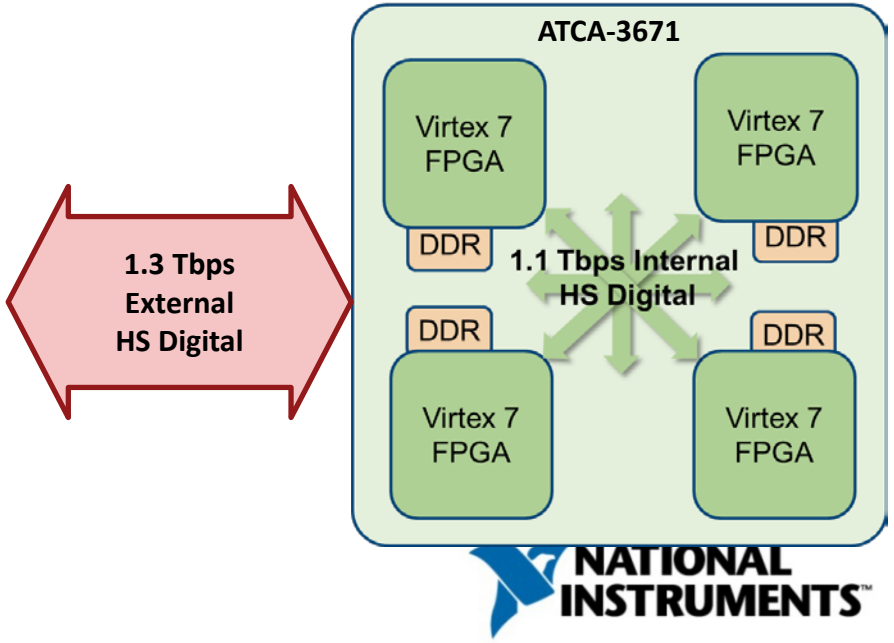
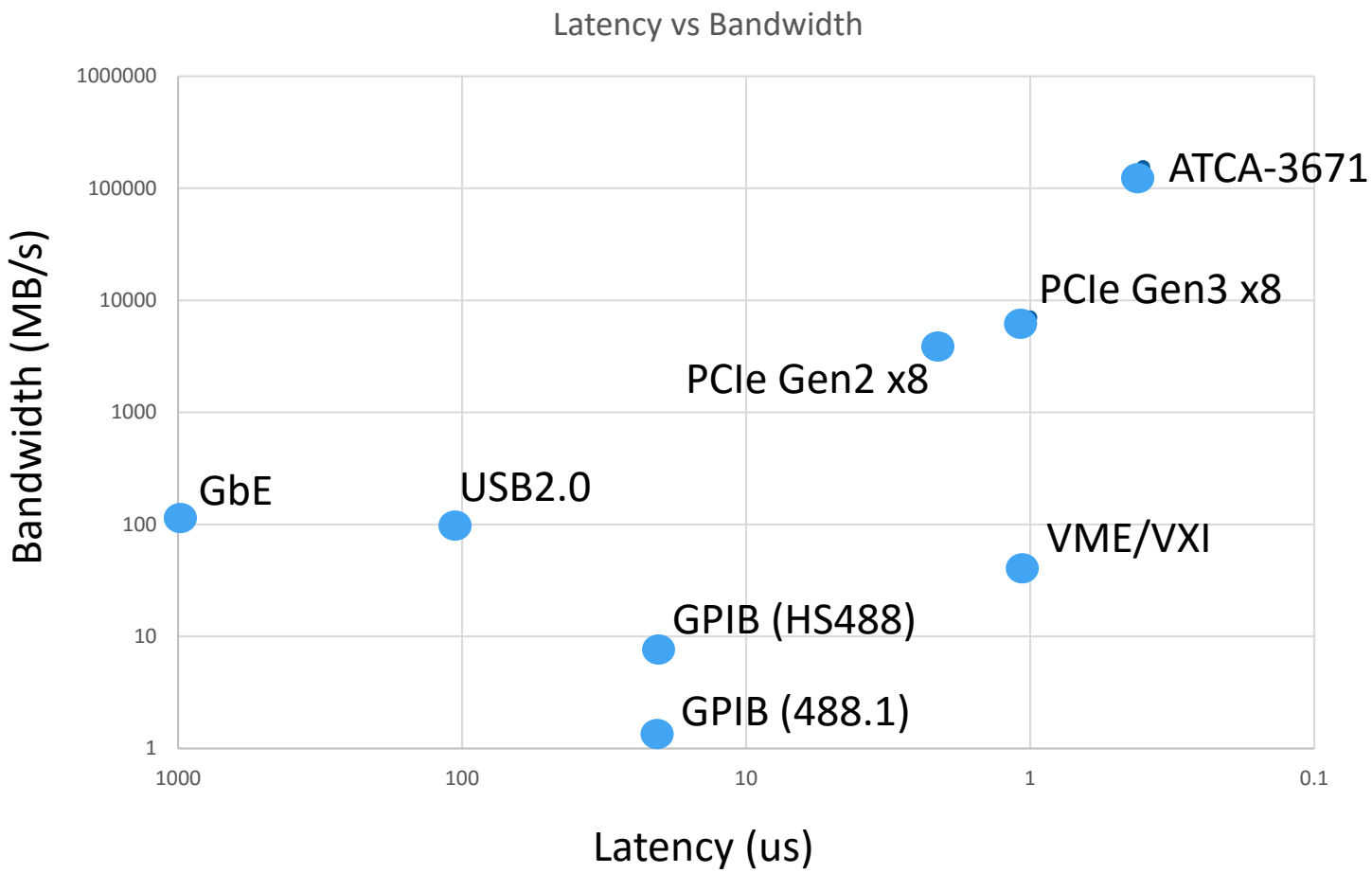
Real-Time Signal Processing – ATCA-3671 Blade

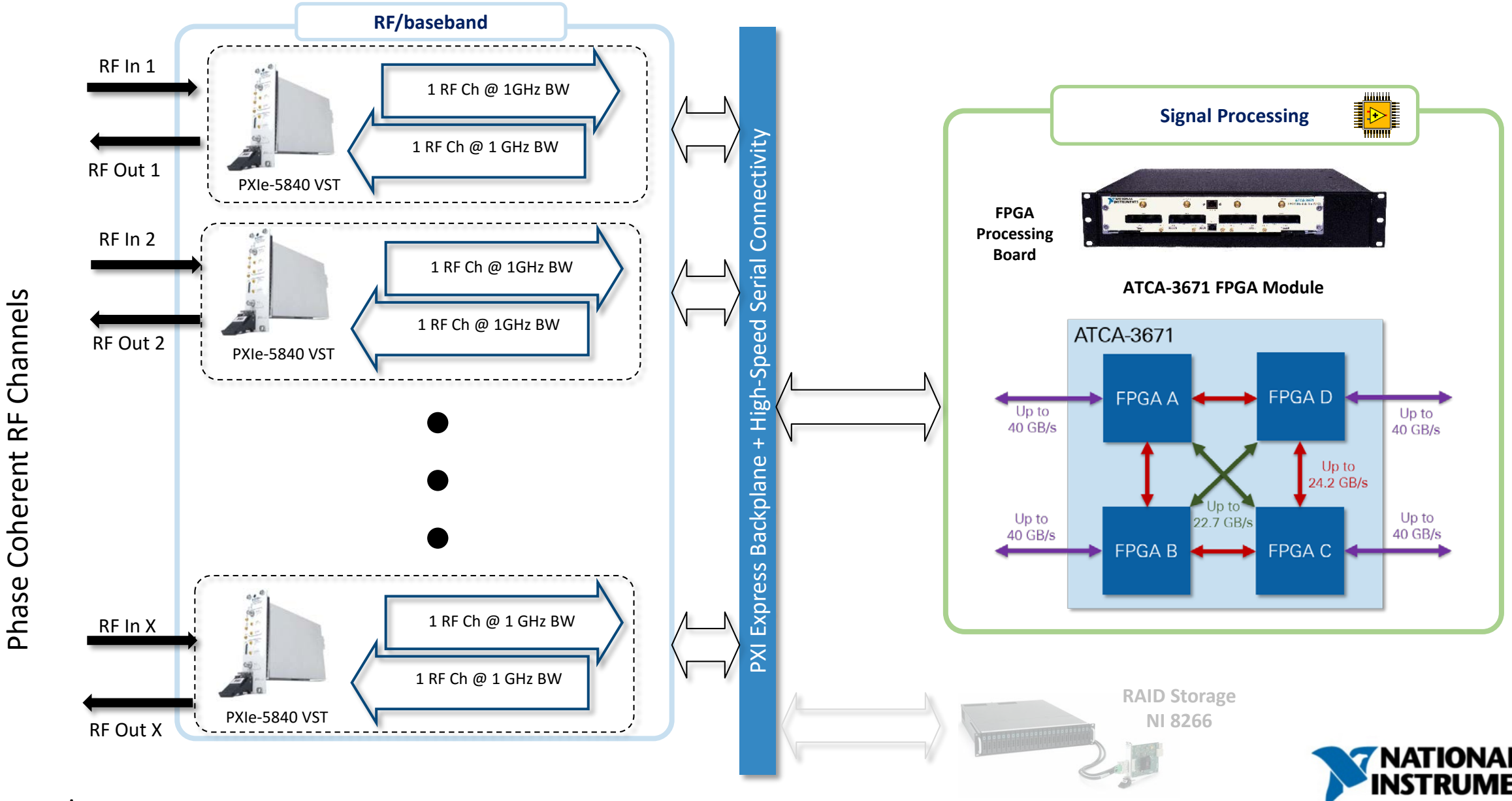
- 4 x Virtex-7 690T
  - 3600 DSP slices per FPGA
  - 64 GB total DDR3 (1333MHz)
- 5.2TMACs/sec
- 1.1 Tbps Internal Connectivity
- 1.3 Tbps External Connectivity
- Software Environment
  - LabVIEW FPGA
  - Traditional (VHDL/MATLAB/Vivado)



Latency versus Bandwidth Options



Proposed System w/ PXIe-5840 & ATCA-3671

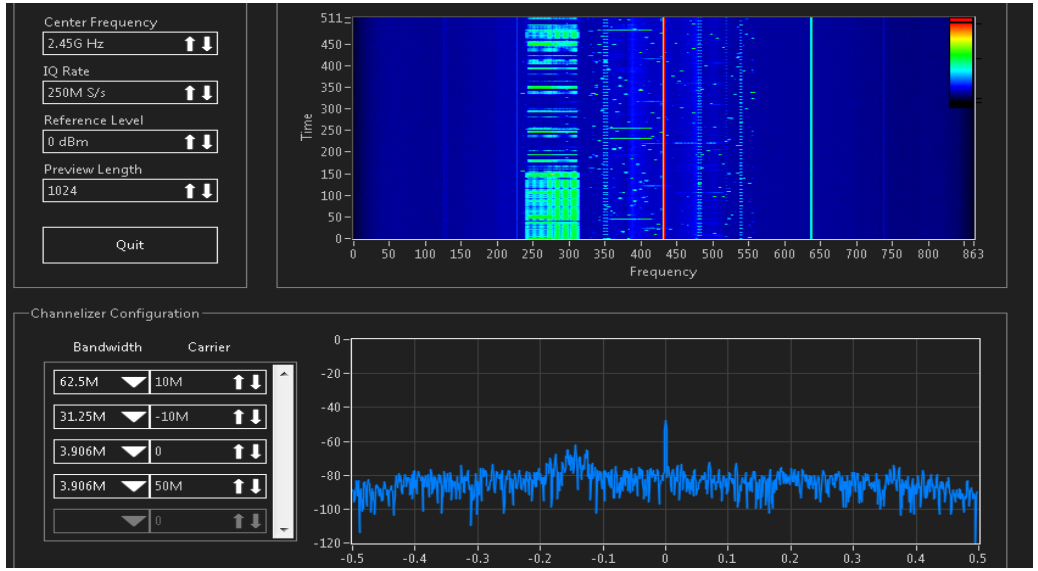


Software Design Flow

- LabVIEW FPGA
  - Out of the box experience with NI's COTS hardware
  - Very high productivity
    - Large toolbox of existing IP for standard DSP and some Aero/Defense applications
  - Proprietary
- Traditional
  - MATLAB/VHDL/Verilog/C++
  - Considered "open flow" for government contracts
  - Requires skilled users (especially for FPGA design)
  - Use with any hardware target

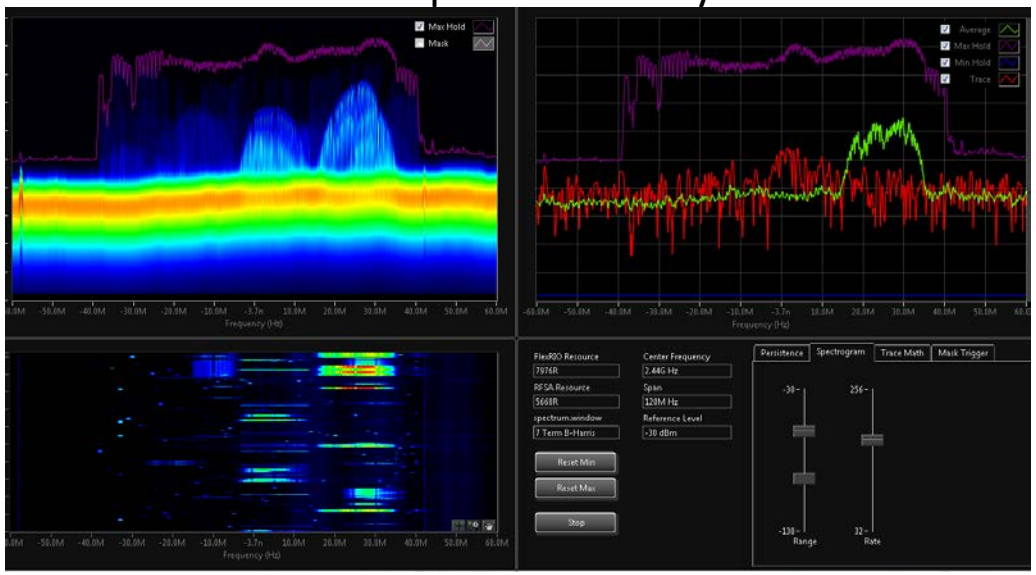
Signal Processing IP Available in LabVIEW FPGA

Channelizer DDC



- Pipelined Frequency Transform (PFT) based
- Up to 512 independent channels
- Variable bandwidths and center frequencies
- Total channelization bandwidth 100 MHz

Real-Time Spectrum Analyzer

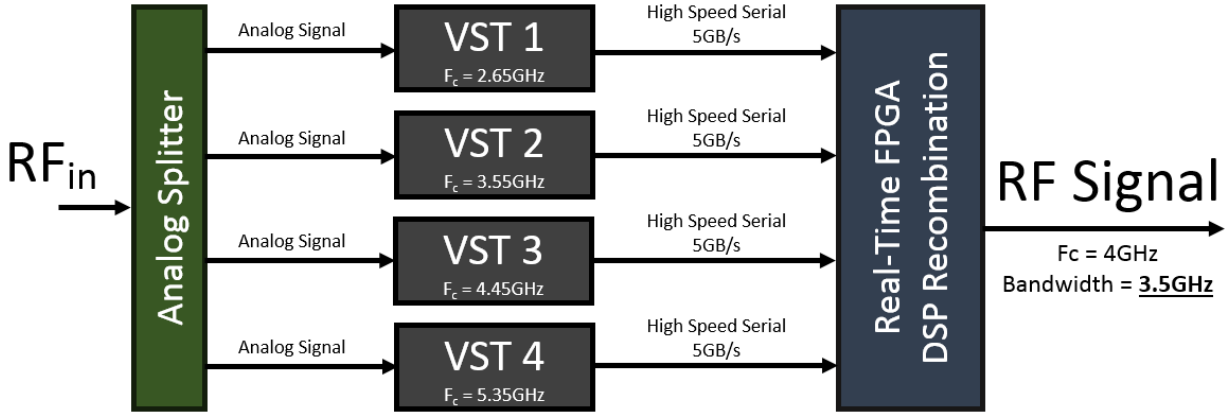


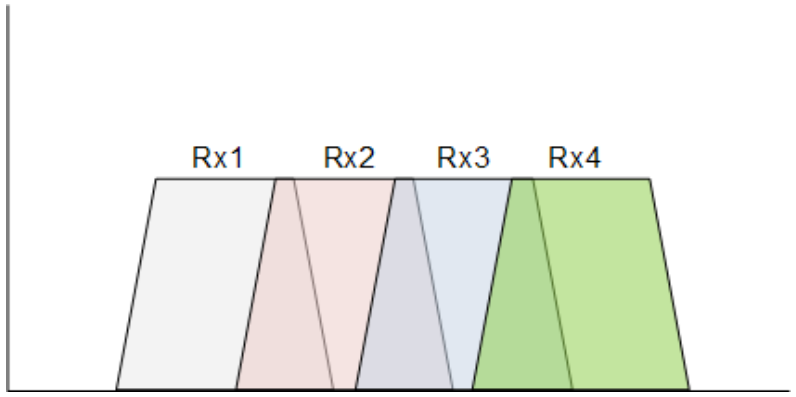
- Persistence & Spectrogram Display
- Frequency Mask Trigger
- Integrated record to disk capability
- < 1.5 us probability of intercept (POI) (5668R)

LabVIEW IP Being Constantly Developed

Example: Spectral Stitching

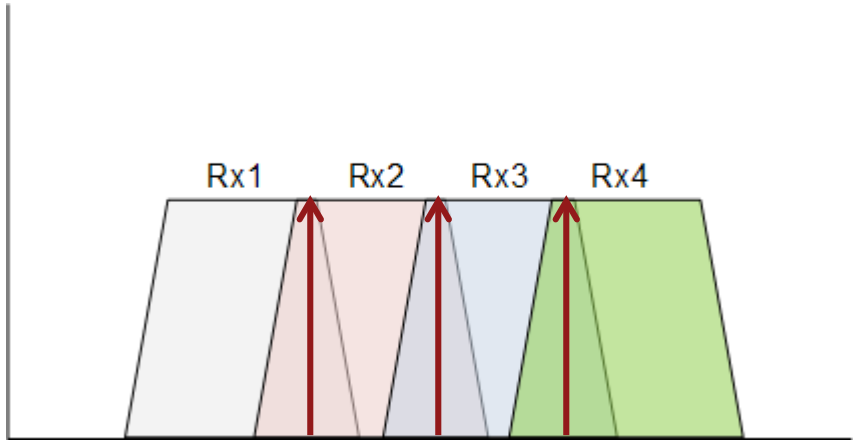
- Combine multiple RF devices together such that they appear as one device



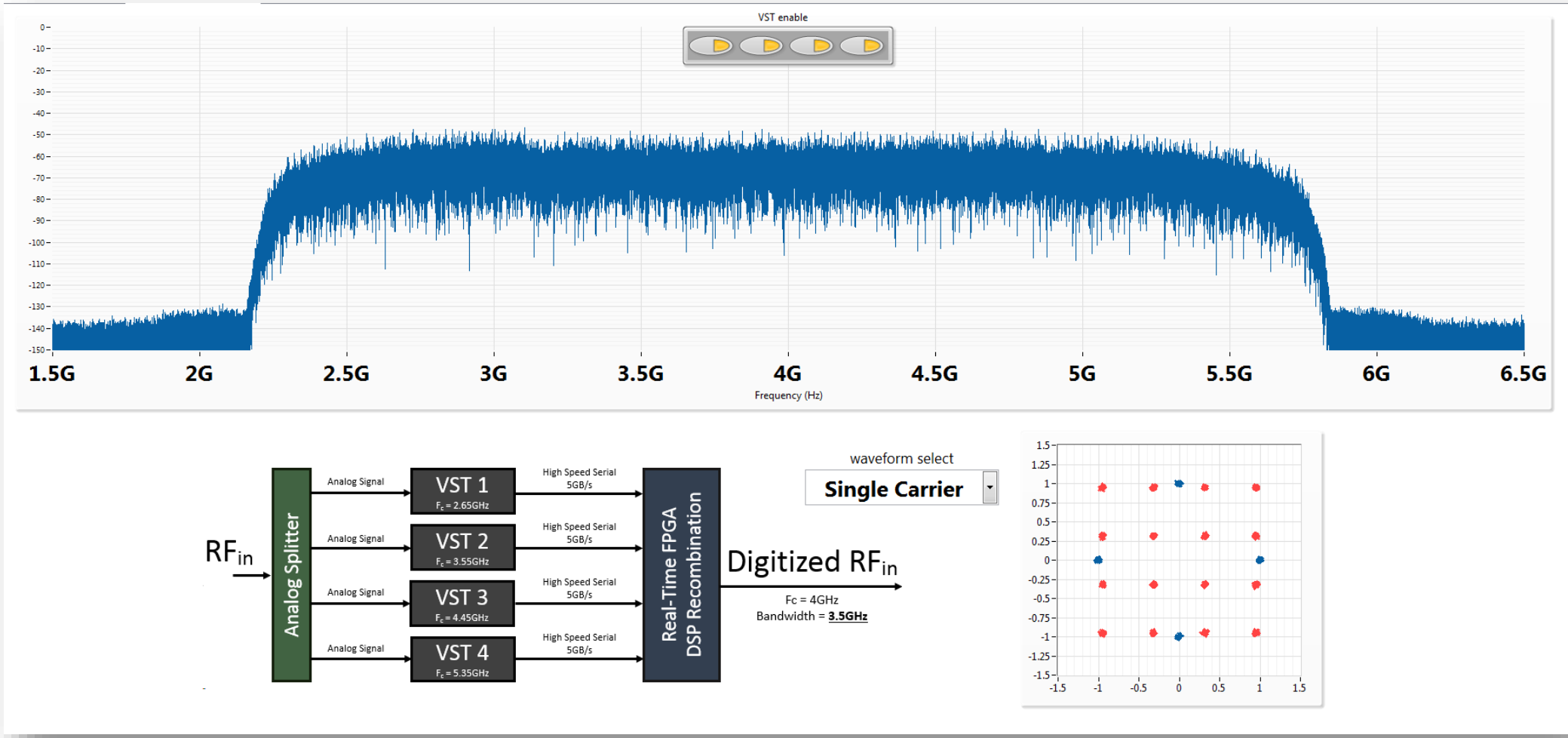


Inject Calibration Signal and Measure

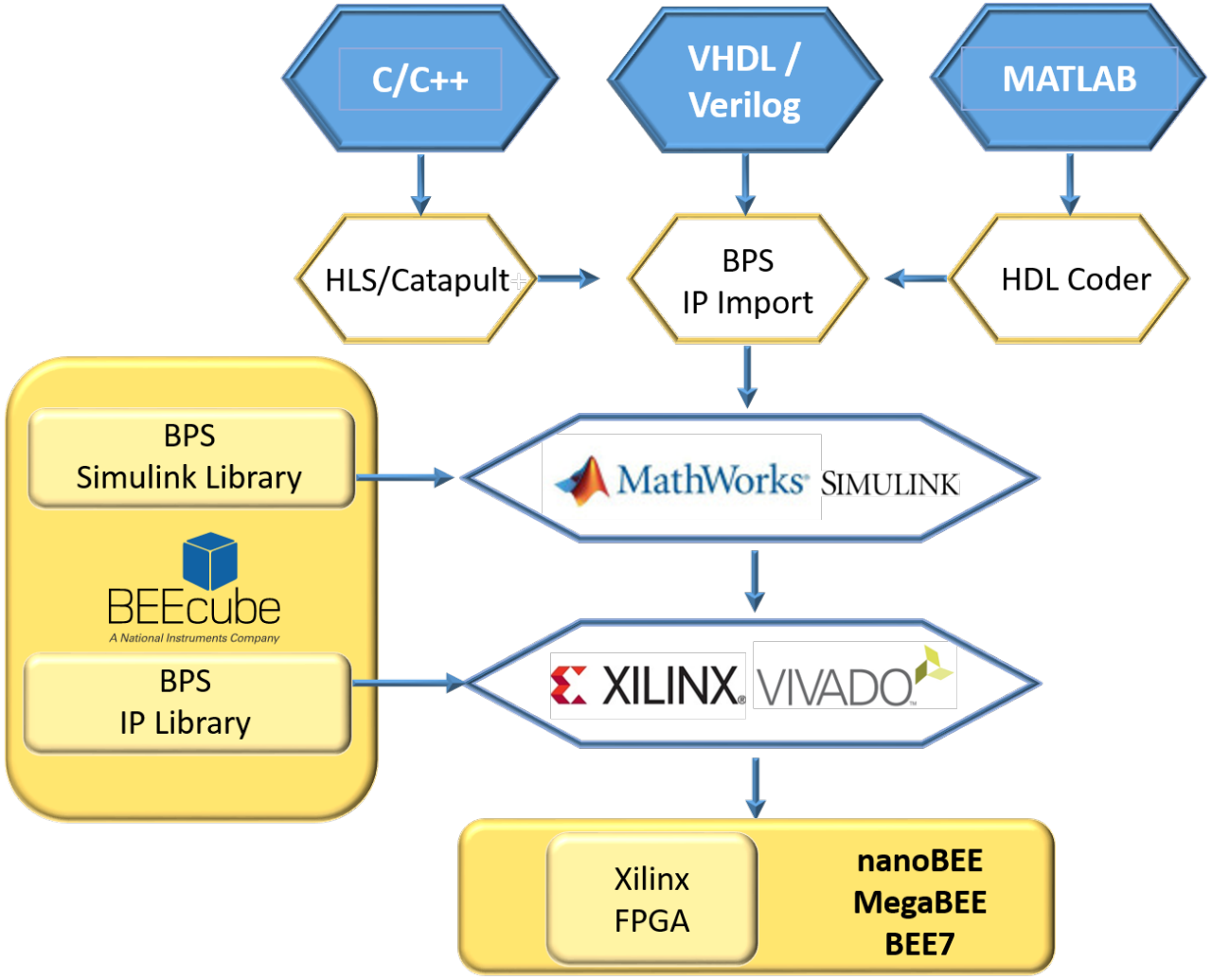
- Need to align the magnitude and phase for each device
- Overlapping devices allow for a common calibration signal to be received by each device
- If the phase of the LO cannot be reset deterministically, this calibration will be required every time the LO is relocked (every time the requested center frequency changes)



Stitched Waveform with Demodulation



ATCA-3671 “Traditional” Design Flow



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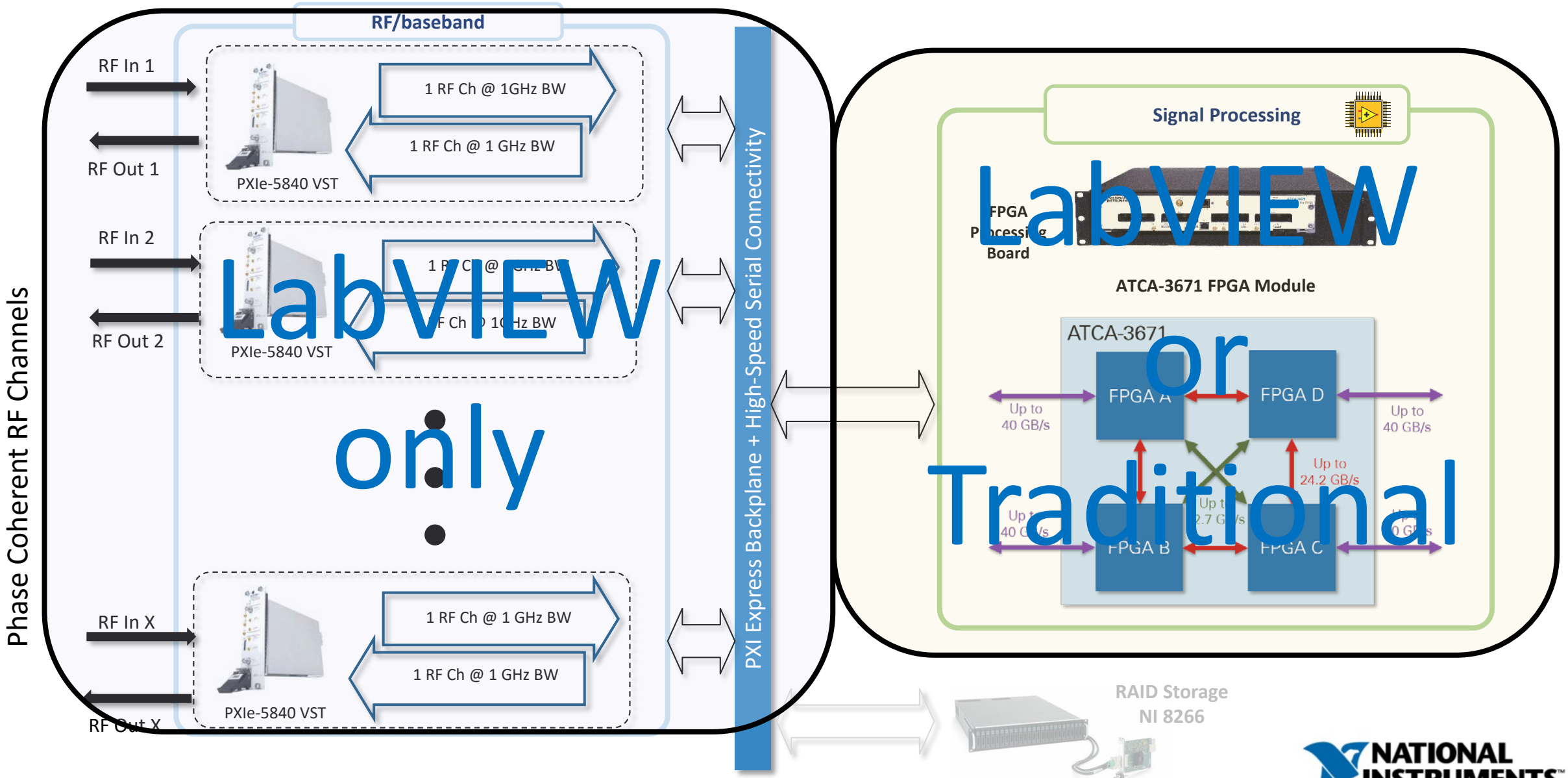
SW Flow Revisited



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Experimental Results: 4 Channel Phase Aligned System

4 Channel RF
- PXIe-5646R VST
- 65MHz-6.6GHz
- 140MHz BW

PXIe Hybrid Chassis
- PXIe-1085
- Gen3 x8
- 8 GB/s/slot; 24 GB/s/chassis

CW Source for Calibration
- PXIe-5652
- 500KHz-6.6GHz

Embedded Controller
- PXIe-8880
- Eight-Core Intel Xeon
- High Performance

FPGA Processing and High Speed Serial Interface to ATCA-3671
- PXIe-6591R
- Kintex 7 FPGA
- MGTs

Timing and Synchronization
- PXIe-6674T
- OCXO
- Multi-chassis synchronization

RAID Drive
- NI 8266
- 3.2 GB/s

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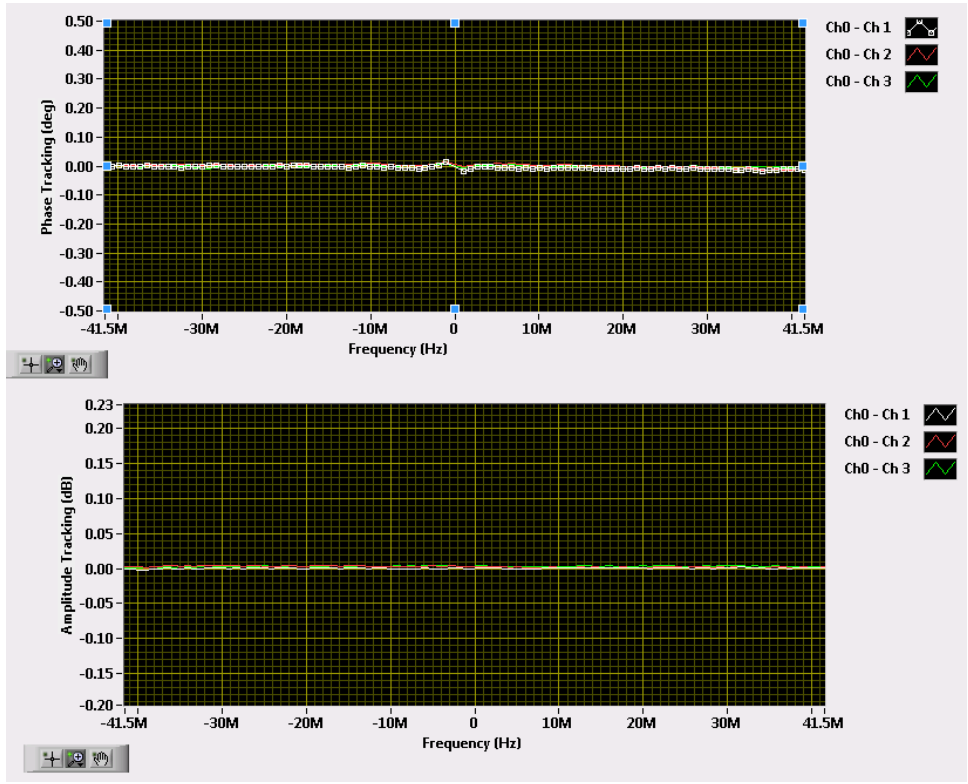
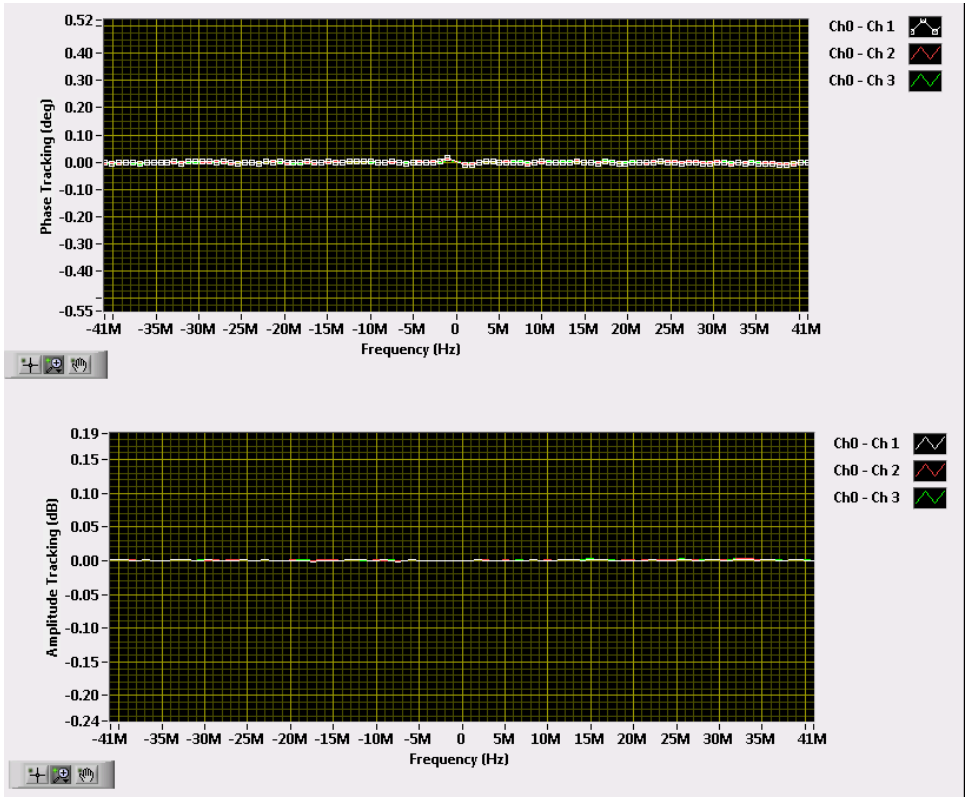
Phase Alignment Results (4x 5646R)

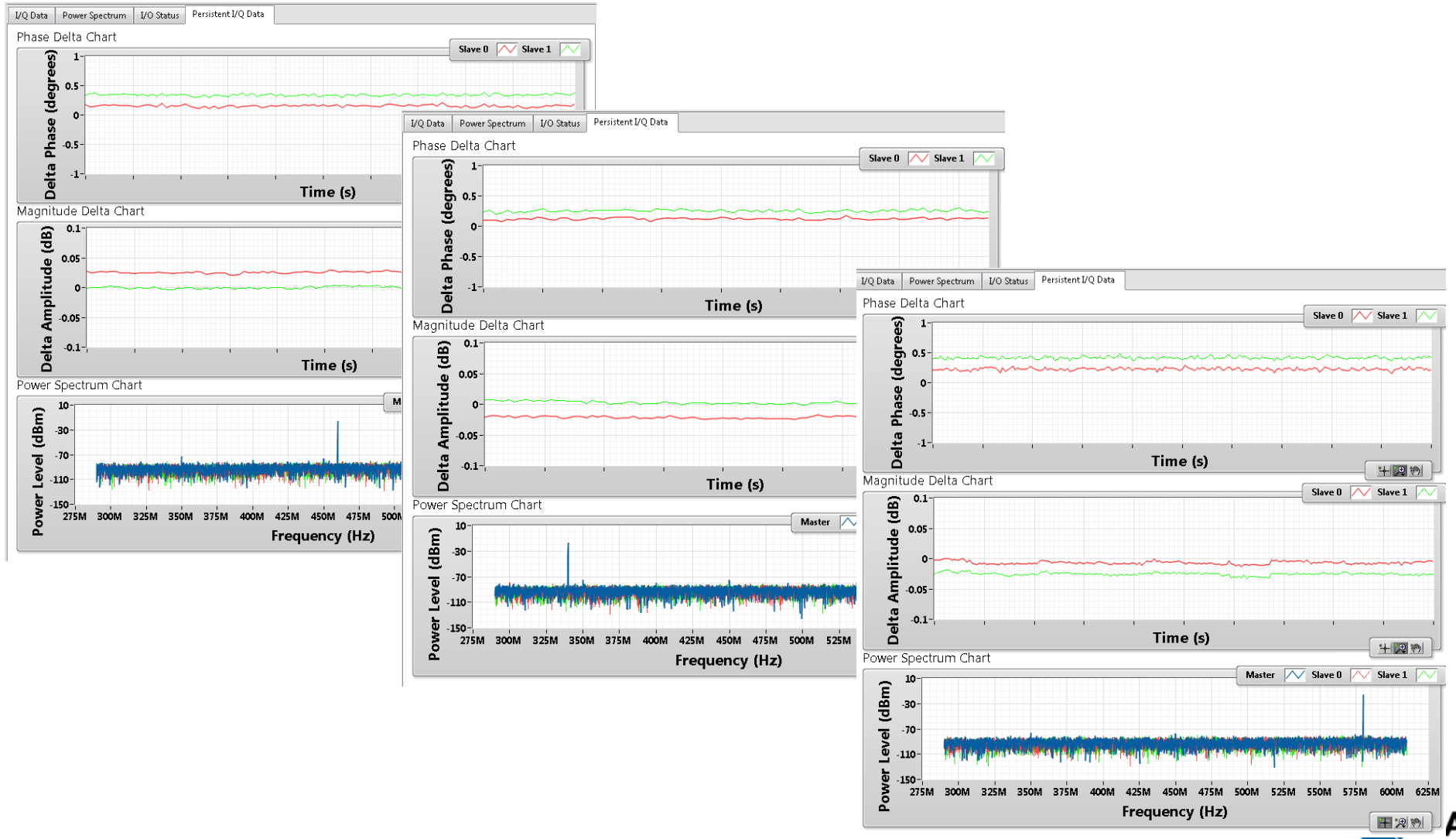
Acquistion



Generation



Phase Aligned Performance Across Entire Bandwidth



Prototype Phase Aligned RF Systems Today with NI

PXI Instruments provide wide selection of phase coherent RF front end solutions

+

ATCA-3671 provides most powerful back end processing platform