Aerospace and Defence Forum 2016
An Industry Event Hosted by National Instruments

Signal Intelligence
Farris Alhorr
RF Specialist and Business Development Manager, MEA
High Performance RF Systems for EW Applications
Modern Challenges in RF Applications

RADAR
- Short duration, non-periodic pulses.
- Weak signals in the presence of strong signals.

Spectrum Monitoring
- Overlapping, crowded bands.
- Weak signals in the presence of strong signals.

Cellular/Wireless
- Wideband bursted transmissions
- Complex modulation algorithms

Electronic Warfare
- Short duration pulses
- Wideband bursted transmissions
- Complex modulation algorithms
- Weak/Strong signals
Aerospace/Defense Target Applications

**Test Focus**
- ATE: Depot Level, Intermediate Level, Organizational Level
- RADAR: Primary Radars, Secondary Radars (Transponders, Interrogators)
- Navigation: Navigation Aids (ILS, VOR, DME), Positioning Systems (GPS, GLONASS)
- MILCOM: SATCOM, Military Radios, Public Safety Radios (TETRA, P25), Telemetry
- SigInt: Spectrum Mon, ELINT, ComInt

**Design Focus**
- Passive Radars, Radar Emulators
- Software Defined Radios, Software Defined Networks, Cognitive Radios

**Av/Comm**
SIGINT – Broad Classification

- **Signal Intelligence**
  - **Communications Intelligence (COMINT)**
    - Voice/Text Interception
    - Signal Detection
    - Channel Interception
    - Direction Finding
    - Spectral Monitoring
    - Intercept Management
    - Traffic Analysis
  - **Electronic Intelligence (ELINT)**
    - Complement COMINT
    - Electronic Support Measure (ESM)
    - Foreign Instrumentation
    - Signal INT
    - Telemetry INT
    - Support ECM and ECCM
  - **Measurement and Signature Intelligence (MASINT)**
    - Non Cooperative Target Detection
    - Unattended ground sensors
    - Signature analysis
    - Electromagnetic Radiation Analysis

ni.com | NI CONFIDENTIAL
Signals intelligence

Channel

Signals Intelligence System

Gathers Intelligence from Communication systems
What does it take to make a SIGINT system

Architecture of a SIGINT System

Signal Intelligence Algorithm
Radio Monitoring – System Overview

- RF/Microwave
- Signal Conditioning
- Down-Converters
- IF/Baseband
- ADCs
- RTSA
- Channelizer
- Data Storage
- Signal Processing for SIGINT
What is a PXI System?

Controller:
Runs a General purpose OS or a Real time OS
Programmable and Used to run algorithms

Configurable I/O Modules:
Digital I/Os up to 12.5 Gbps
Analog digitizers up to 12 GS/s
RF input up to 26.5 GHz
RF output up to 20 GHz
Leveraging PXI platform to build SIGINT Systems

- Run your SIGINT algorithm on a Intel powered controller
- Use Digital Output to send out control signals
- Choose to use a FPGA for inline signal processing
- Use Vector Signal Generators for generating RF signals
- Use a Vector Signal Analyzer to receive RF Signal inputs
Radio Monitoring – System Overview

RF/Microwave

- Signal Conditioning
- Down-Converters

IF/Baseband

- ADCs

Data Bus

RTSA

Channelizer

Data Bus

Data Storage

Signal Processing for SIGINT

- NI HDD-8266

PXle Chassis
- PXle-1085 Gen3

- PXIe-5665
- PXIe-5667
- PXIe-5668R

Vector Signal Analyzers (VSA)

- PXIe-5624R
- PXIe-5170R
- PXIe-5622
- PXIe-5122
- PXI-5922

Direct Sampling Receivers

- PXIe-5622
- PXI-5922

FlexRIO
- PXIe-7976R
- PXIe-7975R

ni.com | NI CONFIDENTIAL
The NI Approach

We call this the LabVIEW Reconfigurable I/O (RIO) architecture.

Highly Productive LabVIEW Graphical Programming Environment for Programming Host, FPGA, I/O, and Bus Interfaces
Radio Monitoring – System Overview

- **RF/Microwave**
  - Signal Conditioning
  - Down-Converters

- **IF/Baseband**
  - ADCs

- **RTSA Channelizer**
  - PXIe Chassis
    - PXIe-1085 Gen3

- **Data Storage**

- **Vector Signal Analyzers (VSA)**
  - PXIe-5665
  - PXIe-5667
  - PXIe-5668R

- **Direct Sampling Receivers**
  - PXIe-5624R
  - PXIe-5170R
  - PXIe-5622
  - PXIe-5122
  - PXI-5922

- **FlexRIO**
  - PXIe-7976R
  - PXIe-7975R
Real-Time Spectrum Analyzer (RTSA)

- Gapless persistence, spectrogram, and trace statistics (max hold, min hold, average) calculated on FPGA
- Process up to 2 M FFTs/s using overlapped, windowed FFTs
- Real-time frequency mask triggering
- 100% probability of intercept (POI) minimum duration options:
  - 1 µs or >15 µs
- Source available upon request (Export Controlled – US Dep. of Commerce)
Demo: Real-Time Spectrum Analysis

- PXIe-5668R VSA + PXIe-7976R FlexRIO in PXIe-1085
  - May use other P2P-capable RF analyzers
- Up to 800 MHz RF bandwidth (3 GB/s)
NI RTSA Block Diagram

VSA

FlexRIO FPGA Module

$|\mathcal{F}(x)|$

Persistence

Spectrogram

Frequency Mask + Trace Math

To Host

To Host

To Host

Triggers

P2P

IQ Data

ni.com | NI CONFIDENTIAL
Channelizer

Channelization Specifikations
- 1024 Channels
- Individually tunable:
  - Center frequency
  - Bandwidth
  - Gain
  - 1 of 32 user configurable filters
  - Channel on/off
- Demodulation and Filtering
  - AM/FM demodulation
  - Audio Filtering
  - Audio Down Sampling
Novator – NCR-2000

- Standalone Ready-To-Run instrument for channelizing the radio signal and decoding with third part COMINT software
- Controlled with local NCR-2000 Software or via TCP/IP
- 50 MHz or 2x50 MHz bandwidth (320 MHz ist. BW with NCR-2500)
- 1024 or 2048 channels with the NC-10 channelizer
- Highspeed Data Output, 10 GbE SFP+
- Option: rugged transport and friendly casing
## NI RTSA Performance

<table>
<thead>
<tr>
<th>Feature</th>
<th>NI RTSA</th>
<th>Other RTSAs</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW</td>
<td>765 MHz</td>
<td>500 MHz</td>
</tr>
<tr>
<td>POI</td>
<td>1.5 us</td>
<td>2 us</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>119 dBC</td>
<td>119 dBC</td>
</tr>
<tr>
<td>Record to Disk</td>
<td>Yes, full bandwidth</td>
<td>Some have it, but not full bandwidth</td>
</tr>
<tr>
<td>IQ Data</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Open FPGA</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Multi-channel</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Modularity</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Radio Monitoring – System Overview

Signal Processing for SIGINT

Data Storage

• NI HDD-8266

FlexRIO
• PXIe-7976R
• PXIe-7975R

PXIe Chassis
• PXIe-1085 Gen3

Vector Signal Analyzers (VSA)
• PXIe-5665
• PXIe-5667
• PXIe-5668R

Direct Sampling Receivers
• PXIe-5624R
• PXIe-5170R
• PXIe-5622
• PXIe-5122
• PXI-5922

Signal Conditionin g

Down- Converters

IF/Baseband

ADCs

RTSA

Channelizer

RF/Microwave

Data Bus

Data Bus

ni.com | NI CONFIDENTIAL
NI Products for Signal Processing
NI Products for Streaming

NI 8260 with SSD

Up to 3.6 GB/s

Three storage capacities available: 24 TB SATA, 3.5 TB SAS, 5.7 TB SSD
Signal Processing for Radio Monitoring\COMINT

Protocol Analysis and Monitoring

Our protocol analysers make use of the DDC framework to extract multiple narrowband signal streams and decodes them in parallel. Therefore we can monitor networks with multiple base stations and carrier frequencies in both downlink and uplink directions including trunked systems.

- Supported protocols: TETRA, NIXON™, DMR, iDMR, P25 and Tetrapol
- Virtually unlimited number of channels
- Fast detection (scan) of all emissions in the available bandwidth
- Manual insertion of channels on the spectrum
- Extraction of broadcast parameters
- Live voice output
- Data output
- Timing output for burst localisation
- Statistics output
- Recording of calls (wav) and short data messages (txt) with corresponding metadata
- Postprocessing of recorded sessions, playing recorded files, filtering by source and destination IDs
- Frequency and sampling rate tracking
- Interface for external crypto-modules
Radio Monitoring Solution based on VSA

Continuous streaming (3.2 GB/s) to the processing on FPGA and to the hard disk.

- PXIe-5665: 20 Hz to 3.6 GHz or 14 GHz, 50 MHz inst. BW
- PXIe-5668R: 20 Hz to 14 GHz or 26 GHz, 750 MHz inst. BW
- NI HDD-8266
- FlexRIO PXIe-7976R
  - RTSA
  - Channelizer
Leveraging PXI Platform: Phase Coherent mimo

- Phase-coherence achieved through shared LO
- System expandable to 4x4 and beyond

Phase-Coherent Four-Channel PXIe-5663 VSA
Phase-Coherent Two-Channel PXIe-5673 VSG
Traditional VSA Architecture

- Traditional VSAs use 3-stage superheterodyne architecture
- Can share 10 MHz reference – not the local oscillators (LO_1, etc.)
Traditional Synchronization Method

10 MHz Reference

Phase Detector

Filter

VCO

RF

ADC

DDC

I_1

Q_1

÷ N

Frequency Divider

Phase Detector

Filter

VCO

LO_1

RF_1

ADC

DDC

I_2

Q_2

÷ N

Frequency Divider
Better Synchronization through Modularity

Use of a common local oscillator for synchronization improves measurement quality.
Channel-to-Channel Phase Accuracy

Histogram of Phase Offsets at 2 GHz

- STDEV = 0.37°
- STDEV = 0.045°
Four-Channel Phase-Coherent Acquisition

- Local Oscillator
- Downconverters
- Digitizers
- Shared LO
- Shared ADC Clock
Two-Channel Synchronized Generation

Upconverters

AWGs

Local Oscillator

Shared DAC Clock

Shared LO
Reducing Complexity in Design and Size!

Traditional Instruments

PXI
Example: Direction Finding

Objective: To extract information about signal sources direction by using phase information at multiple receiver antennas.

SIGINT Algorithm is a Direction Finding Algorithm running on a general purpose processor or FPGA.

Signals Input is multiple RF inputs.

Output is a Display Of the analysis.
Multi Channel Receiver
Multi Channel Receiver
RF Environment Simulator
NI 2nd Generation VST
How Big Was the 1st Generation VST?

Total number of VST’s NI customers are using, stacked on top of one another is taller than any man-made structure on earth.

- **Burj Khalifa**
  - Dubai, UAE
  - 2722’

- **Taipei 101**
  - Taipei, Taiwan
  - 1667’

- **Empire State**
  - New York, NY
  - 1454’

- **Eiffel Tower**
  - Paris, France
  - 984’

- **Great Pyramid**
  - Giza, Egypt
  - 455’
Powerful Software Experience

INTERACT

Soft Front Panel

AUTOMATE

RFmx

CUSTOMIZE

LabVIEW FPGA
NI’s 2nd Generation VST is better in **EVERY** Aspect

- **NEW** high speed serial interface (12 Gbps, 4 Tx & 4 Rx Lanes)
- 6.5 GHz VSG with 1 GHz Instantaneous BW
- 10dB Higher Output Power
- 60 MHz, 8 port high-speed parallel digital interface
- 4.7X More DPS481 Slices on Virtex-7 FPGA
- Only 2 PXI Slots!!
- 6.5 GHz VSA with 1 GHz Instantaneous BW
- Better EVM Performance
Wider Frequency Coverage

1st Generation VST

2nd Generation VST

Avionics

GSM/UMTS/LTE

GNSS

GSM/UMTS/LTE

Wi-Fi/Bluetooth

LTE

GSM

WCDMA

LTE

CDMA2K

TD-SCDMA

EV DO

Flexible measurement IP for applications from avionics to Wi-Fi

9 kHz

65 MHz

6.5 GHz

DC 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz 7 GHz

ni.com | NI CONFIDENTIAL
Small 2-Slot PXI Footprint

Externally Share TX and RX LOs for MIMO Configurations

Synchronize up to 8 VST’s in a Single 18-slot chassis

NI-TCLK Ensures Scalable Synchronization

NI WLAN SFPs Support up to 8x8 MIMO
Flexible Digital Interfacing Options

Digital I/O ports are directly connected to FPGA fabric and can be synchronized with VSG and VSA in real-time.

Stand-Alone MCX PFI Trigger Line

42-Pin Nano-Pitch Digital Connector

50 MHz, 8 port high-speed parallel digital interface

12.5 Gbps, 8 port high-speed serial multi-gigabit transceiver (MGT)
Customize with FPGA Extensions

The **FUNCTIONALITY** of industry-standard measurement software

The **FLEXIBILITY** of LabVIEW programmable FPGA

Instrumentation **TAILORED** for your application
Radar Design and Test

- FPGA-based emulation and host-based generation & analysis API
- Phase Coherent Radar Tx and Rx
- User configurable radar parameters such as # of targets, RCS, doppler-shift & range
- Resolve small changes in distance with wider bandwidth
RF Record and Playback

- Record and Playback up to 1 GHz of instantaneous BW with a single instrument
- Examples support streaming to N RAID volume simultaneously
- Analyze waveforms offline
- Stream 1 GHz BW from each of the 2 VSTs in 1085 Chassis @10GB/s to 2 SAS/SSD RAIDs

NI VST
1 GHz Bandwidth
Zero Copy Streaming
- Multi-Device Streaming
- Multi-RAID Streaming

NI LabVIEW
NI RFSA/RFSG
NI LabVIEW FPGA

PXI System
Controller
RAID
VST

Antennas
Multi-DDC Channelizer

- Wideband signal acquisition of up to 1 GHz instantaneous bandwidth
- Individually configurable narrow channels
- FPGA based Multi-DDC channelization technique
- Future Support for DDC, Polyphase, PFT channelizer on FlexRIO
Thank You