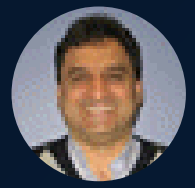
MATLAB EXPO

Wireless Standards + AI: Enabling Future Wireless Connectivity

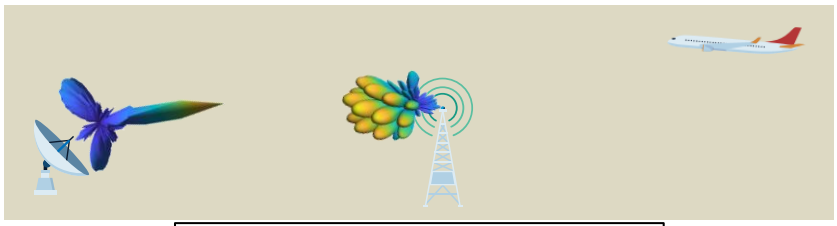


Houman Zarrinkoub
MathWorks

John Wang
MathWorks

MathWorks

Recent 5G Deployment Challenge at US Airports



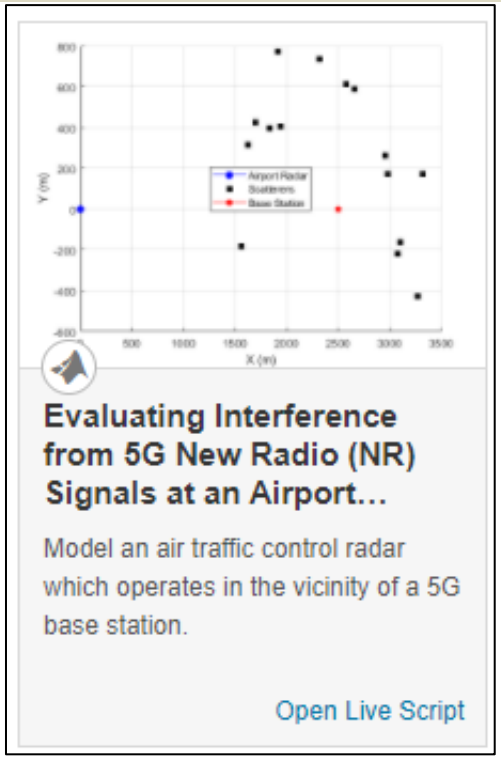
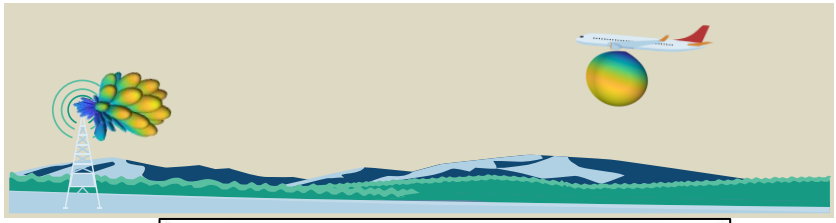
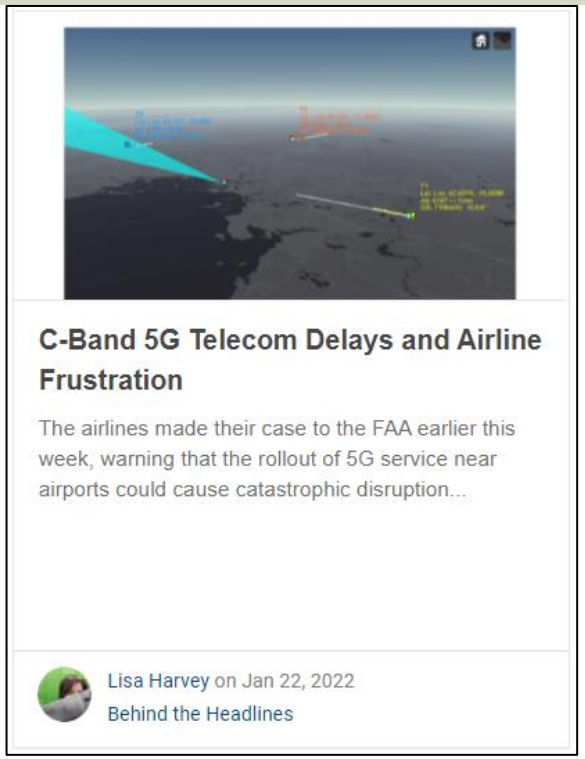


Image Credit: Toronto Star

Airport Surveillance Radar & 5G Base Station





Radar Altimeter & 5G Base Station

C-Band 5G Telecom Delays and Airline Frustration

Future of Connected World

Diverse standards

Diverse frequencies

Diverse Use cases

Diverse technologies

3 Challenges of achieving ubiquitous connectivity

Handle Complexity

Coordinate Early

Need standards

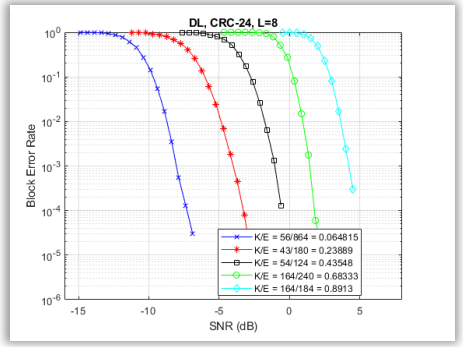
Ensure Reliability

Test Everything

Need lots of testing data

Push for Performance

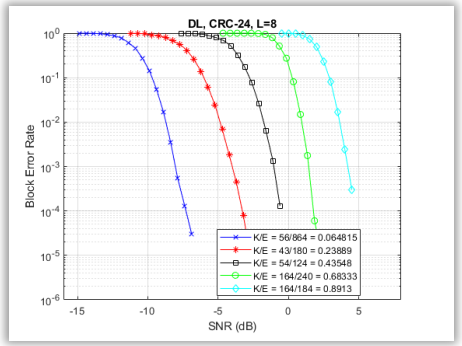
Optimize Everything

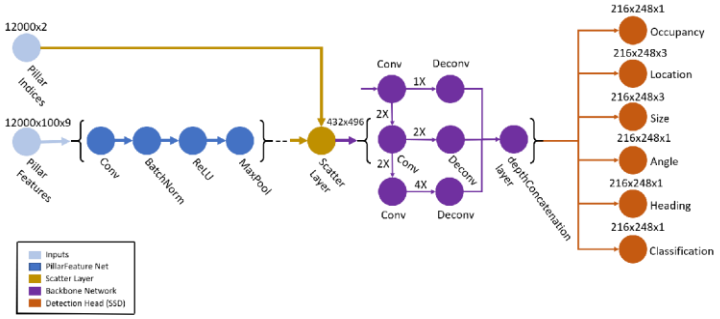


Need AI deployment

Agenda

1. Handle Complexity with Standards
2. Test Everything with Hardware Connectivity
3. Optimize Everything with AI
4. Summary





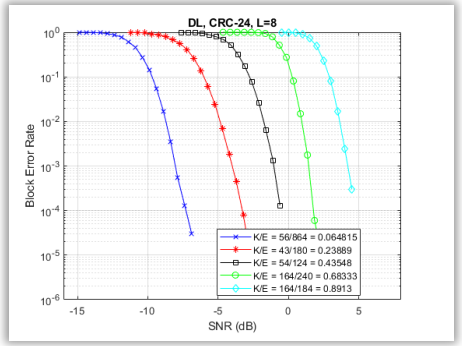
Agenda

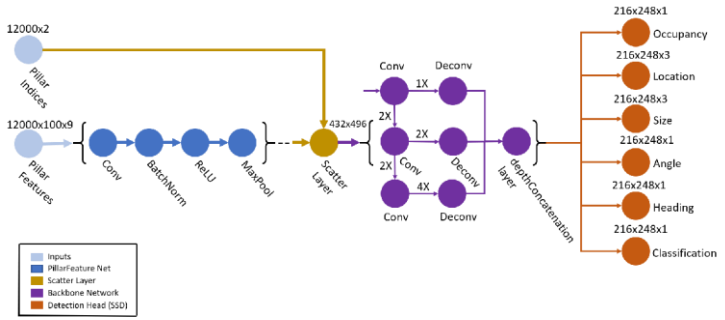
1 **Handle Complexity with Standards**

2 Test Everything with Hardware Connectivity

3 Optimize Everything with AI

4 Summary





Ubiquitous connectivity – technologies & standards

Cellular

Satellite communications

WLAN

5G

GNSS

CCSDS

LTE

DVB-S*

Bluetooth

Wi-Fi

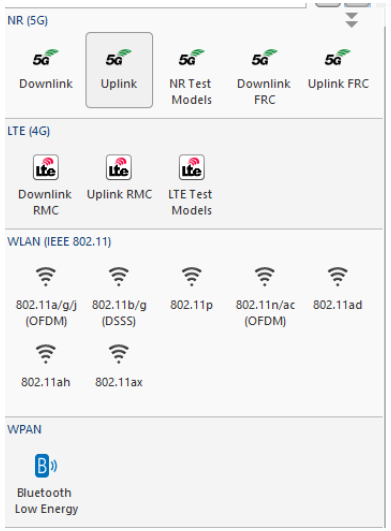
Personal Area Network

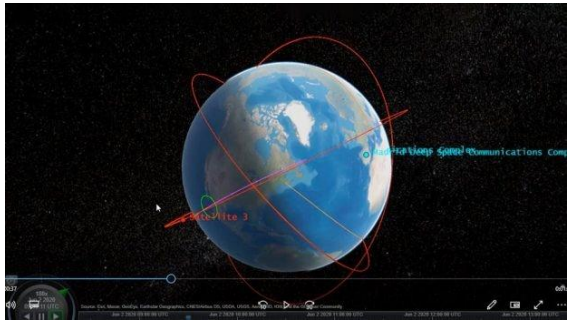
Local Area Network

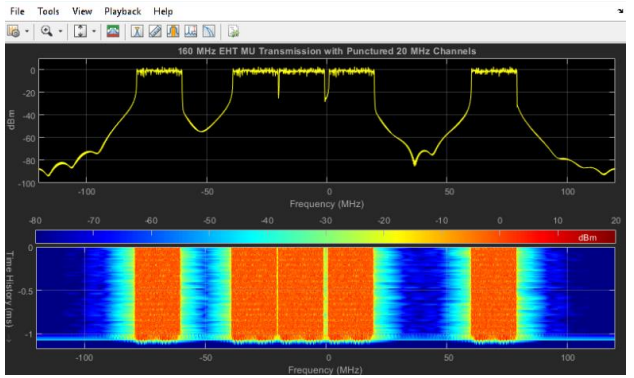
Wide Area Network

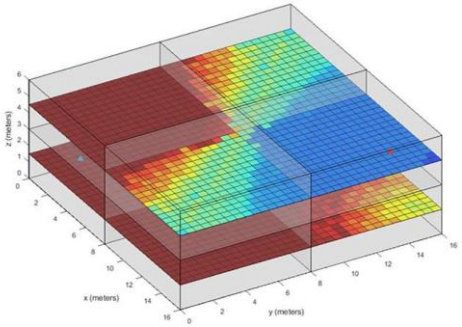
Our new investments in Wireless standards …

Satellite Communications









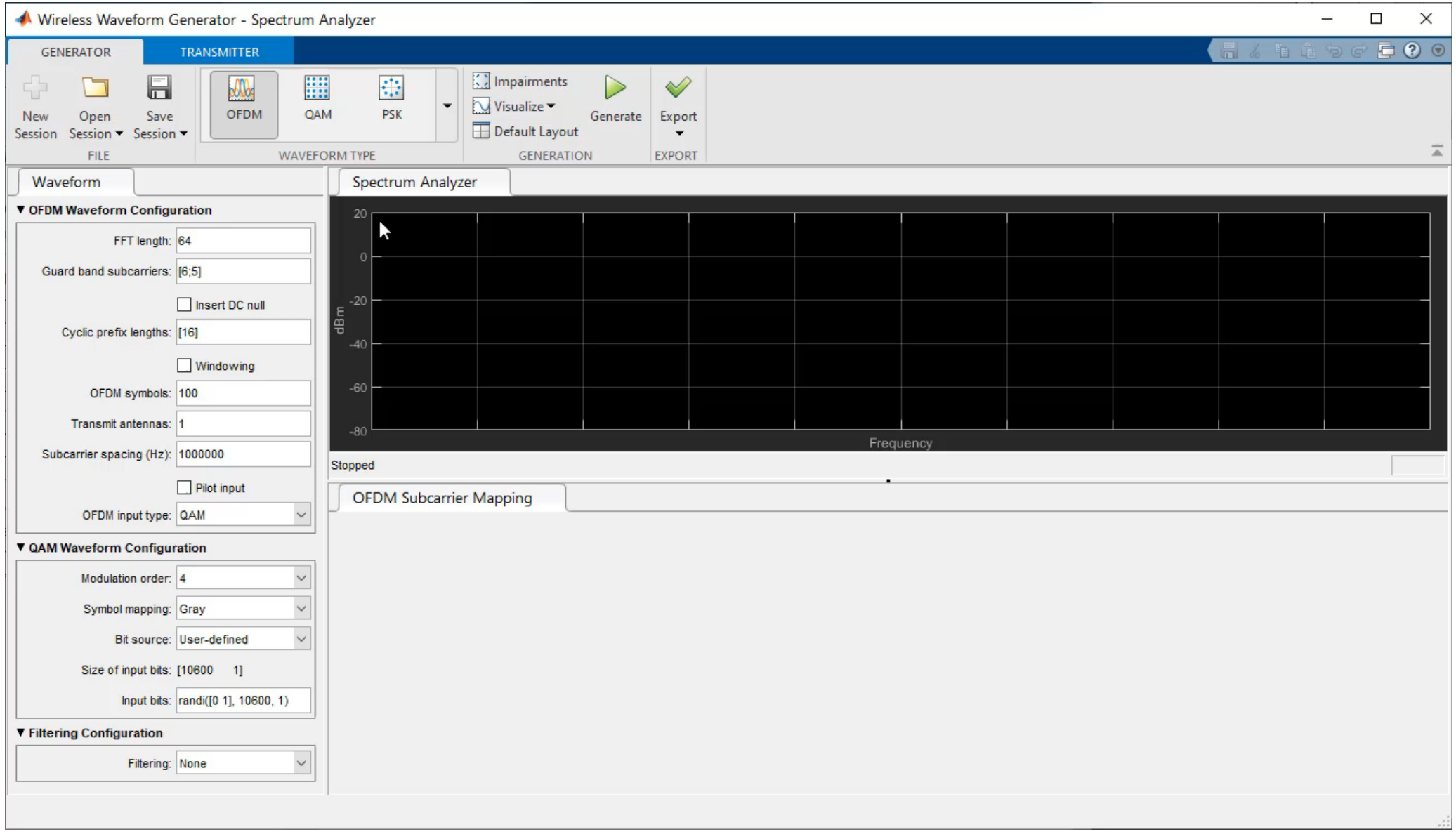
Waveform Generation

Non-terrestrial Networks (NTN)

Wi-Fi 7 IEEE 802.11be

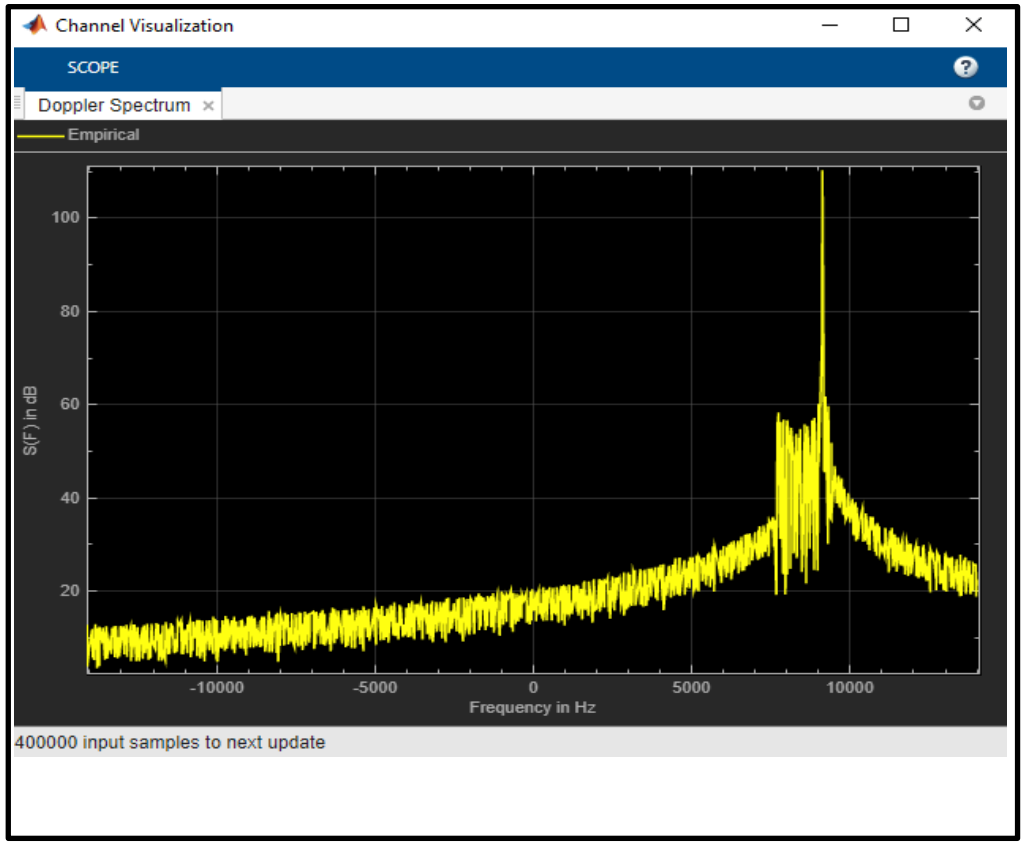
New Bluetooth Toolbox

Wireless Waveform Generator App

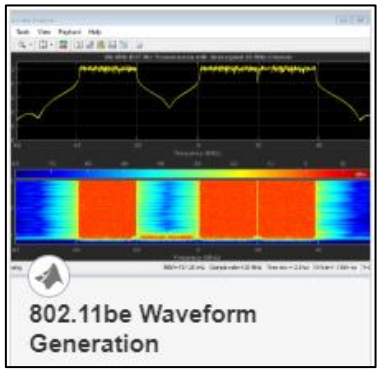


Non-terrestrial network (NTN) Narrowband Channel

- Supports flat fading narrowband channel model as per 3GPP TR 38.811
- Supports different frequency ranges and types of environment as per ITU-R P681.11
- Supports visualization of Doppler spectrum, impulse & frequency responses)

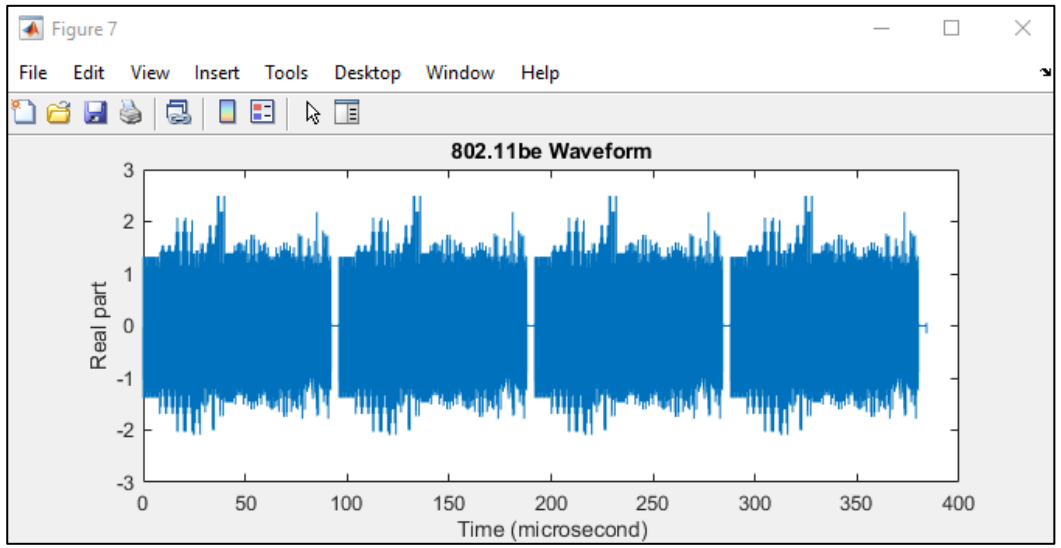


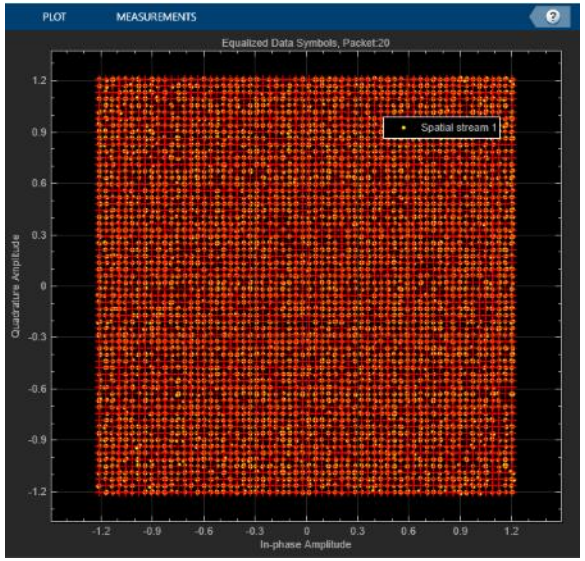
Generate 802.11be (Wi-Fi 7) Waveforms



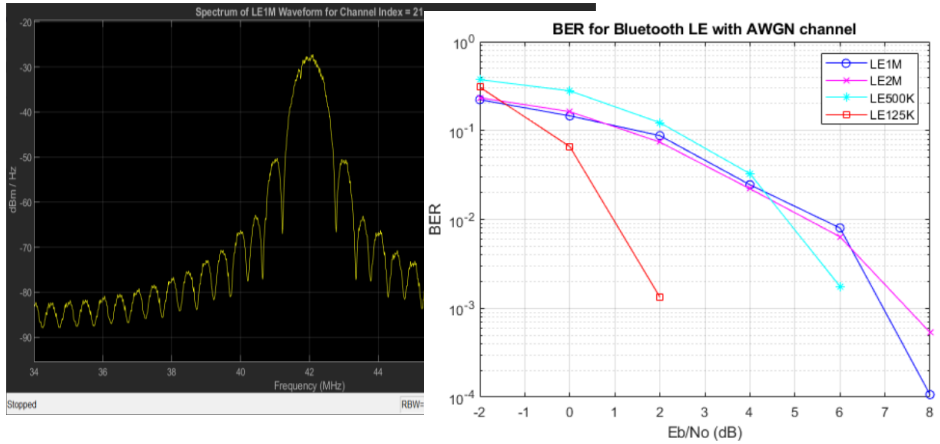
- Up to 320 MHz channel bandwidth
- Up to 4096QAM

```
Command Window
>> cfgEHT = ehtMUConfig('CBW320');
>> txWaveform = ehtWaveformGenerator(data,cfgEHT,'NumPackets',4,'IdleTime',4*1e-6);
>>
```

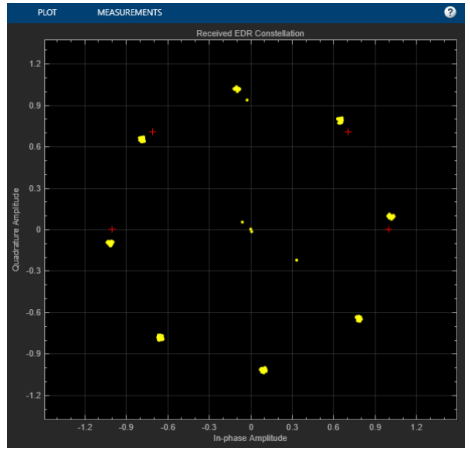




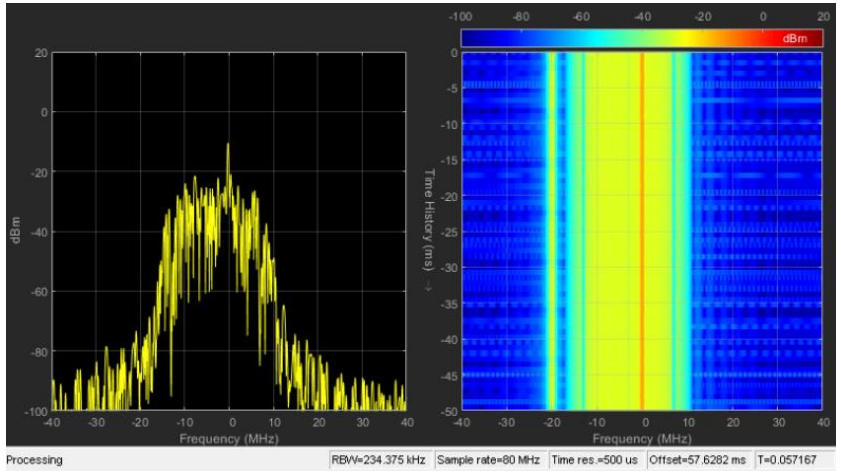
Bluetooth Toolbox



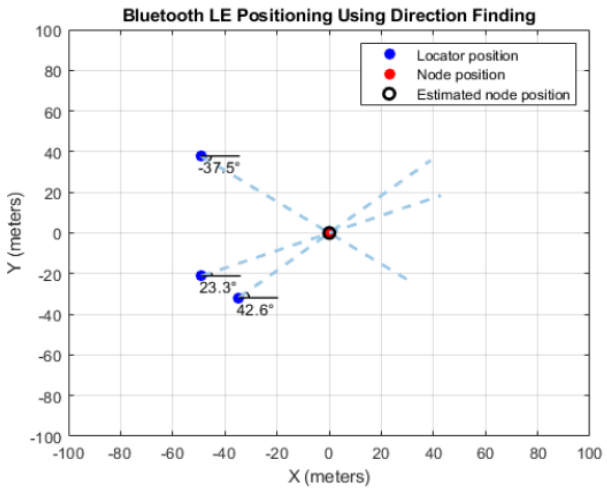
Waveform Generation and End-to-End Link Simulation



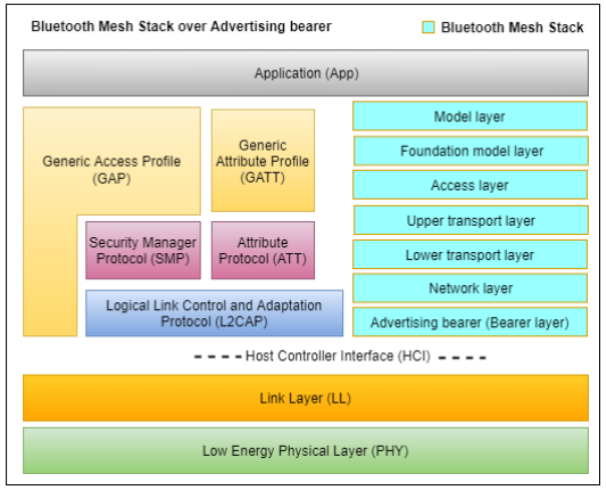
Signal Recovery and Analysis



Bluetooth/WLAN Coexistence



Localization



Network Modeling

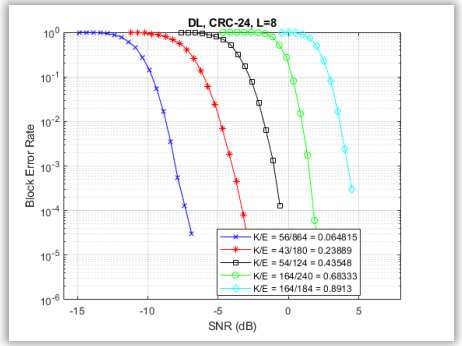
Agenda

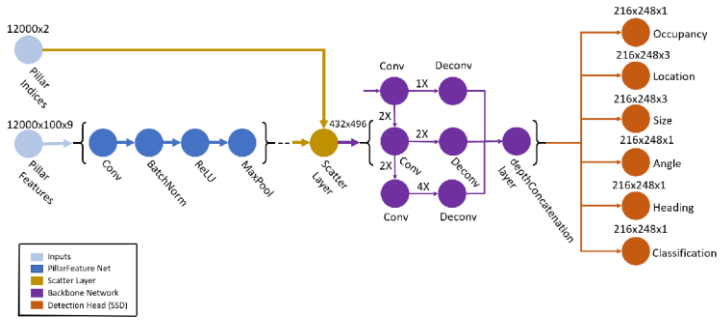
1 Handle Complexity with Standards

2 **Test Everything with Hardware Connectivity**

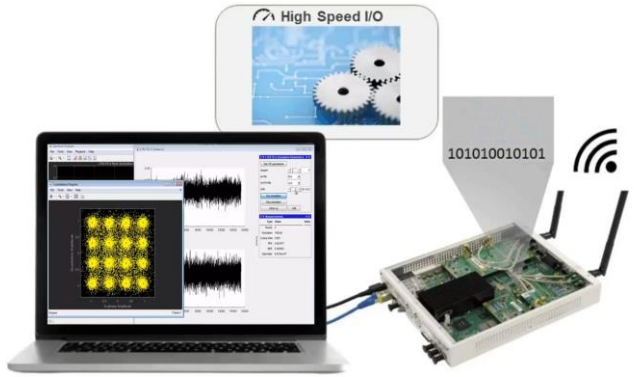
3 Optimize Everything with AI

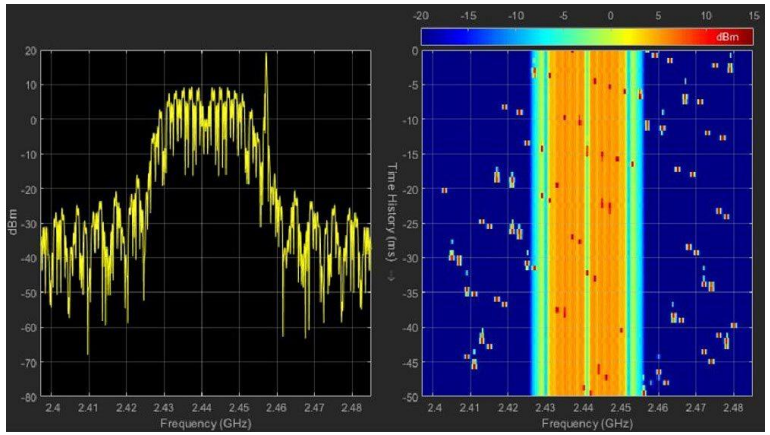
4 Summary





Our new investments in Wireless testing





SDR Connectivity

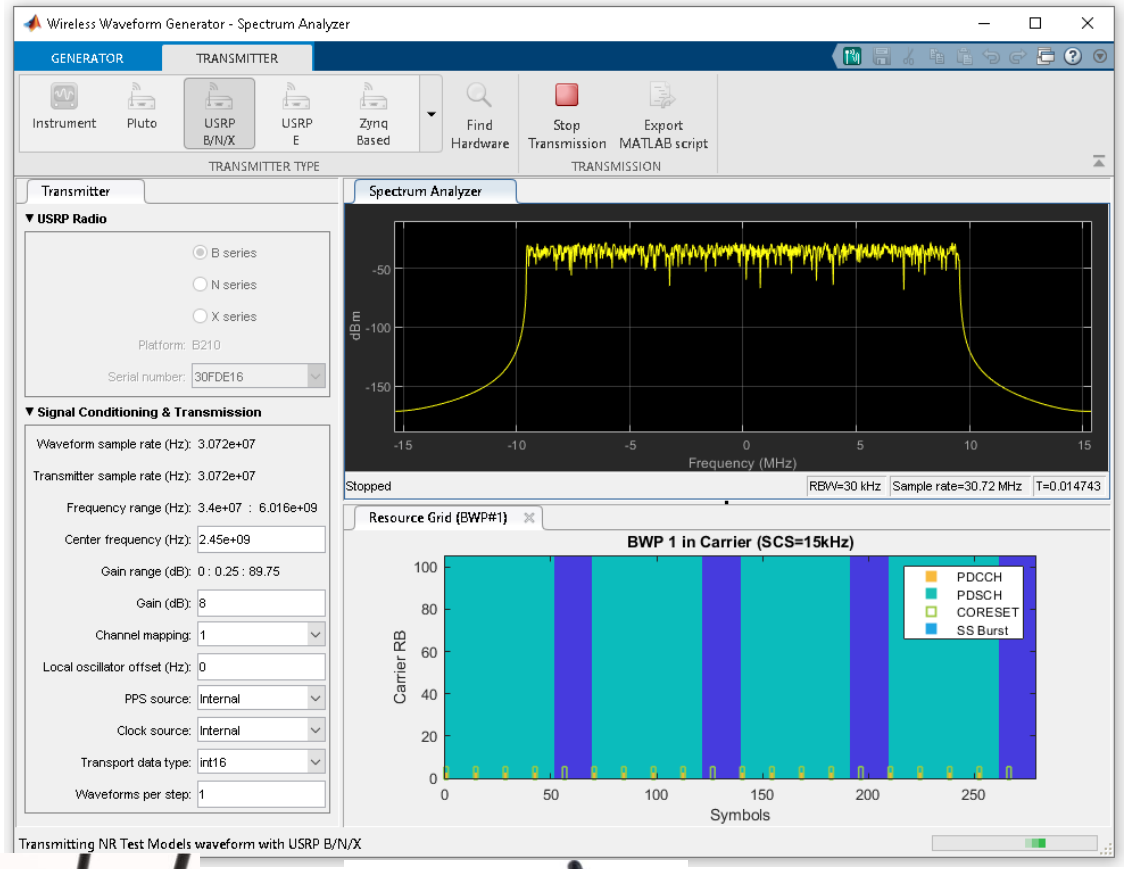
Wireless Testbench

Interference & Coexistence

Connect easily to SDRs in Wireless Waveform Generator App

Easy and graphical transmission of wireless signals with Pluto, USRP B/N/X, USRP E, Zynq software-defined radios

- Support for all waveform types (5G, WLAN, LTE, Bluetooth, Comms)
- Automatic sample rate selection for USRP B/N/X and waveform resampling
- Generation of equivalent MATLAB code

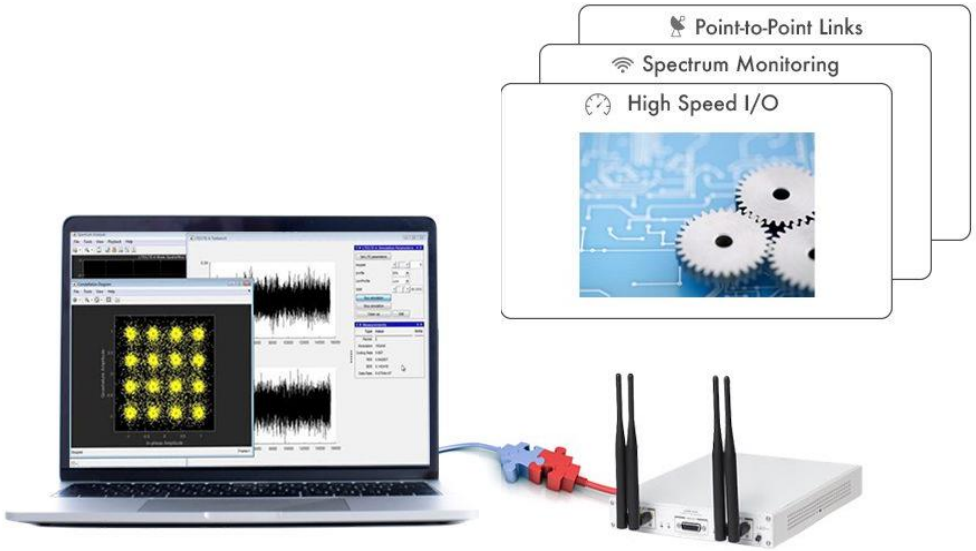


Wireless Testbench

Explore and test wireless designs using intelligent, high-speed data transmit/capture

Use cases/Applications

- Spectral conformance
- Signal detection
- Spectrum monitoring
- Signal classification
- Cognitive radio



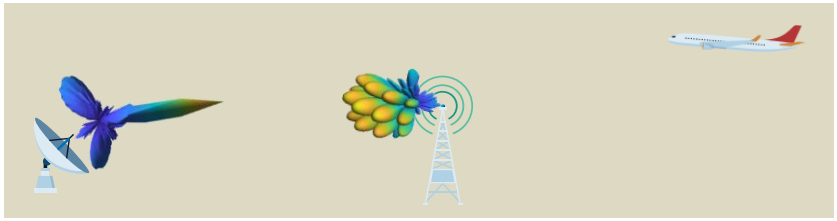
Transmit and capture wideband signals at up to 250 Msps

End-to-end transceiver design, standard-based and custom signal transmitter/receiver design

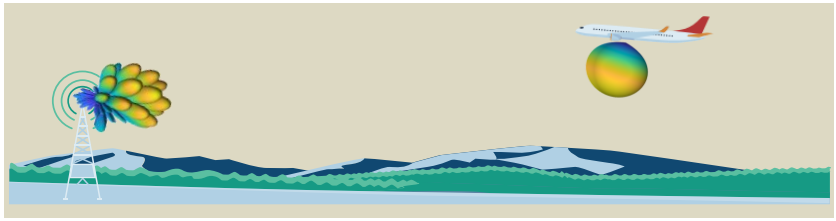
Intelligent data capture

Reduce data sent to host computer by capturing only waveforms of interest by preamble detection

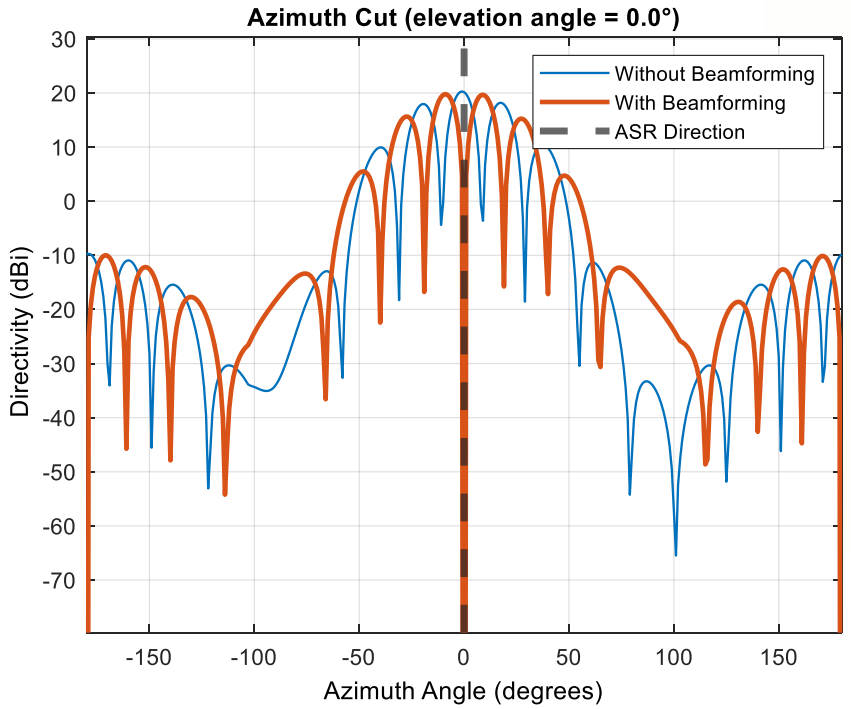
Ensure Reliability and Coexistence with Interference Mitigation

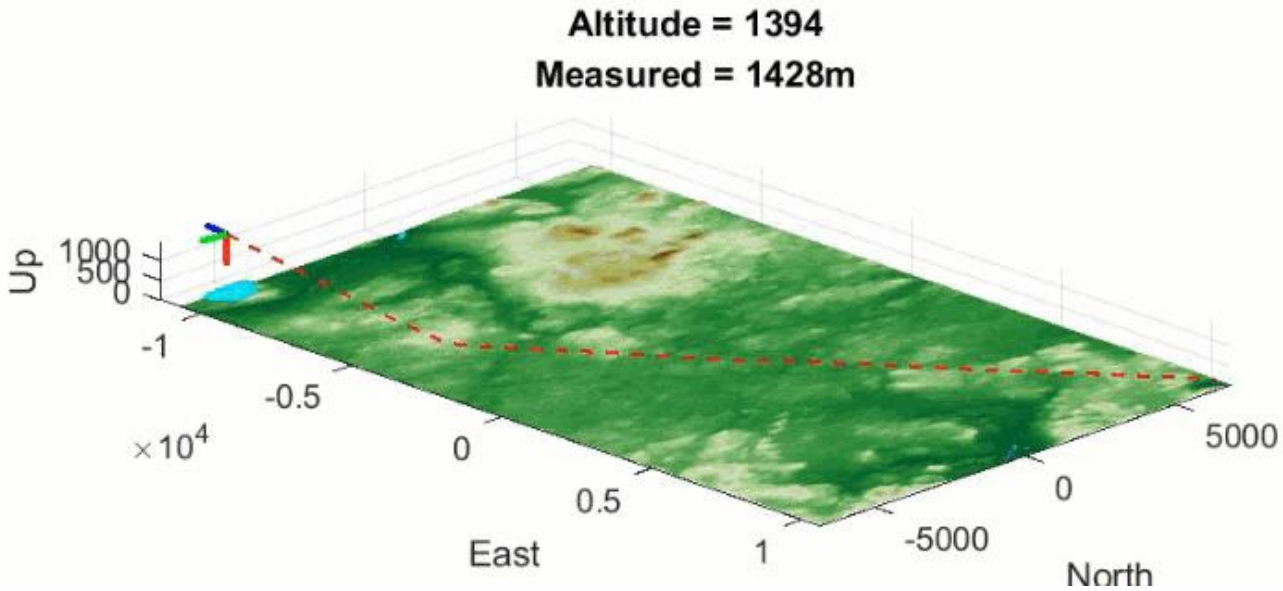


Airport Surveillance Radar &
5G Base Station



Radar Altimeter & 5G Base Station





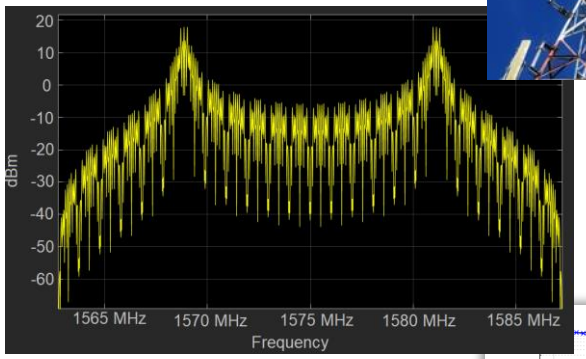
Agenda

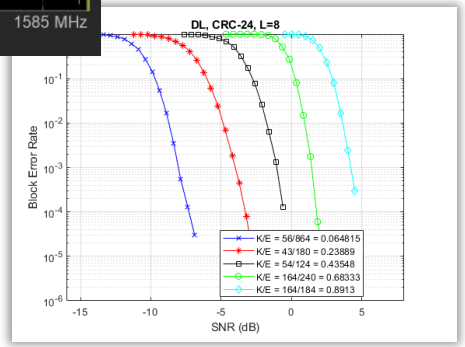
1 Handle Complexity with Standards

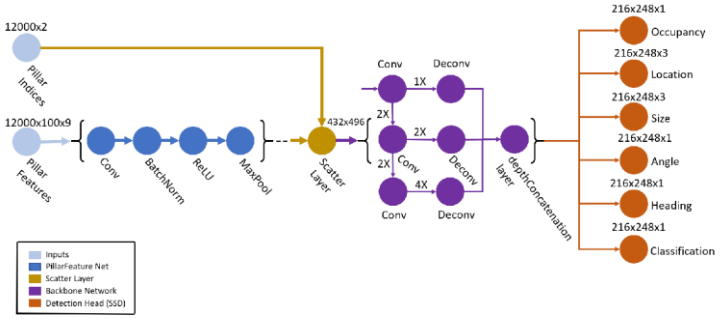
2 Test Everything, Ensure Reliability

3 **Optimize Everything with AI**

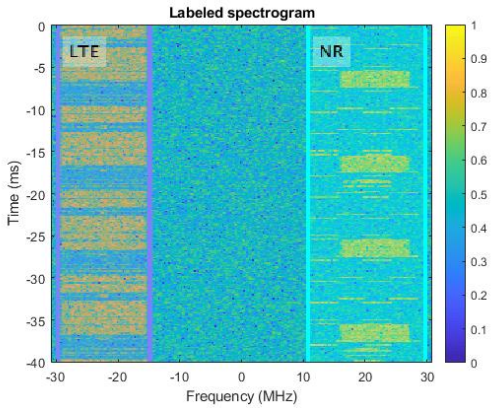
4 Summary







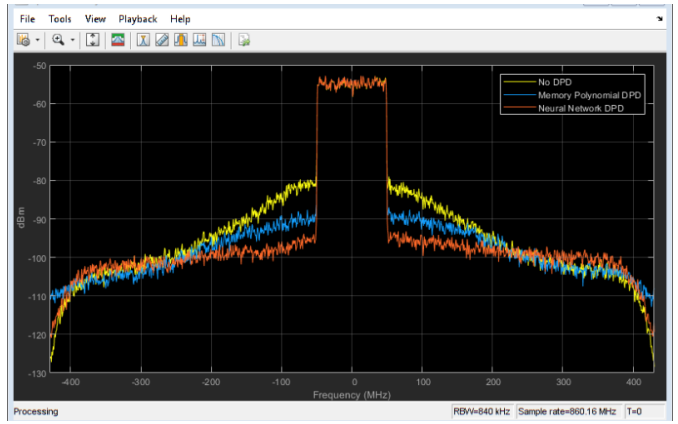
Our new investments in AI for Wireless Communications



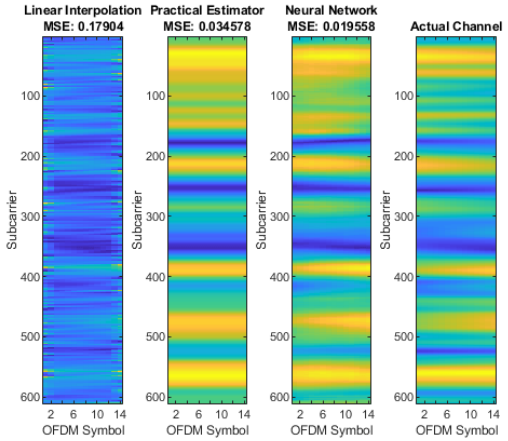
Spectrum Sensing &

Signal Classification

Device Identification

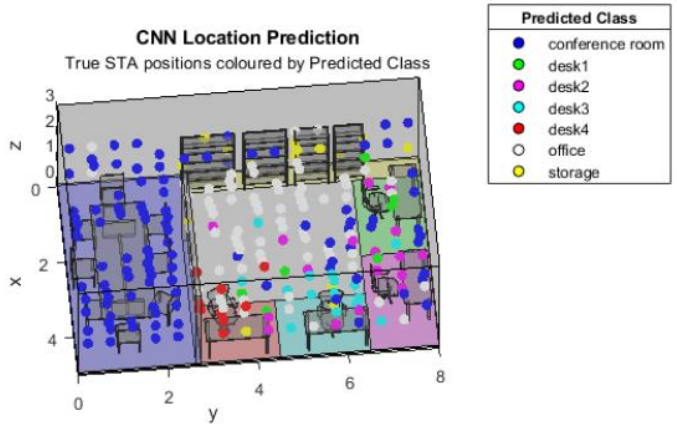


Digital Pre-Distortion



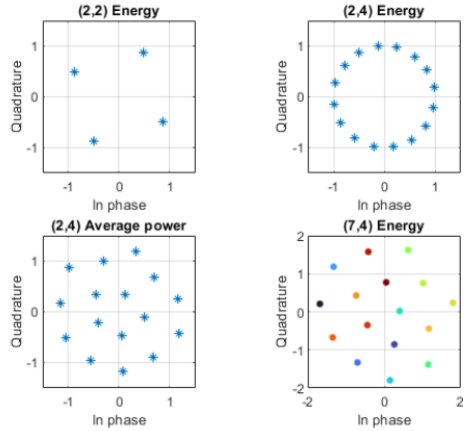
Beam Management &

Channel Estimation



Localization &

Positioning



Transceiver design

AI-Driven Wireless System Design

Data Preparation

- Data cleansing and preparation
- Human insight
- Simulation-generated data

AI Modeling

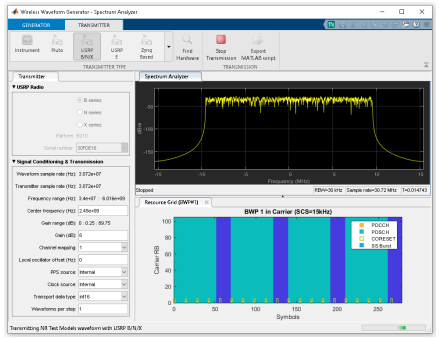
- Model design and tuning
- Hardware accelerated training
- Interoperability

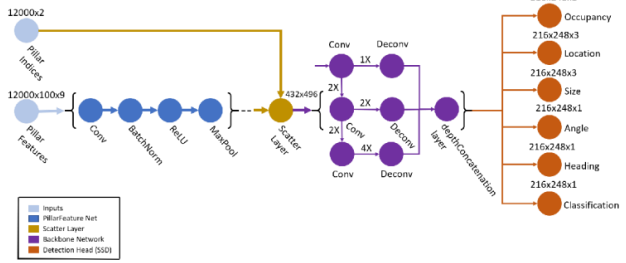
Simulation & Test

- Integration with complex systems
- System simulation
- System verification and validation

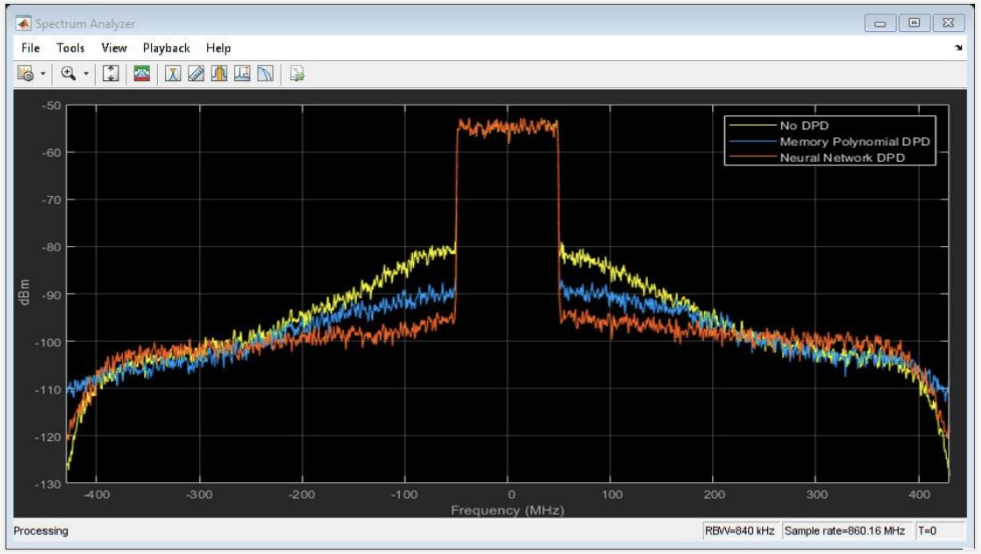
Deployment

- Embedded devices
- Enterprise systems
- Edge, cloud, desktop





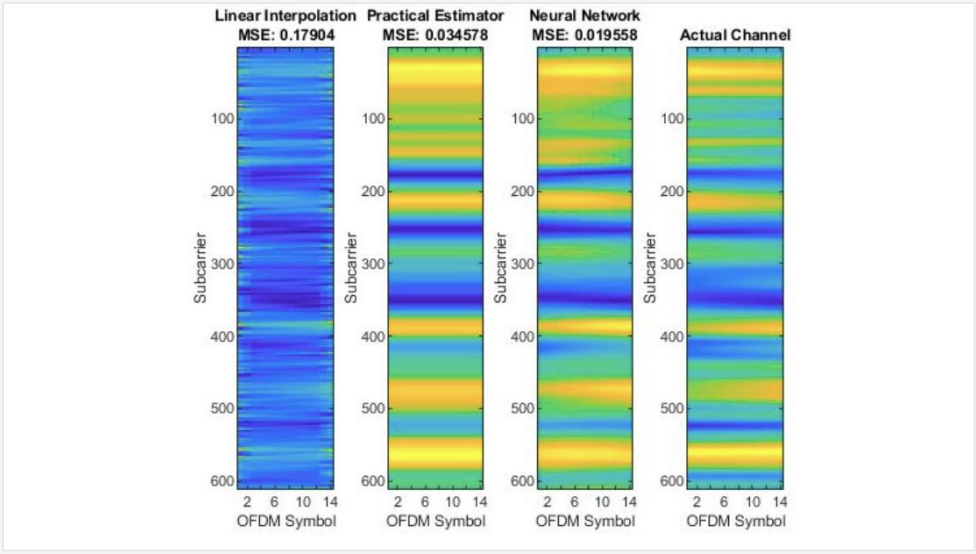
Examples: How to Use AI for Wireless with MATLAB



Digital Pre-Distortion

Apply neural network-based digital predistortion (DPD) to offset the effects of nonlinearities in a power amplifier (PA).

- Neural Network for Digital Predistortion Design - Offline Training



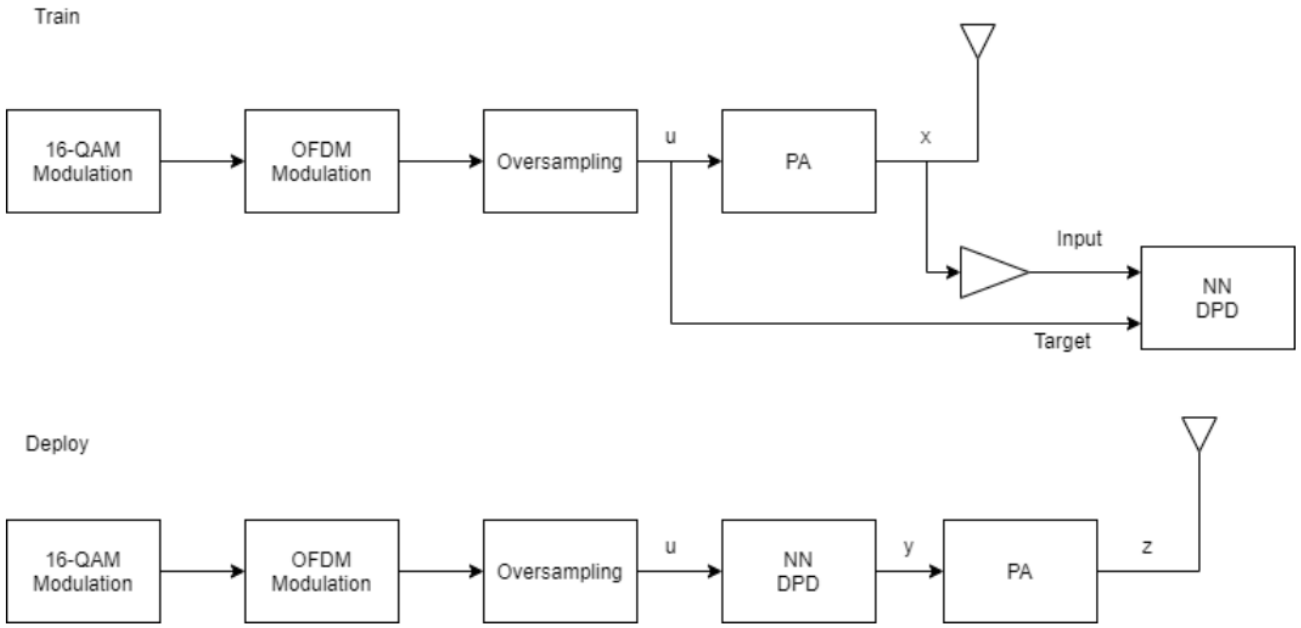
Beam Management and Channel Estimation

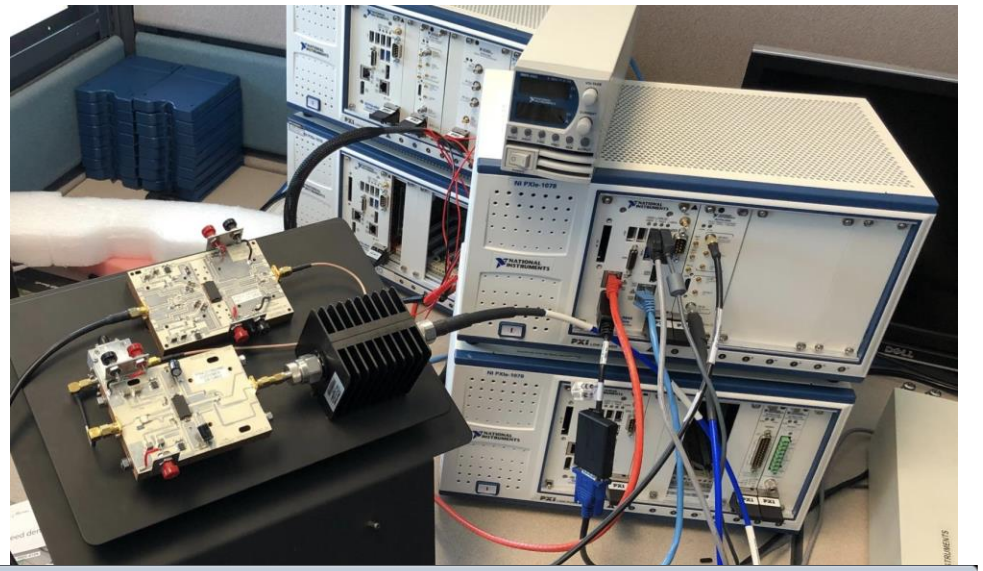
Use a neural network to reduce the computational complexity in the 5G NR beam selection task. Train a CNN for 5G NR channel estimation.

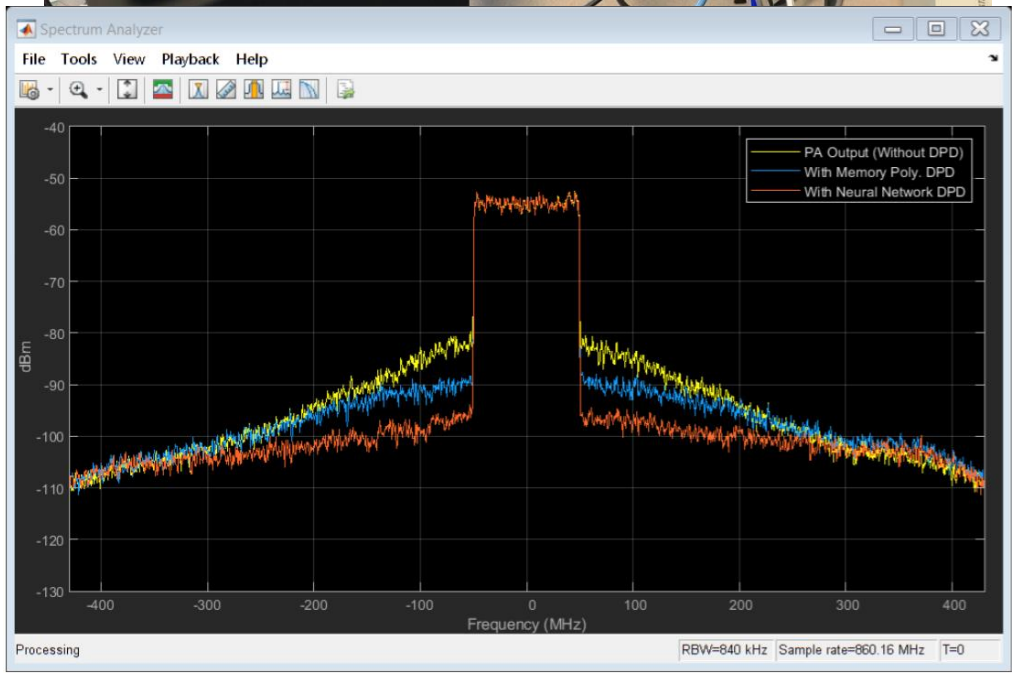
- Neural Network for Beam Selection
- Deep Learning Data Synthesis for 5G Channel Estimation

https://www.mathworks.com/solutions/wireless-communications/ai.html

AI for Digital Pre-Distortion with training and deployment







Workflow

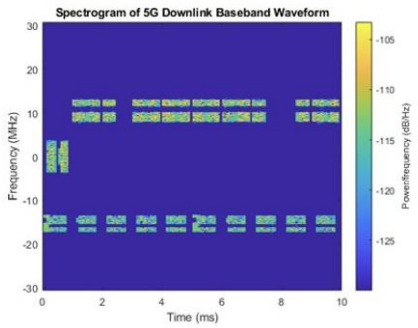
- Collect data from a real PA using test instrument hardware or characterize the PA and use the model for simulation
- Train a neural network using real PA data or simulation data
- Test the network with real data using the hardware
- Once satisfied, prune and quantize the network
- Target an FPGA and deploy the algorithm with HDL

AI for Channel Estimation

Data Preparation | **AI Modeling** | **Simulation & Test** | **Deployment**

Data Synthesis

Generate 5G Standard-compliant Waveforms



Algorithm Design

Deep Learning Design & Training

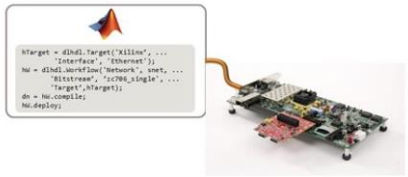
Simulate 5G Transmission

Visualization and Performance Comparison

Automate

Hardware Deployment

Generate and Deploy FPGA HDL Code

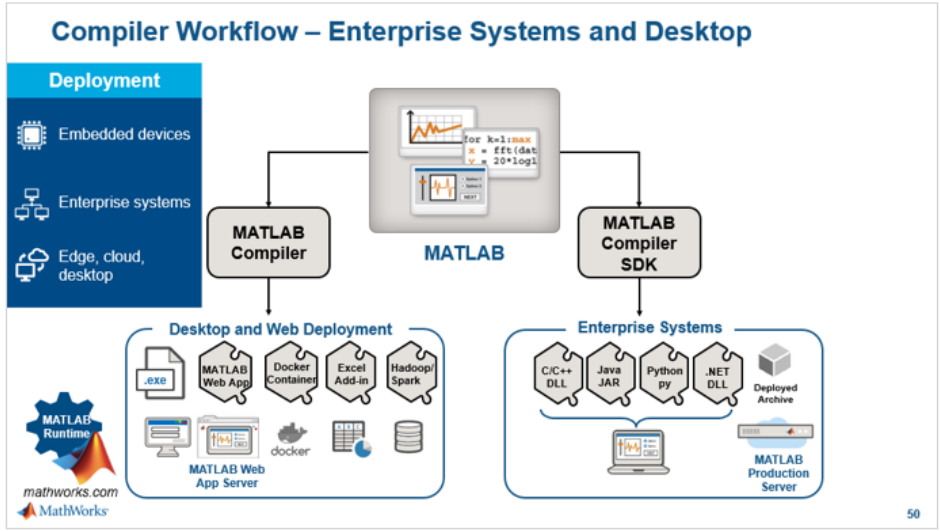


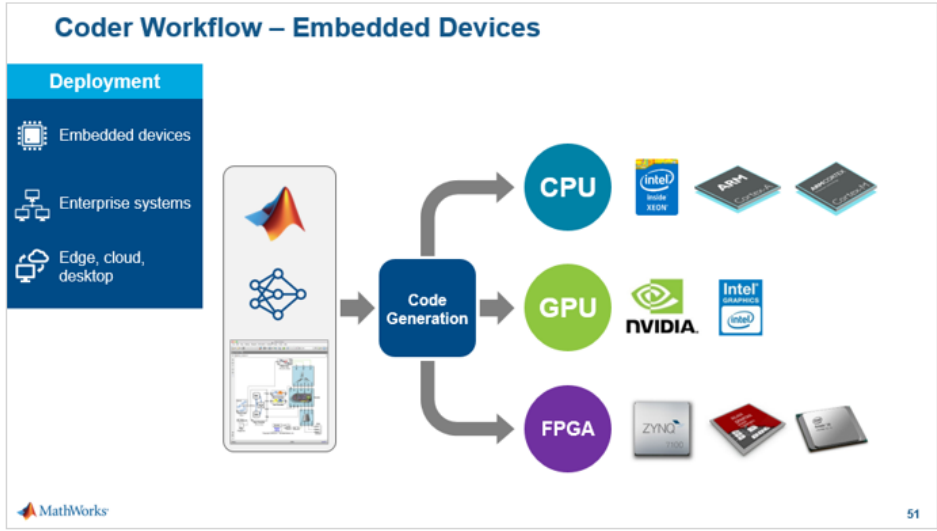
Deploy to any processor with best-in-class performance

AI models in MATLAB and Simulink can be deployed on embedded devices, edge devices, enterprise systems, the cloud, or the desktop.

Deployment

- Embedded devices
- Enterprise systems
- Edge, cloud, desktop





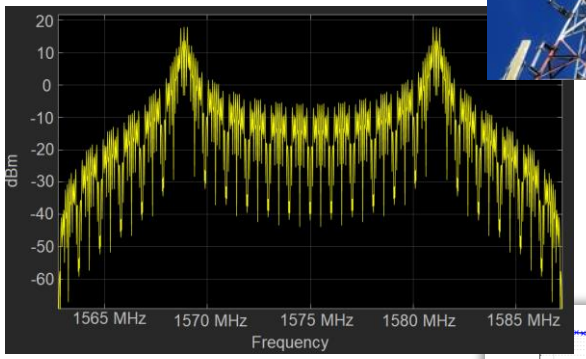
Agenda

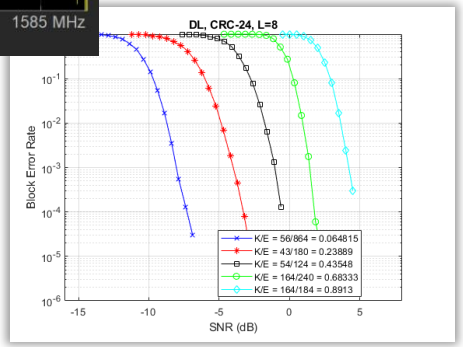
1 Handle Complexity with Standards

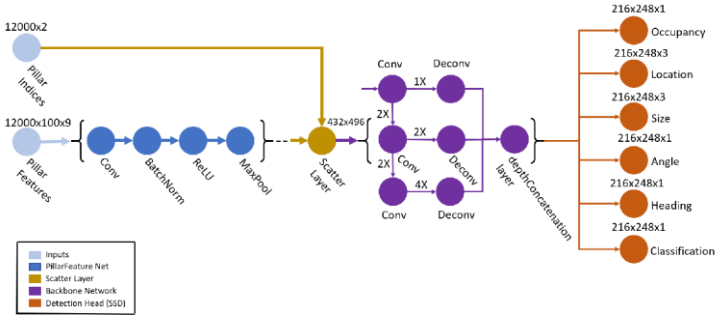
2 Test Everything, Ensure Reliability

3 Optimize Everything with AI

4 **Summary**



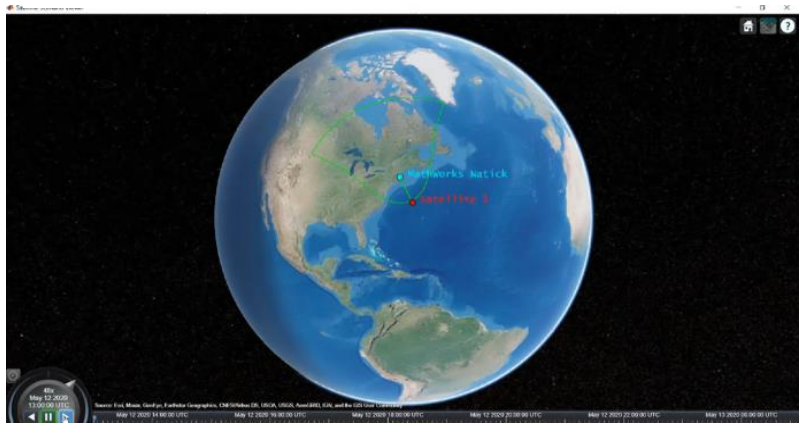


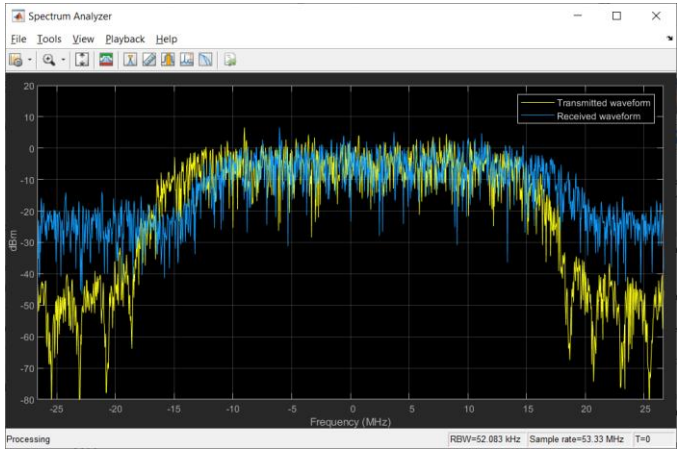


How to Learn More

Wireless Communications product pages

- 5G
- LTE
- WLAN
- Satellite-communications
- Bluetooth
- Wireless Testbench





Wireless communications solution page

mathworks.com/solutions/wireless-communications.html

Summary

MATLAB and Simulink enable efficient design of end-to-end wireless communications systems. They enable you to handle complexity of wireless design with standards-based tools, to ensure reliability with enhanced testing and verification tools, and to optimize your designs with AI models and tools.

These capabilities include:

- New Standards-based 5G, Wi-Fi, satellite communications and Bluetooth
- Testing and verify your design with hardware connectivity and assess performance and coexistence in the presence of interfering signals
- New applications of AI for wireless design