New Capabilities for Comms, Radar, & EW with an SDR-based Research Platform

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Evolution of the Wireless World

- Transforming All Industries
- Software-Defined Solutions
- High-Performance Requirements

Higher Frequency  Wideband  Multi-Channel
Evolving Application Requirements of 5G and Beyond

**Applications**
- Wireless Cognition
- Wireless Sensing
- Immersive XR
- Device Location
- Imaging & Radar
- Mobile Hologram
- AND MORE

**Requirements**
- Throughput
- Reliability
- Coverage
- Latency
- Energy & Cost
- Massive Connectivity

**Enabling Technologies**
- Terahertz Frequencies
  - 6 GHz
  - 52 GHz
  - 3000 GHz
- Extreme MIMO
  - More Antennas and Distributed Radios
- Joint Communication & Sensing
- Spectrum Efficiency & Sharing
- AI and Machine Learning

**5G**
- eMBB
- URLLC
- mMTC

**6G**
- Throughput
- Reliability
- Coverage
- Latency
- Energy & Cost
- Massive Connectivity

**Beyond**
- More Antennas
- Distributed Radios
- AI and Machine Learning
Overview of 6G

Enabling Technologies That Could Drive 6G

Evolution of MIMO
Build on multi-antenna techniques from 5G with more elements and distributed architecture.

Sub-Terahertz
Utilize extremely wide bandwidths at frequencies once thought impractical for commercial wireless.

Joint Communications and Sensing
Improve spectral usage by combining sensing and radar functions with communications channels.

Machine Learning and Artificial Intelligence
Leverage new techniques across all 6G – from the signal chain to the network topology.
## USRP Product Portfolio Overview

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>70 MHz – 6 GHz</td>
<td>3 MHz-6 GHz (N32X)</td>
<td>*10MHz – 6 GHz</td>
<td>70 MHz – 6 GHz</td>
<td>1 MHz – 8 GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>56 MHz</td>
<td>200 MHz (N32X)</td>
<td>*160 MHz</td>
<td>56 MHz</td>
<td>400 MHz</td>
</tr>
<tr>
<td>Channels</td>
<td>2 Tx, 2 Rx</td>
<td>2 Tx, 2 Rx (N32X)</td>
<td>2 Tx, 2 Rx</td>
<td>2 Tx, 2 Rx</td>
<td>4 Rx, 4 Tx</td>
</tr>
<tr>
<td>RF Performance</td>
<td>Good</td>
<td>Best</td>
<td>Best</td>
<td>Good</td>
<td>Better</td>
</tr>
<tr>
<td>Architecture</td>
<td>Integrated</td>
<td>Integrated</td>
<td>*Configurable w/ Daughterboards</td>
<td>Integrated</td>
<td>Integrated</td>
</tr>
<tr>
<td>Communication</td>
<td>USB</td>
<td>10 GbE or PCIe</td>
<td>10 GbE or PCIe</td>
<td>10 GbE</td>
<td>100/10/1 GbE or PCIe</td>
</tr>
<tr>
<td>Synchronization</td>
<td>2x2 MIMO</td>
<td>Up to 128x128 (N32X) Full Phase Synchronization</td>
<td>*2x2 MIMO</td>
<td>2x2 MIMO</td>
<td>4x4 MIMO</td>
</tr>
<tr>
<td>SW Support</td>
<td>GNU Radio, C++, Python, MatLab, LabVIEW</td>
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<td>GNU Radio, C++, Python, RFNoC, LabVIEW *Q4 2021</td>
</tr>
<tr>
<td>Key Features</td>
<td>Low SWAP-C, Highly portable</td>
<td>Stand Alone, Wide bandwidth, Multi-Channel Sync Ready (N32X)</td>
<td>*Configurable RF Front End, Programable FPGA</td>
<td>Low SWAP, Embedded Deployable, Standalone</td>
<td>RFSOC Based, 5G Ready, Wide Band, Multi-Channel</td>
</tr>
</tbody>
</table>
NI Ettus USRP X410 Product Overview

**RF Capabilities**
- Frequency Range: 1 MHz - 8 GHz
- Signal Bandwidth: 400 MHz
- Receive Channels: 4X
- Transmit Channels: 4X
- Max TX Power: up to 22 dBm
- Max RX Power: 0 dBm

1 see specification for details

**Digital Capabilities**
- Xilinx Zynq Ultrascale+ RFSOC
  - Built-in quad core ARM processor
- Onboard IP: SD-FEC, DDC, DUC
- Interface options: dual QSFP28, PCIe Gen 3 x8
- Synchronization: 10 MHz / PPS, GPS DO option
- Software:
  - Open source (GNU Radio, RFNoC, UHD)
  - NI-USRP², LabVIEW FPGA²

² available in September 2021
The NI Ettus USRP X410 | Hardware Features

**RF Section**
- FC: 1 MHz - 8 GHz | 400 MHz IBW
- SUPERHET ARCHITECTURE
- ZBX DAUGHTERBOARD X2
- 4x TX/RX
- 4x RX
- TRIGGER IN/OUT
- GPS ANTENNA
- REF IN 10 MHz
- PPS IN

**Digital Section**
- DAC
  - ANALOG OUTPUT
- ADC
  - ANALOG INPUT
- CPU
- STREAMING DSP
- SECURITY
- XILINX ZU28DR
- ZYNQ US+ RFSOC
- Debug and Control
- High-Speed Interconnect
- 4 GB EMMC
- 32 GB
- 4 GB Memory
- 1 GBE, USB
- JTAG, DIO
- 100 GBE X2
- PCIE GEN 3 X8
The NI Ettus USRP X410 | Software Features

**System Model**
- C/C++, MATLAB, Simulink

**CPU Design**
- Embedded Coder®
- MATLAB

**FPGA Design**
- RFNoC via GRC
- Xilinx Vivado, HDL Coder®

**Deploy**
- LabVIEW FPGA
USRP/FlexRIO FPGA Resource Comparison

LUTs/FF
BRAM+URAM
DSPs
DRAM

- USRP 294/5x, 2974
- USRP N320/1
- PXIe-7902
- PXIe-7915
- USRP X410
USRP X410 Overview – Front Panel

RF Channel 0
- 1 MHz – 7.2 GHz
- Up to 400 MHz BW

RF Channel 1
- 1 MHz – 7.2 GHz
- Up to 400 MHz BW

RF Channel 2
- 1 MHz – 7.2 GHz
- Up to 400 MHz BW

RF Channel 3
- 1 MHz – 7.2 GHz
- Up to 400 MHz BW

Digital I/O
- 12 bits
- 100 Mbit/s

Daughter board 0

Daughter board 1
USRP X410 Overview – Rear Panel

- **PCIe Gen3 x8**
  - ~7 GB/s
- **8 Lanes @ up to 25 Gbps:**
  - 10/100 GbE, Aurora

**Clocking SMA Connectors**
- REF IN, PPS IN, TRIG I/O, GPS Antenna

**Front to back airflow**
- Field replaceable fan housing

**ARM APU Connections**
- Console/JTAG, USB, 1 GbE

**12V Power**
Introducing the Most Powerful USRP Yet!  
The NI Ettus USRP X410

See the demo in the NI / Ettus Research Booth  
(Virtual and In Person)

See more at  
www.ni.com/sdr  
www.Ettus.com
Radar/EW Research Platform for SDR
Radar/EW Research Platform for SDR

Abhay Samant – Chief Software Engineer Aerospace and Defense Systems R&D
Radar/EW Research Platform Reference Architecture

- Enables radar/EW researchers struggling to rapidly prototype new concepts to move quickly from software simulation to hardware demonstration, ultimately turning novel concepts into fielded capability faster.

- Key Features
  - Direct Conversion RF Sampling (200 MHz IBW) with NI USRP (L, S, C band)
  - Coherent operation through duration of experiments w/ LO, RefClk, and PPS sharing
  - 32 Channel TxTx,RxRx,TxRx Synchronization and Streaming (Ref C++ code, System Configuration)
  - Waveform Generation from File (C++) using RFNoC Replay blocks
  - Multiple open-source software programming options, including C++ and Python
  - System specification datasheet for array synchronization and waveform generation/acquisition example code for USRP
    - Repeatability better than 10deg, Stability better than 1deg
    - Target: Full rate streaming 8 channels, reduced rate streaming at higher channel count
  - Documentation for integrating GPU-based DSP and MATLAB Host programming
  - NI-Supported Code available for open-source access on GitHub
  - NI Technical Consulting Services for project acceleration and risk mitigation

NI USRP-based CogRF Test Bed

- 24-channel SDRs+Clk+LO distribution
- Expansion slot for higher channel count
- Server

Testbed side view
Getting from the Whiteboard to Proven Concept

**Software Simulation** → **Hardware Test Bed** → **Tactical System**

- Develop and simulate algorithms and system in software
- Develop hardware test bed, iterate with offline processing, migrate processing to hardware
- Validate algorithms against simulator and real-world scenarios, iterating as necessary
- Migrate validated algorithms to mission hardware, perform integration testing/validation
USRP N320 / N321

Common:
- 3 MHz – 6 GHz range
- 200-MHz BW per channel
- 2X2 MIMO
- 200/245.76/250-MHz sample rates
- Preselection filters
- Dual SFP+ ports (1 GbE, 10 GbE, Aurora)
- QSFP+, RJ45
- GPSDO
- Ethernet-based sync (White Rabbit)
- Stand-alone operation

N320:
- Zynq XC7Z100-2FFG900I
- External LO input ports

N321:
- LO Distribution for up to 128x128 MIMO
LO Distribution CCA Inside The N321

Star LO Distribution

Support up to 128x128 MIMO

LO Distribution CCA Inside The N321
Software Architecture of Reference Architecture

- System Components
- System Specifications
- System Details
- Interconnect Diagrams
- Assembly Instructions
Hardware Architecture of Reference Architecture
Data Movement and Synchronization
Engineer Ambitiously.