Ettus Research USRP

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3rd OpenAirInterface Workshop
April 28, 2017
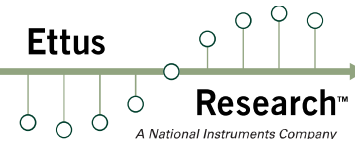
Agenda

Ettus Research™
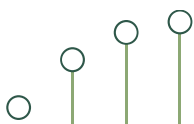*A National Instruments Company*

- Company Overview

- USRP Software Ecosystem

- Product Line
  - B-Series (Bus)
  - N-Series (Network)
  - X-Series (High Performance)
  - Synchronization

- USRP for 5G Research & Development

- Selected Applications
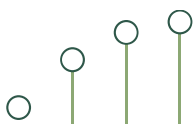
Ettus Research Overview

- Maker of Universal Software Radio Peripheral (USRP™)

- Support a diverse software ecosystem

- RF from DC - 6 GHz, MIMO capability

- Wireless Innovation Forum – 2010 Technology of the Year

- Wireless Innovation Forum – 2014 International Achievement Award

- About The Company
  - Founded in 2004
  - Located in Silicon Valley, California, USA
  - Stand alone subsidiary of National Instruments since 2010
  - Partner with Corad Technology for China distribution since 2012

National Instruments

- Supplier of Computer-Based Measurement and Automation

- Long-term Track Record of Growth and Profitability

- $1.23B Revenue in FY-2016

- Invest ~16% of revenue in R&D

- > 8,000 employees; operations in 49+ countries

- Significant investments in RF test, microwave design, and software defined radio

VSAs & VSGs

Power Meters

FPGA I/O & Co-processing

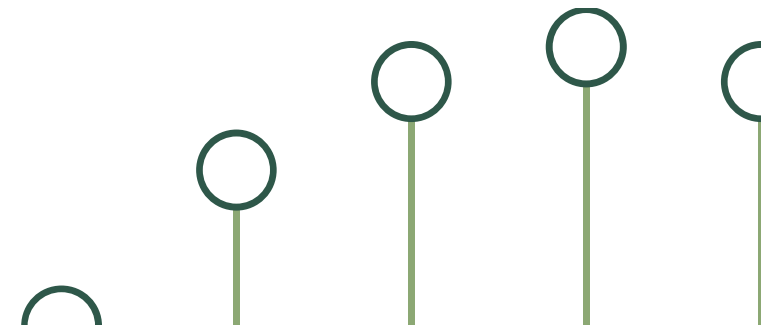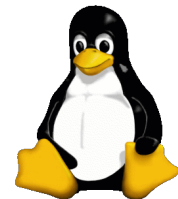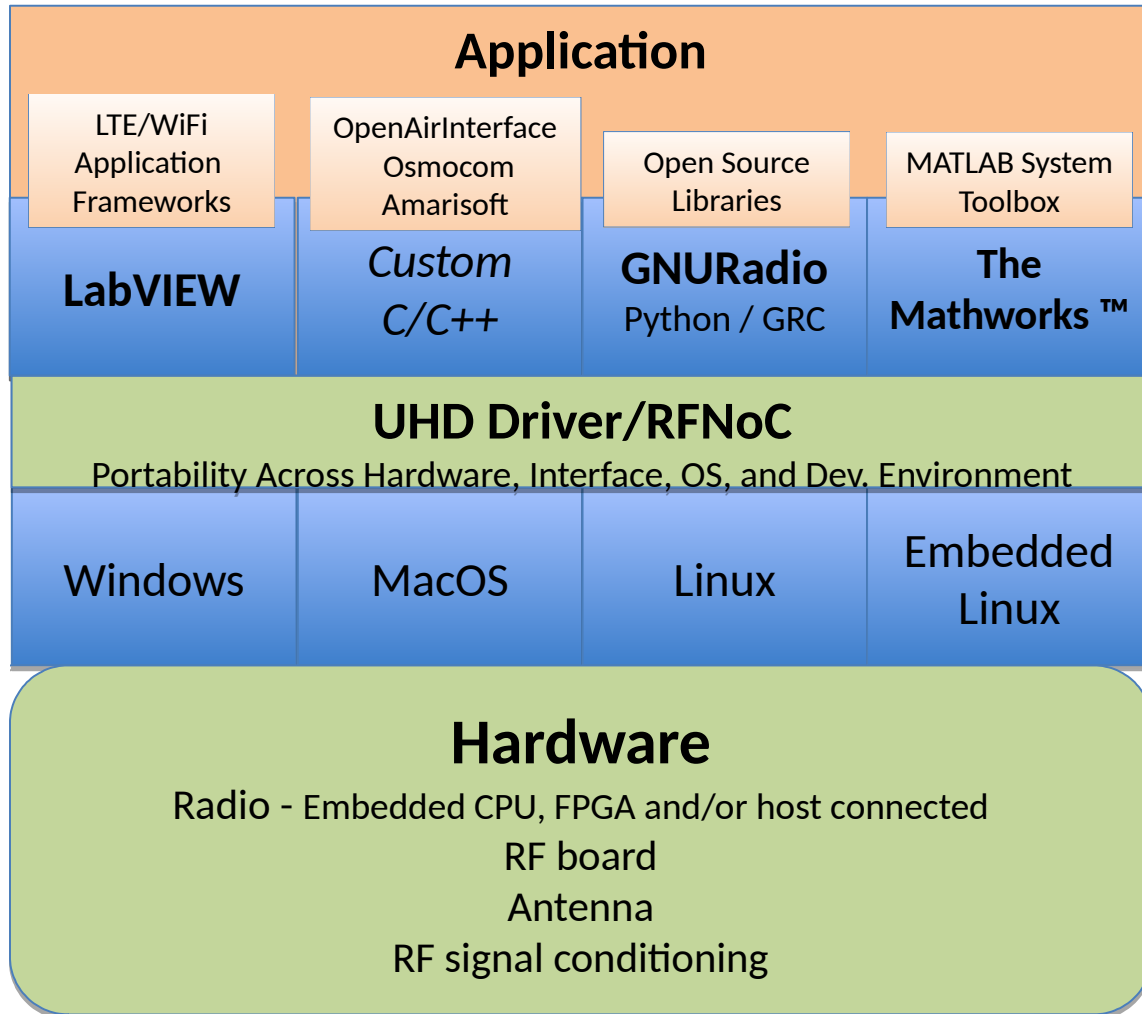**Amplifiers & Attenuators**

Switching

Software Defined Radio

Development for a Range of Industries

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Communications & RF
Identification

Utilities & Infrastructure

Medical Devices

Research Topics

Data rate

Capacity

Power Consumption

Spectrum Sharing

Interference

Security

Monitoring

Latency

Aerospace &
Defense

Automotive

Land Mobile &
Safety Radio

Satellite Communication
& Navigation

Research/Education

USRP Software Ecosystem

USRP Software Ecosystem

Application

LTE/WiFi Application Frameworks	OpenAirInterface Osmocom Amarisoft	Open Source Libraries	MATLAB System Toolbox
LabVIEW	*Custom C/C++*	**GNURadio** Python / GRC	**The Mathworks ™**

UHD Driver/RFNoC

Portability Across Hardware, Interface, OS, and Dev. Environment

Windows	MacOS	Linux	Embedded Linux

Hardware

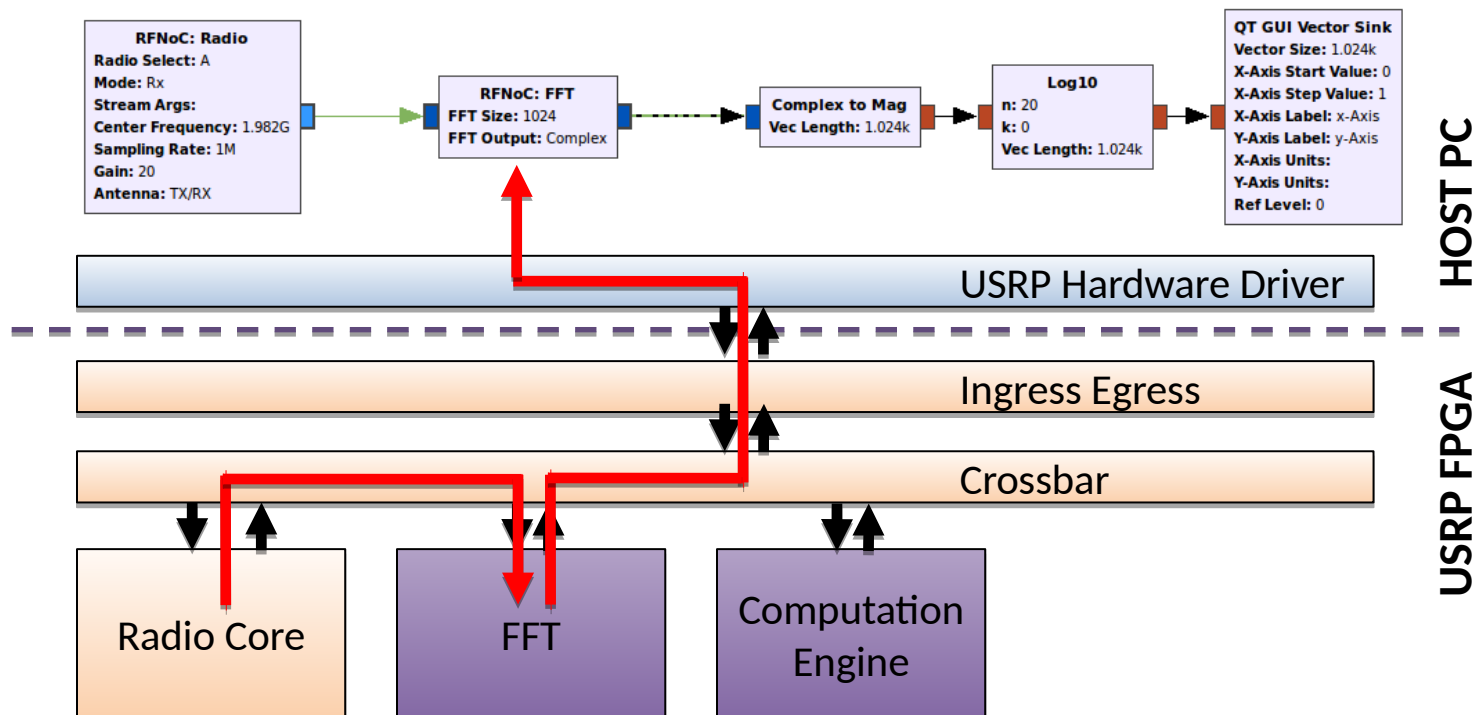Radio - Embedded CPU, FPGA and/or host connected
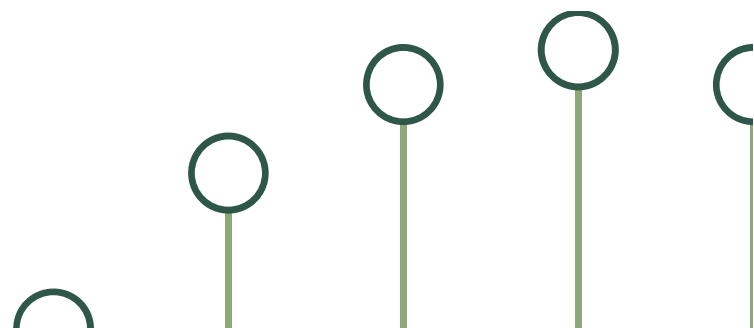
RF board

Antenna

RF signal conditioning

USRP Radios

RFNoC – RF Network on a Chip

- Heterogeneous Digital Signal Processing with FPGA
- Support composable and modular designs using GPP and FPGA
- Modular IP and interface points within FPGA

USRP Product Line

# USRP B-Series Overview

Specs

- Low Cost integrated RF solution

- Based on Analog Devices AD9361 RFIC

- RF Frequency Range: 70MHz – 6GHz

- Configurable clocking 1.92 MHz – 61.44 MHz

- USB 3.0 interface

- USRP B200

    - 1 TX / 1 RX Half or Full Duplex

    - Up to 56MHz single channel bandwidth

- USRP B210

    - 2 TX / 2 RX Half or Full Duplex, Coherent

    - Up to 56 MHz single channel bandwidth

    - Up to 30.72 MHz dual channel bandwidth

    - MICTOR, JTAG, and GPIO connectors

B200mini

- ## Small form-factor B200
    - Up to 56MHz single channel bandwidth
    - USB 3.0 bus powered
    - Tx/Rx & Rx2 antenna ports
    - Shared 10 MHz/PPS input
    - 89 × 55 mm (3.5 × 2.17 in)
    - Industrial version – B200mini-I
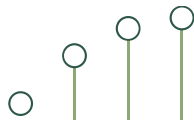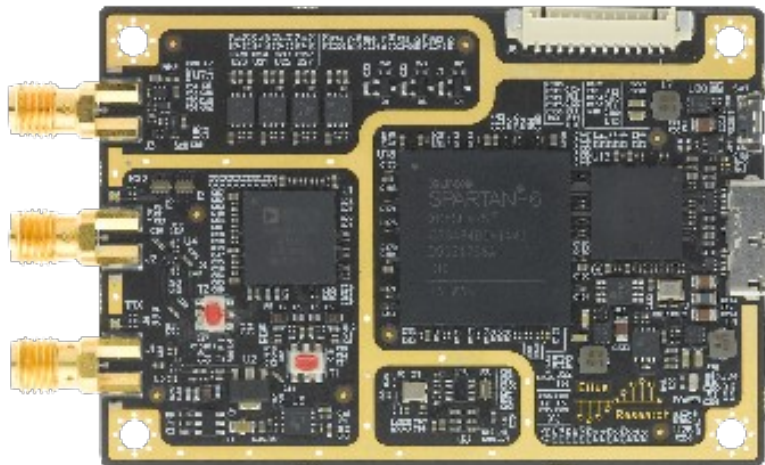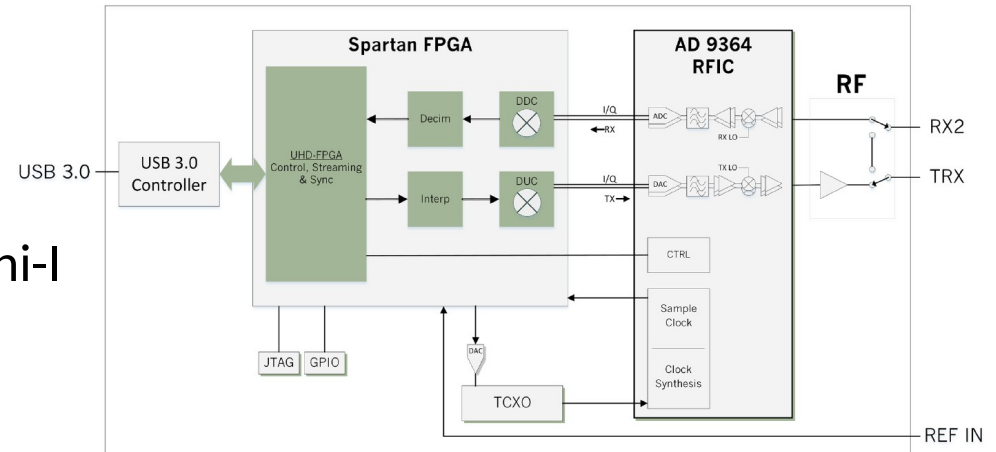
USRP N-Series

- **Specifications**
  - Freq Range: DC – 6 GHz
  - Up to 25 Msps @ 16-bit samples and 50 Msps @ 8-bit samples
  - ADC: 14-bit
  - DAC: 16-bit
  - Interface: 1 GigE

- Fixed rate FPGA clock – 100 MHz

  - Sample rate conversion to 30.72 MHz required for LTE

  - Amarisoft LTE eNodeB

USRP X-Series

X Series

- Two wideband RF daughterboard slots (2x2 MIMO)
    - Up 160MHz RF bandwidth per channel at 200 Msps
    - Selection covers DC to 6 GHz
    - ADC – 14 bit
    - DAC – 16 bit
- Large, customizable Kintex-7 FPGA
    - USRP X300 - XC7K325T
    - USRP X310 – XC7K410T
- Multiple high-speed interfaces
    - Dual SFP(+) ports for 1 or 10 Gigabit Ethernet
    - PCIe x4
- Clocking architecture
    - 200 MHz, 184.32 MHz for LTE
    - Optional GPSDO
    - External 10 MHz/1 PPS reference input
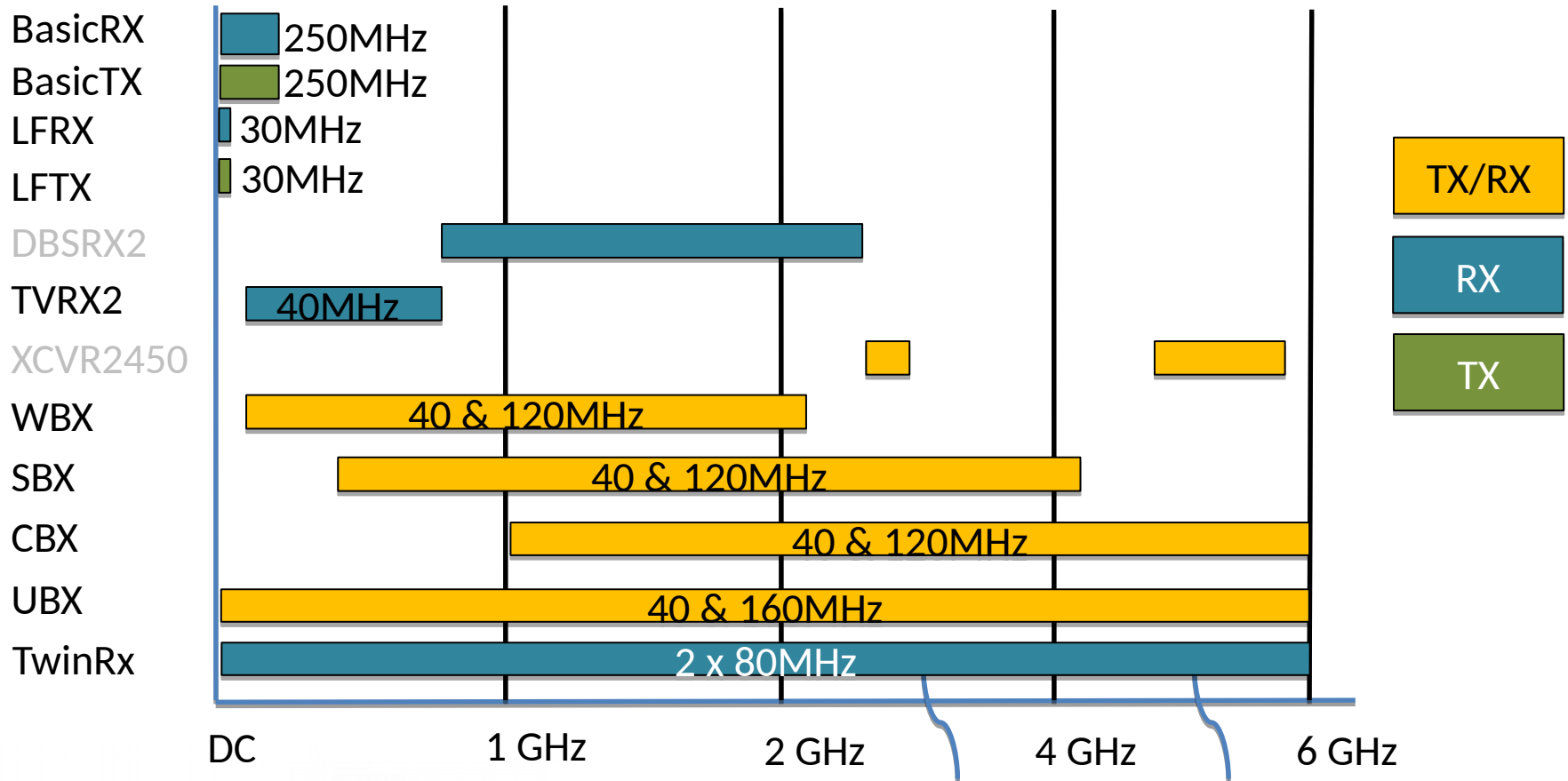- Half-width 1U form factor

Front

Back

Daughterboard Frequency

		DC	1 GHz	2 GHz	4 GHz	6 GHz
BasicRX	250MHz					
BasicTX	250MHz					
LFRX	30MHz					
LFTX	30MHz					
DBSRX2						
TVRX2	40MHz					
XCVR2450						
WBX	40 & 120MHz					
SBX	40 & 120MHz					
CBX	40 & 120MHz					
UBX	40 & 160MHz					
TwinRx	2 x 80MHz					

Legend: TX/RX, RX, TX
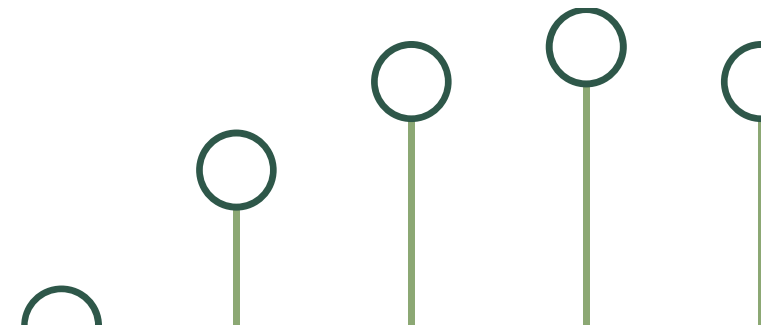
TwinRx   UBX   WBX   DBSRX2   BasicRX

UBX

- 10 MHz to 6 GHz

- Up to 160 MHz RF bandwidth

- Full duplex transceiver

- Available synthesizer synchronization for phase aligned operation

- 40 MHz on N200, 160 MHz on X300

- Full shield, high dynamic range

- High performance – 8dB NF @ +5dBm IP3
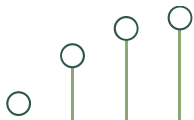
Frequency and Time Synchronization

Board Mount GPS-Disciplined Oscillator

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| Module Specifications	
1 PPS Accuracy	±50ns to UTC RMS (1-Sigma) GPS Locked
Holdover Stability	<±20µs over 3 hour period at +25C
1 PPS Output (OCXO Flywheel Generated)	3.3VDC CMOS
RS-232 Control	NMEA & SCPI-99 Control Commands, Integrated into UHD
GPS Frequency	L1, C/A 1574MHz
GPS Antenna	Active (5V compatible) or Passive
GPS Receiver	50 Channels, Mobile, WAAS, EGNOS, MSAS capable
Sensitivity	Acquisition -142dBm, Tracking -168dBm

| Oscillator Specifications	
Frequency Output	10MHz
10MHz Retrace	±2E-08 after 1 hour at 25C
Frequency Stability Over Temperature (Unlock Condition)	±2.5E-08
Warm Up Time	< 1 min at +25C

OctoClock – 8 Channel Clock Synchronization
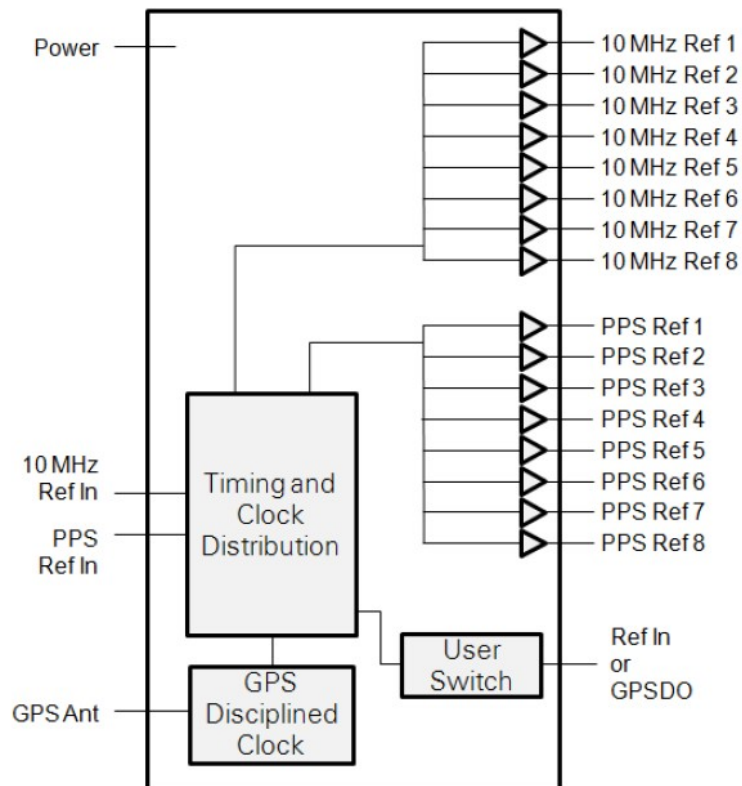
Applications

- Scalable time and frequency synchronization for large channel count systems

Features

- 8 Channel 10 MHz and PPS Distribution
- Choose between Internal / External sources
- Optional integrated GPS disciplined clock

USRP for 5G
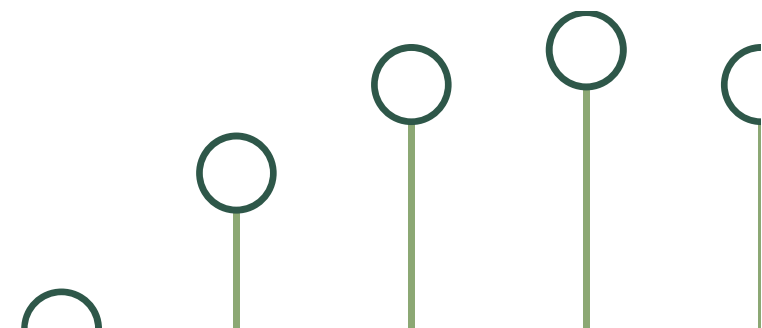
Requirements for 5G

Range of 5G RF bandwidths

NB-IoT
180 kHz - Massively
connected M2M
devices

4G LTE
Up to 20 MHz single
carrier

5G NR
Up to 100 MHz < 6 GHz
More than 100 MHz > 6 GHz

- 100 MHz RF bandwidth with 2x2 MIMO

- Up to 6 GHz frequency coverage

- 3G/4G/5G capable RF performance

- Ability to support multi-carrier operation (LTE Carrier Aggregation)

- 10 Gig Ethernet connectivity

- Available FPGA resources for DSP offload

USRP Product Comparison

|	Bus B2xx	Networked N2xx	High Performance X3xx
Frequency	70 MHz – 6 GHz	Baseband – 6 GHz	Baseband – 6 GHz
RF Bandwidth	56MHz (30.72 MHz in 2x2)	40 MHz	160 MHz
Channels	2 Tx, 2 Rx	1 Tx, 1Rx	2 Tx, 2 Rx
RF Performance	Good	Better	Best
Architecture	Integrated RF	RF Daughterboard	RF Daughterboards
Communication	USB	1 GbE	10 GbE or PCIe
MIMO Capability	Up to 2x2	Up to 2x2	Up to 256x256
LabVIEW Support	Yes	Yes	Yes
FPGA/CPU	Spartan 6	Spartan 6	Kintex 7
NI Version	USRP-290x	USRP-292x USRP-293x	USRP-294x USRP295x
S/W Ecosystem	UHD C/C++ GNU Radio MatLab Xilinx ISE	UHD C/C++ GNU Radio MatLab Xilinx ISE	UHD C/C++ GNU Radio MatLab Xilinx Vivado

Analog Devices AD9371 RFIC
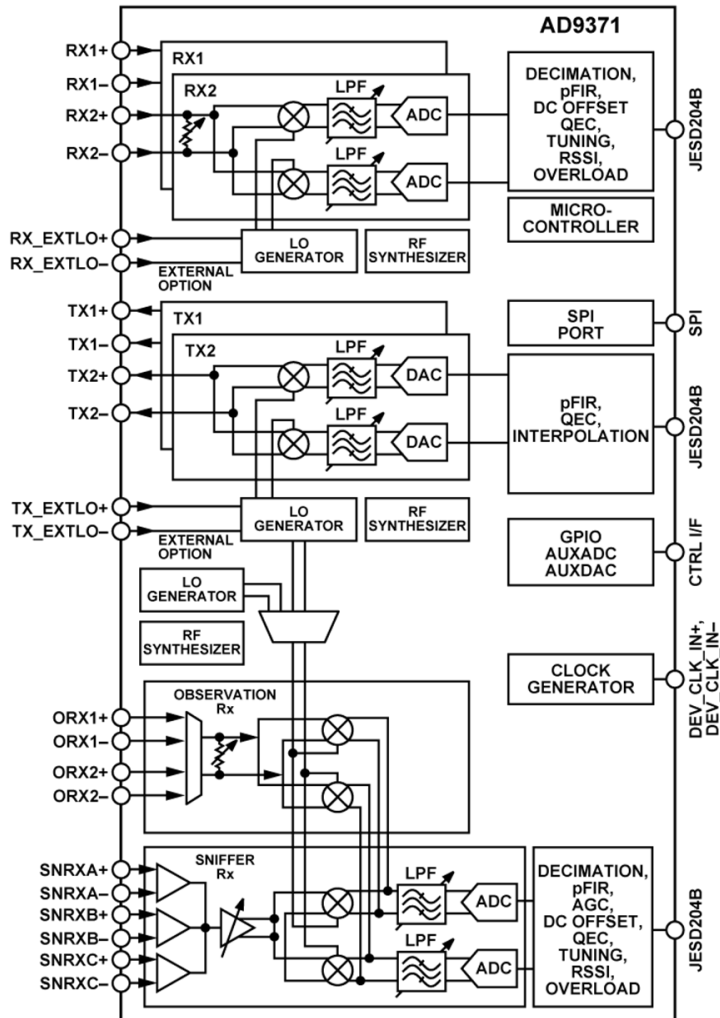
- Rx and Tx bandwidth up to 100 MHz
  - Increased from 56 MHz on AD9361 (B200/B210)
- Overall improved RF performance
  - 16-bit ADC and 14-bit DAC resolution
  - Improved quadrature and LO leakage calibration
- Applications
  - 3G/4G Micro and Macro single carrier
  - 3G/4G Picocell multi-carrier
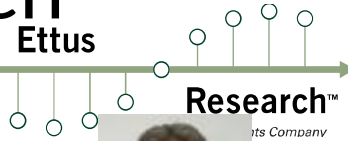 - 5G development

Applications
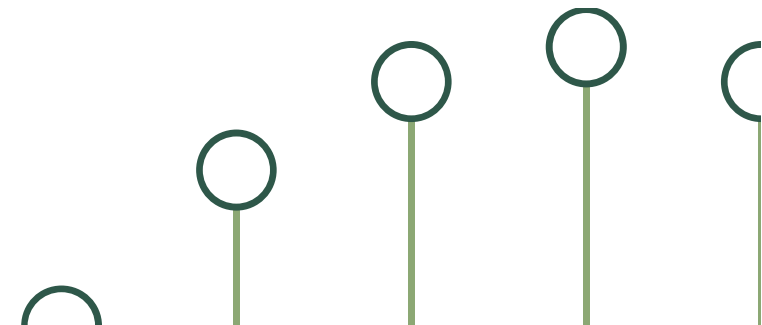
X300 – RFNoC Real Time Spectrum Analyzer

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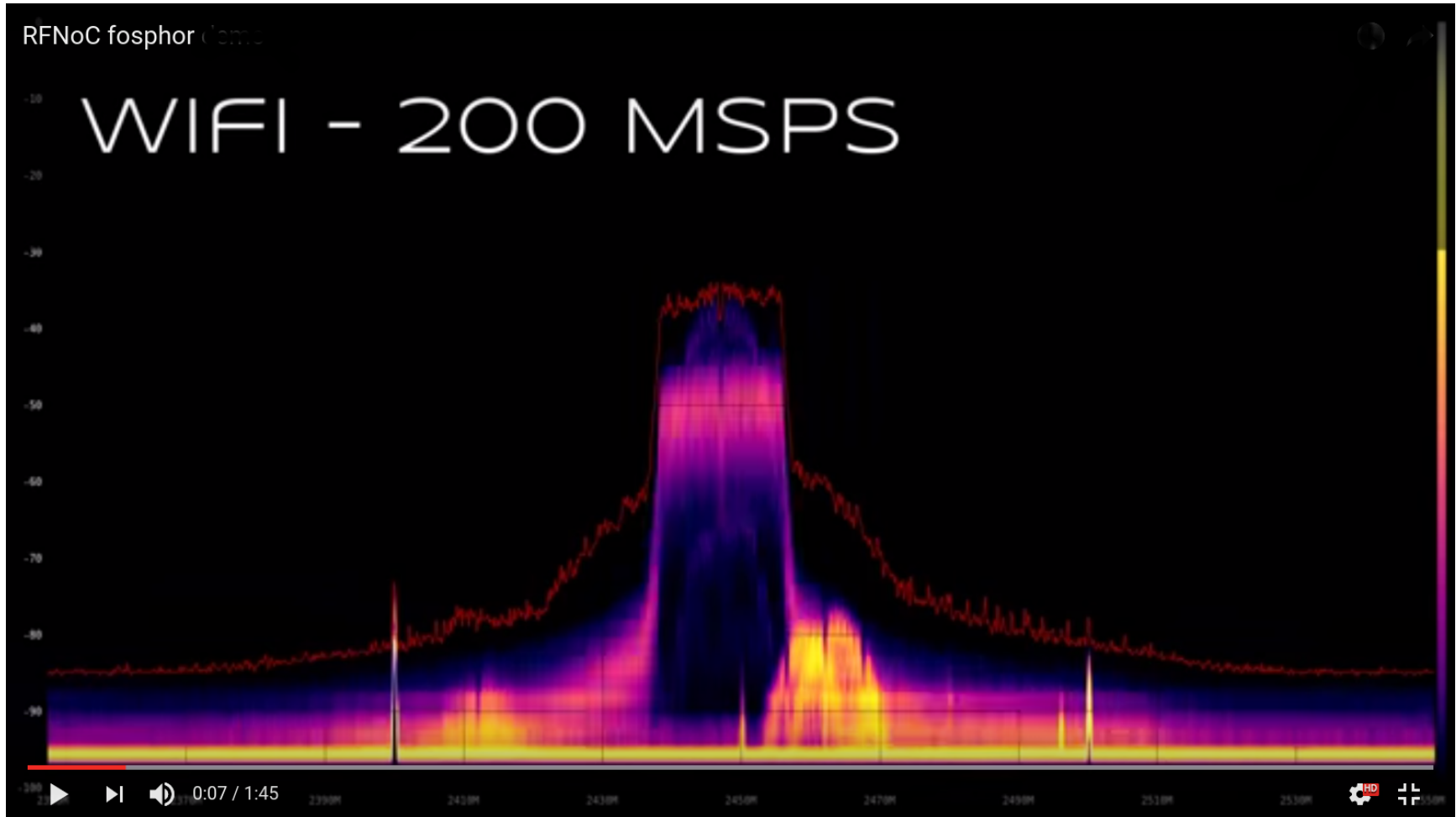
5G Massive MIMO at Lund University, Sweden

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

Prof Ove Edfos

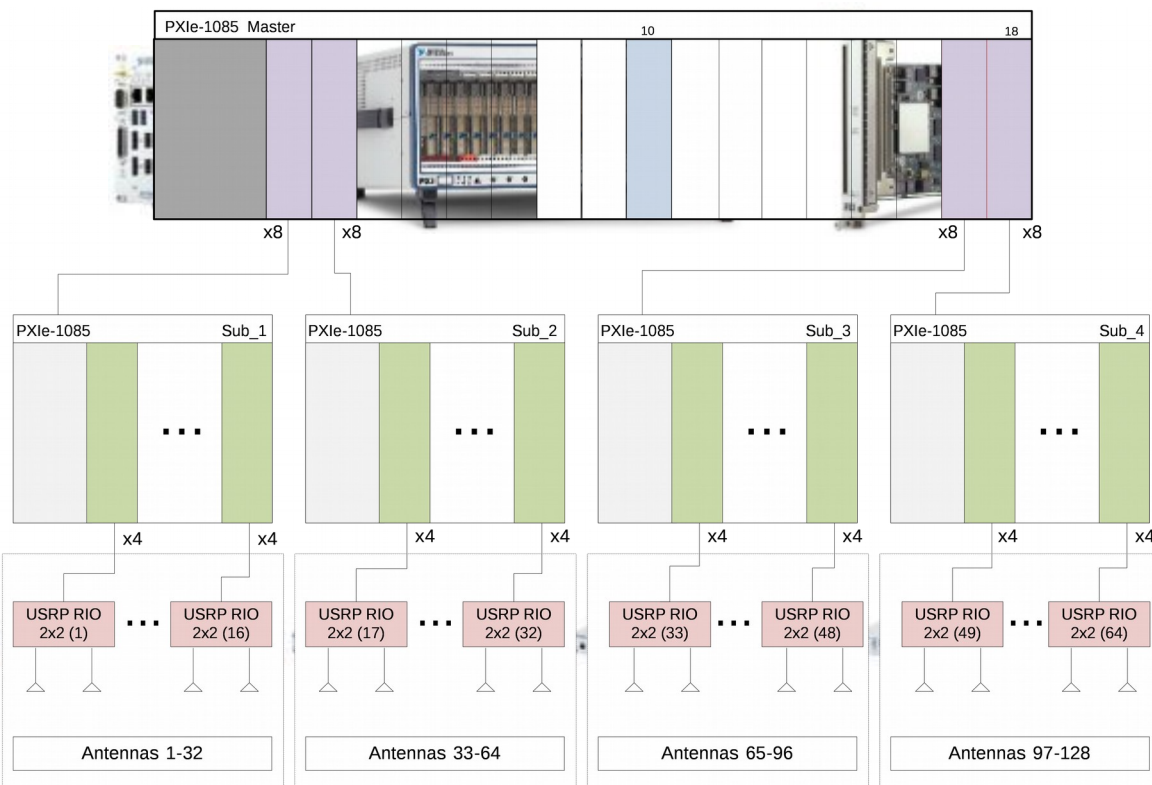Prof Fredrik Tufvesson

5G Massive MIMO Application Framework

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

System Parameters

Parameter	Values
No. of base station antennas	64 - 128
RF Center Frequency	1.2 GHz – 6 GHz
Bandwidth per Channel)	20 MHz
Sampling Rate	30.72 MS/s
FFT Size	2048
No. of used subcarriers	1200
Slot time	0.5 ms
Users sharing time/freq slot	10

- MIMO base station communicating with a single channel mobile user
- IQ sampling of 15.7GB/s on the uplink and downlink
- TDD operation enabling channel reciprocity

Bristol University (UK) Massive MIMO

New York Polytechnic University - 5G mmWave

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Legend
- ☆ Transmitter Site
- ● Receiver Site
- ■ Receiver Site behind a building

- Channel sounding at 28, 38, 60, 72 GHz
- Prototype system uses NI FlexRIO and LabVIEW software
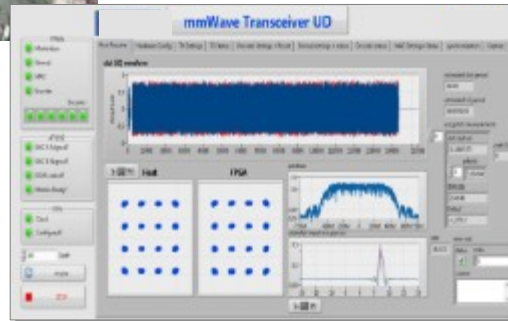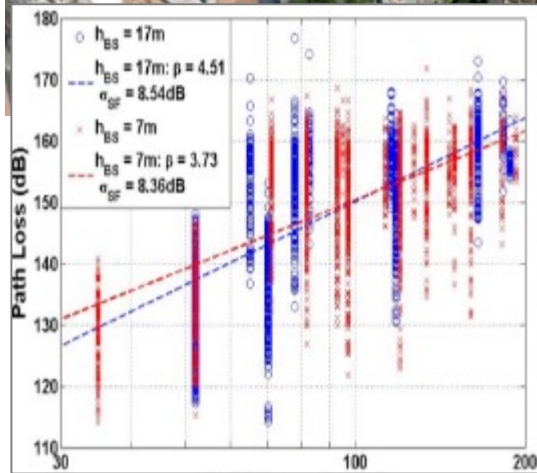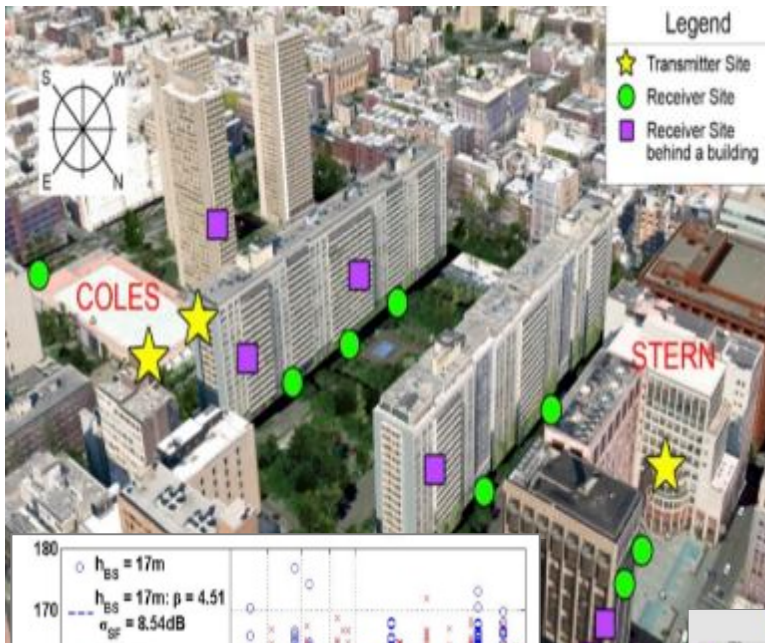
Prof Ted Rappaport

Thank You