NIDays

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Prototyping with Software Defined Radio for Industry, Academic and Defense Applications

Jeremy Twaits
Senior Marketing Engineer
RF & Communications

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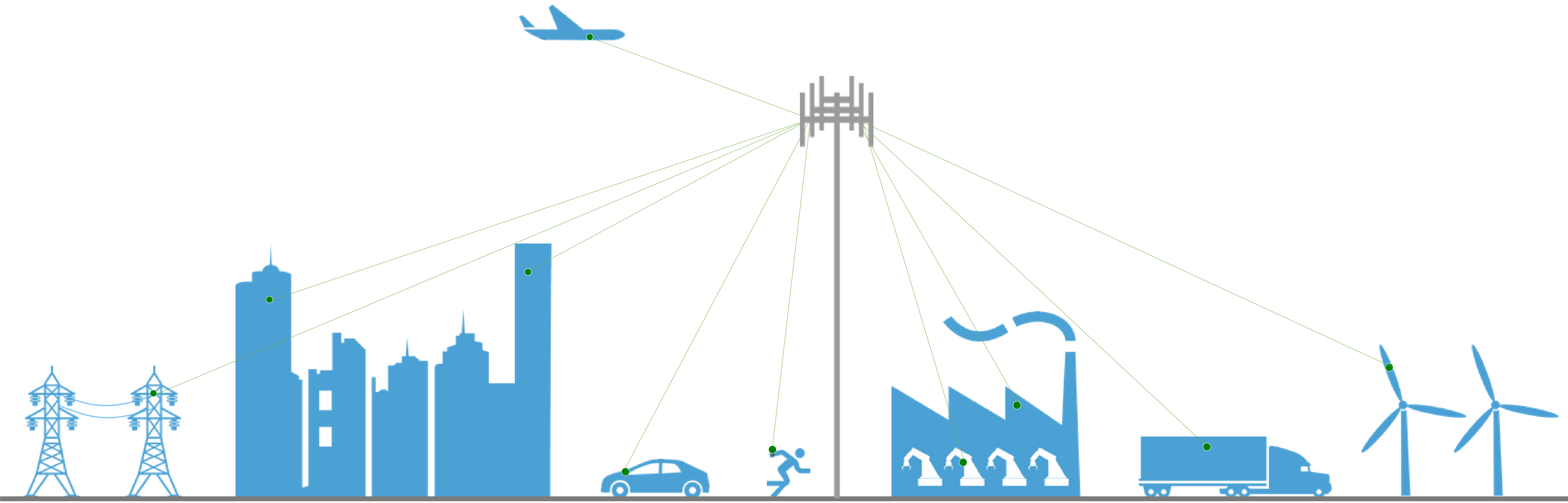
Agenda

- Introduction and Applications
- Software Defined Radio Architecture and Platforms
  - Hardware
  - Software
- 5G Vectors of Research
  - PHY Enhancements
  - Massive MIMO
  - mmWave
  - Wireless Networks

Connecting the Hyper Connected Everything

Starts with Prototyping



Data Rate

Capacity

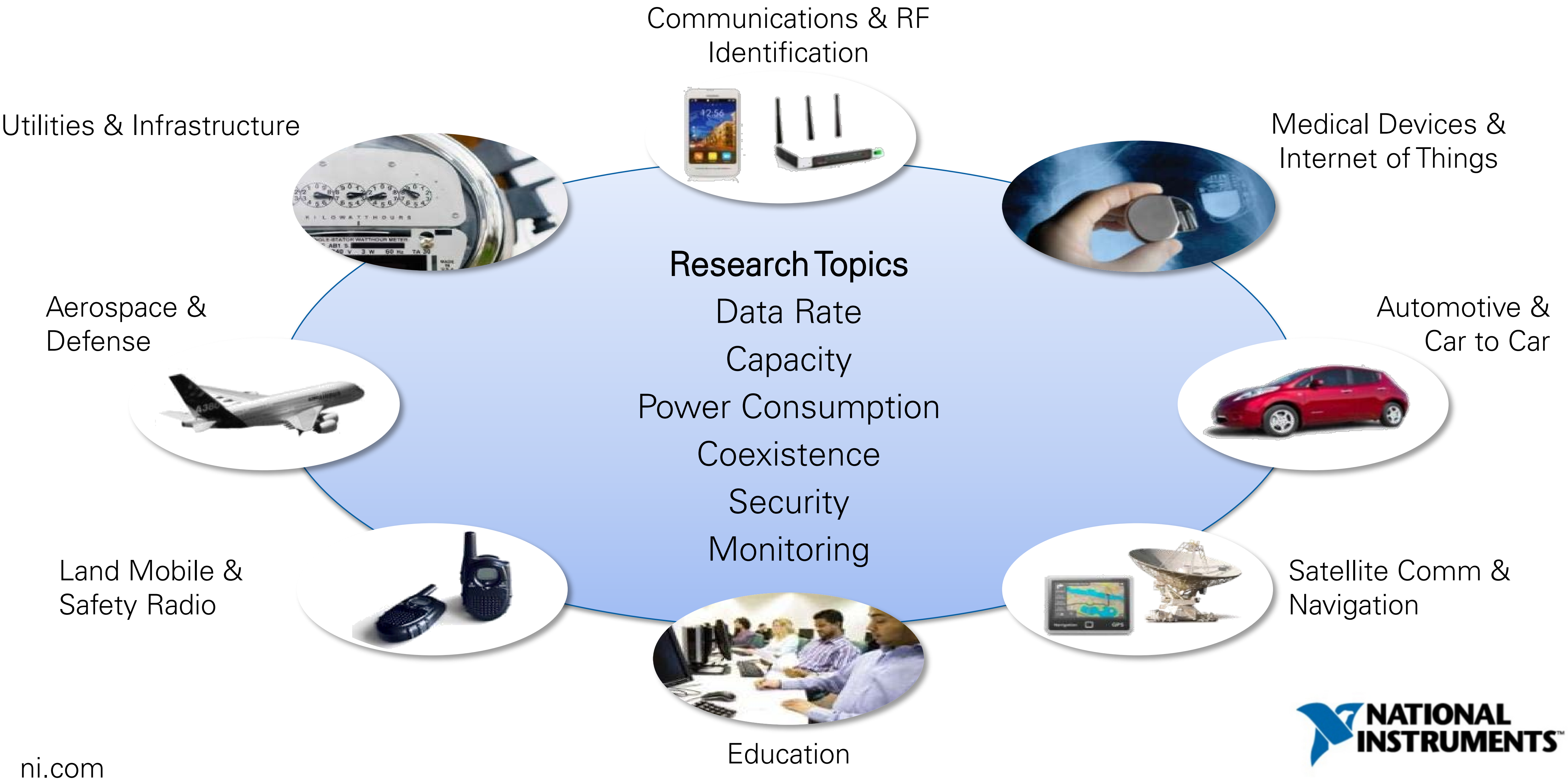
Power Consumption

Coexistence

Security

Monitoring

SDR Algorithm Prototyping Applications



High-Resolution Software Defined Radar System for Target Detection

Sandra Costanzo, Università della Calabria

Flexible Radar Prototyping

- Rapidly switch between synthetic-aperture radar (SAR), Radar Meteo, Doppler, etc.
- Easy implementation of new radar signal processing algorithms.
- Low overall system cost with wide frequency coverage

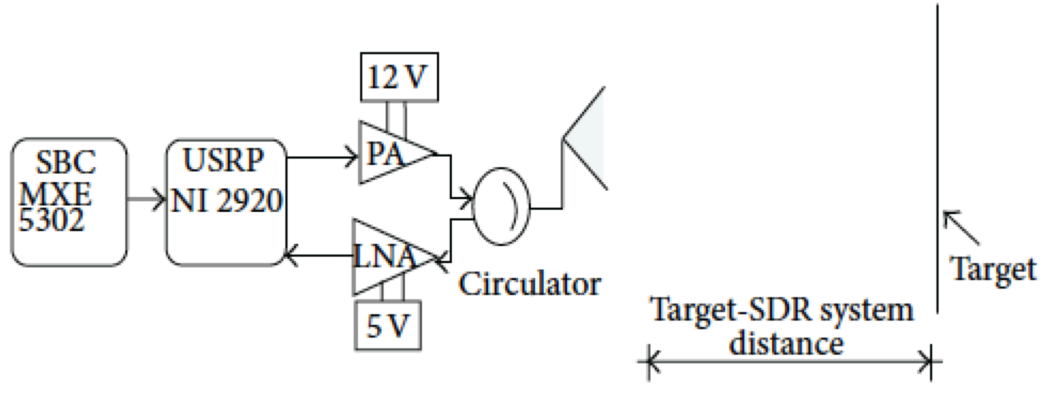


FIGURE 10: Scheme of indoor test setup.

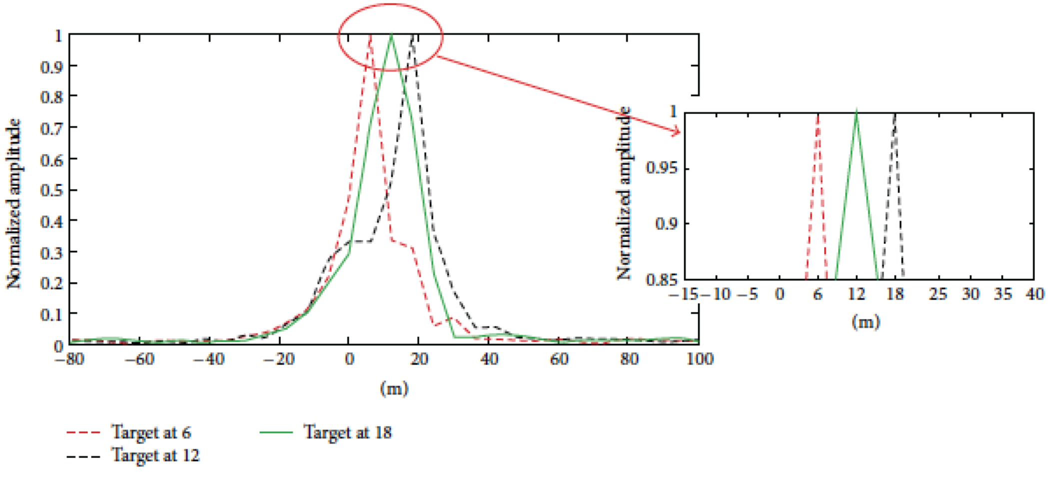


FIGURE 8: Retrieved signal peaks for different target positions.

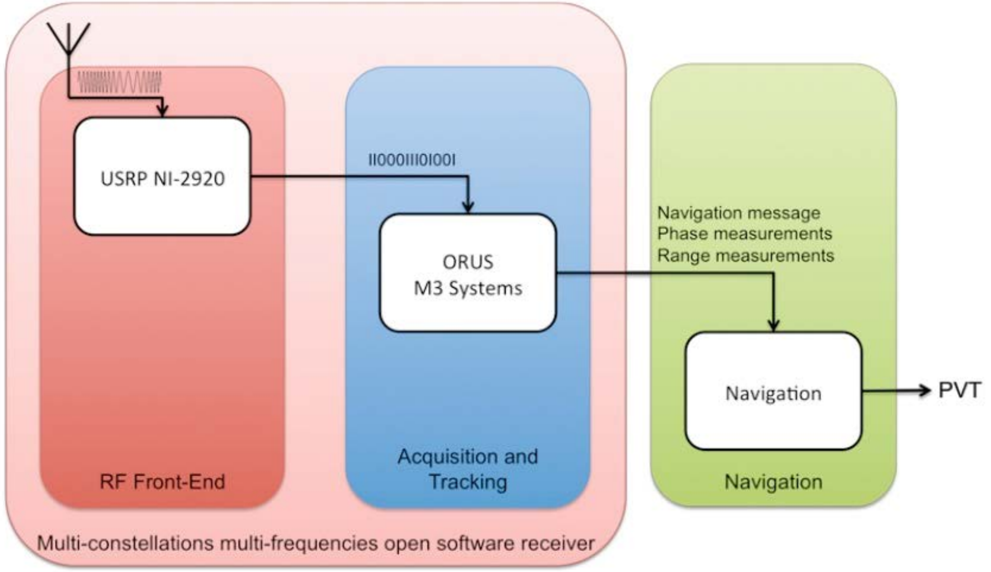
Journal of Electrical and Computer Engineering
Volume 2013, Article ID 573217, 7 pages
http://dx.doi.org/10.1155/2013/573217

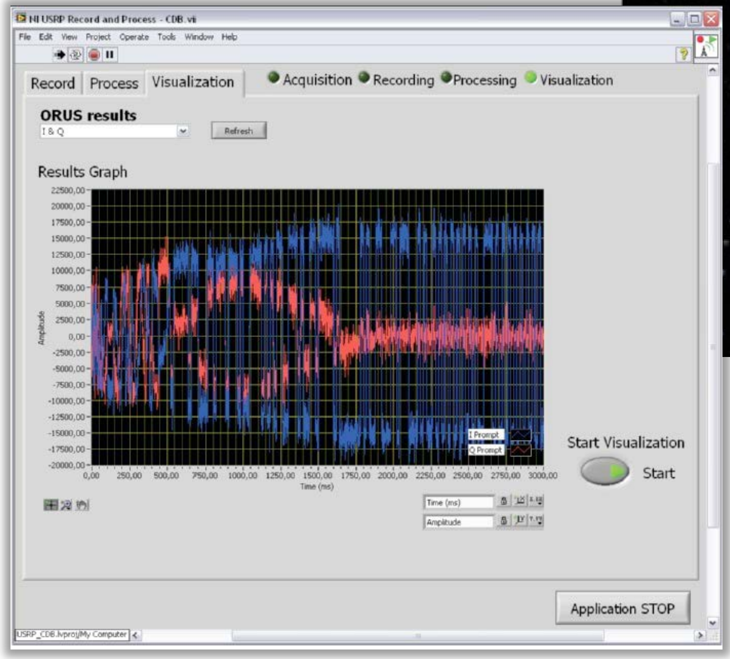
Developing an Open Multiconstellation GNSS Receiver

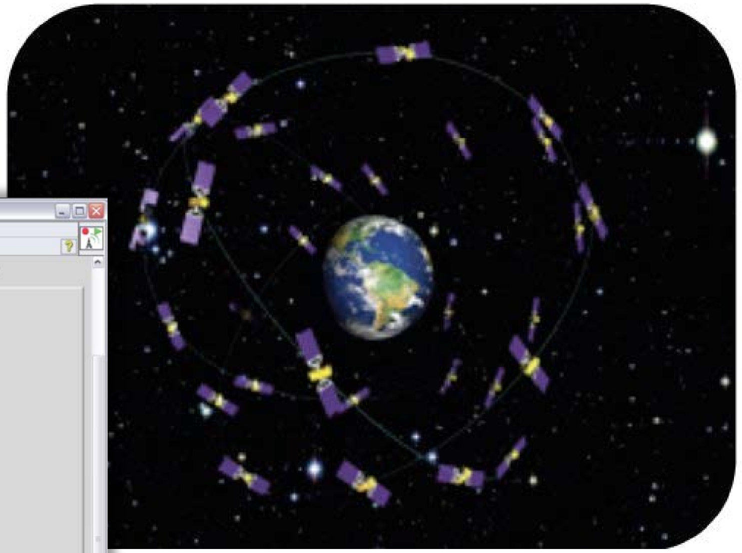
Olivier DESENFANS, M3 Systems

Multiconstellation Position Tracking

- Track multiple global navigation satellite constellations concurrently, recording, processing, and visualizing the results
- Acquisition performed by ORUS (open software receiver developed by M3)
- Current coverage for both GPS (United States) and Galileo (Europe) constellations







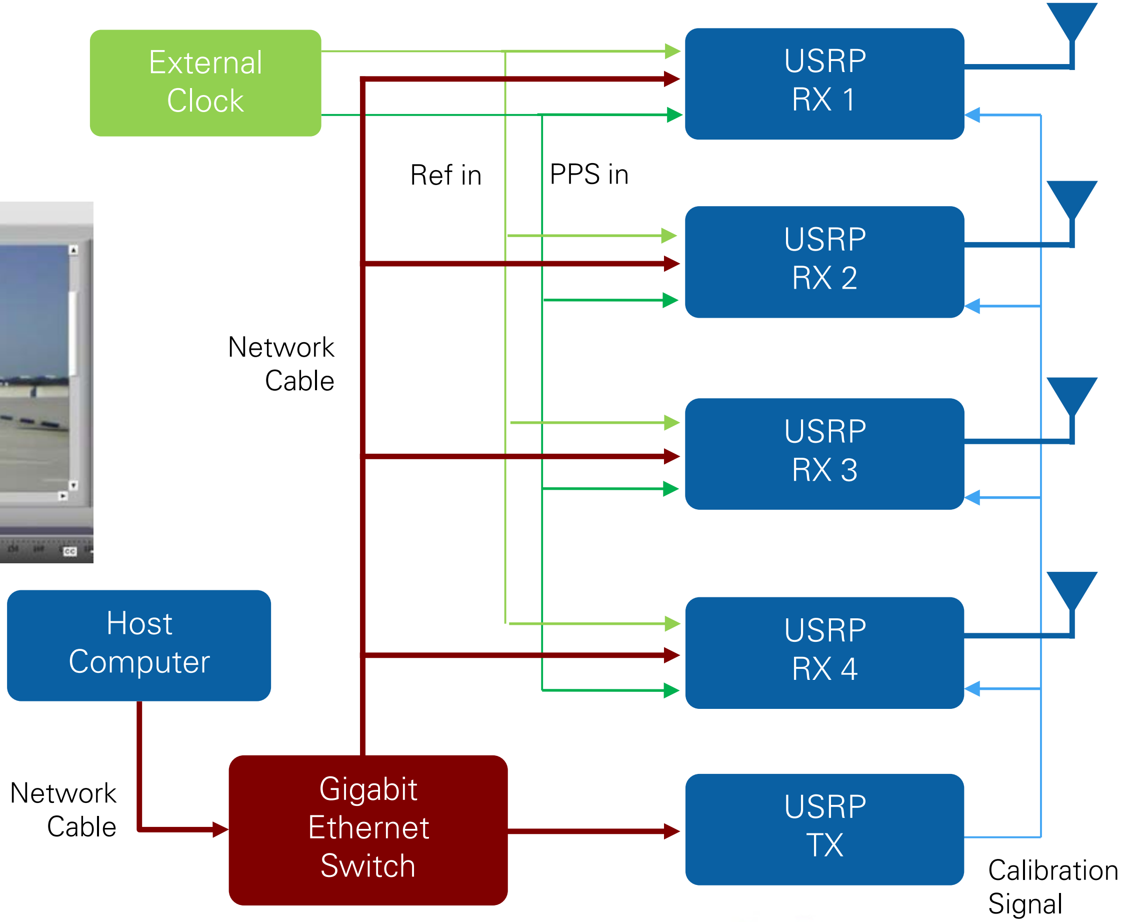
http://sine.ni.com/cs/app/doc/p/id/cs-15407

Position Detection & Localisation

Dr. Athanassios Manikas, Imperial College

- Testing MUSIC direction finding algorithm
- Rapid prototyping in LabVIEW with MathScript RT
- Synchronized up to 12 USRP devices
- Reference provides continuous phase alignment compensation

Direction Finding (uniform linear array)



Live Demonstration & Source Code: https://youtu.be/qBvpllCqDR0

Software Defined Radio Architecture

Multiprocessor Subsystem

Real-time signal processor

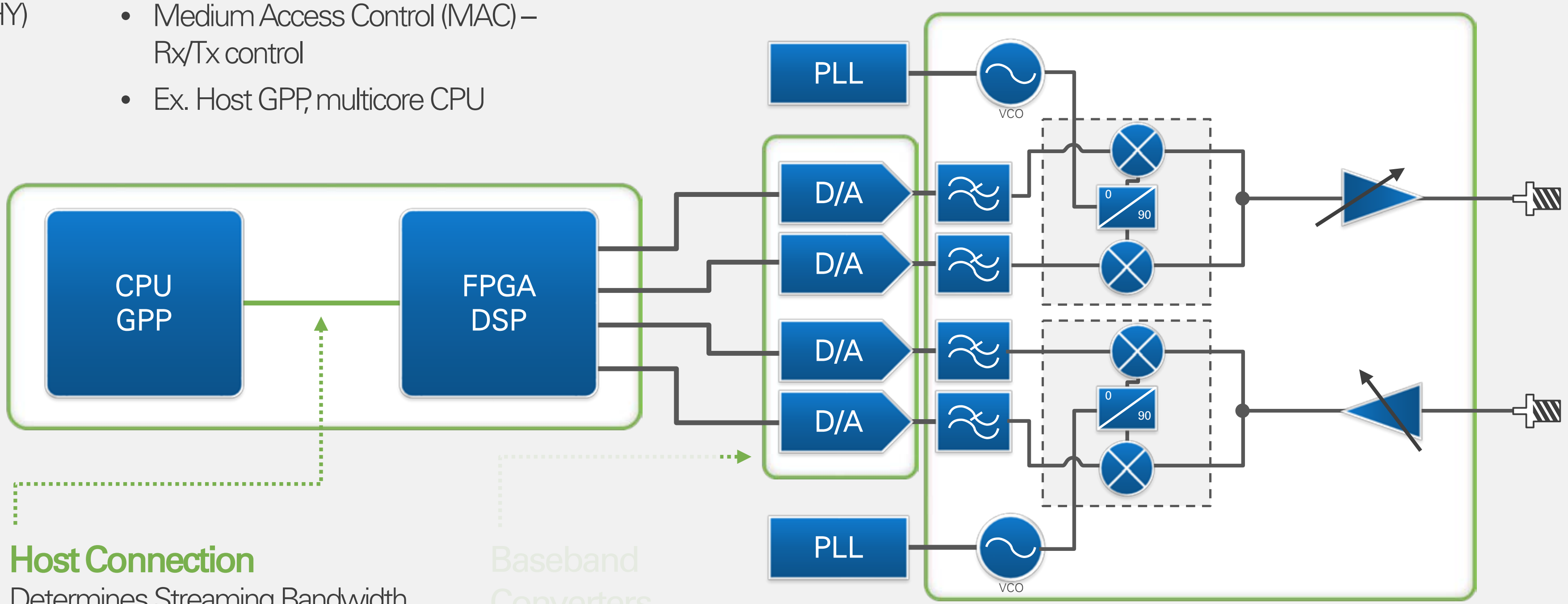
- Physical Layer (PHY)
- Ex. FPGA, DSP

Host processor

- Medium Access Control (MAC) – Rx/Tx control
- Ex. Host GPP, multicore CPU

RF Front End

- General Purpose RF
- Dual LOs
- Contiguous Frequency Range



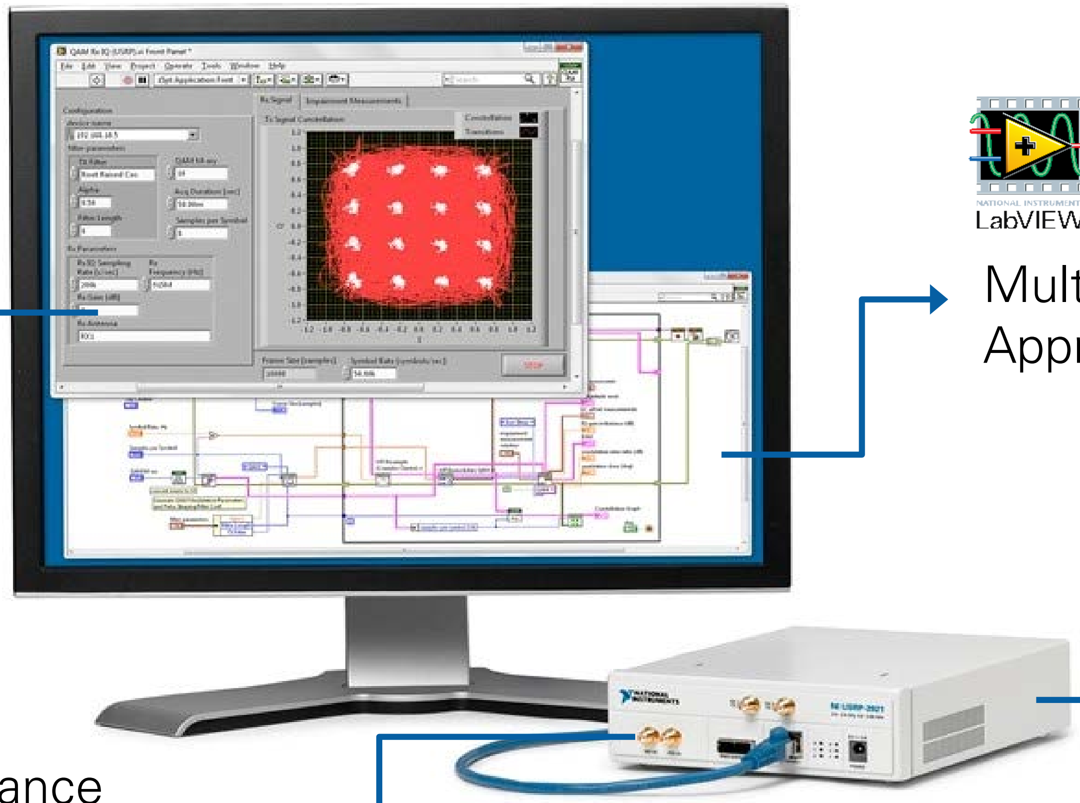
Host Connection

Determines Streaming Bandwidth
Ex. Gigabit Ethernet, PCI Express.

Baseband Converters

NI USRP
Software Defined Radio Ecosystem

Extensive Analysis Libraries



GNURadio

GCC

LabVIEW

Multiple Programming Approaches

NI Universal Software Radio Peripheral (USRP) Up to 6 GHz

High-performance FPGA-Based Architecture

NI SDR Hardware Platforms

FlexRIO, NI 579x

- Frequency Range: 200 MHz to 4.4 GHz (aligned)
- FPGA: Kintex-7 410T
- Bandwidth: 100 MHz/200 MHz
- Host Bus: PXI Express x4 (~1600 MB/s)
- Calibration: Minimal, system

Wide BW & Shared LO

USRP RIO 294xR/295xR

New!

- Frequency Range: 50 MHz to 6 GHz options (coherent)
- FPGA: Kintex-7 410T
- **Bandwidth:** ***120 MHz bandwidth***
- Host Bus: PXI Express x4 (~800 MB/s)
- Calibration: Minimal, system

Advanced Research

USRP-292x/293x

- Frequency Range: 50 MHz to 6 GHz options (coherent)
- FPGA: Host processing
- Bandwidth: 20 MHz bandwidth
- Host Bus: 1 Gb Ethernet (100 MB/s)
- Calibration: None, user

Host Streaming

USRP-290x

New!

- **Frequency Range: 70 MHz to 6 GHz**
- FPGA: Host processing
- Bandwidth: 56 MHz bandwidth (theoretical)
- Host Bus: USB 3.0/USB 2.0
- Calibration: None, user

Teaching

NI USRP-2900 / NI USRP-2901 Teaching Platform

New!

Turnkey Courseware Topics

- ✓ Intro to Communications
- ✓ Digital Communications

Key Benefits

- Affordable
- Plug and Play (USB 3.0/USB 2.0)
- Expanded performance (frequency, bandwidth, channels)

Reducing the cost of building a teaching lab by more than 60%!

Features

- Built-in 2x2 MIMO Support
- Continuous coverage from 70 MHz to 6 GHz
- Up to 56 MHz of bandwidth
- Convenient USB 3.0 connectivity
- LabVIEW Comms ONLY

NI USRP RIO: 120 MHz Bandwidth

Software Defined Radio

Applications

- 5G wireless prototyping
- High-channel-count MIMO
- Wide bandwidth, low latency

Features

- 2 channel Tx and Rx with RF options 50 MHz–6 GHz
- Customizable Xilinx Kintex-7 FPGA, 410T
- Optimized RF performance (400 point characterization)
- Powered by the LabVIEW RIO Architecture
- **120 MHz Real-time Bandwidth**
- PCI Express x4, 800 MB/s streaming
- GPS disciplined clock option

New!

Audience

- Industry research
- Mil/aero/gov
- Academic research

Front

Back

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NI USRP RIO Cabled PCIe Interface Options

PXI Interface

MXIe x4 Cabled PCIe

800 MB/s (200 MHz BW)

Host PC

MXIe x4 Cabled PCIe

800 MB/s (200 MHz BW)

Host Laptop

MXIe x4 to x1 Cabled PCIe

200 MB/s (50 MHz BW)

* Max possible data rate (theoretical real-time bandwidth)

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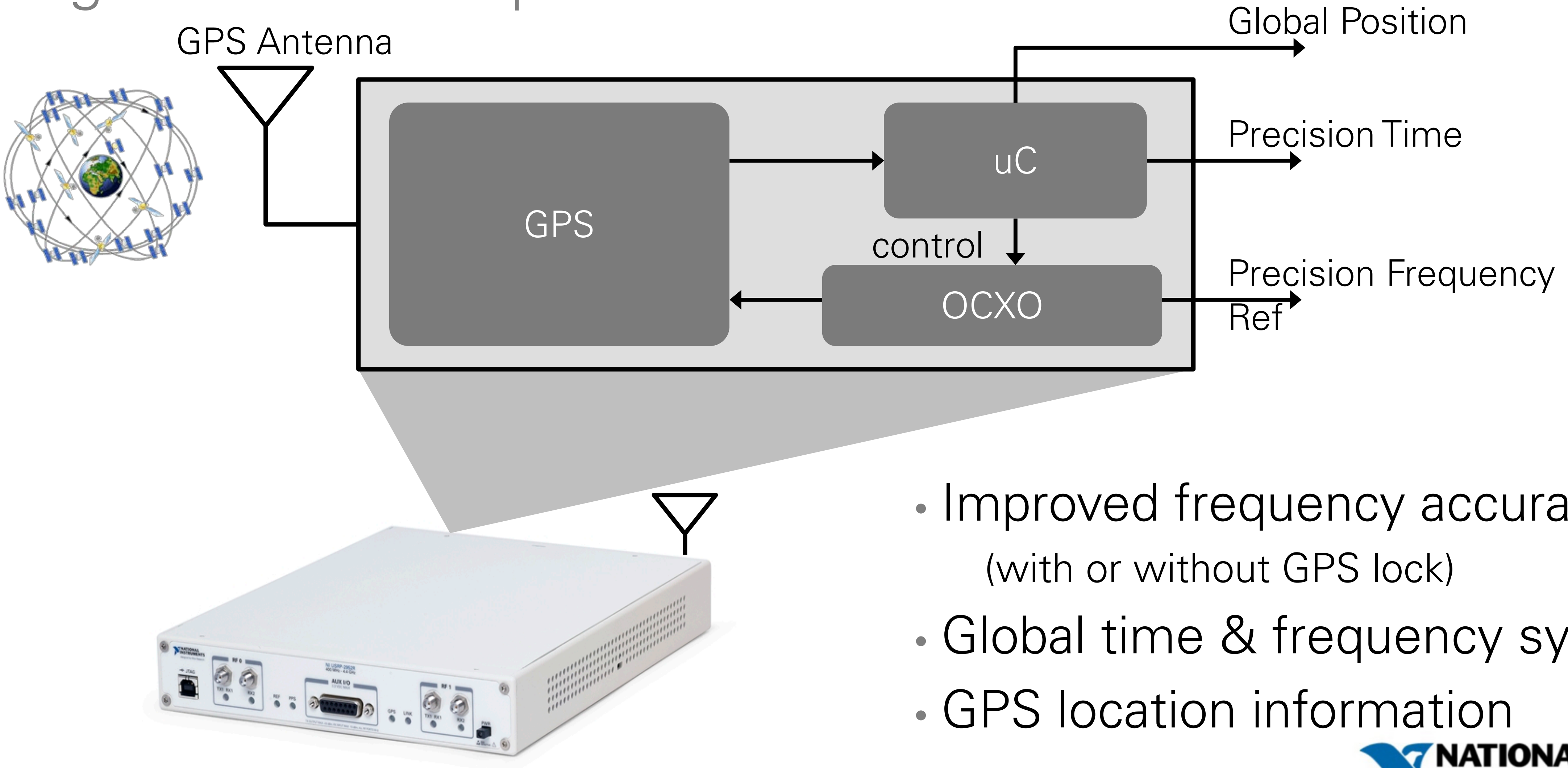
NI USRP RIO

Integrated GPS-Disciplined Clock



NI USRP-295xR Devices

- Improved frequency accuracy
  (with or without GPS lock)
- Global time & frequency sync
- GPS location information

Software Defined Radio Architecture

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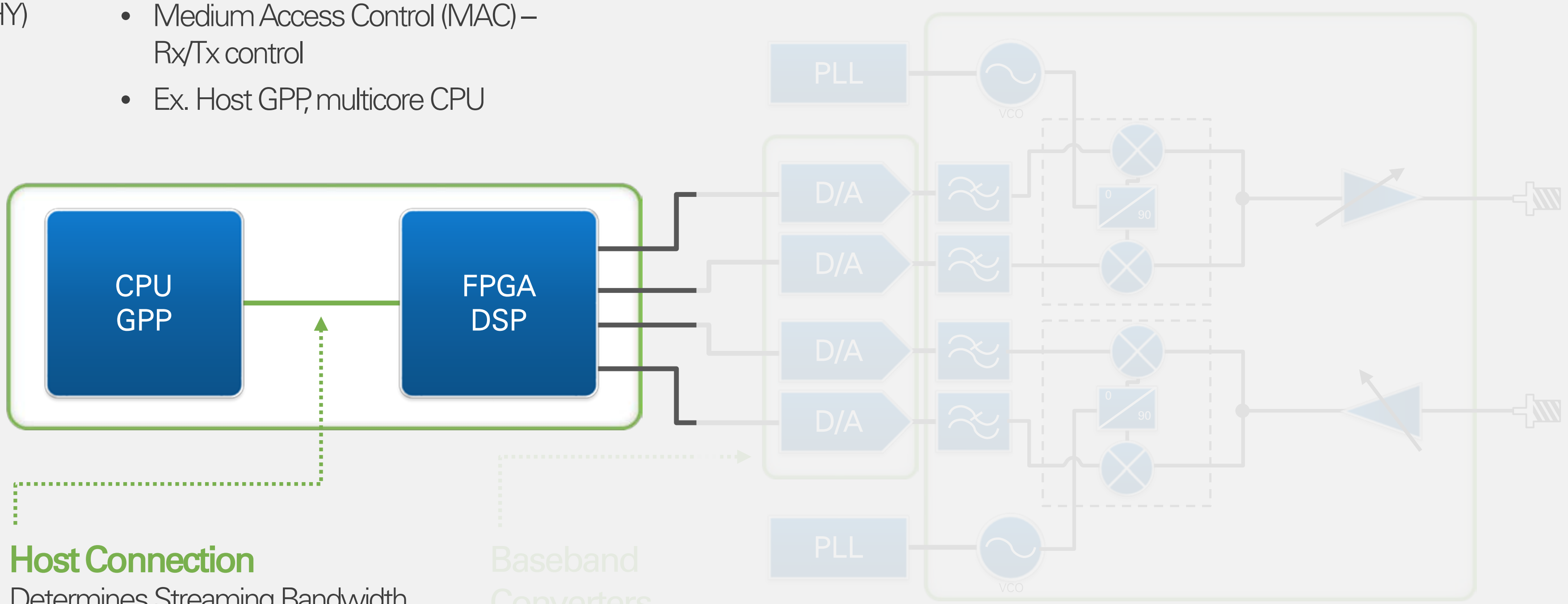

RF Front End
- General Purpose RF
- Dual LOs
- Contiguous Frequency Range

Host Connection

Determines Streaming Bandwidth
Ex. Gigabit Ethernet, PCI Express.

Baseband Converters

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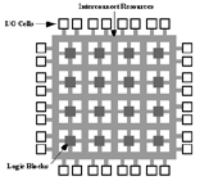
Today’s Development Challenge

Tools

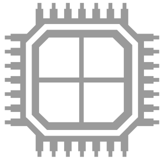
- Math (.m files)
- Simulation (Hybrid)
- User Interface (HTML)
- FPGA (VHDL, Verilog)

- Host Control (C, C++, .NET)
- DSP (Fixed Point C, Assembly)
- H/W Driver (C, Assembly)
- System Debug

Targets



FPGAs



Multicore Processors

- SDR development requires multiple, disparate software tools
- Software tools don’t address system design

- **Long Learning Curves**
- **Limited Reuse**
- **Need for “Specialists”**

- **Increased Costs**
- **Increased Time to Result**

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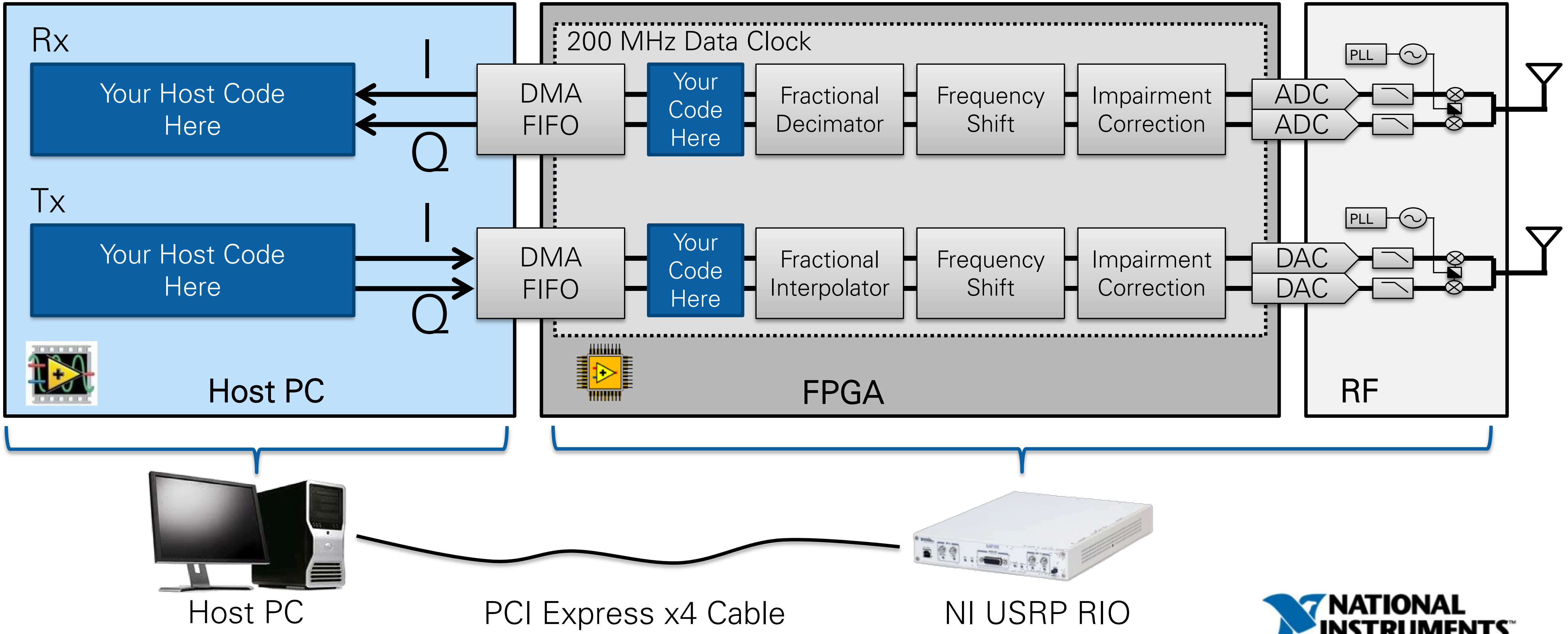
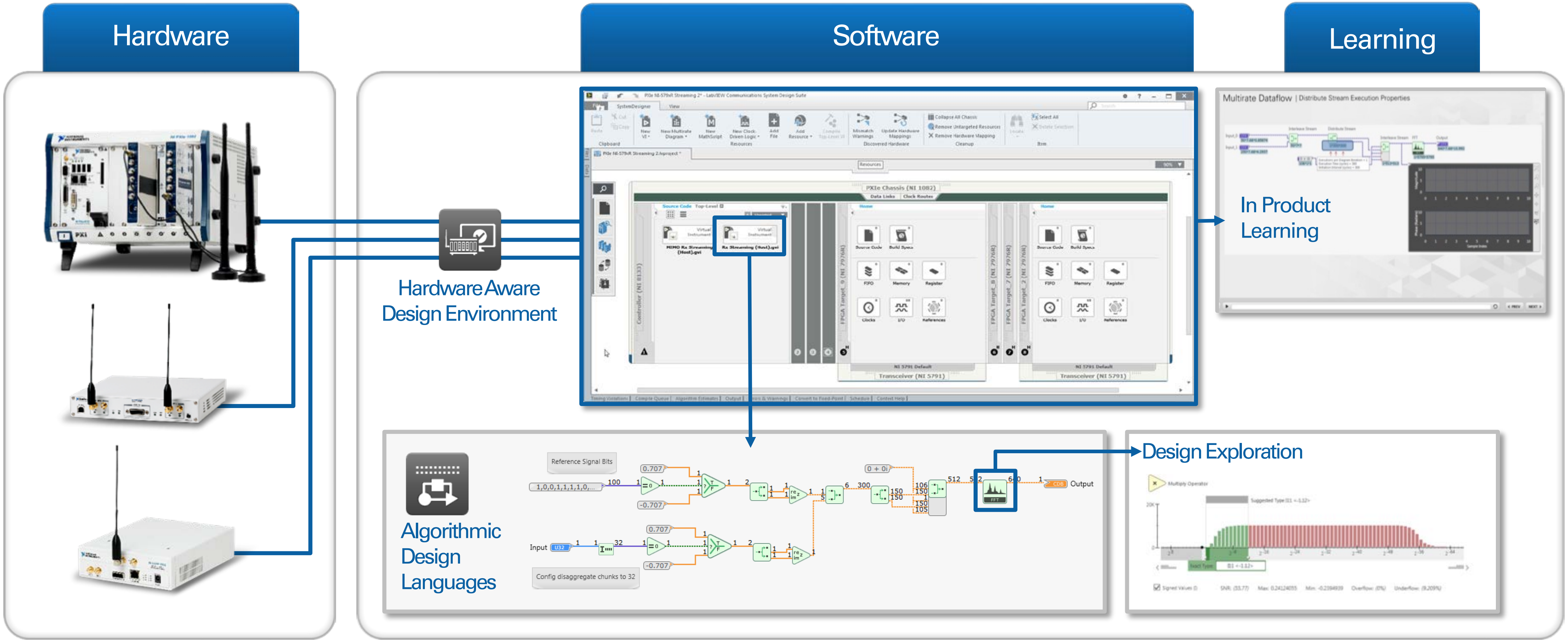
NI USRP RIO Driver Software (Host + FPGA)



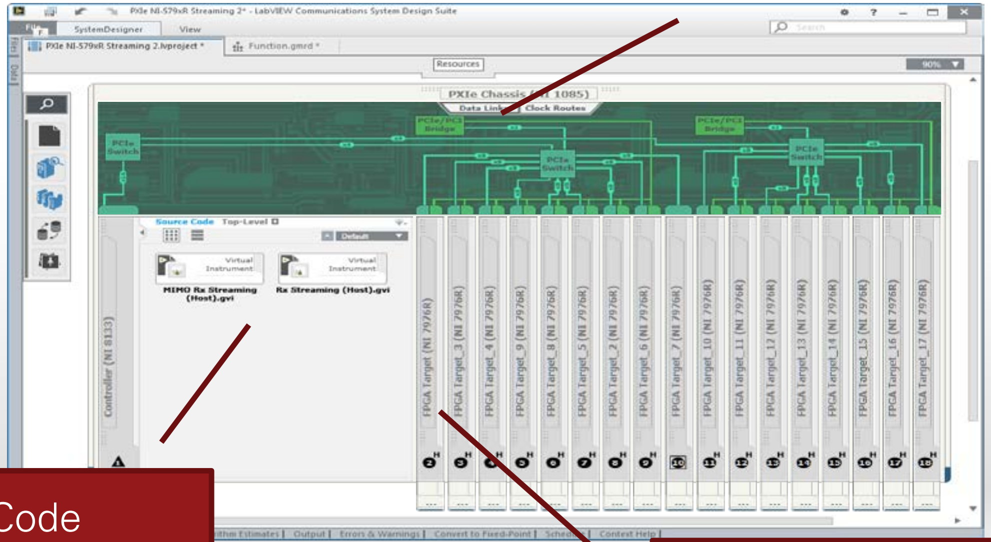
LabVIEW Communications System Design

The Next Generation Platform for Software Defined Radio



Hardware-Aware Design Environment

System Throughput and Latency



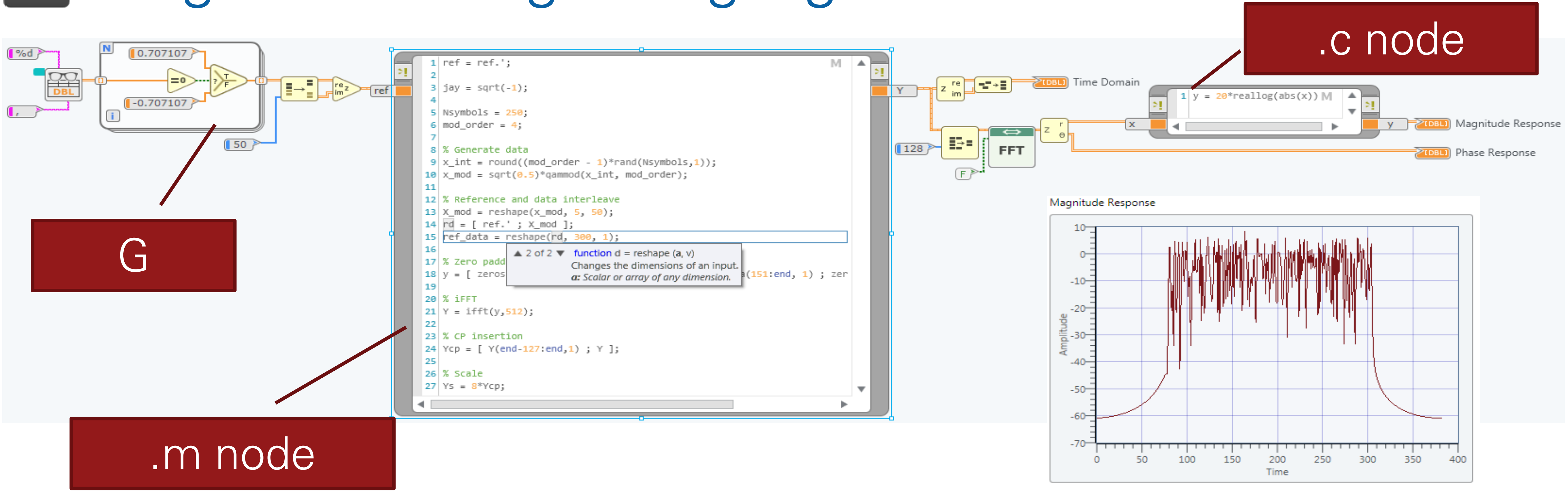
Source Code Management & Synchronised Execution

Hardware Management

Interactive, visual representation of the physical system that:

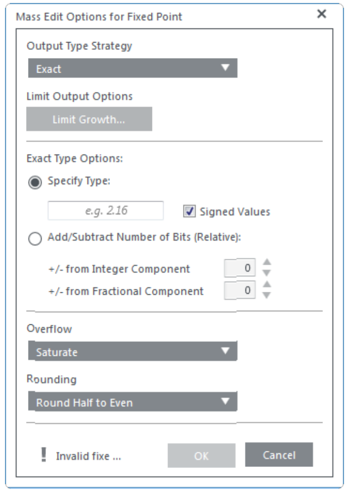
- Enables system discovery and verification of system setup
- Provides hardware documentation and visualisation of available resources
- Allows for design partitioning and deployment
- Enables articulation of system architecture

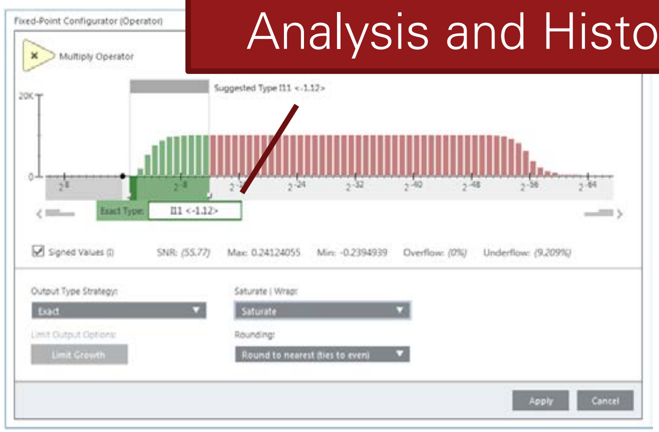
Algorithm Design Languages: Processor



- Flexible design approach with dataflow (G) and text nodes for C and .m
- Text nodes for C and .m support syntax highlighting and function completion
- Both G and the text nodes support full debugging with breakpoints and probes

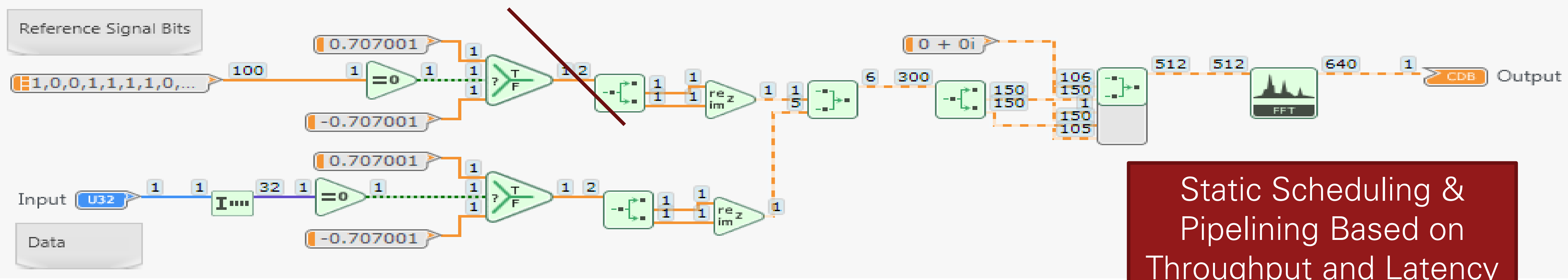
Multirate Design Exploration



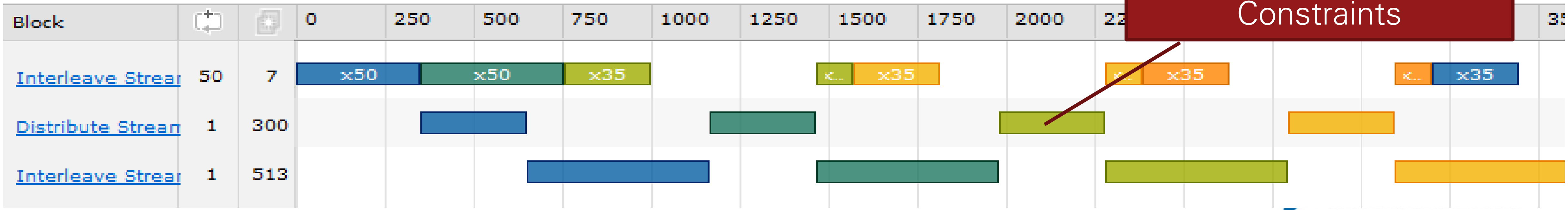


Float to Fixed Analysis and Histogram

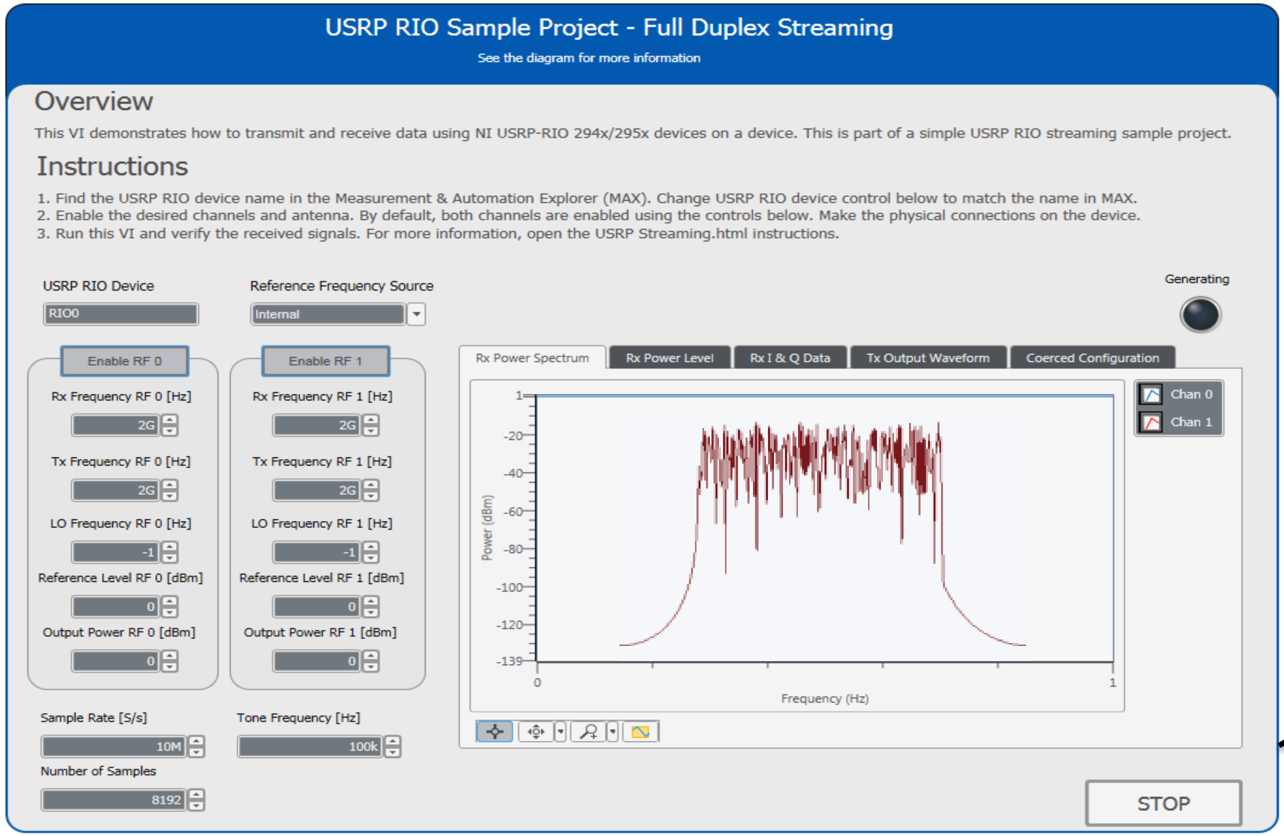
Intuitive Multirate DSP Design



Static Scheduling & Pipelining Based on Throughput and Latency Constraints



Ready-to-Run Examples



FlexRIO (Xilinx-7 Series) & 579x RF Adapters*

NI USRP (292x/293x)

NI USRP RIO (294x/295x)

Sample Projects: Source Code to Start Your Design

- Synchronization and Timing Control across multiple RF Front-Ends & FPGAs
- Corrected RF, Arbitrary Rate Conversion, Frequency Shift

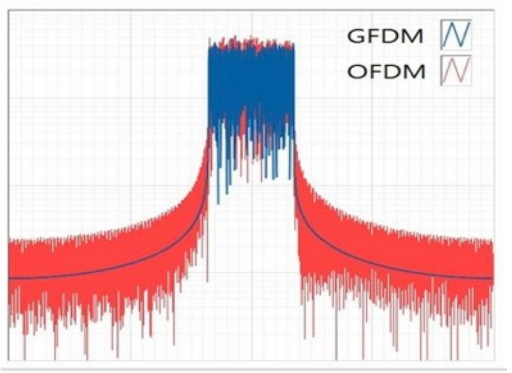
* Check FAQ for list of supported FlexRIO HW

5G Vectors

PHY Enhancements

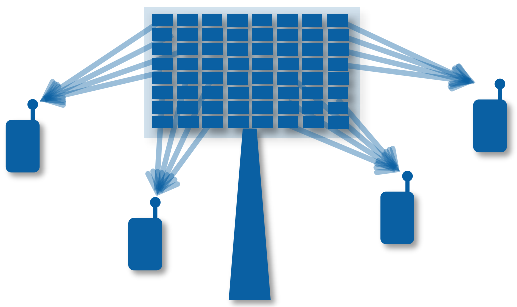
Improve bandwidth utilization through evolving PHY Level

- GFDM
- FBMC
- UFMC
- NOMA
- Full duplex
- LAA



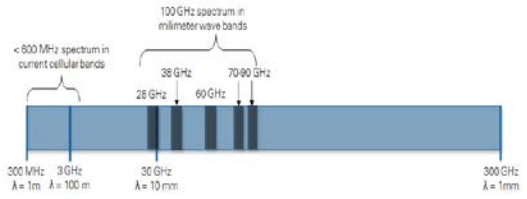
Massive MIMO

Dramatically increase number of antenna elements on base station



mmWave

Use potential of extremely wide bandwidths at frequency ranges once thought impractical for commercial wireless.



Wireless Networks

Consistent connectivity meeting the 1000X traffic demand for 5G

- Densification
- SDN
- CRAN

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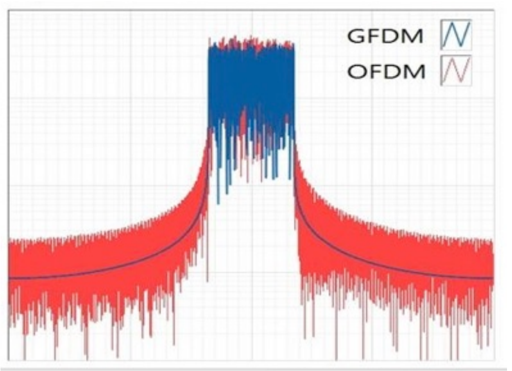

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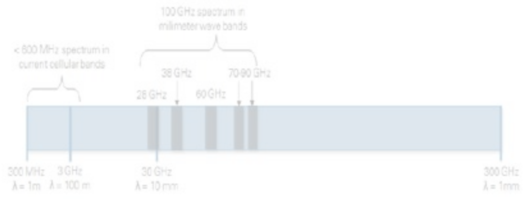

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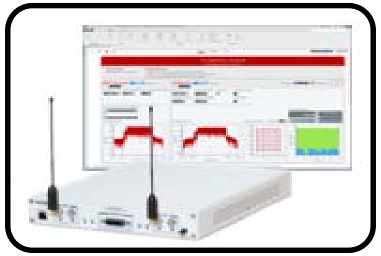
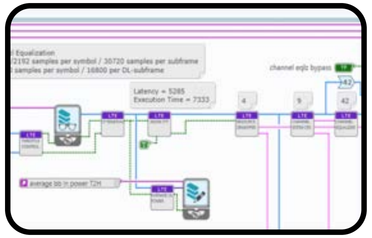
LTE and 802.11 Application Frameworks



Real-time wireless system implementation

- Ready to run PHY and basic MAC
- Communicate between devices or in loop-back mode



Open and Modular Source Code

- ~50% of FPGA resources available for customization
- Replace existing blocks with your own waveform designs

Fastest path from algorithm to prototype

- Single language for host and FPGA design in LabVIEW
- Documented for ease of use and understanding

Applications

- Customize LTE and 802.11
- LTE/802.11 coexistence
- New 5G waveforms

Updated!
16μS SIFS timing!

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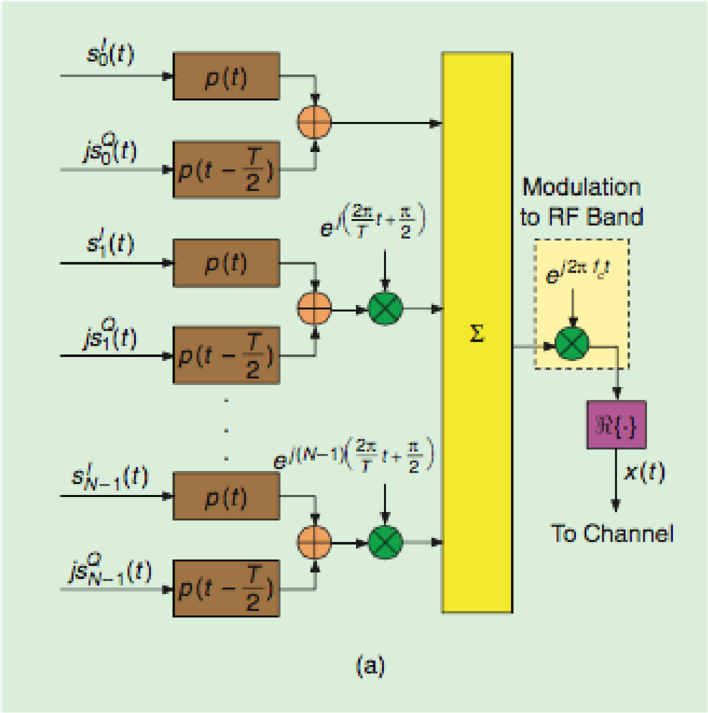
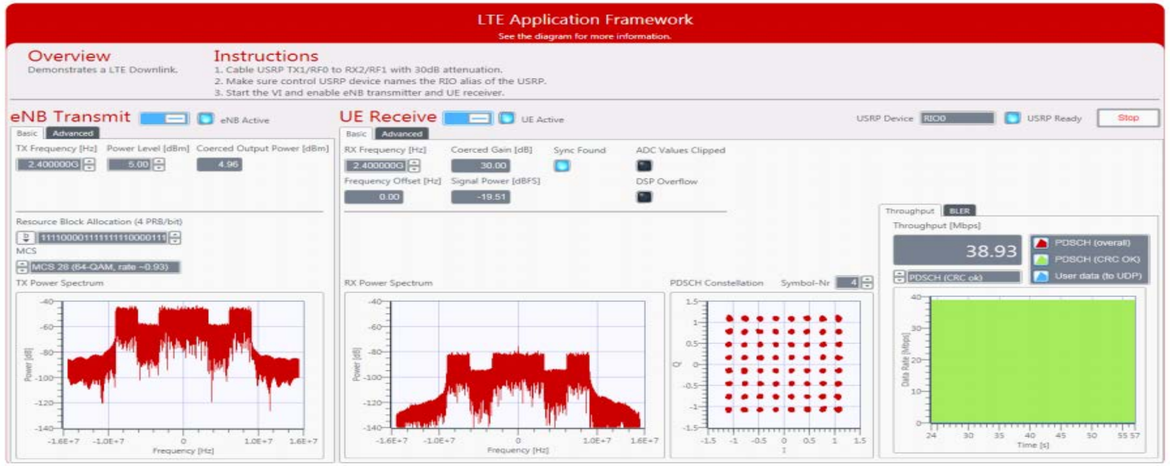
LTE Application Framework: New Waveforms

Go quickly from **concept**…



Source: B. Farhang-Boroujeny, "OFDM Versus Filter Bank Multicarrier," *IEEE Signal Processing Mag.*, Vol. 28, No. 3, pp. 92 – 112, May 2011.

…to **real-world prototyping**



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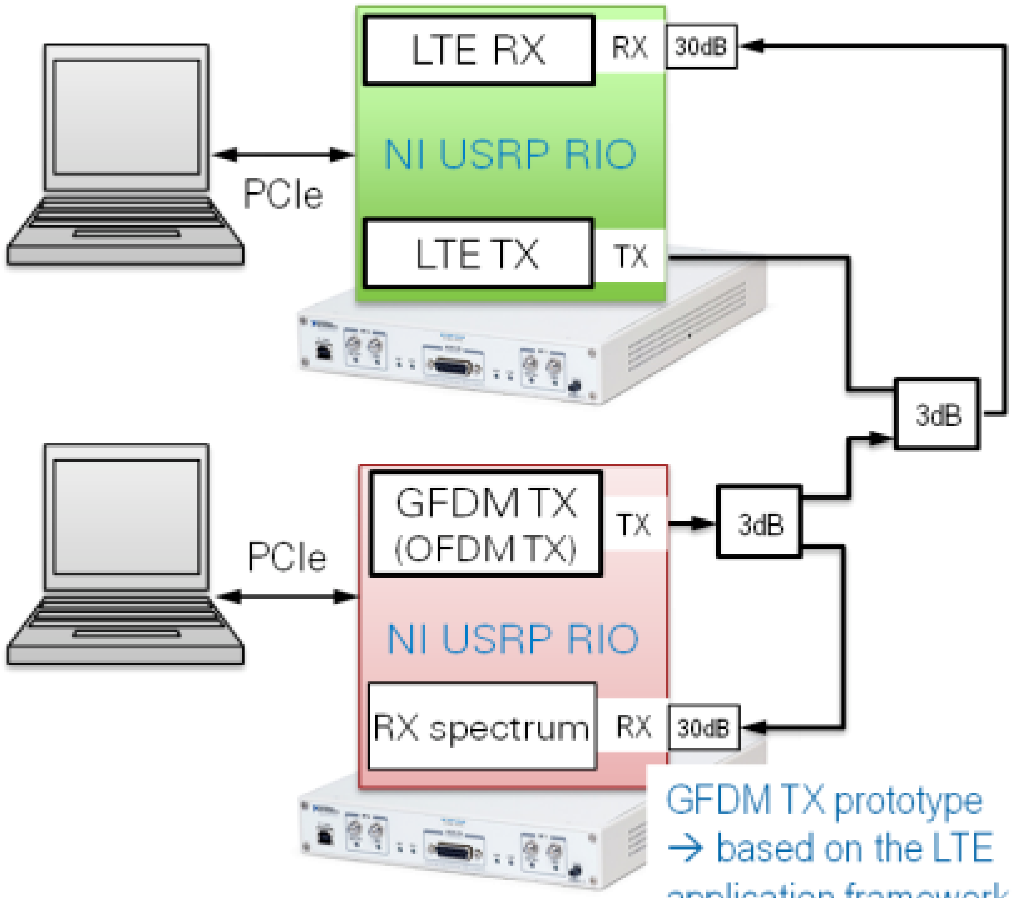
GFDM–LTE Coexistence Prototyping

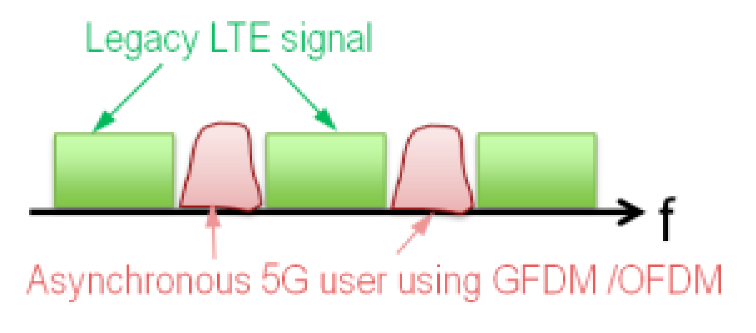


5G demo scenario

5GNOW

Fragmented spectrum use case with

- Synchronous LTE legacy link +
- Asynchronous 5G user using non-orthogonal GFDM waveform



Visualization/KPIs

- BLER of the legacy LTE system
- RX QAM constellations
- TX + RX power spectra

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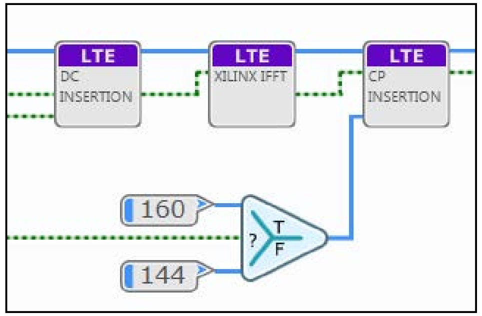
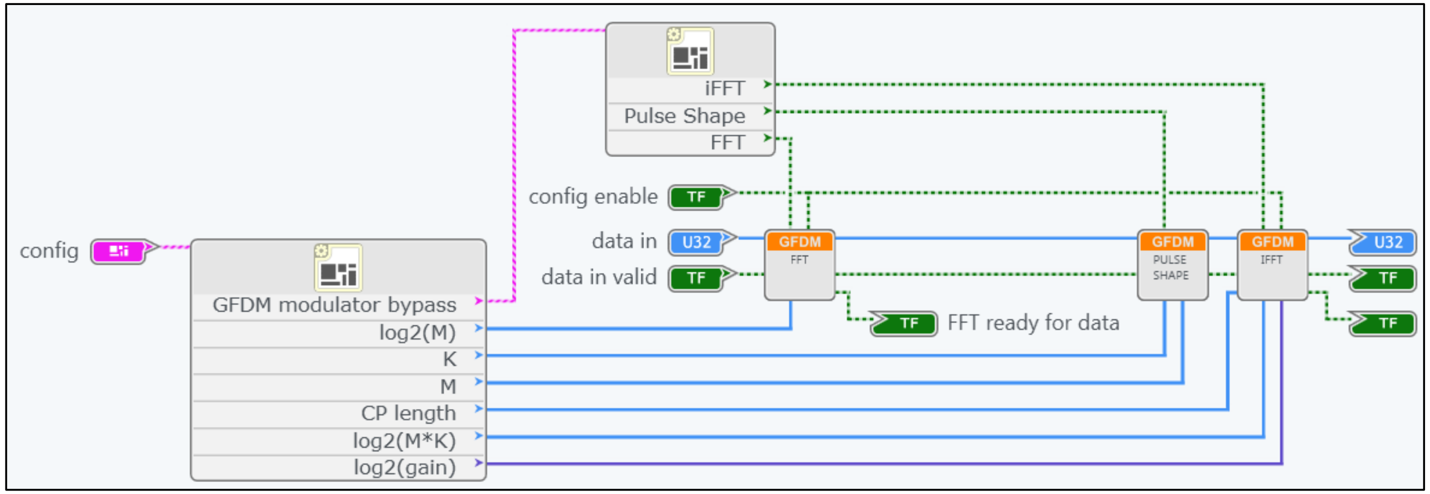
Modifying the LTE Application Framework for GFDM

- OFDM modulation:
  - Inverse FFT conversion
  - Cyclic prefix (CP) insertion



- GFDM modulation:
  - FFT conversion
  - Pulse shaping filter
  - Inverse FFT conversion



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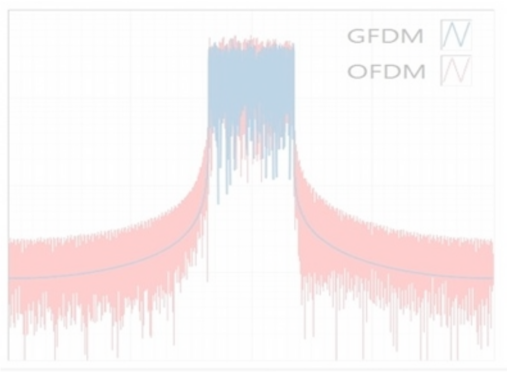

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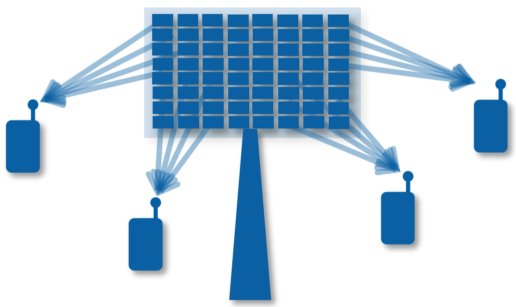

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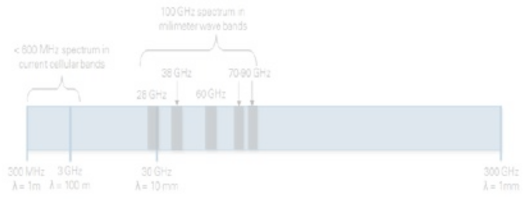

Wireless Networks

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NI and Massive MIMO

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National Instruments and Lund University Announce Massive MIMO Collaboration

New test bed leads the way for next-generation wireless systems research.

AUSTIN, Texas - Feb. 24, 2014 - National Instruments and Lund University today announced a collaboration on the development of a test bed capable of prototyping a massive multiple input, multiple output (MIMO) system. The test bed will consist of a massive MIMO base station with 100 transmit and receive nodes. Researchers can link several pieces of user equipment that simulate mobile devices with the massive MIMO base station. They can emulate a real-world scenario in order to evaluate how the performance of massive MIMO compares to theory.

LUND UNIVERSITY

KU LEUVEN

University of BRISTOL

SOUTHEAST UNIVERSITY

ZHENGZHOU UNIVERSITY

FUDAN UNIVERSITY

INDUSTRY

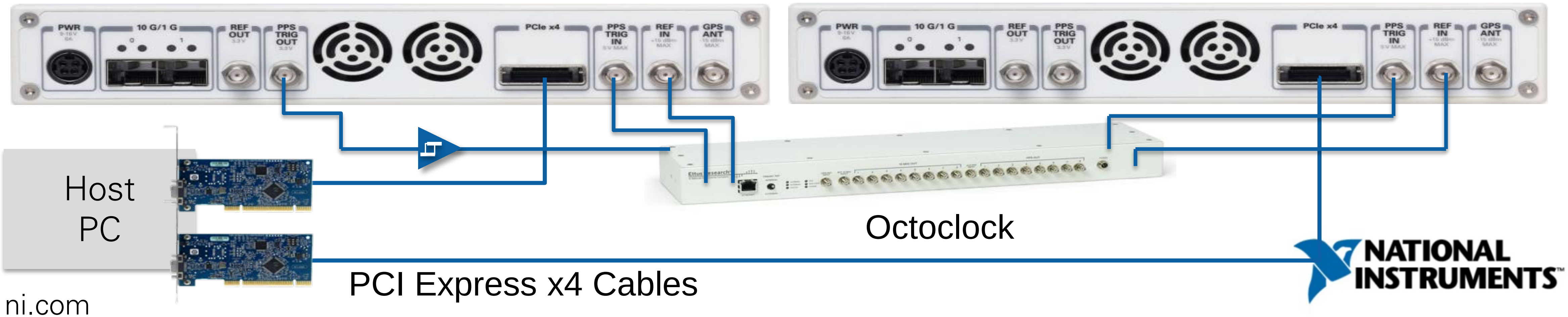
Industry leaders who wish to not be named.

Building High-Channel-Count Systems

- Mount 2 units in a compact 1U rack
- Sync time and freq with external 10 MHz and trig

Front: USRP RIO – 4x4 MIMO

Back: USRP RIO – 4x4 MIMO

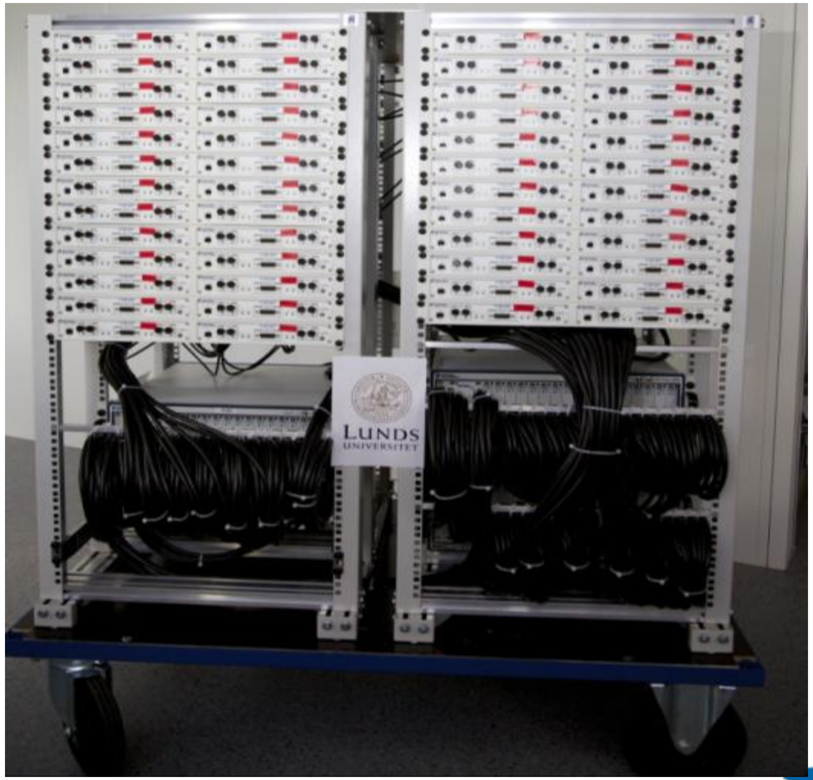


5G Massive MIMO at Lund University, Sweden

Goal: Build a cellular massive MIMO, 100x10 antenna system to validate theoretical results with real-time processing

Prof Ove Edfors

Prof Fredrik Tufvesson



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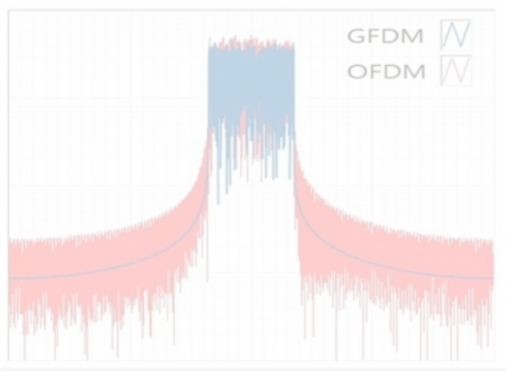

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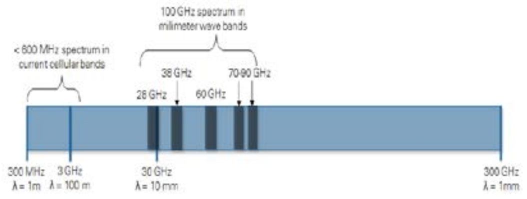

Wireless Networks

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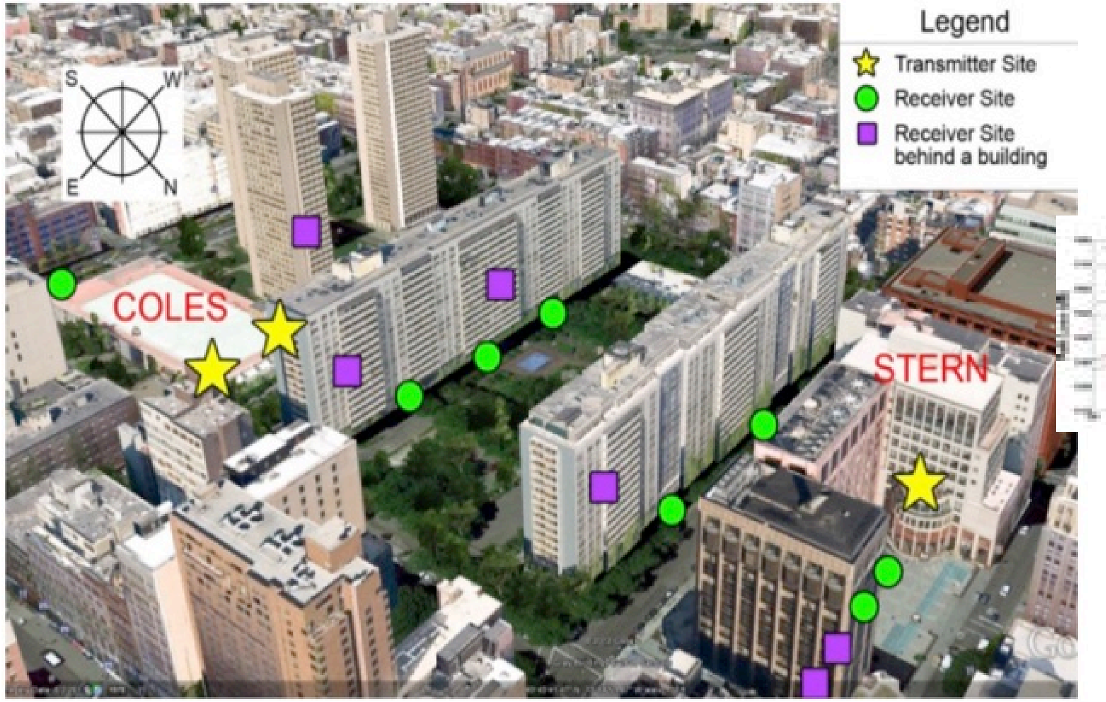
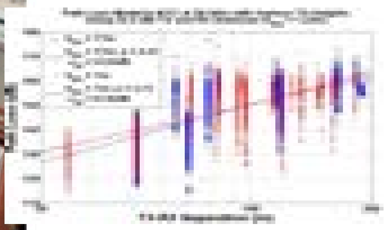
NYU Wireless: mmWave Channel Sounder

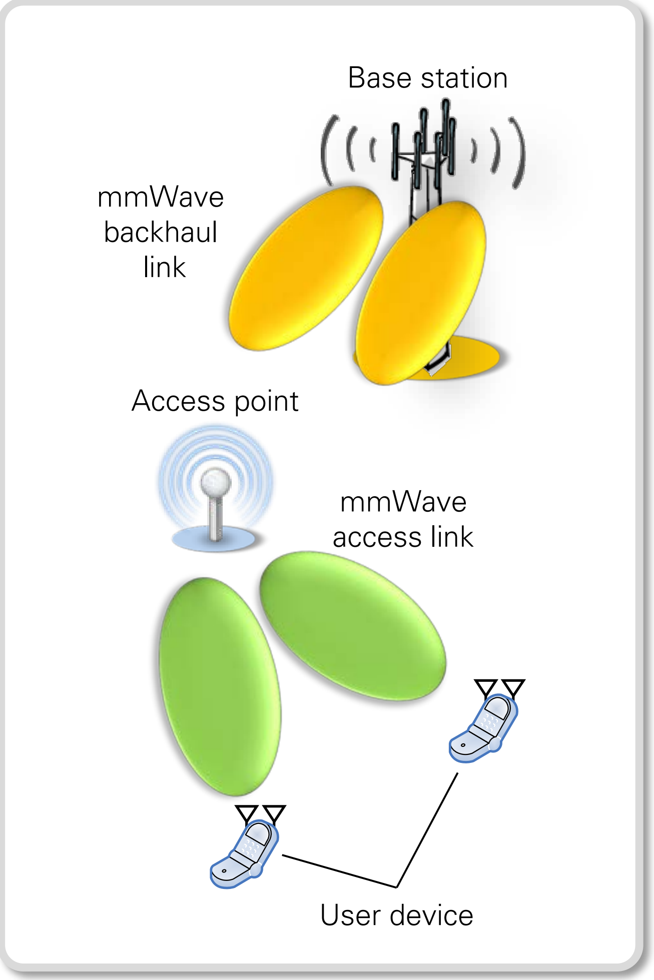
- Channel sounding at 28, 38 and 72 GHz
- Prototype system uses FlexRIO and LabVIEW

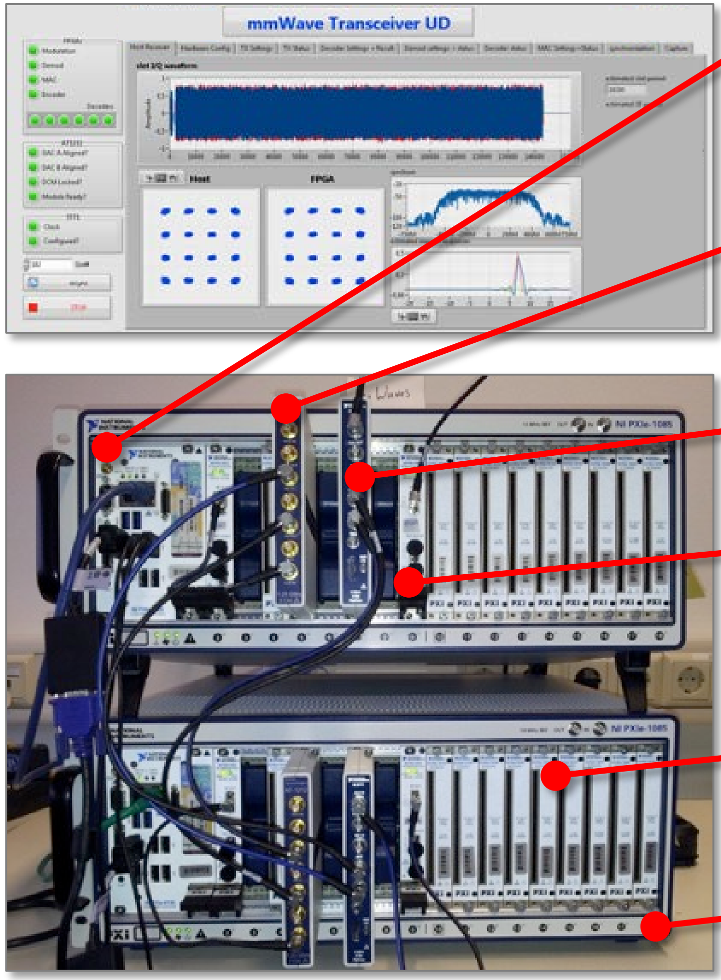




Multi Gbps Cellular Access and Backhaul Prototype

1 GHz BW baseband using shipping NI products!





PXIe-8135 Controller (RealTime OS/Windows)
2.3 GHz Intel Core i7-3610QE

AT 1212
2 channels, 1.25 GS/s
650 MHz analog BW, 14 Bit

NI 5771
2 channels, 1.5 GS/s,
900 MHz analog BW, 8 bit

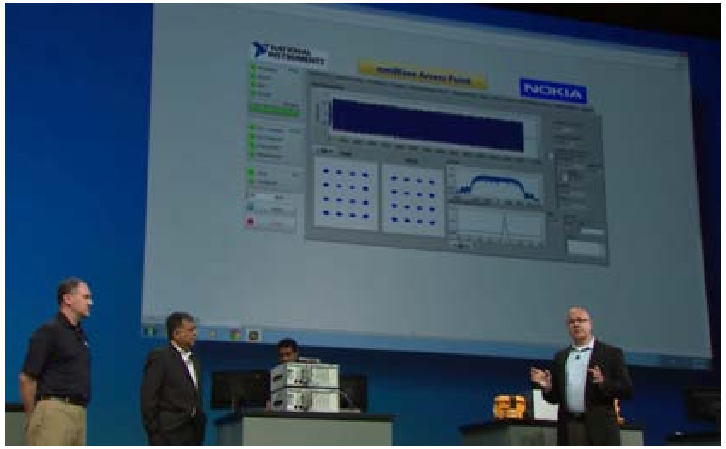
PXIe-5652
Signal Gen. 500kHz-6.6GHz
freq res. < 1ppb

PXIe-7975R
Kintex-7 FPGA, 2GB DRAM
DRAM BW: 10.6 GB/s

PXIe-1085
18 slot, Gen2x8 PCIe

2014 Nokia mmWave Prototype

"The development took the Nokia team one calendar year, half the time of other approaches."



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Nokia and NTT DOCOMO pave the way for 5G

Cooperate on 5G research and innovation to develop and validate next-generation mobile broadband technology

May 8, 2014

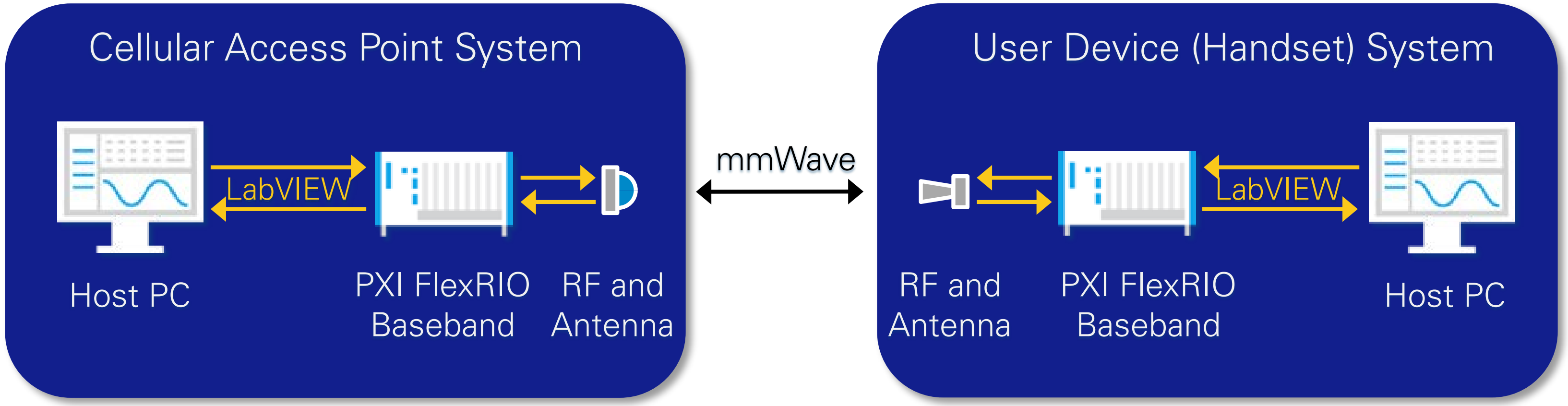
Espoo, Finland – Nokia announced today that the company and NTT DOCOMO INC. have agreed to collaborate on research and standardization of 5G technologies and to work jointly on a 5G proof of concept (PoC) system. This move builds on the Memorandum of Understanding (MoU) signed by the two companies in January 2014 to research future radio access experimental systems.

To meet the demand for extreme capacity and performance, future 5G networks will need to overcome the challenges that will become relevant for operators, such as guaranteeing cell-edge rates in excess of 100 Mbps and reducing latency by a factor of 10. Nokia's hands-on innovation approach builds on existing cutting edge technologies, enabling the transition towards higher bandwidths and superfast mobile broadband.

Downloads

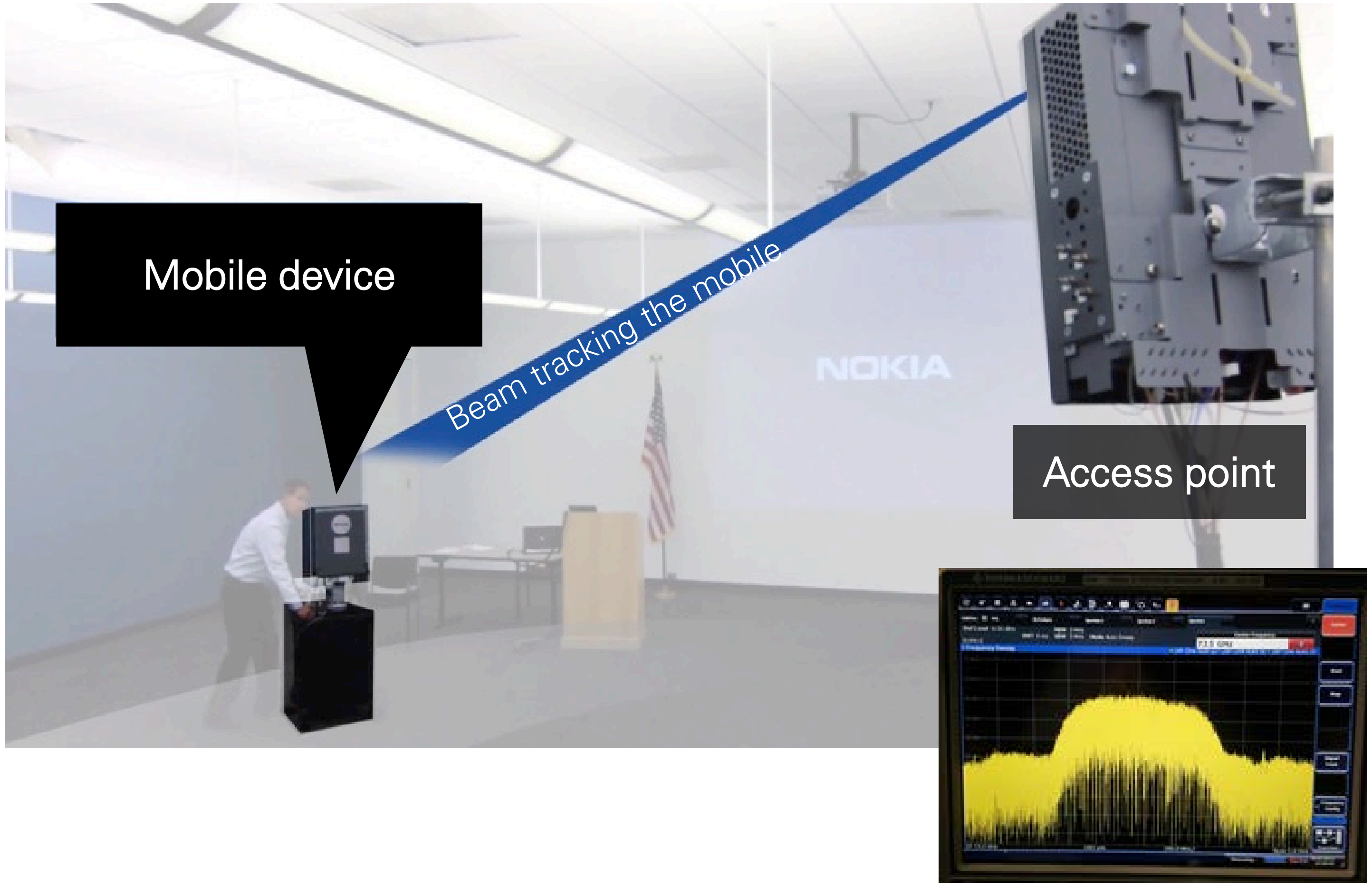
Press releases

Networks 2014-05-08 NTT DOCOMO 5G coll (English) (PDF, 206.49 KB)



The experimental 5G PoC system will be implemented using National Instruments' baseband modules which make up the state-of-the-art system for **rapid prototyping** of 5G air interfaces today.

Nokia 5G mmWave Beam Tracking Demonstrator (1 GHz BW)



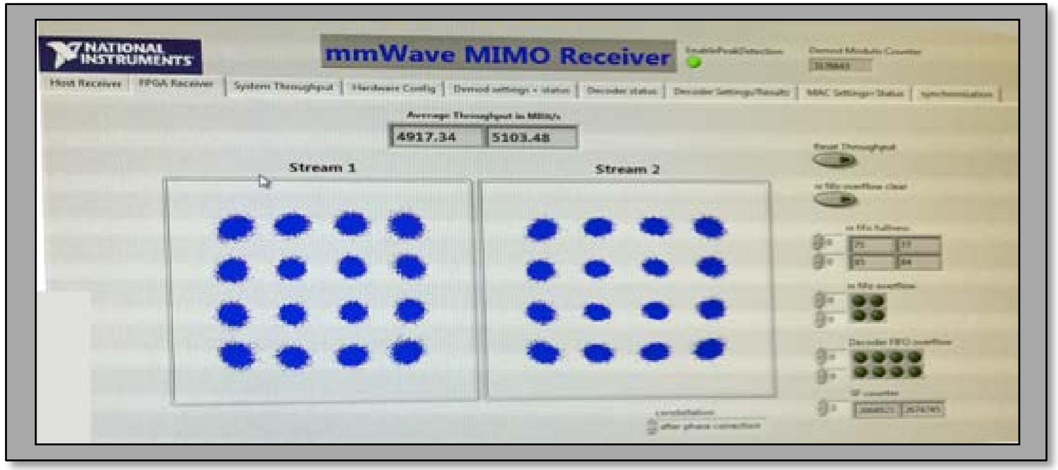
Source: Nokia

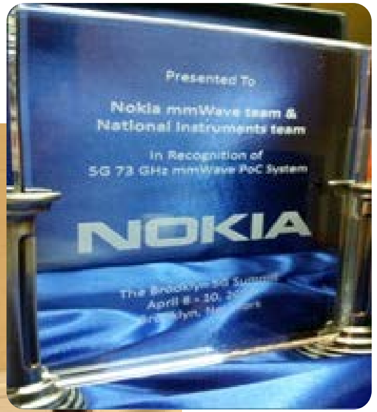
NATIONAL INSTRUMENTS

NI and Nokia Demonstrate 10 Gbps Wireless Link

Brooklyn 5G Summit

World's First 10 Gbps mmWave Link - April 2015



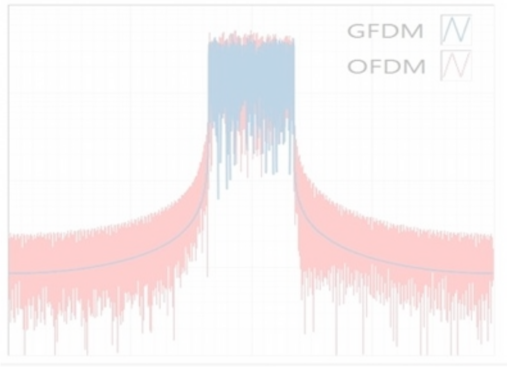


5G Vectors

PHY Enhancements

Improve bandwidth utilization through evolving PHY Level

- GFDM
- FBMC
- UFMC
- NOMA
- Full duplex
- LAA

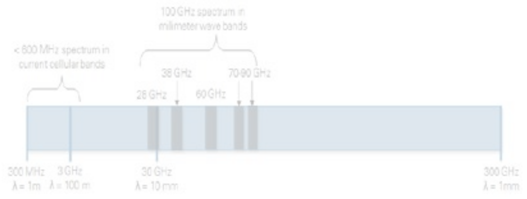


Massive MIMO

Dramatically increase number of antenna elements on base station

mmWave

Use potential of extremely wide bandwidths at frequency ranges once thought impractical for commercial wireless.



Wireless Networks

Consistent connectivity meeting the 1000X traffic demand for 5G

- Densification
- SDN
- CRAN

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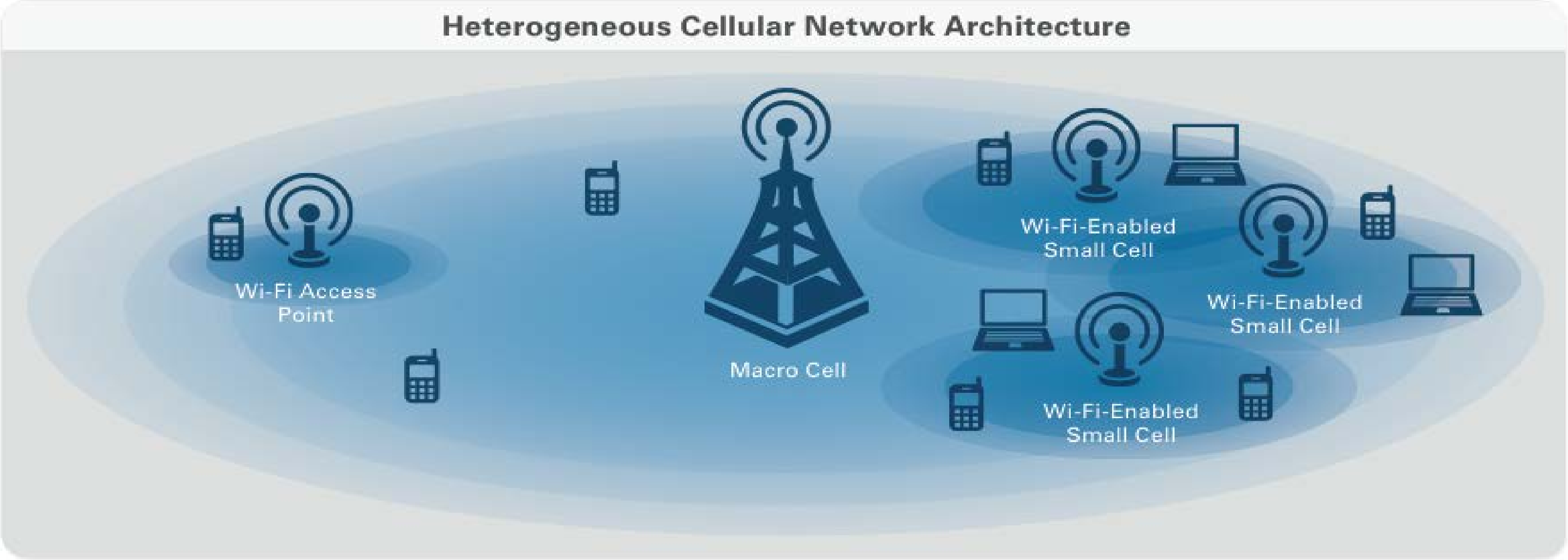
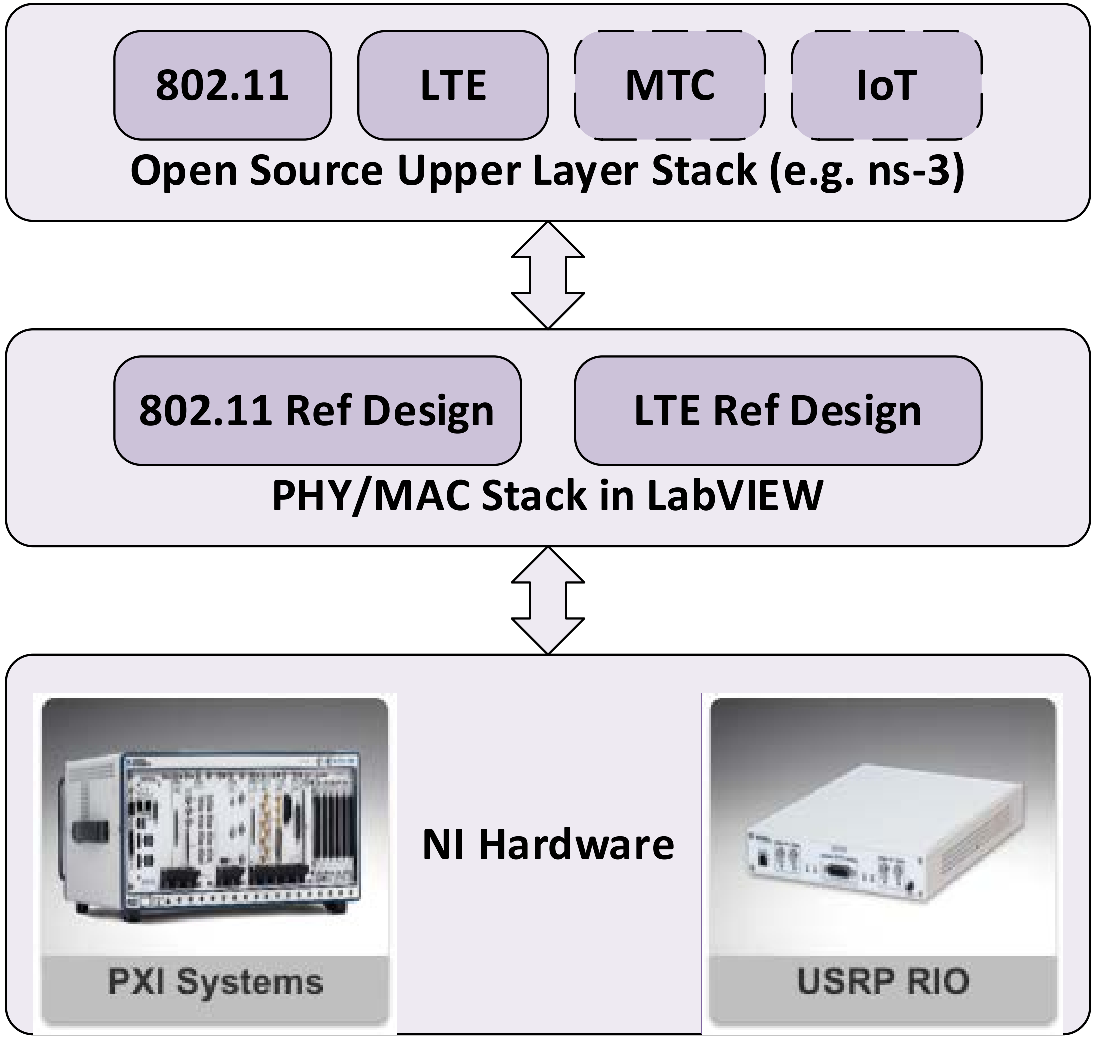
5G Wireless Networks: Design Directions



- Hyperdense networks
- Software defined networking (SDN)
- Cloud radio access network (cRAN)
- Cellular/802.11 coexistence and coordination
- Next-generation 802.11 stack

Architecture for Protocol Stack Explorations



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LabVIEW

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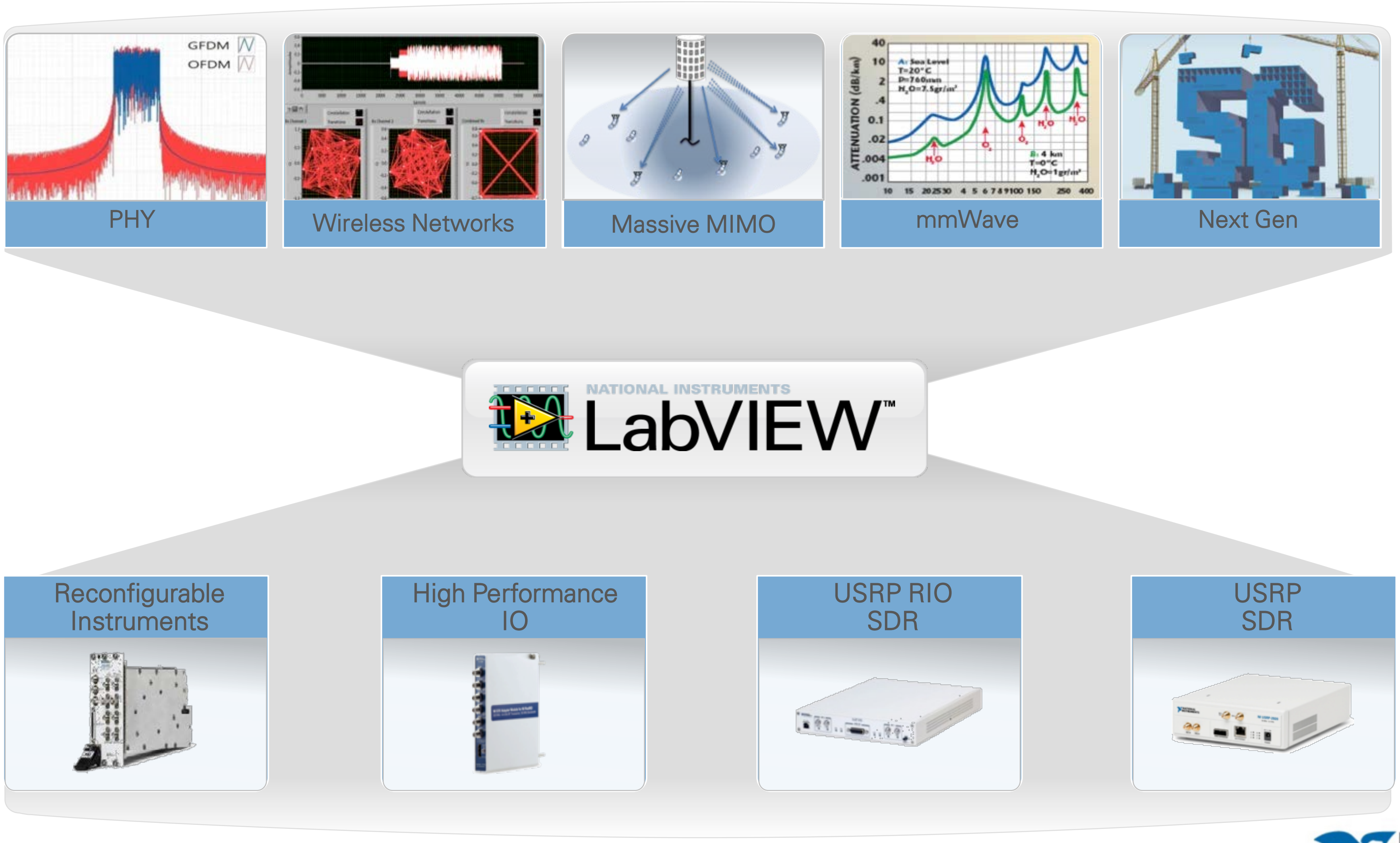
Platform-Based Design for 5G



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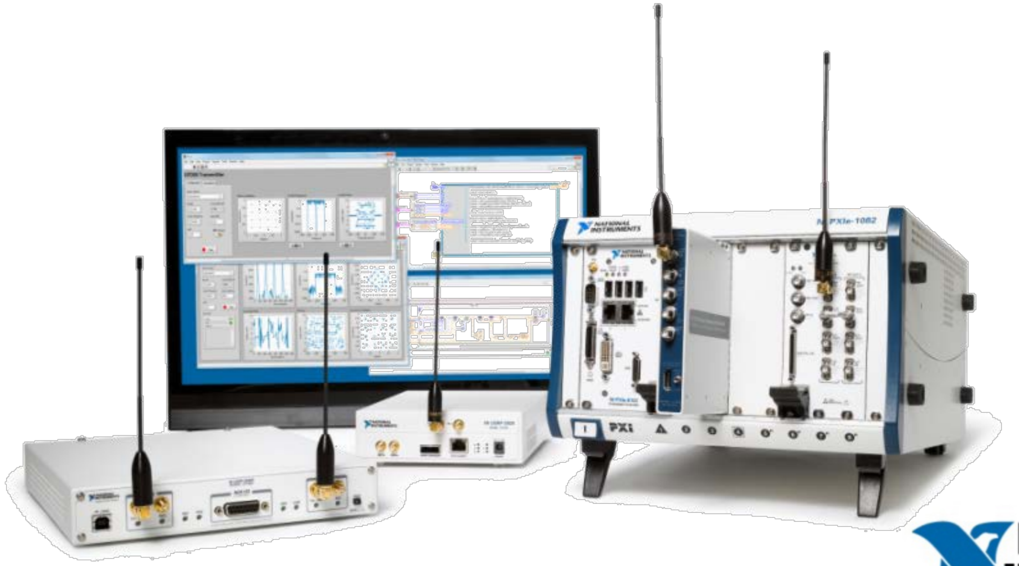
Summary

- SDR is rapidly advancing wireless technologies across industry, academic, and defense applications.
- Platform-based design is accelerating the design flow, significantly improving time to results.
- Learn more at: [ni.com/sdr](ni.com/sdr)



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NIDays

Recommended Next Sessions

13:45 - Fleming Room
(Keynote Room)

Afternoon Keynote

Inspiring and Enabling Generations of Innovation

Joined by Professor Danielle George – University of Manchester

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