MATLAB EXPO

6G Wireless Technology - Accelerate your R&D with MATLAB

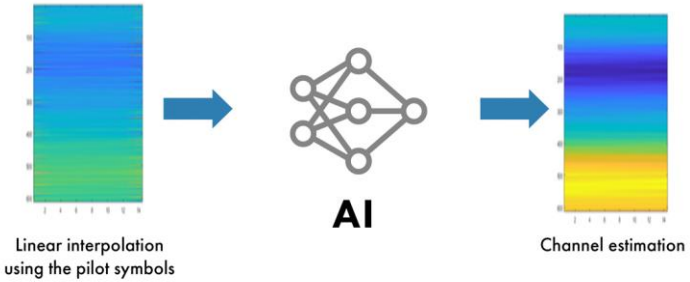
Dr. Houman Zarrinkoub, MathWorks

Dr. Ahmad Saad, MathWorks

MathWorks®

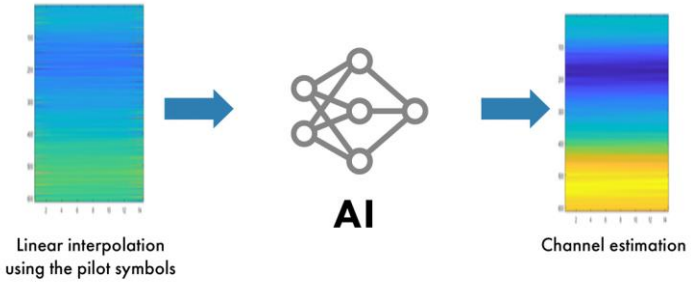
Agenda

- 6G Goals, requirements and evolution
- 6G enabling technologies
- Accelerate your 6G exploration and design with MATLAB®



Agenda

- 6G Goals, requirements and evolution
- 6G Enabling Technologies
- Accelerate your 6G exploration and design with MATLAB®



Ubiquitous Connectivity with wireless ecosystem

Cellular

Satellite communications

WLAN

LTE

GNSS

5G

CCSDS

5G advanced

Bluetooth

Wi-Fi

DVB-S*

6G

Personal Area Network

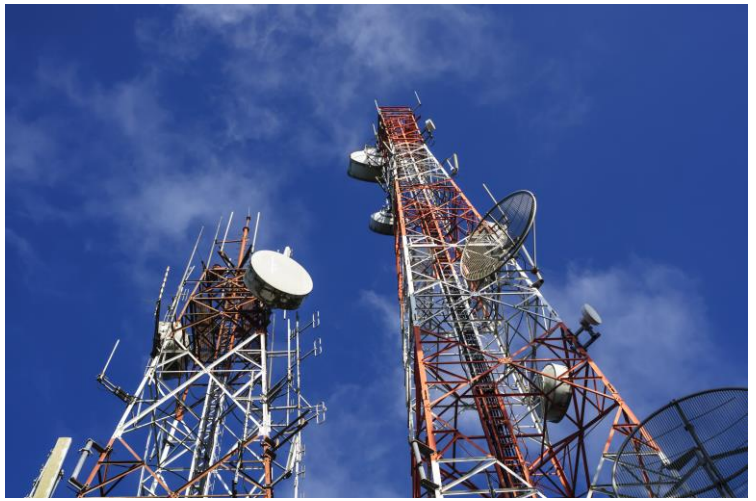
Local Area Network

Wide Area Network

Non-terrestrial Network

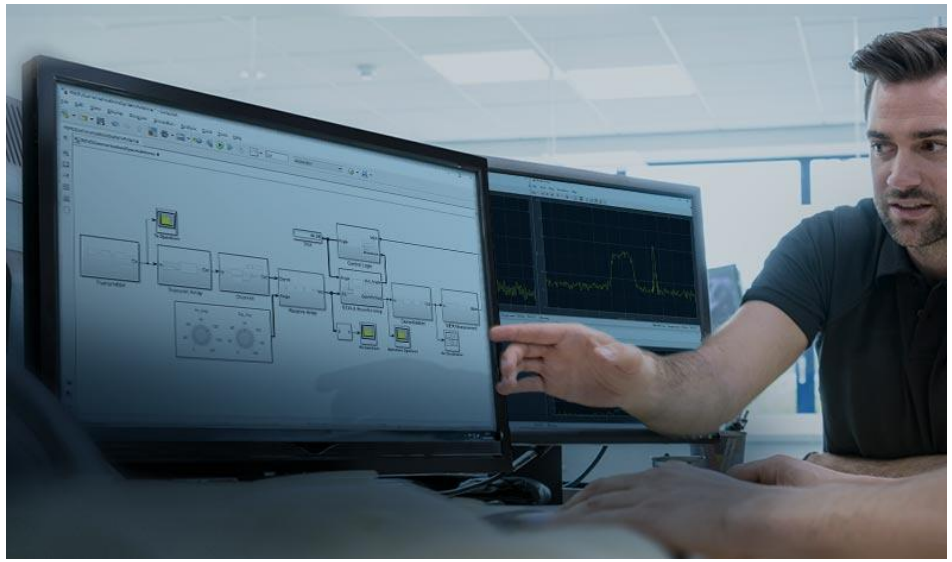
6G: Next generation of wireless systems

	2G	3G	4G	5G	6G
Time period	1990s	2000-2008	2008-2018	2018-Now	?
Technology	NA: D-AMPS EMEA: GSM, Edge, GPRS	NA: CDMA-2000 EMEA: UMTS, HSPA+	LTE, LTE-Advanced	5G, 5G-Advanced	
Maximum data rates	9.6-437 kbits/s	1.92-84 Mbps	300 Mbps – 1 Gbps	20 Gbps	



6G R&D: Setting goals and requirements

- Global collaboration is ongoing
- Goals?
- More inclusive, immersive, and sustainable wireless connectivity
  - Superior performance to 5G
  - Flexibility and expanded use cases
  - Scale
  - Bridge the digital divide
- Requirements?
  - Max. data rate ~ 100 Gbps ?
  - Min. latency ~ 0.1 msec ?
  - Max. positioning accuracy ~ 1 mm ?

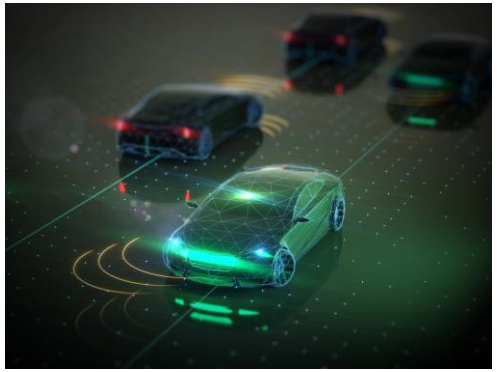


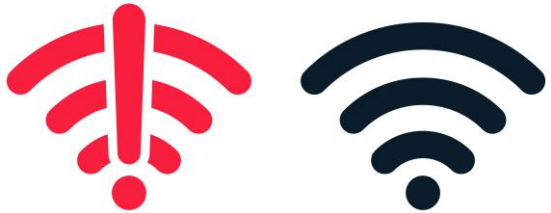
6G projected timeline and evolution

ITU – International Telecommunications Union
IMT-2030 International Mobile Telecommunications
3GPP Third Generation Partnership Project

New applications enabled by 6G systems

- Virtual and Augmented Reality (VR/AR)
- Artificial intelligence (AI)
- Connected Cars, Industries and Automation
- Ubiquitous wireless coverage
- Joint communications and sensing,
- Low-power wireless communications.

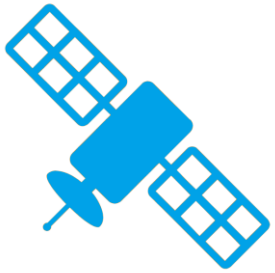




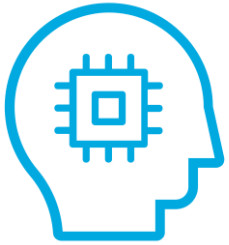
Agenda

- 6G Goals, requirements and evolution
- 6G enabling technologies
- Accelerate your 6G exploration and design with MATLAB®

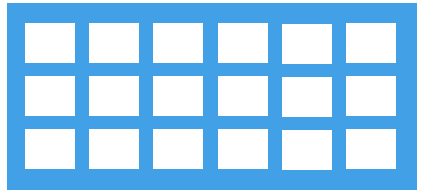
6G Enabling Technologies



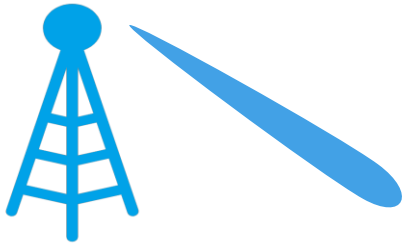
Non-Terrestrial Networks (NTN)



Artificial Intelligence (AI)



Reconfigurable Intelligent Surfaces (RIS)



THz / sub-THz Communication

New Waveforms for 6G

Non-Terrestrial Networks (NTN)

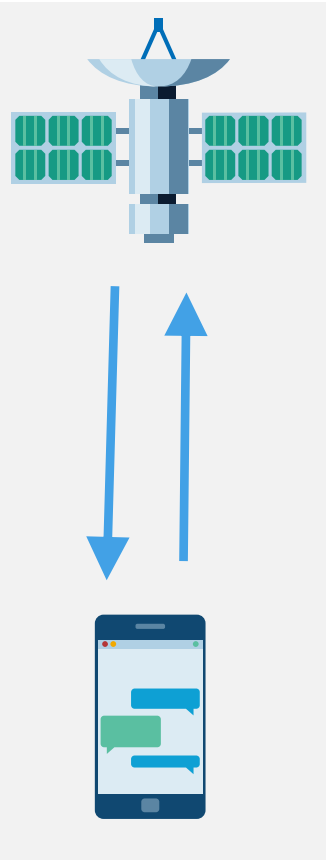
WHAT IS NTN

- Satellites & commercial drones acting as base stations in the sky
- Complement and partially replace parts of existing terrestrial cellular networks

→ Coverage and service anywhere anytime

→ Bridge the digital divide by providing ubiquitous connectivity

→ Realize critical applications in natural disasters



NTN- How MATLAB can help

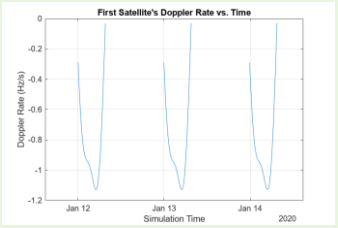
Satellite and Multi-domain Scenario Modeling and Visualization

Multi-domain scenarios (aircraft-to-satellite communication)

Scenarios and constellation visualization

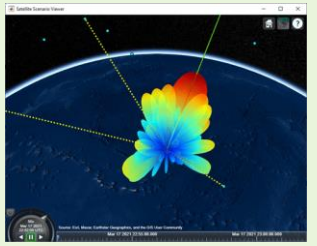
Access analysis between constellations and ground stations

Link Analysis between Satellites, Constellations and Ground Stations



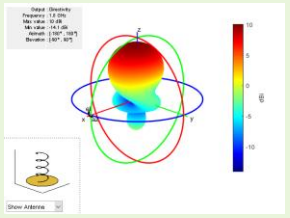
Latency and doppler analysis

Multi-hop communication links

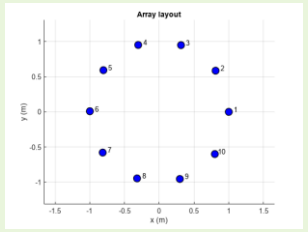


Interference analysis

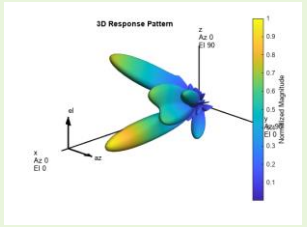
Design Antennas to Realize Beamwidth Requirements



Design antenna elements

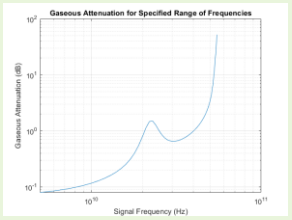


Design antenna arrays

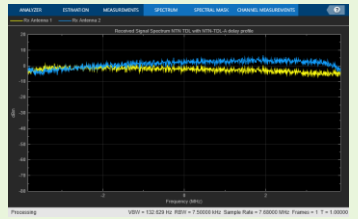


Beamforming

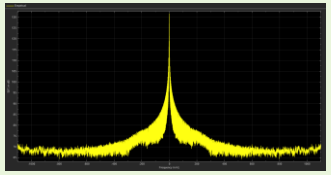
Standard-based Propagation and Channel Models



ITU-R P.618 Propagation Model



3GPP NTN Fading Channels



ITU-R P.681-11 LMS

Reconfigurable Intelligent Surfaces (RIS)

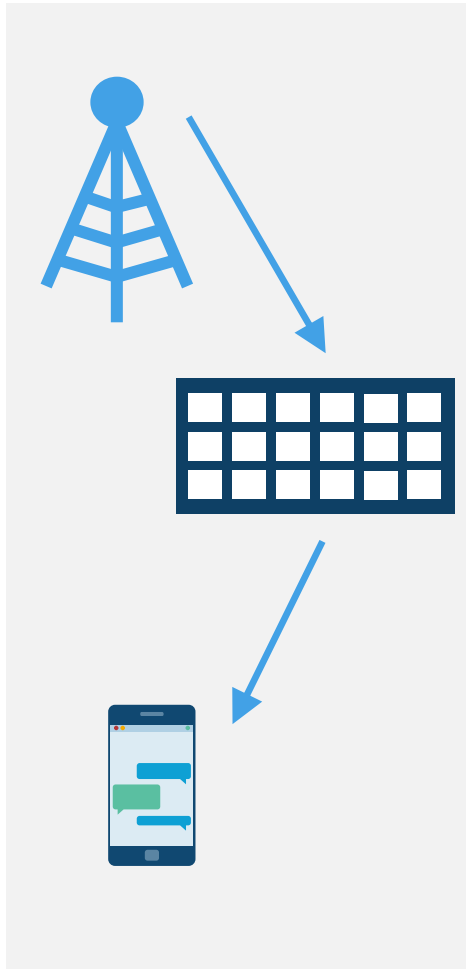
WHAT IS RIS

- Surfaces of tunable reflecting elements that passively influence phases of signals
- Provide active control over the wireless channel

→ Provide reliable coverage and eliminate propagation blockage

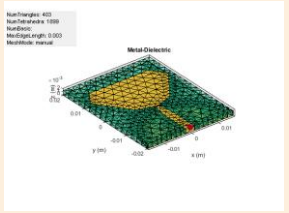
→ Enhance spectral efficiency and power consumption

→ Provide controllable nodes for localization services

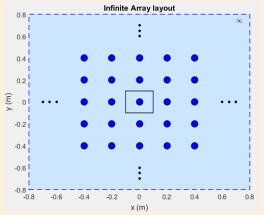


RIS- How MATLAB can Help

Model Reflecting Surfaces with the Antenna Toolbox

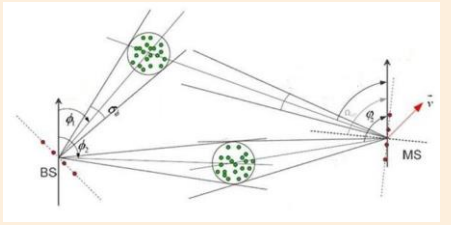


Full EM solver to design materials and surfaces



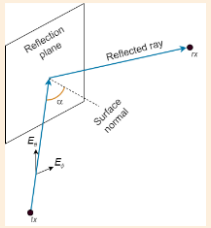
Analyze surfaces with large numbers of reflectors

Model Scattering MIMO Channels



Model propagation including time delay, gain, Doppler shift, phase change, and atmospheric loss

Use Raytracing to Model Reflections



Accurately model reflections using image or SBR methods

Manipulate phase of reflected rays by changing the material

Artificial Intelligence (AI)

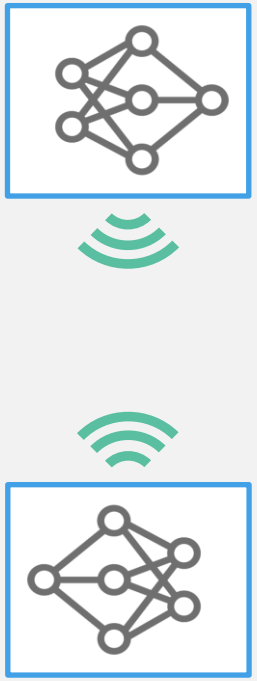
MOTIVATIONS FOR AI IN WIRELESS

- Success of AI in other application areas (image processing, NLP)
- Hardware and computation power advancements

→ Improve performance using data-driven vs model-based approaches

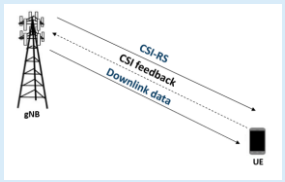
→ Reduce algorithm complexity

→ Facilitate joint optimization of network and device operations

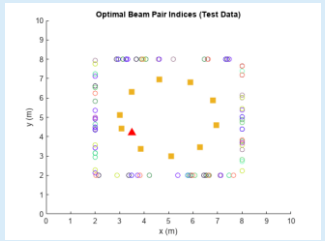


AI for 6G – How MATLAB can Help

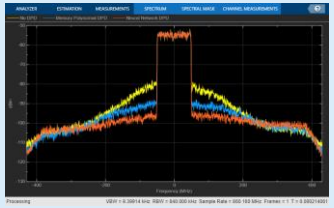
Ready-to-use AI Workflows for Wireless



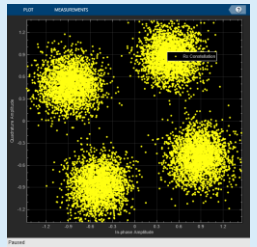
CSI Feedback with Autoencoders



Neural Networks for Beam Selection

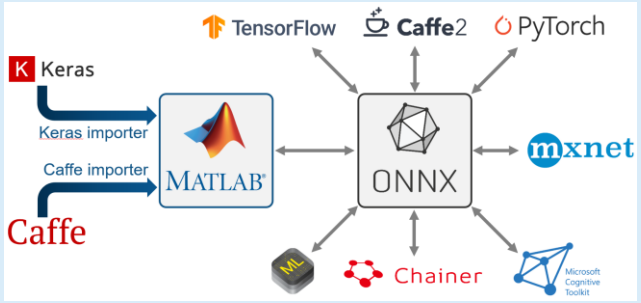


Neural Networks for Digital Predistortion

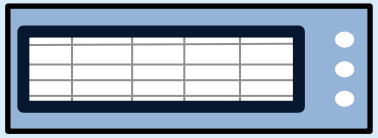


E2E Comms Systems with Autoencoders

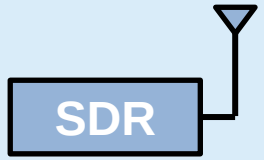
Interoperate and Exchange Models with Python and other Frameworks



Capture Over the Air Signals to Train AI Models



Test and Measurement Devices



Software-Defined Radios

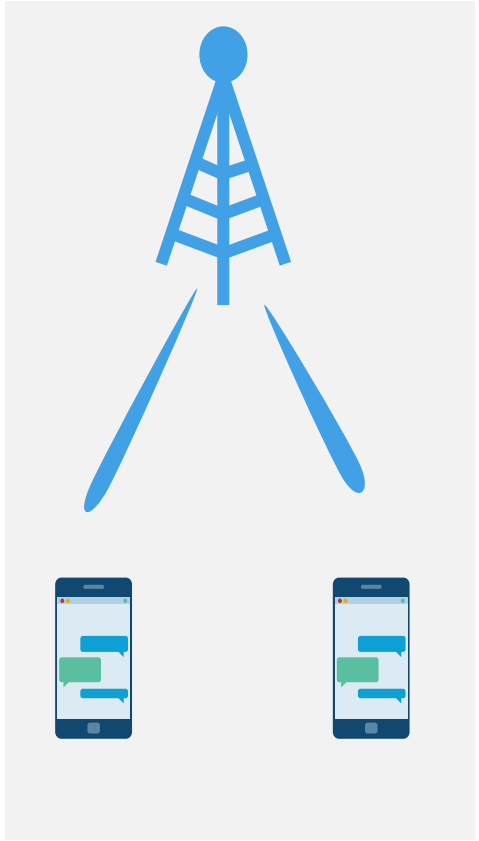
THz/Sub THz

MOTIVATIONS FOR THZ IN 6G

- ❑ Unprecedented increase in data traffic requirements
- ❑ Scarcity in existing sub 6 GHz Spectrum

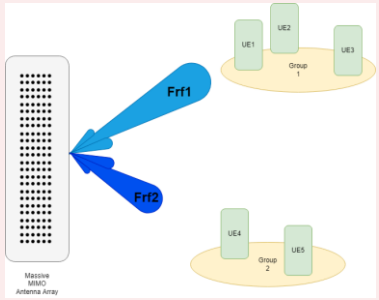
→ Support extremely high bandwidths up to hundreds of Gbps

→ Enable ultra-precise localization

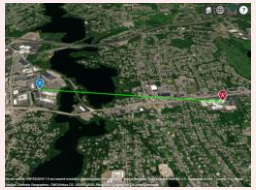


THz/Sub THz - How MATLAB can Help

Model Massive MIMO and Hybrid Beamforming to Counter High THz Attenuation



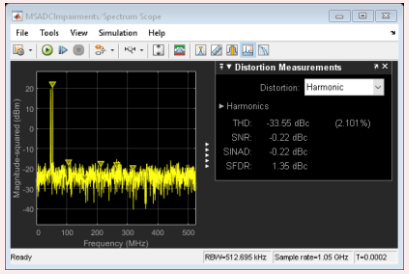
Accurate Models for Environmental Losses at High Frequencies using Raytracing



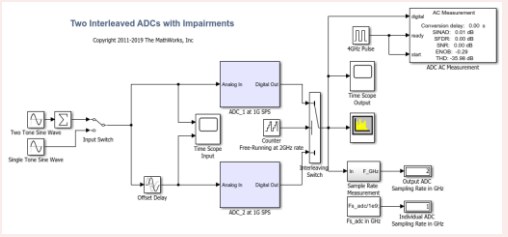
Model terrain and atmospheric losses due to gas, rain, fog

Model losses due to reflection, refraction and diffraction

Explore Data Converter Architectures for Extremely High Data Rates



Analyze ADC with Impairments: quantization, saturation, nonlinearity, jitter



Design and evaluate ADC architectures

New Waveforms for 6G

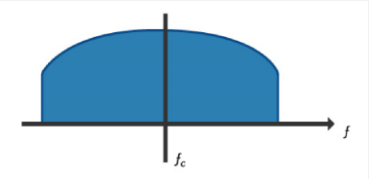
MOTIVATION FOR NEW WAVEFORMS

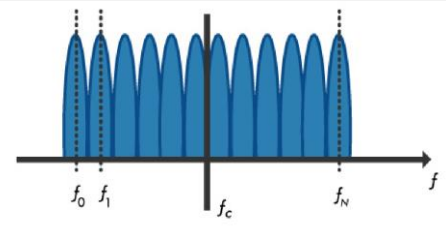
- Newly introduced frequency bands need new waveforms
- Resilient waveforms needed to compensate HW limitations

→ Improve spectrum and power efficiency

→ Improve coverage and support high throughput

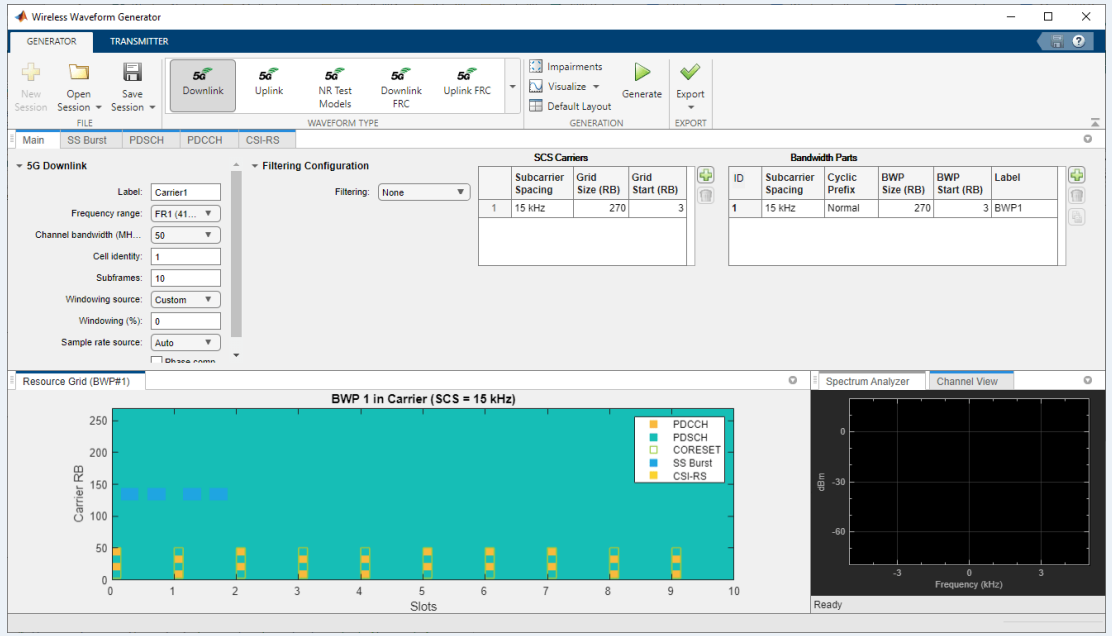
→ Enable new use cases: positioning, sensing, PHY security





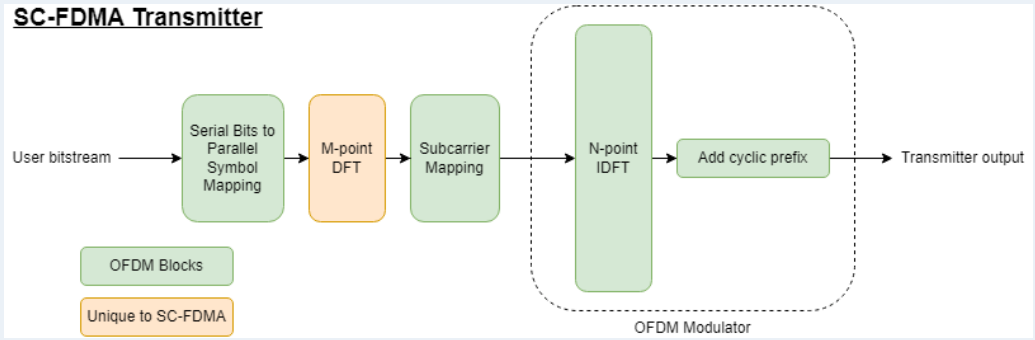
Waveform Design for 6G - How MATLAB can Help

Customize and Build on Existing 5G Waveforms to Explore New Waveforms for 6G



5G Waveform Generator App

Explore SC-FDMA vs. OFDM



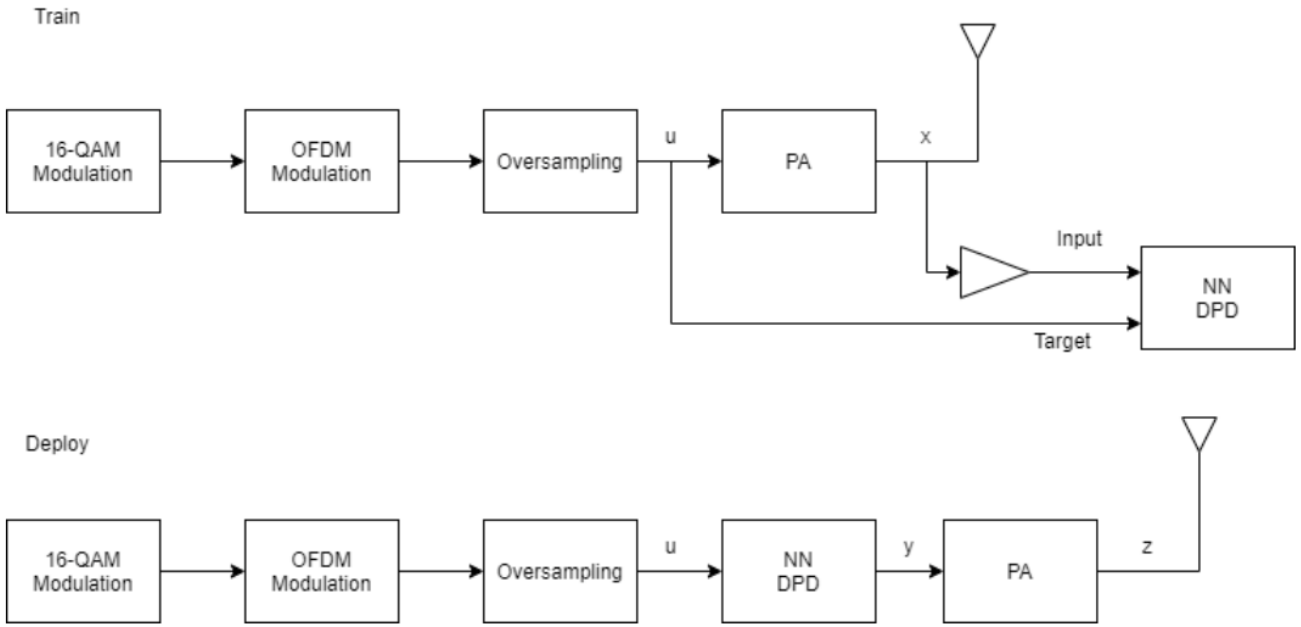
Functions and blocks to design and test OFDM and SC-FDMA Systems

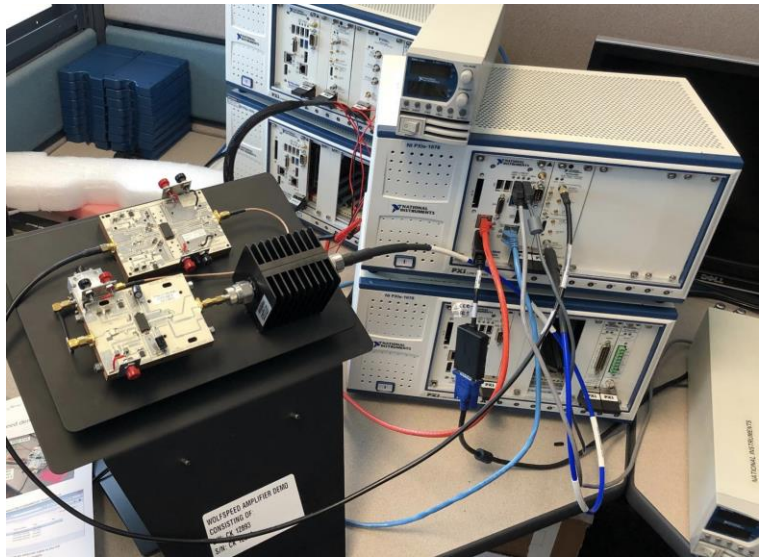
Agenda

- 6G Goals, requirements and evolution
- 6G enabling technologies
- Accelerate your 6G exploration and design with MATLAB®

AI for Digital Pre-Distortion with training and deployment

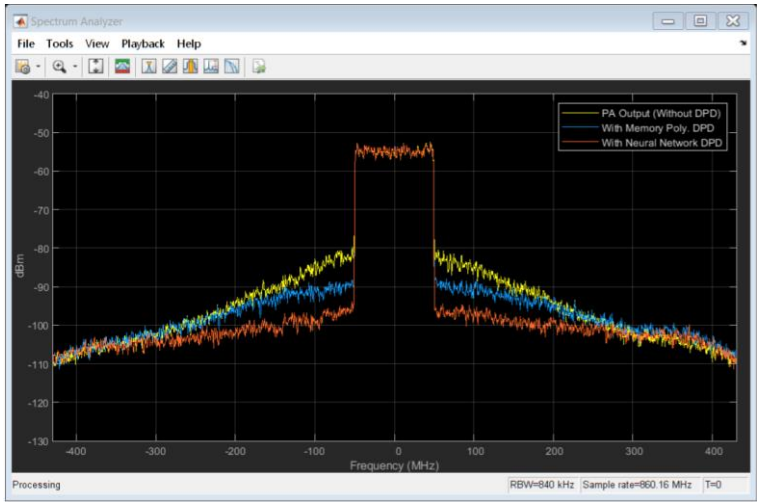
R2023a





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

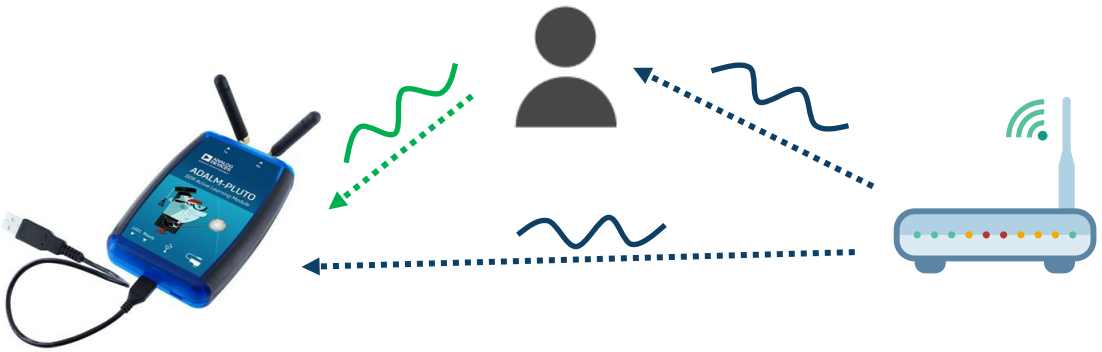


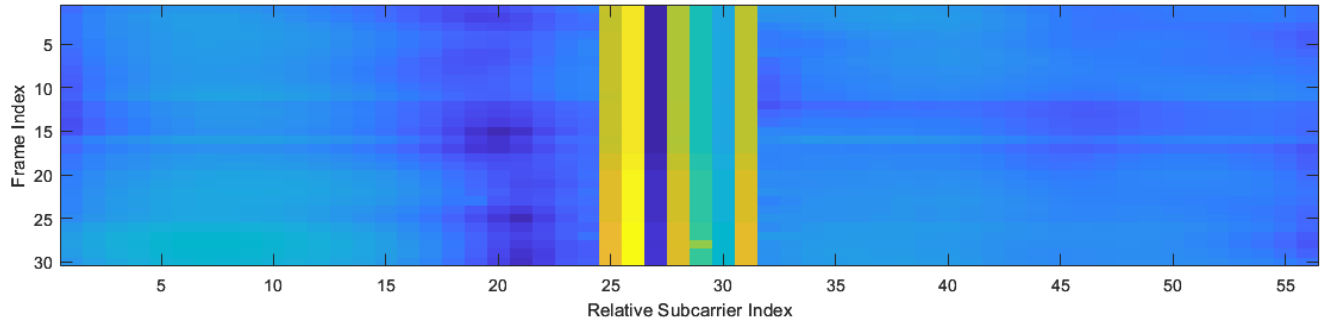
Presence detection using Wireless sensing

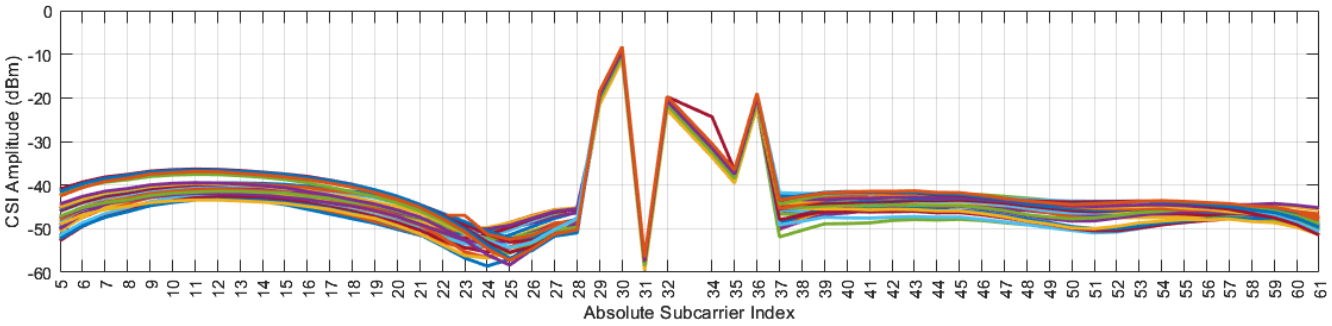
R2023a

Use Wi-Fi channel state information to detect the presence of people in a room

- Capture Wi-Fi beacon CSI with SDR and WLAN Toolbox with and without movement to create a data set or use downloaded 3P data set
- Train a neural network to classify presence





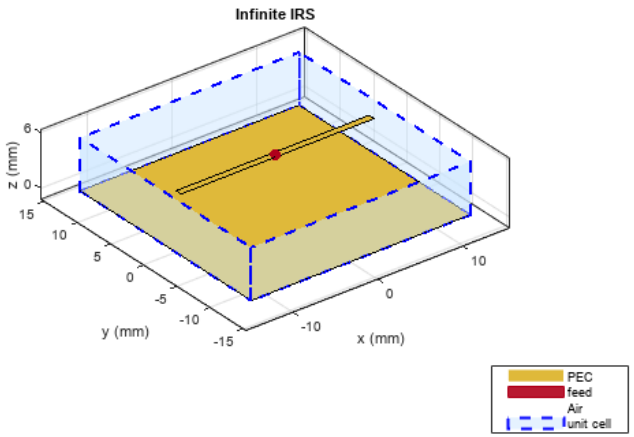


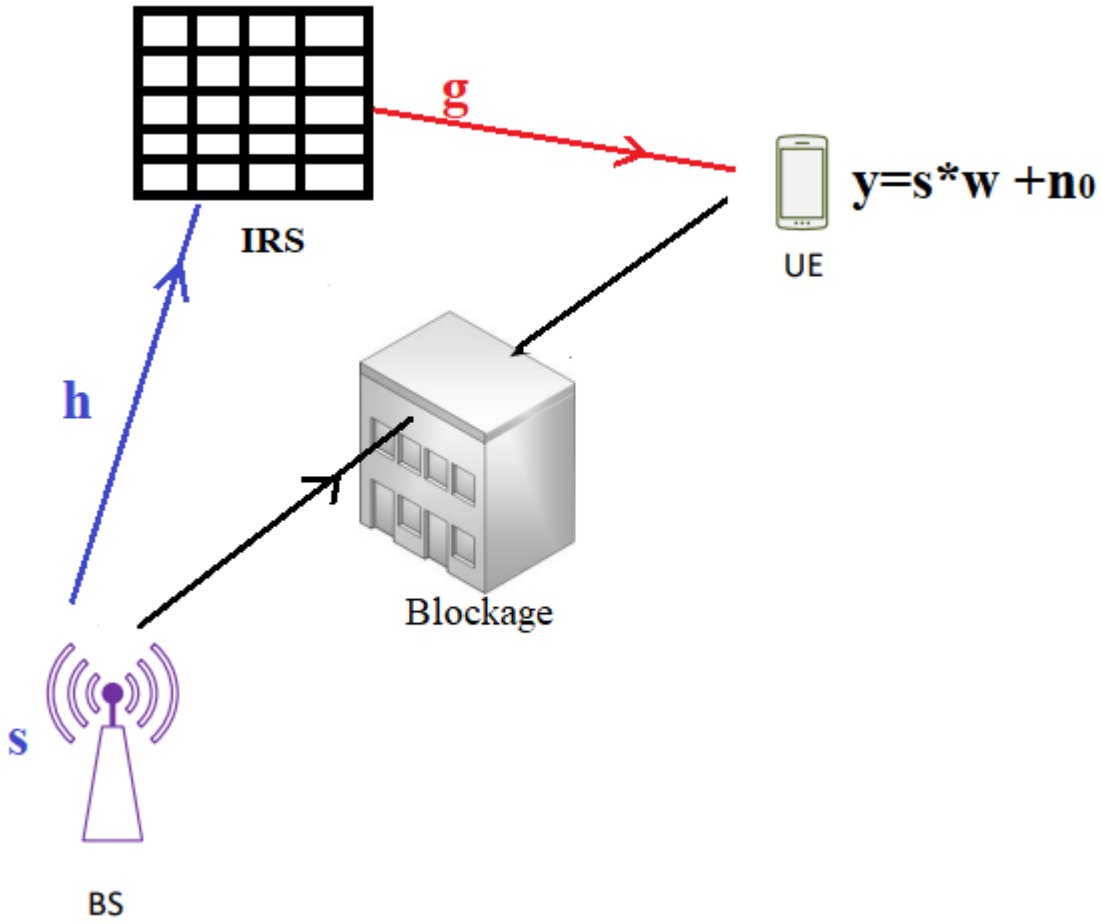
Electromagnetic Analysis of Intelligent Reflecting Surface

R2023a

Model the response of an IRS using full-wave electromagnetic simulation.

- Create and Visualize the Infinite IRS
- Assign Direction and Polarization
- Visualize Reflection Characteristics



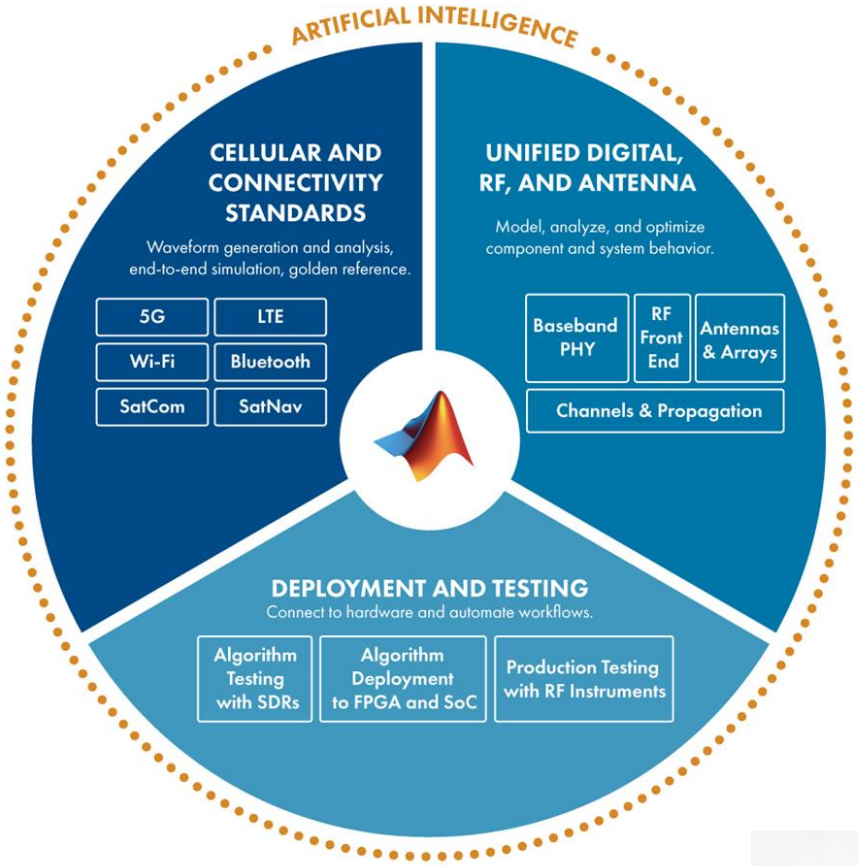


MATLAB for faster 6G design exploration and research

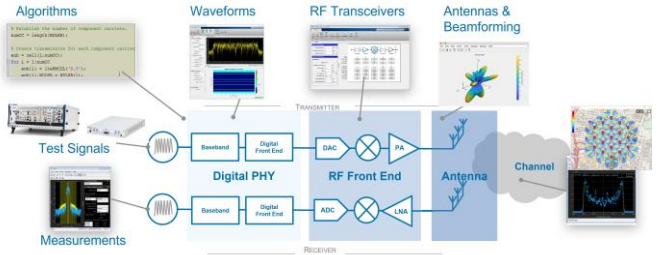
Algorithms in open editable, customizable MATLAB functions

```
% Encode the DL-SCH transport blocks
codedTrBlock = encodeDLSCH(pdsch.Modulation,pdsch.NLayers,...
    pdschIndicesInfo.G,harqProcesses(harqProcIdx).RV,harqProcIdx-1);

% PDSCH modulation and precoding
pdschSymbols = nrPDSCH(codedTrBlock,pdsch.Modulation,pdsch.NLayers,gnb
pdschSymbols = pdschSymbols*wtx;
```



Jointly optimize Digital, RF and Antenna of 6G systems



Continuous and easy prototyping and testing with hardware connectivity

How to Learn More

Wireless communications solution page

mathworks.com/solutions/wireless-communications.html

Wireless Communications product pages

mathworks.com/products/

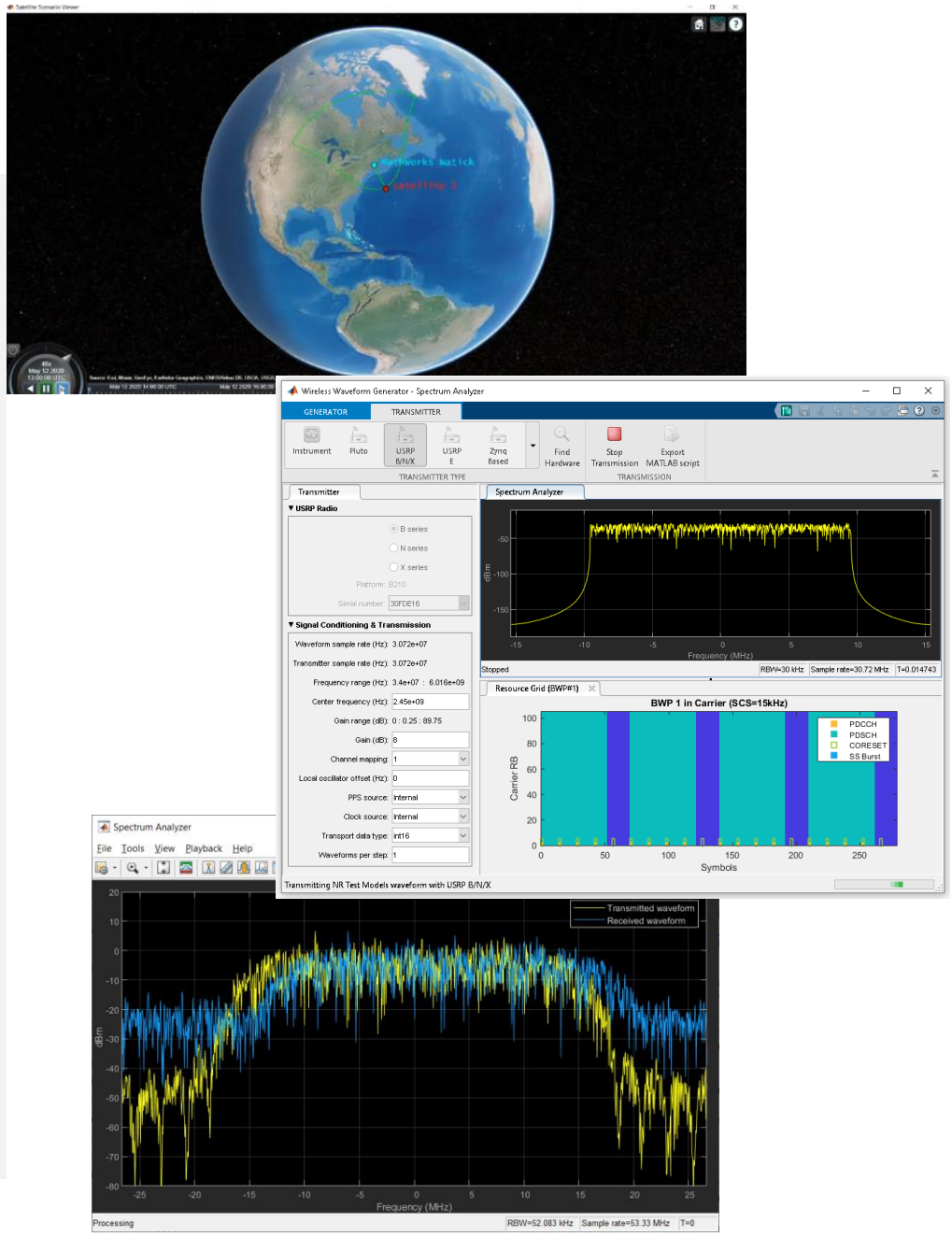
5G, WLAN, Satellite-communications

Wireless Communications Workshops

Satellite Communications (NTN)

AI for Wireless

5G Training Course



MATLAB EXPO

Thank you