SDR Solutions with NI Hardware and MathWorks Software

Jeremy Twaits, Principal Solution Marketer, NI
Mike McLernon, Principal Engineer, MathWorks

MATLAB EXPO 2021

Your Hosts

Jeremy Twaits

Principal Solution Marketer, Aerospace, Defense & Gov't,
NI

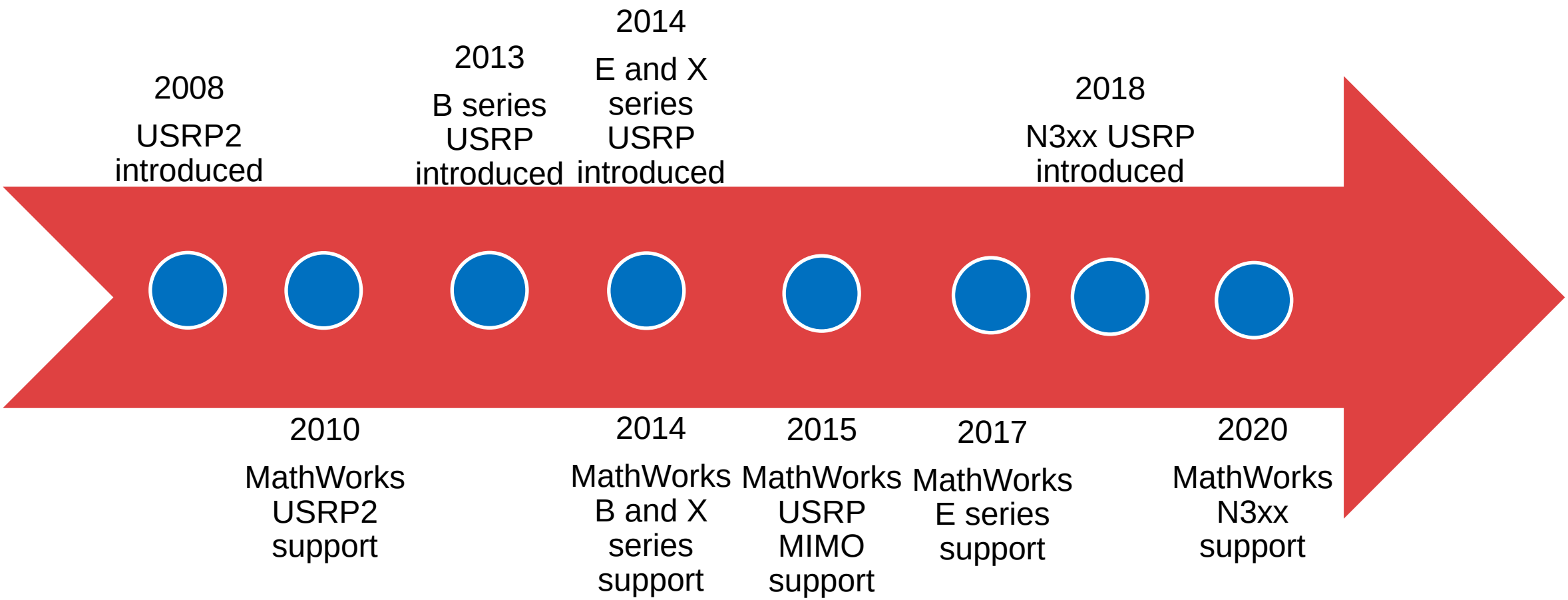
Mike McLernon

Principal Engineer, Communications Development,
MathWorks

Agenda

- History of MathWorks support for Ettus Research and NI platforms
- Current MathWorks support of NI SDR hardware
- Use cases
  - Streaming for data demodulation
  - Burst mode data capture for offline processing
  - Transmit beamforming
  - Ad hoc network creation
  - Power amplifier characterization
  - Signals intelligence with deep learning
- Future directions

A History of MathWorks/NI SDR Collaboration



Hardware Poll

USRP Support from Communications Toolbox

Supported Radios

Ettus Research:

- B200 and B200mini series
- X300 series
- N200 series
- N300 series

NI:

- USRP-294X and USRP-295X series
- USRP-292X and USRP-293X series

Example Applications

Real-time data capture

Burst mode data capture

Standards-based demodulation (e.g. FM, ADS-B, AIS)

MATLAB Workflow with NI Vector Signal Transceiver (VST)

- Generate waveforms in MATLAB
  - 5G, WLAN, Bluetooth, LTE, generic
- Upload to VST and transmit
- Run the signal through a device
- Capture the device output in the VST
- Perform offline analysis in MATLAB

Use Case – Streaming for Data Demodulation

1 0 1 1 1 0 0 0 1 1 0 0 0 0 1 1 0 0 1 0 1 0 0
0 0 0 1 1 0 0 0 0 1 1 0 0 1 0 1 0 0 1 0 1 0 1
1 0 0 0 0 1 1 0 0 1 0 1 0 0 1 0 1 0 1 1 1 0 0
1 1 0 0 1 0 1 0 0 1 0 1 0 1 1 1 0 0 0 0 1 1 1
1 0 1 0 0 1 0 1 0 1 1 1 0 0 0 0 1 1 1 0 0 0 1
0 1 0 1 0 1 1 1 0 0 0 0 1 1 1 0 0 0 1 1 0 0 0
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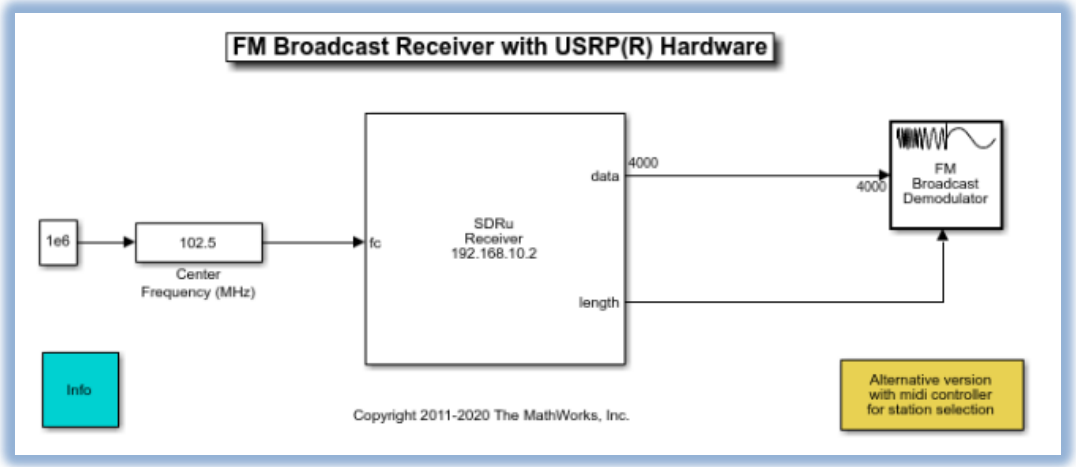
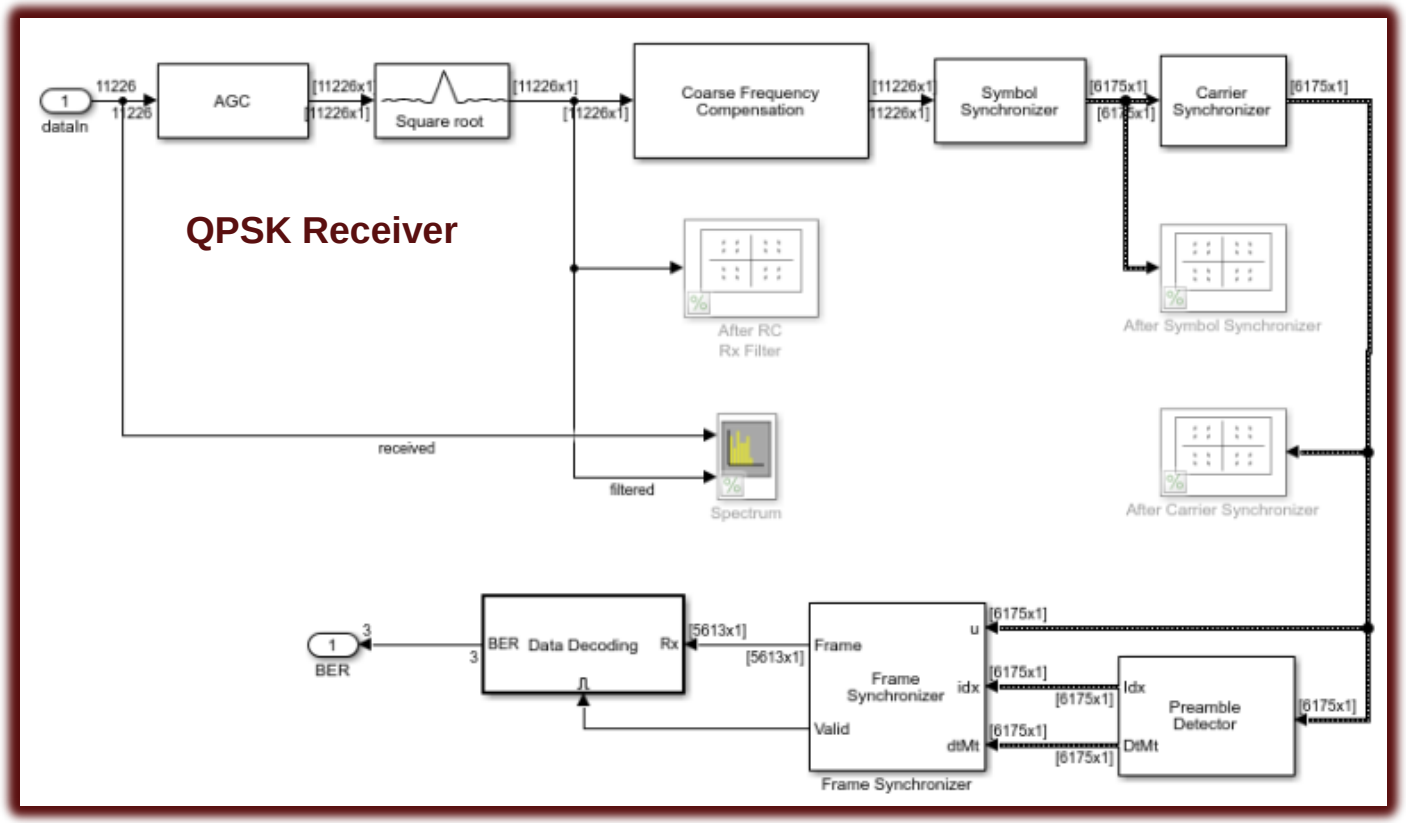
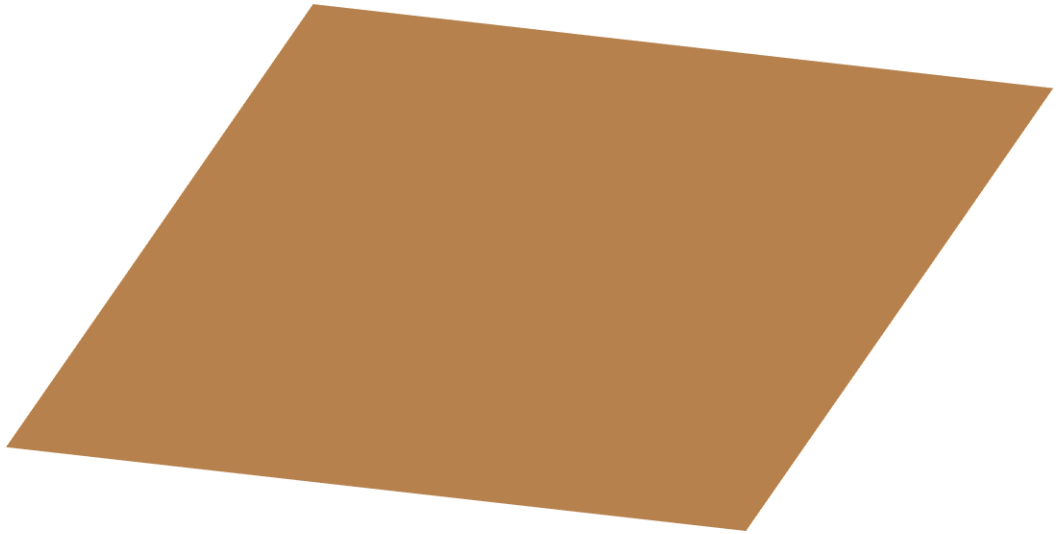


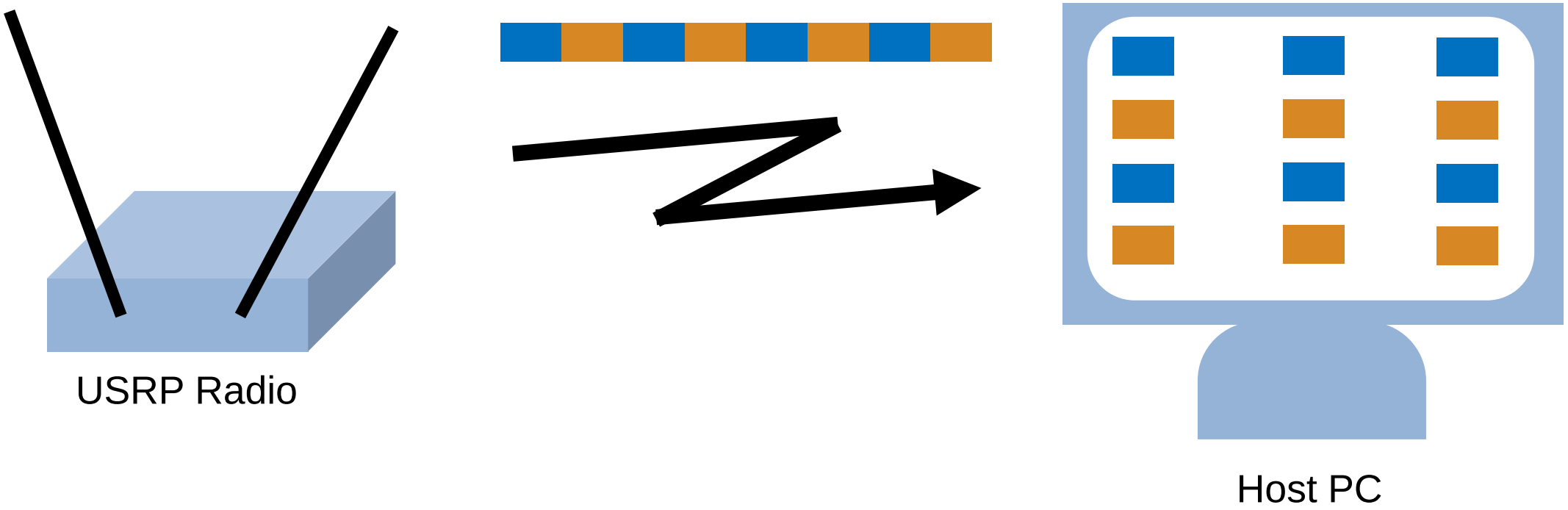


Use Case – Burst Mode Data Capture for Offline Processing

1 0 1 1 1 0 0 0 1 1 0 0 0 0 1 1 0 0 1 0 1 0 0
0 0 0 1 1 0 0 0 0 1 1 0 0 1 0 1 0 0 1 0 1 0 1
1 0 0 0 0 1 1 0 0 1 0 1 0 0 1 0 1 0 1 1 1 0 0
1 1 0 0 1 0 1 0 0 1 0 1 0 1 1 1 0 0 0 0 1 1 1
1 0 1 0 0 1 0 1 0 1 1 1 0 0 0 0 1 1 1 0 0 0 1
0 1 0 1 0 1 1 1 0 0 0 0 1 1 1 0 0 0 1 1 0 0 0
1 1 1 0 0 0 0 1 1 1 0 0 0 1 1 0 0 0 0 1 1 0 1
0 0 0 1 1 1 0 0 0 1 1 0 0 0 0 1 1 0 1 0 1 1 0



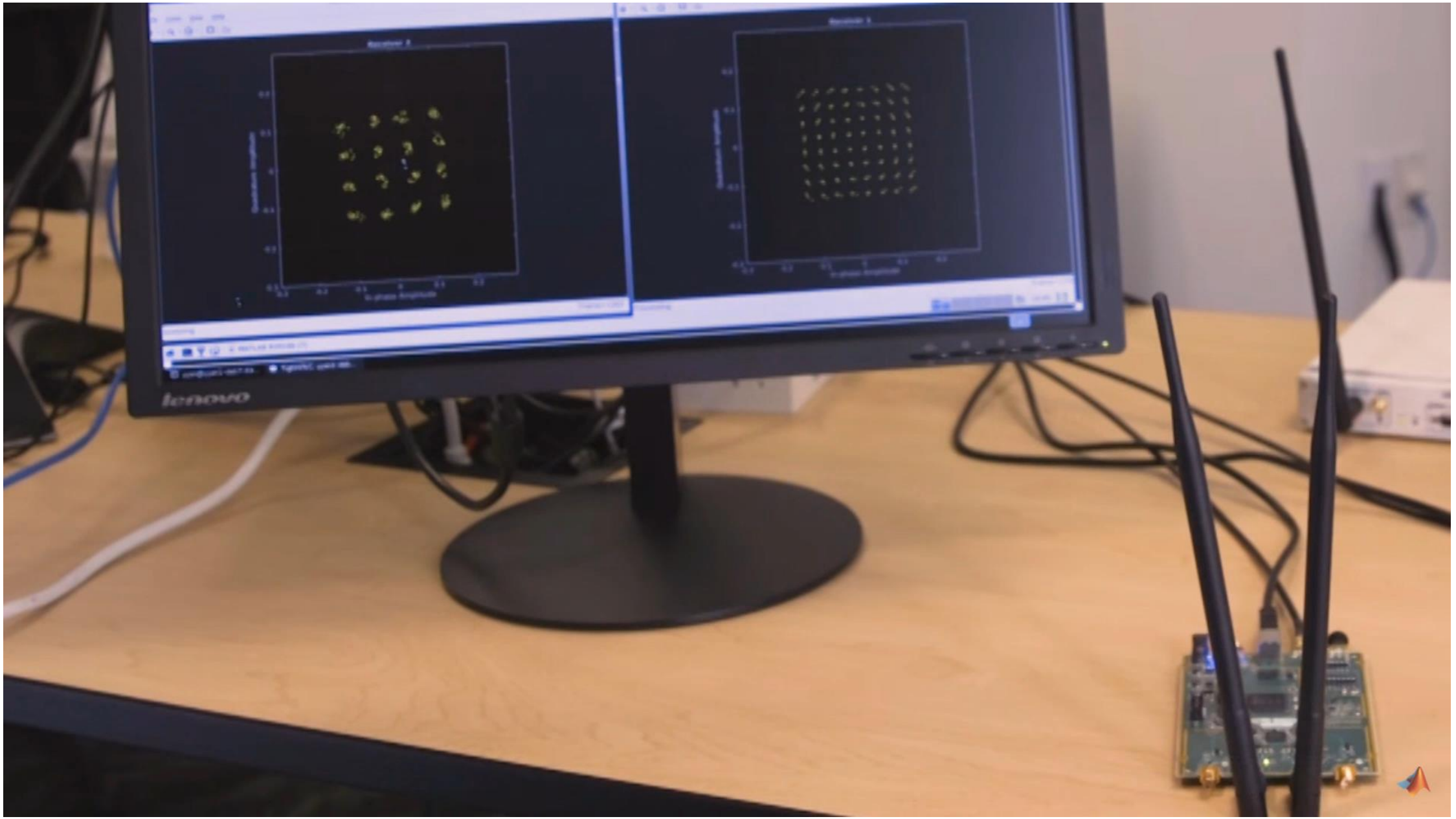
Use Case – Burst Mode Data Capture for Offline Processing



Software Poll

Use Case – Transmit Beamforming

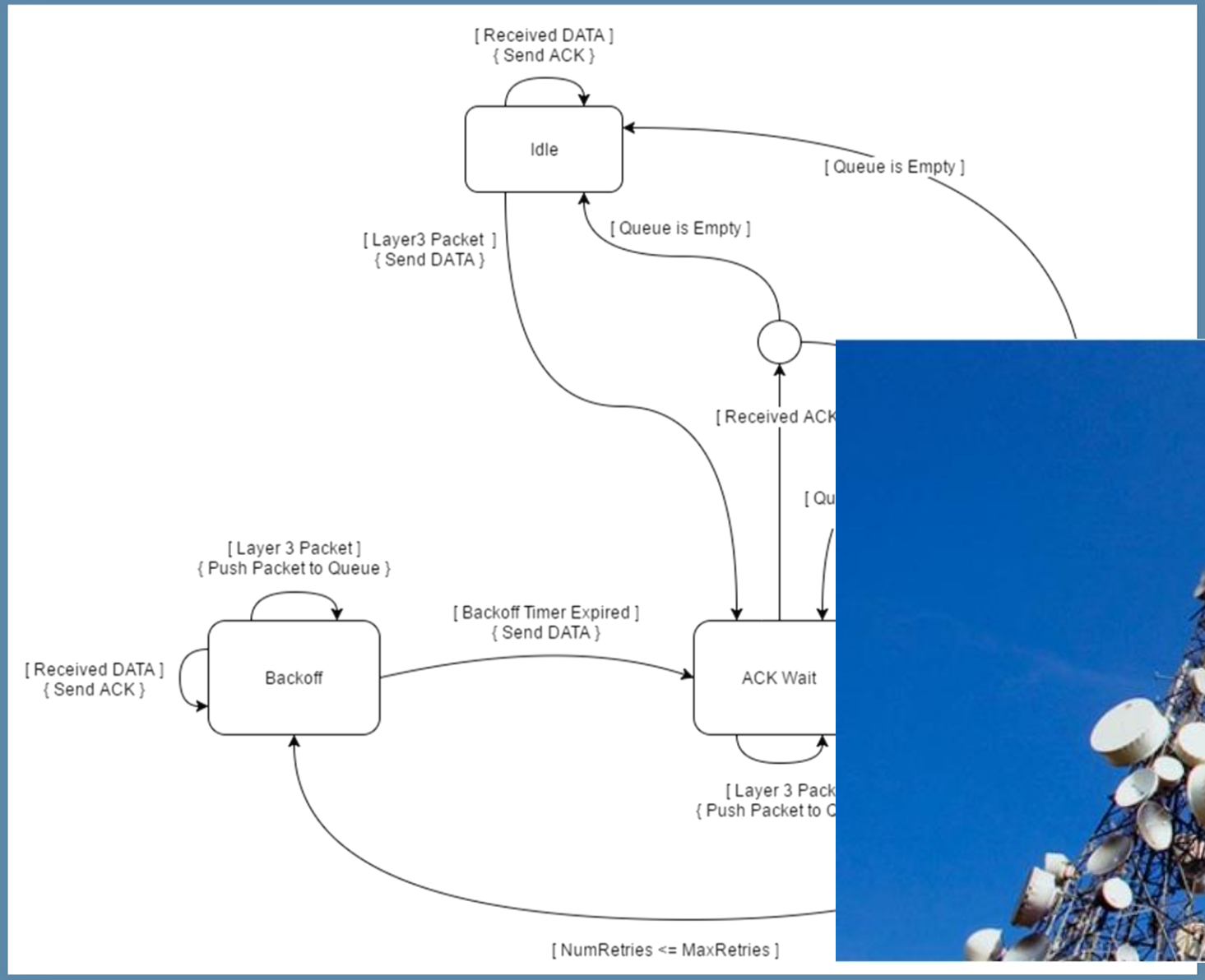
Use Case – Transmit Beamforming



Use Case – Transmit Beamforming

Search Multi-User Transmit Beamforming USRP

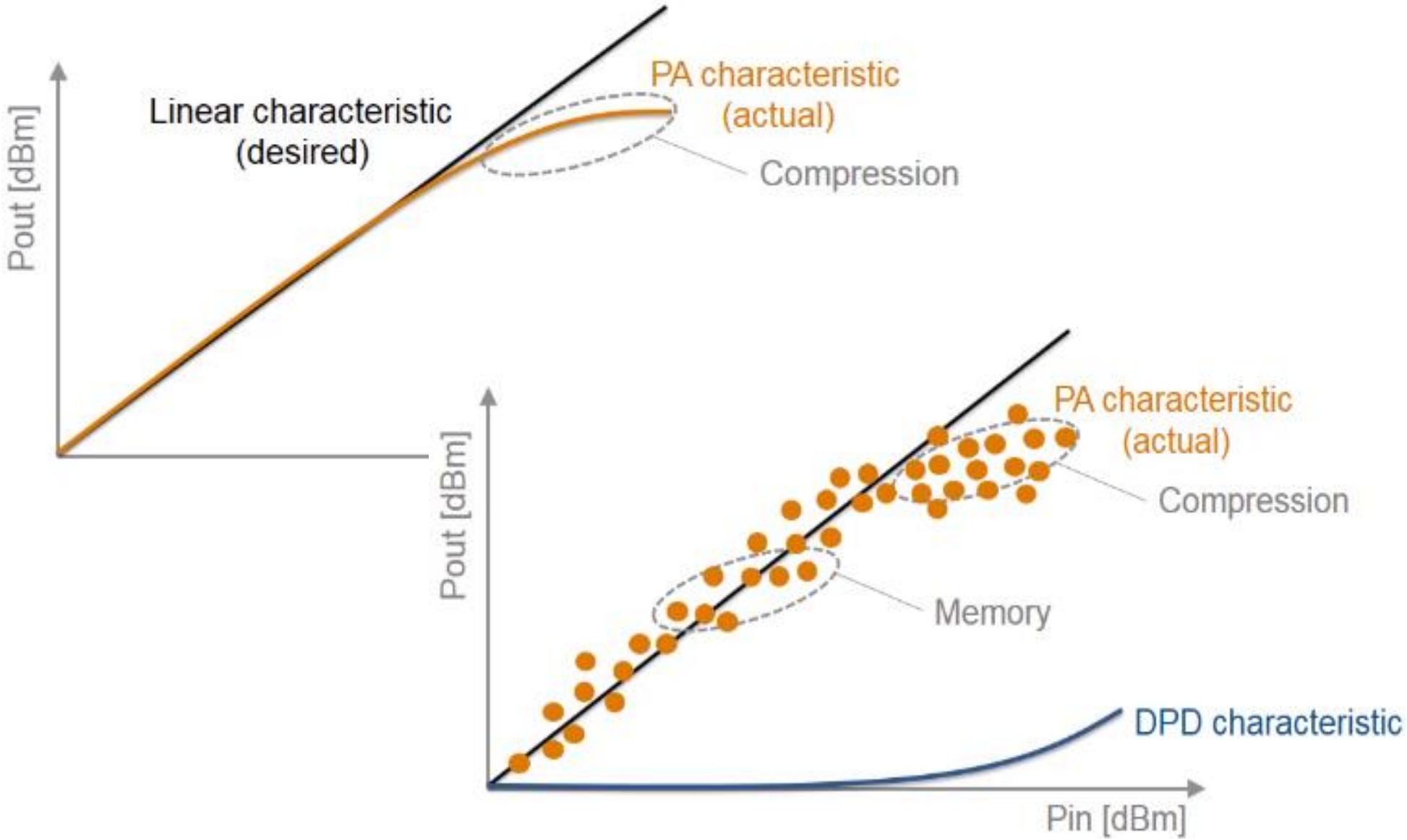
Use Case – Set Up Your Own Ad Hoc Network



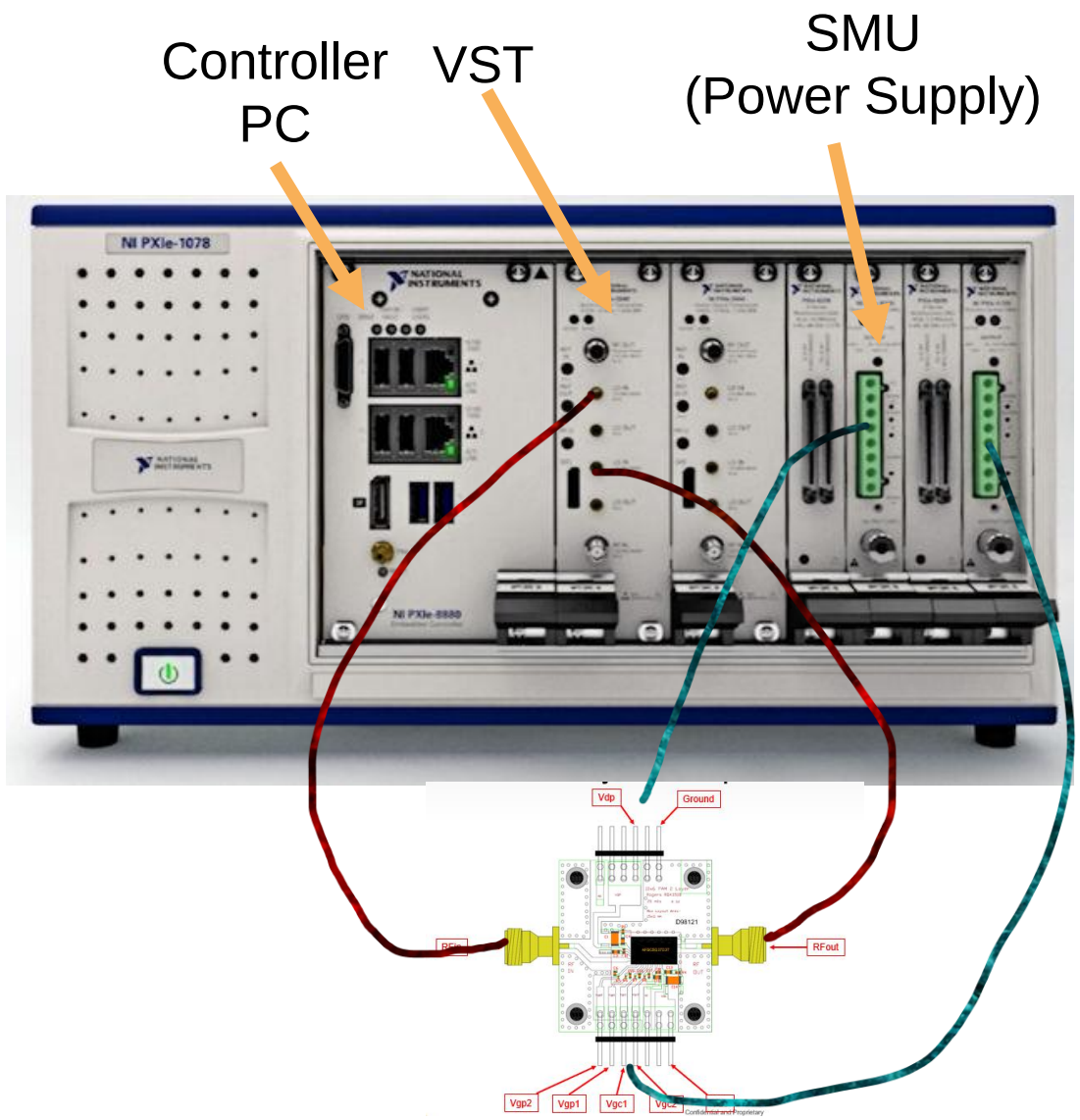
Search [Packetized Modem MATLAB]

Use Case – Power Amplifier Modeling with an NI PXIe VST

- Why?

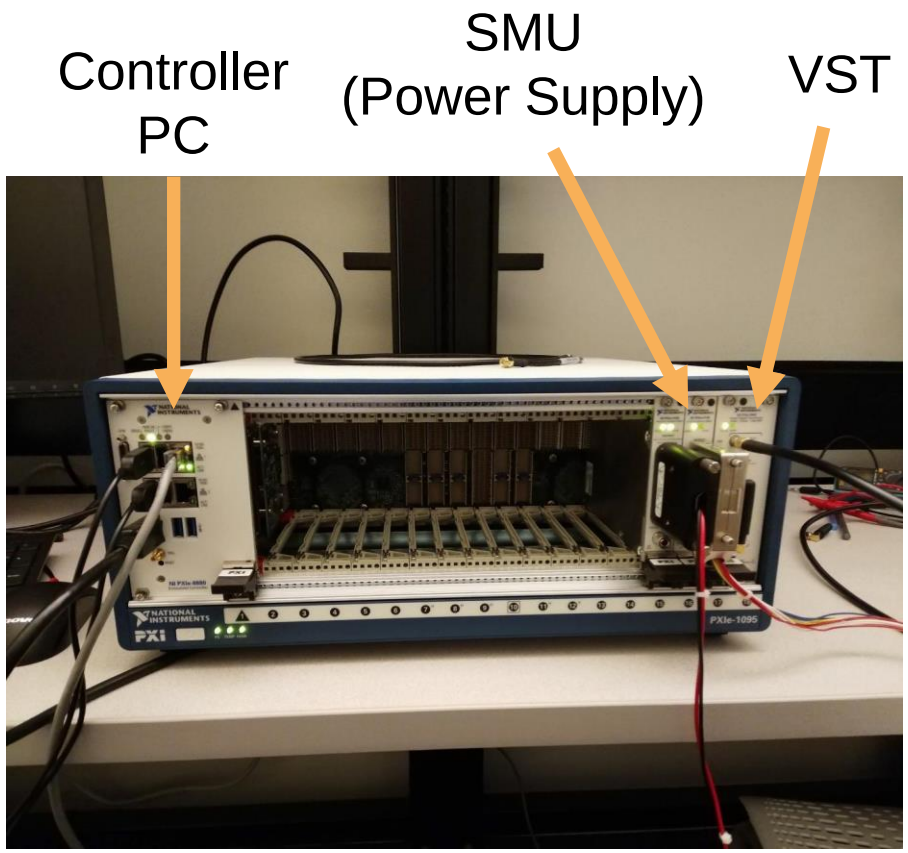


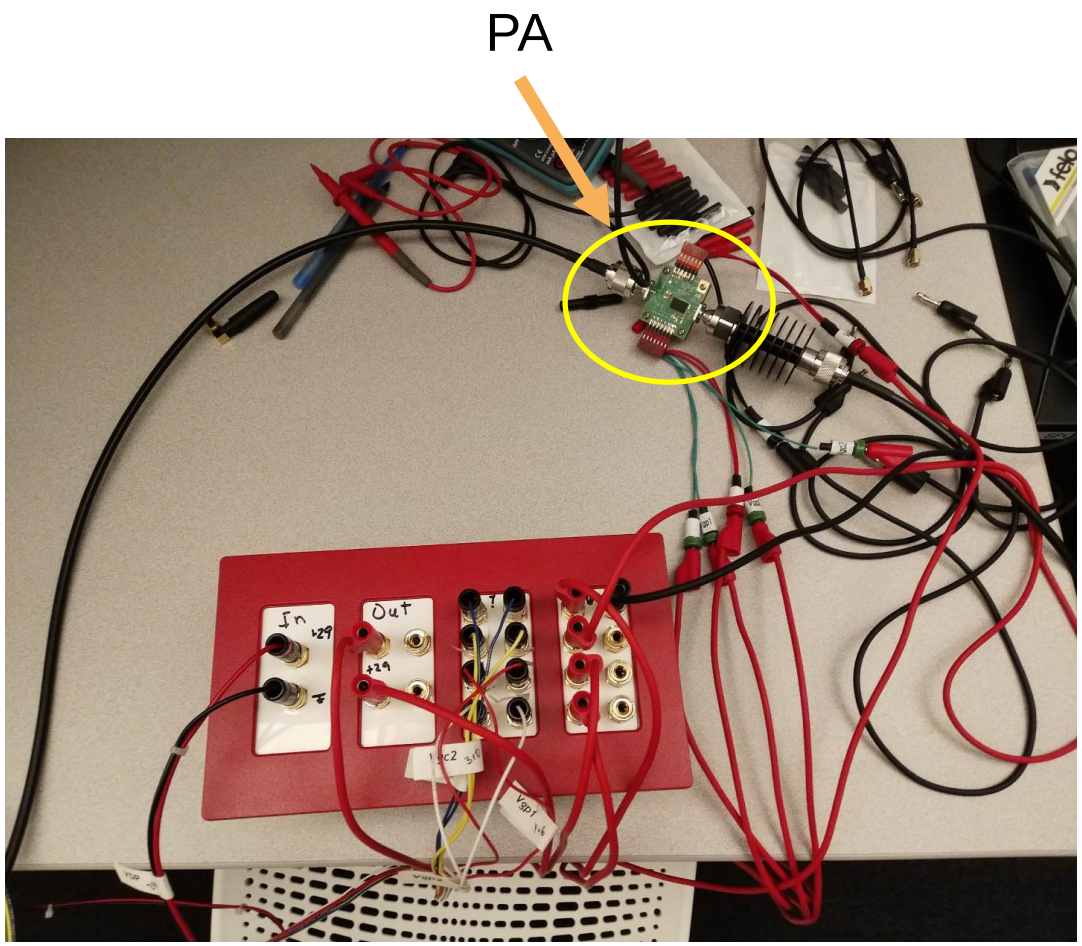
Generic Hardware Setup



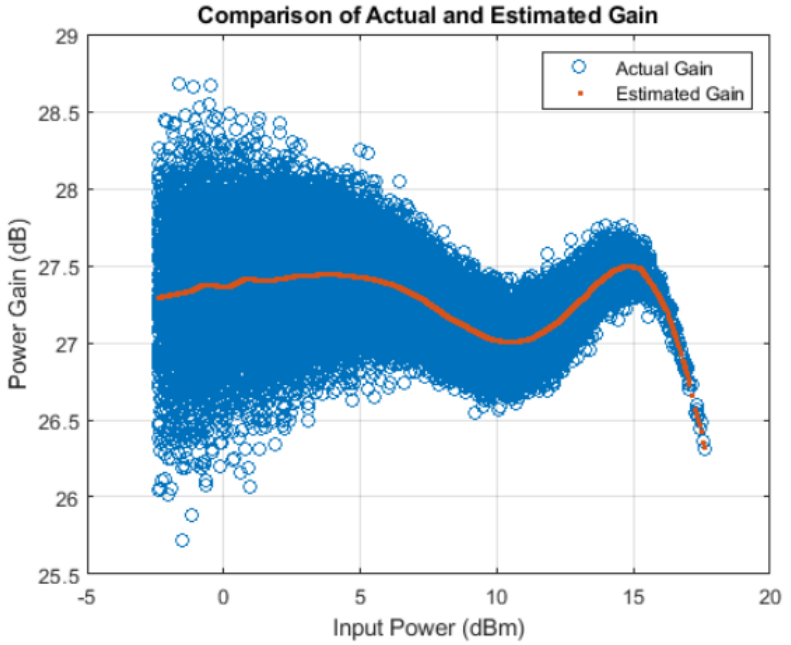
- Connect to NI PXIe box to
  - Send signals through a PA
  - Capture received signals
  - Take measurements
- Use captured signals to model the PA
- Perform HW-in-the-loop tests with PA and DPD

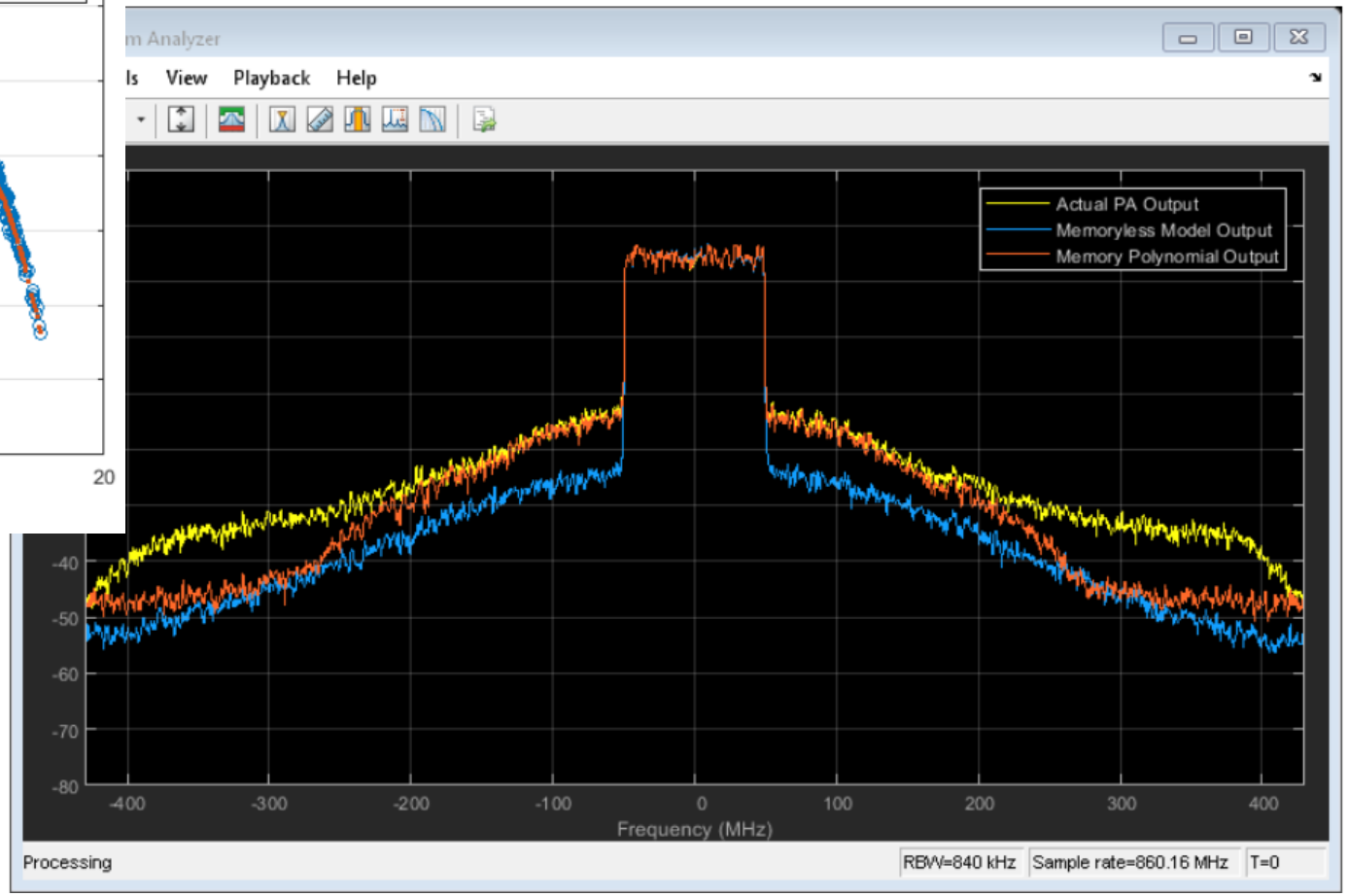
MathWorks Hardware Setup

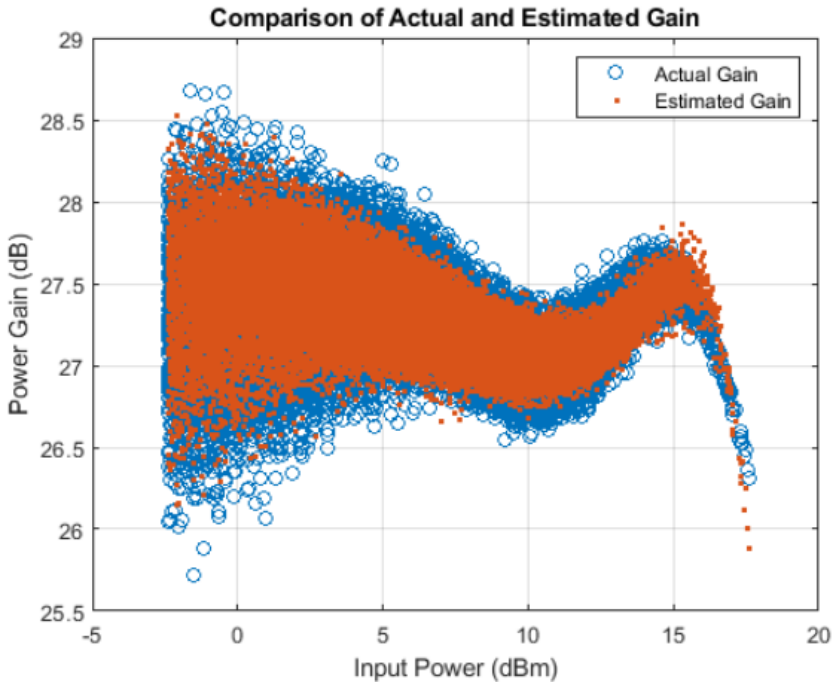




Demo


Comparison of Actual and Estimated Gain
Actual Gain
Estimated Gain
Power Gain (dB)
Input Power (dBm)


Actual PA Output
Memoryless Model Output
Memory Polynomial Output
Frequency (MHz)
Processing
RBW=840 kHz
Sample rate=860.16 MHz
T=0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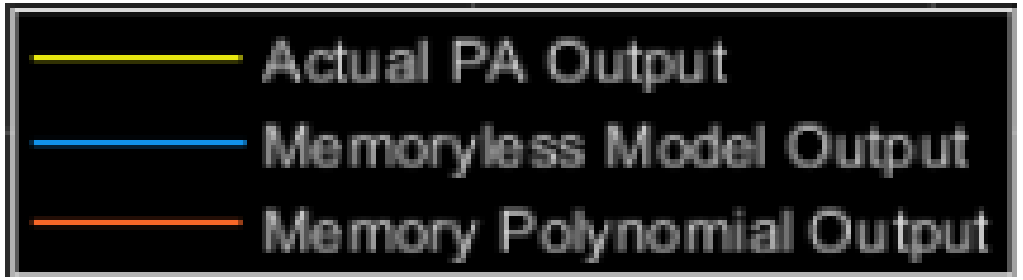
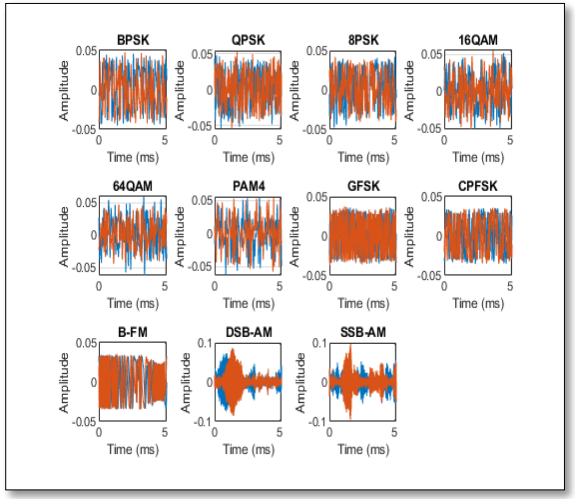
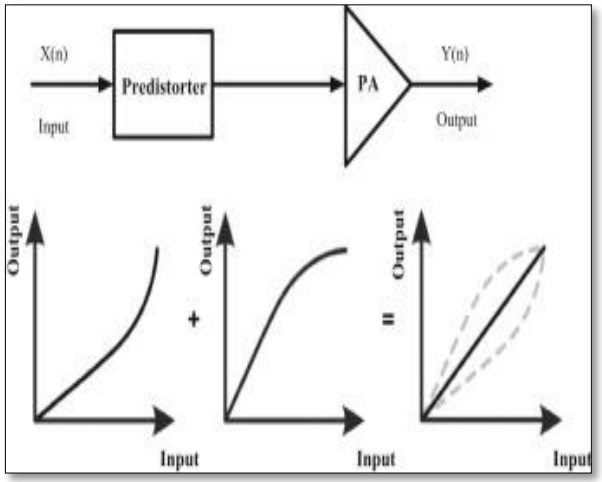

Actual PA Output
Memoryless Model Output
Memory Polynomial Output

Use Case – Signals Intelligence and Deep Learning

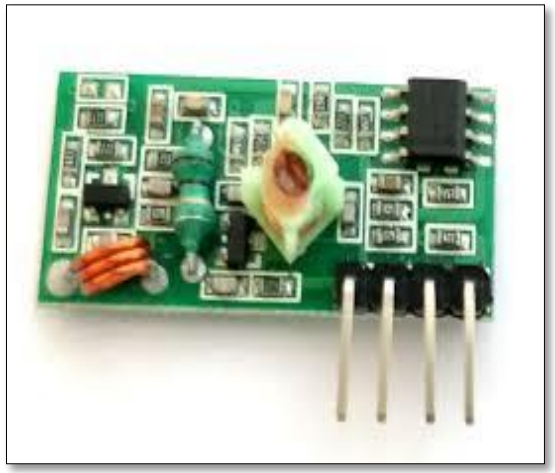


Signal Classification

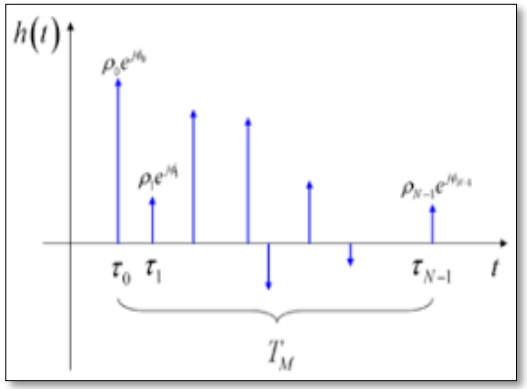
Device Identification



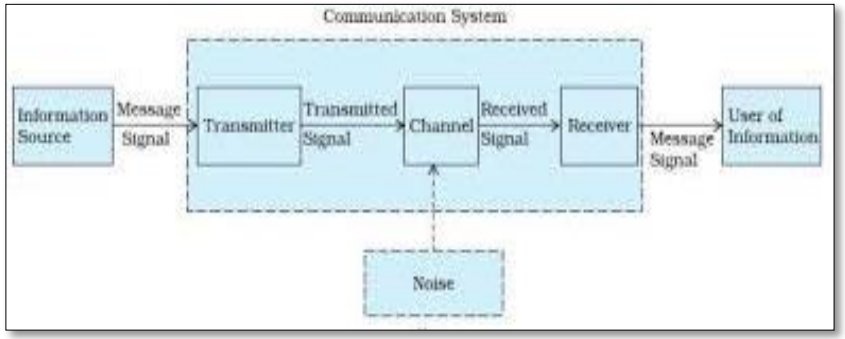
Digital pre-distortion



Receiver design



Channel models and channel prediction

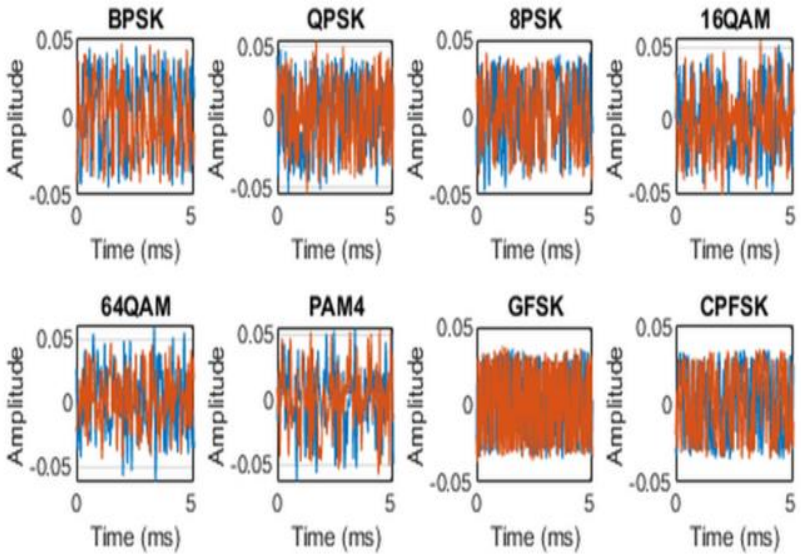


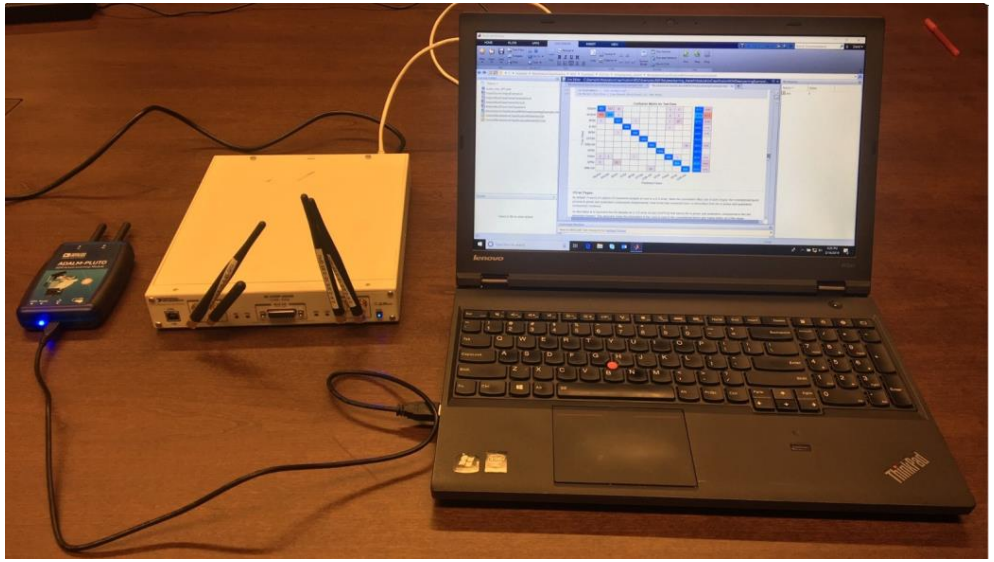
Autoencoder

Wireless network

Synthetic Data + Real-World Data = Better Deep Learning Models

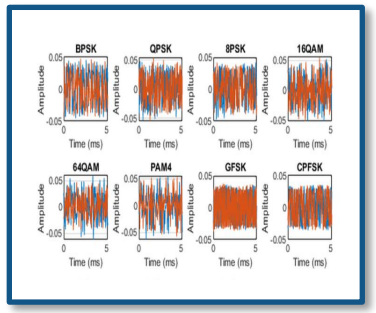
- Generate synthetic data with impairments using MATLAB
- Gather real-world data over-the-air with NI SDR hardware



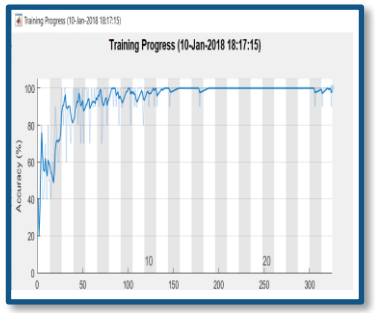


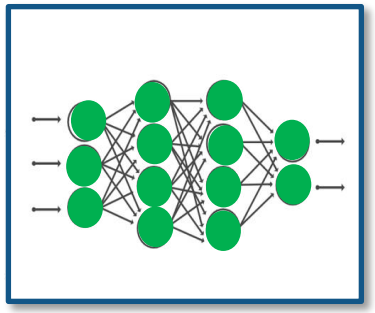
Model Development with Synthetic Signals

Train



- Noise
- Multipath fading
- Frequency offset
- Sampling rate offset

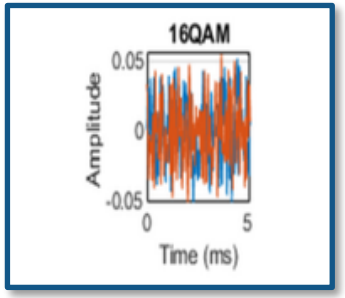


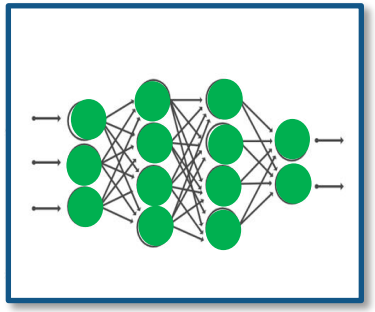


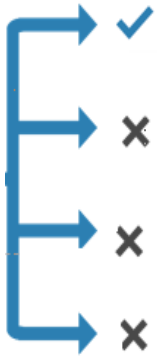
Synthesize labeled data → Add impairments → Train Network → Trained Model

Test

New Signal → Pre-Trained Model → Classification

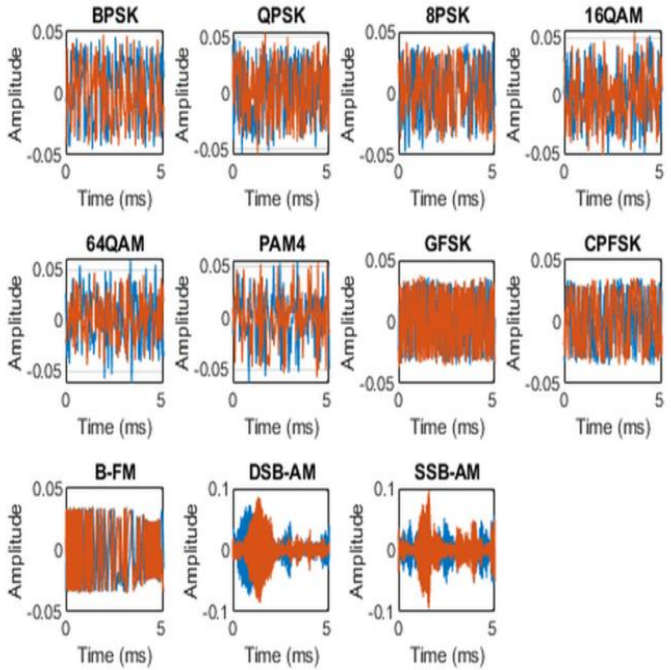


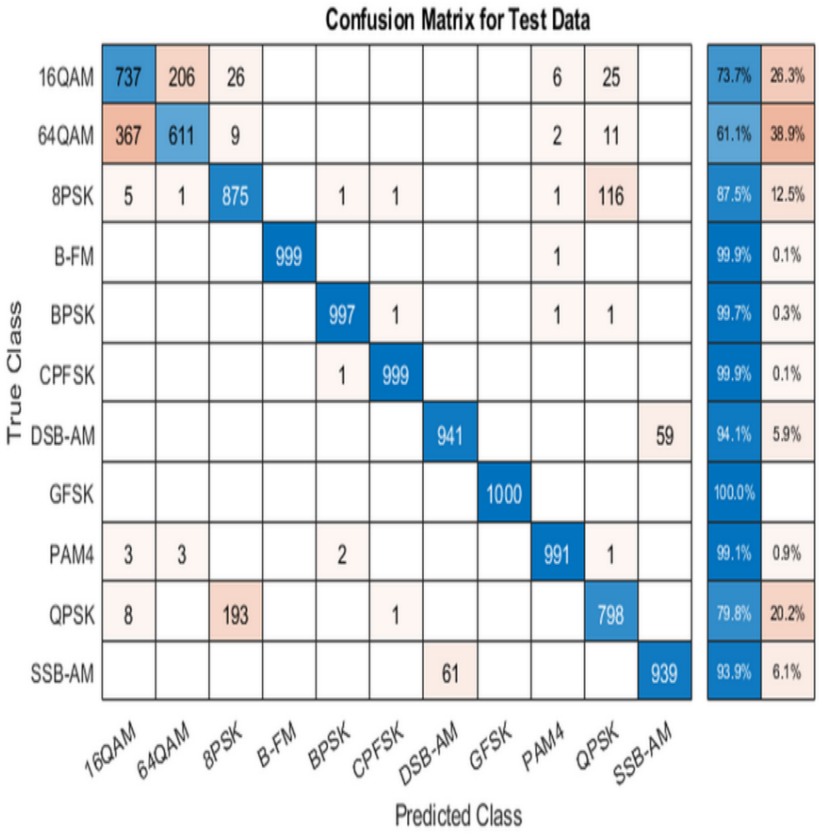


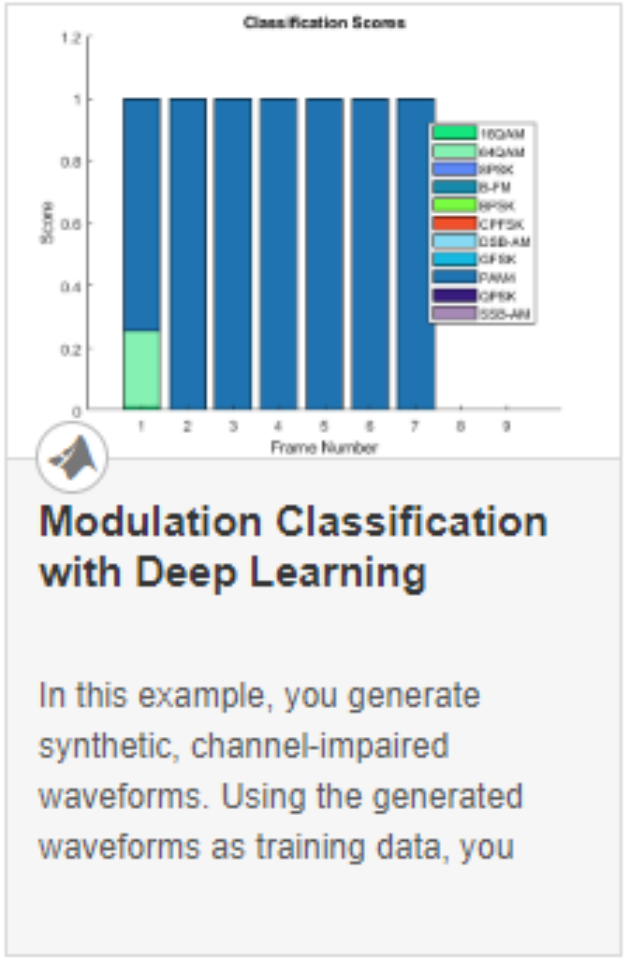


Wireless Modulation Classification with Deep Learning

- Generate synthetic modulated signals
- Apply channel impairments
- Train a CNN to classify modulation types
- Search “modulation classification MathWorks”

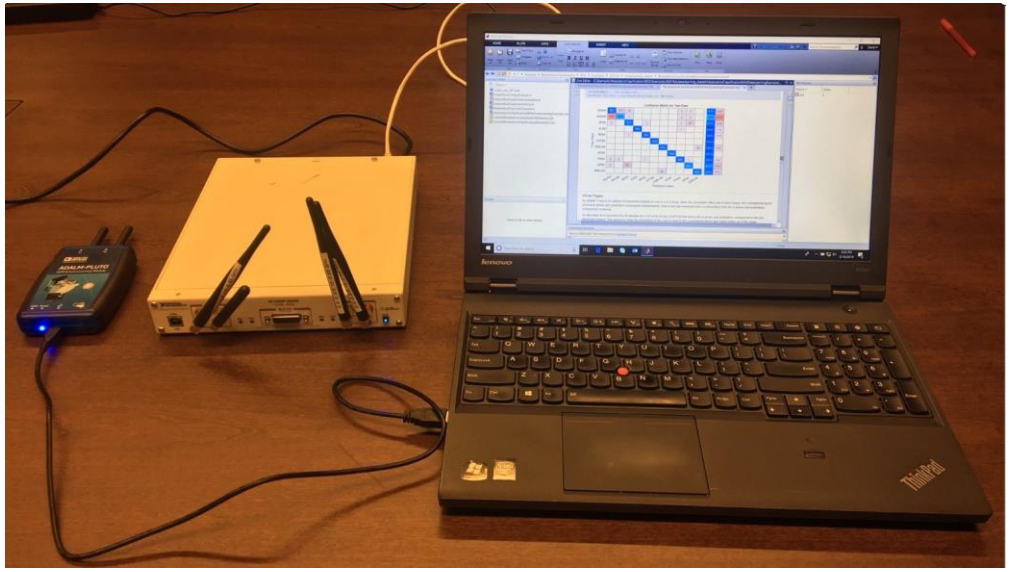


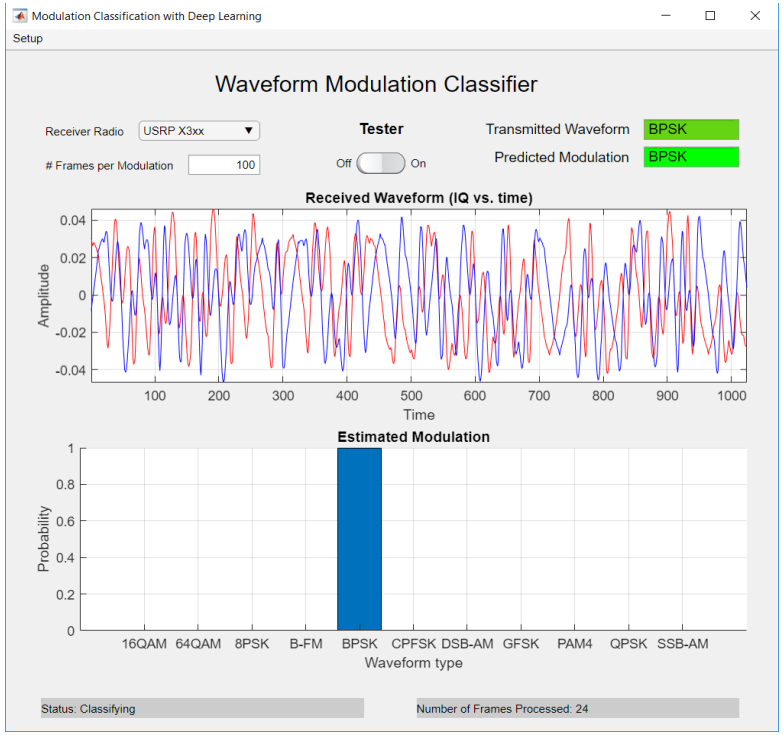


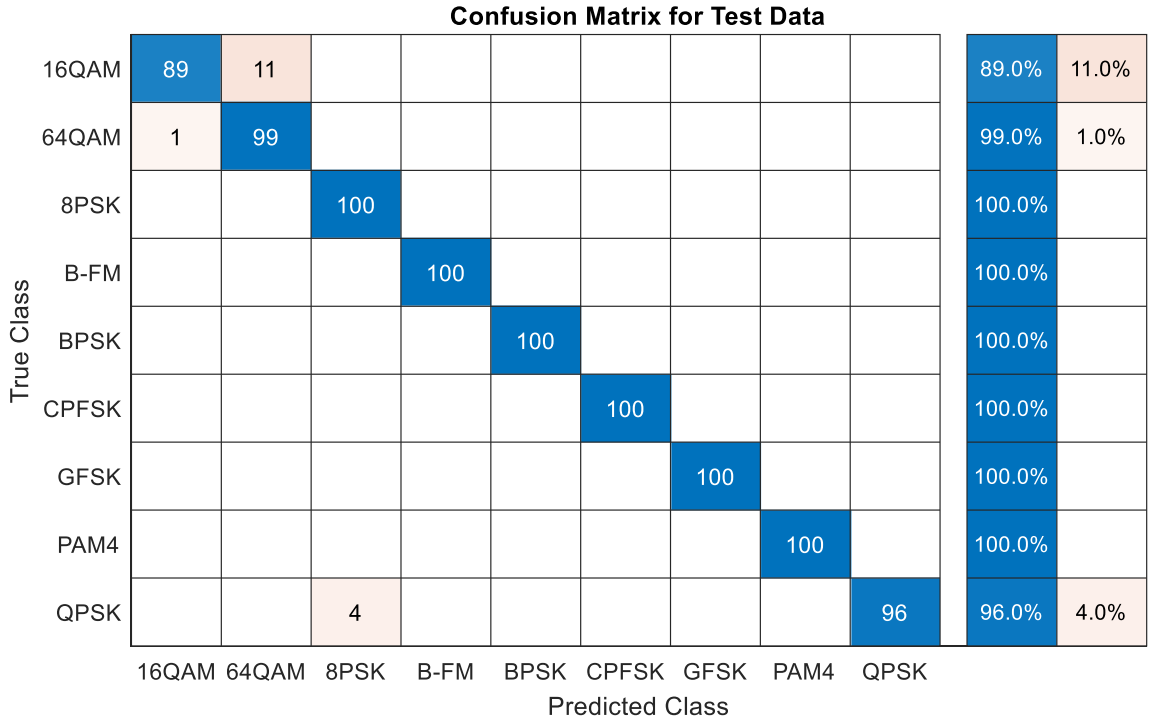


Over-the-air Test with NI SDR

- Generate OTA test signals using any source
- Connect MATLAB to NI SDR to receive signals
  - USRP-29xx or Ettus B2xx, N2xx, and X3xx
- Process real-time data in MATLAB







Future Directions

- NI will continue to incorporate the latest:
  - Data converters
  - Processing technologies
  - Data movement interfaces
- MathWorks will:
  - Stay current with UHD
  - Focus on performance
  - Plan more development for the N3xx radio

For more information, please visit:

- Virtual booth for more demonstrations of NI hardware with MathWorks software
- mathworks.com/hardware-support/usrp
- ni.com/sdr

Application Poll

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Thank you