

# 5G, WLAN, and LTE Wireless Design with MATLAB

Marc Barberis – Application Engineering Group

# Agenda

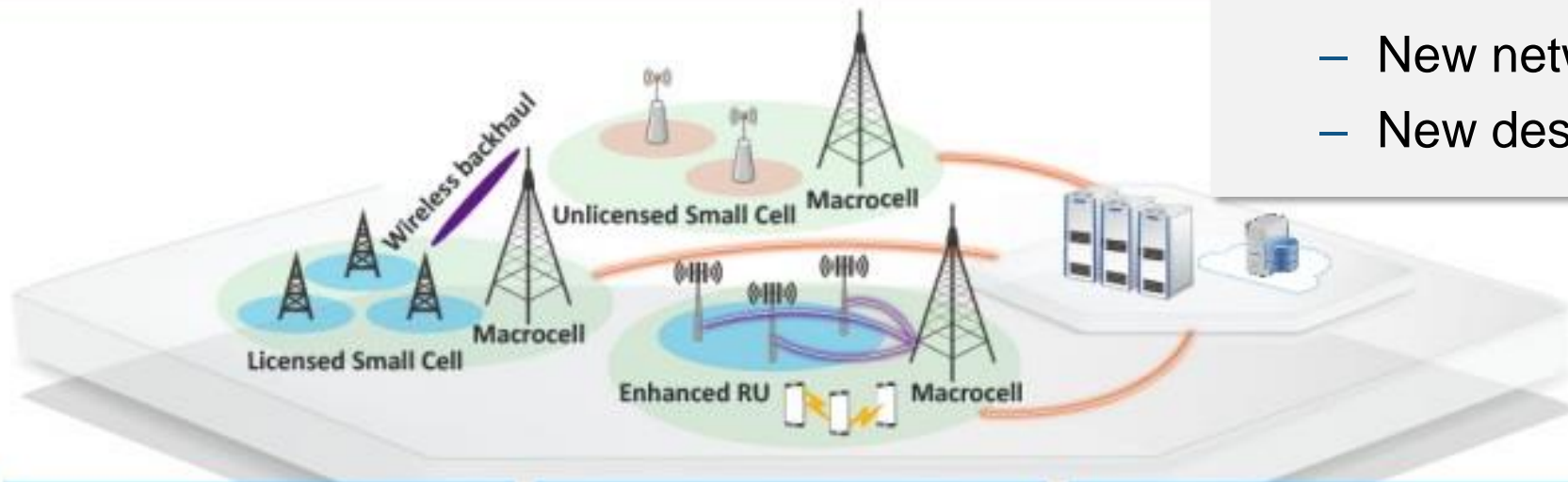
- The 5G Landscape
- Designing 5G Systems
  - Generating waveforms
  - Designing baseband algorithms
  - Propagation channels and interference
  - Antennas and antenna arrays
  - Beamforming
  - RF impairments
- Summary

# 5G Vision and Use Cases

*Not just mobile phones*

To do all of this, 5G will require:

- New physical layer architecture
- New radio (RF) architecture
- New network architecture
- New design and testing approaches



**Massive Machine-type Communications      Ultra Reliable & Low Latency      Enhanced Mobile Broadband**



U-health / Wearables      Smart Home / Smart City      Smart Vehicle      Industrial Automation      Mobile Cloud Computing      UHD Streaming

**IoT**

**V2X**

**Ultra-Fast Mobile**

# Standardization Efforts



IEEE 802.11 WLAN standards



802.11ax

Flexible Numerology

802.11ay

Sidelink / D2D

Verizon5G

3D Channel Models

FD-MIMO

Cellular V2X



NB-IoT

F-OFDM  
W-OFDM

mmWave

Hybrid Beamforming

Cat-M

Wideband Signals

Polar Codes

LDPC Codes

# Addressing Wireless Engineering Challenges

## Standard compliance

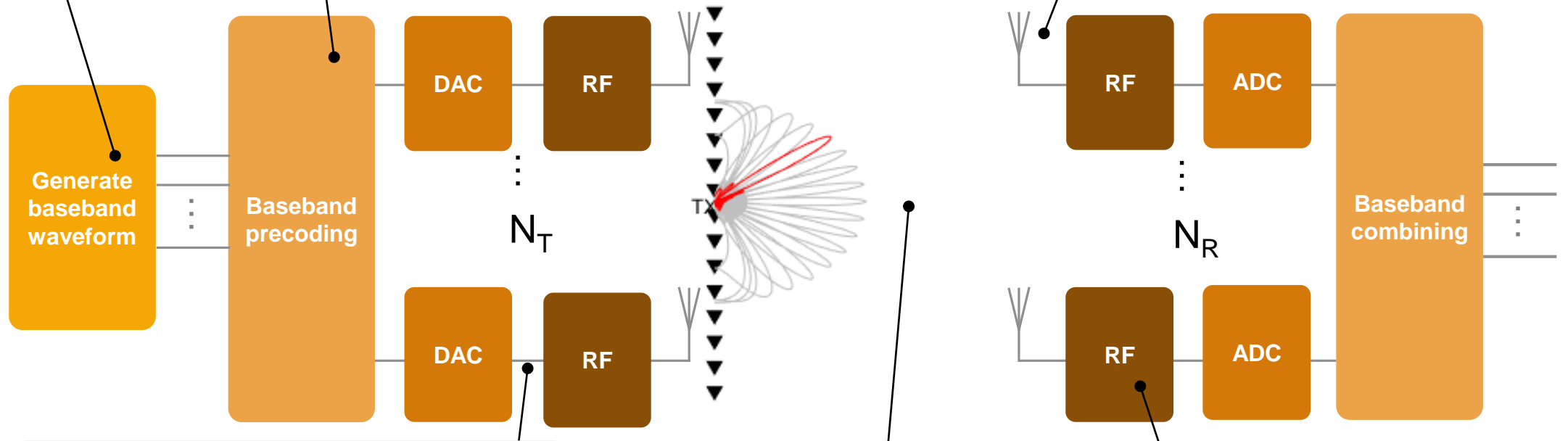
- Generate all physical channels and signals

## Baseband DSP development

- DSP challenges due to large bandwidths
- Is my implementation correct?
- How can I evaluate link performance with my algorithm?

## Antenna array design and evaluation

- Element coupling
- Edge effects
- Imperfections



## Explore beamforming trade-offs

- Baseband, analog or hybrid beamforming?
- Simulate capabilities and limitations
- Analog/Digital/RF components trade-off

## Channel and Interference

- Multiple UEs/Stations
- 3D propagation channel

## Investigate the impact of RF impairments

- Frequency dependency
- Non-linearities
- Mismatches and coupling

# Testimony

*“We need a multidomain platform for simulation, rapid prototyping, and iterative verification from the behavior model to testbed prototyping to the industrial product.*

*MATLAB and Simulink are helping us to achieve these goals.”*

- Kevin Law, director of algorithm architecture and design, Huawei -

Can you tell us more about how MATLAB and Simulink are helping you?

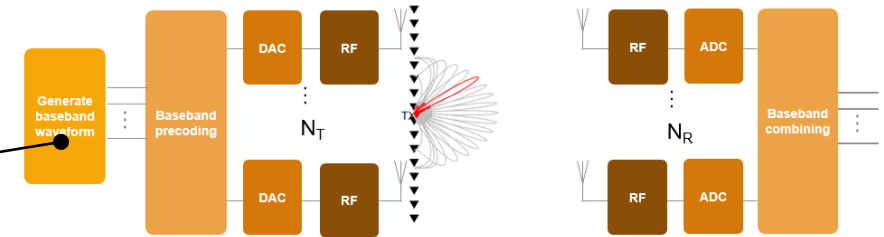
These two platforms play an important role in our innovation areas like 5G, optical communication, and wireless terminals. The tools give us top-down Model-Based Design, a product ecosystem that covers multiple domains, and code generation and iterative verification.

[https://www.mathworks.com/content/dam/mathworks/tag-team/Objects/h/80861v00\\_Huawei\\_QA.pdf](https://www.mathworks.com/content/dam/mathworks/tag-team/Objects/h/80861v00_Huawei_QA.pdf)

# Standard-Compliant Waveforms

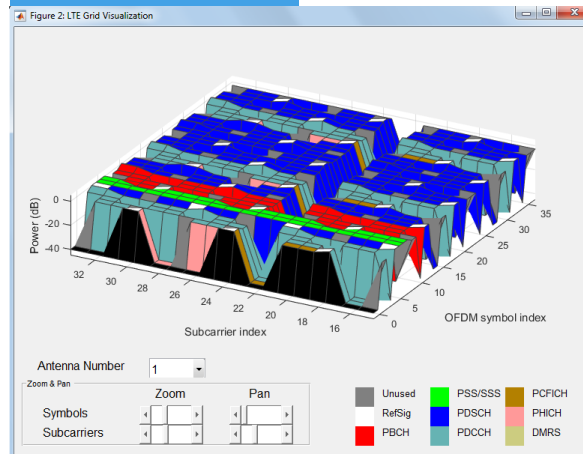
## Standard compliance

- Generate all physical channels and signals

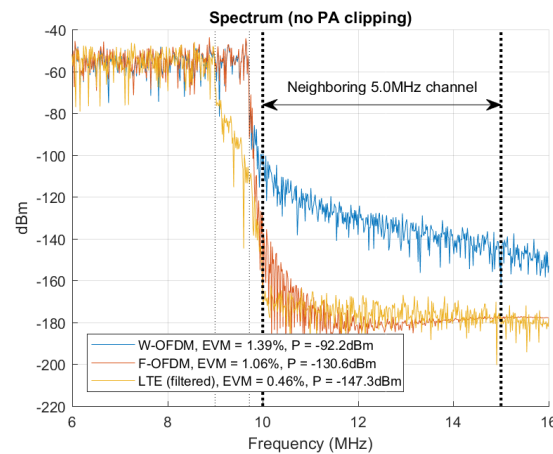


- Full custom and off-the-shelf waveforms

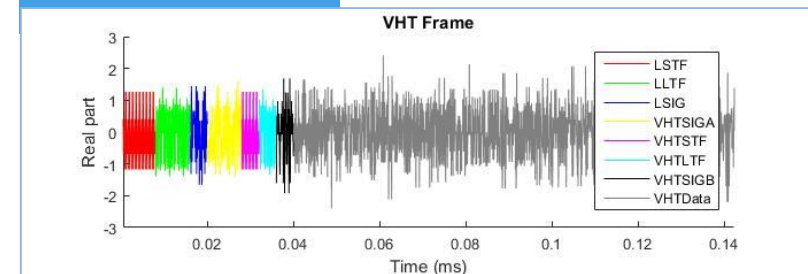
## LTE System Toolbox



## 5G Library



## WLAN System Toolbox



# Standard-Compliant Waveforms

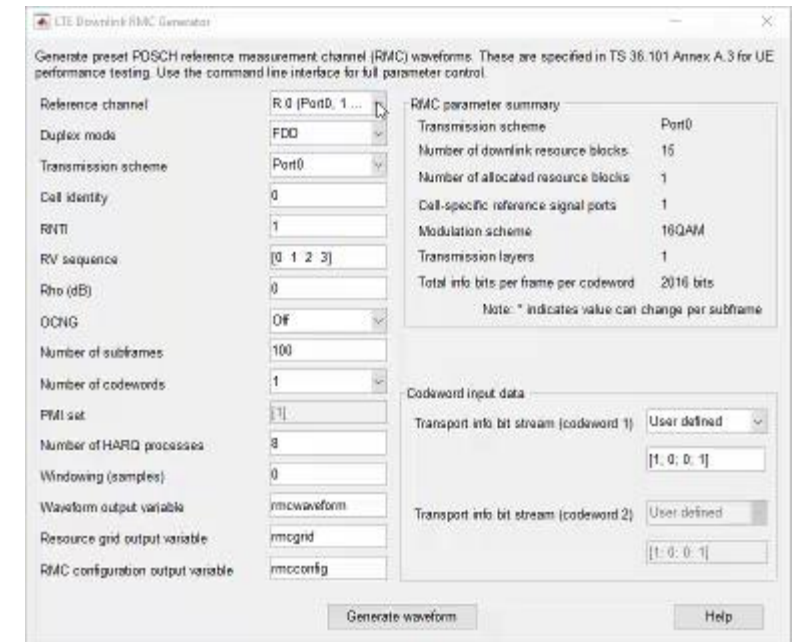
- Main standards offered:

## IEEE 802.11

- ✓ 802.11ad
- ✓ 802.11ah
- ✓ 802.11ac
- ✓ 802.11a/b/g/n
- ✓ 802.11p/j

## 3GPP

- ✓ LTE & LTE-Advanced
- ✓ NB-IoT
- ✓ D2D Sidelink
- ✓ V2X Sidelink
- ✓ 5G New Radio





# Baseband DSP Development

## Baseband DSP development

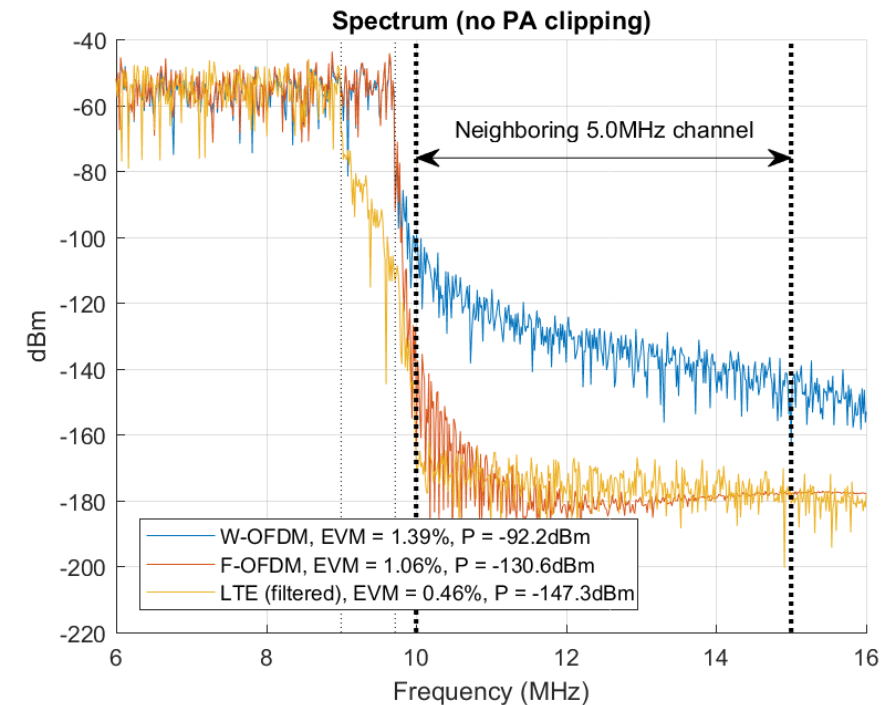
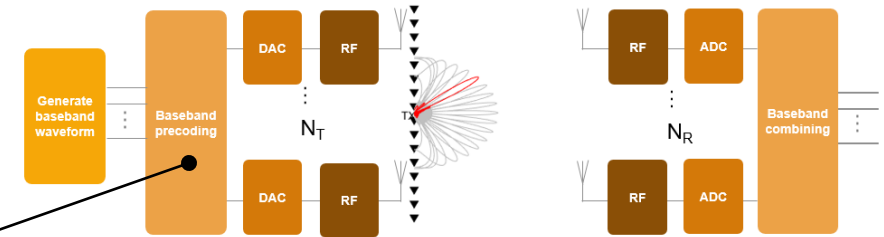
- DSP challenges due to large bandwidths
- Is my implementation correct?
- How can I evaluate link performance with my algorithm?

## • 5G waveforms

- F-OFDM = Filtered OFDM
- W-OFDM = Windowed OFDM
- CP-OFDM = Cyclic-Prefix OFDM

## • Wideband signals

- Variable subcarrier spacing: 15,30,60,120,240kHz

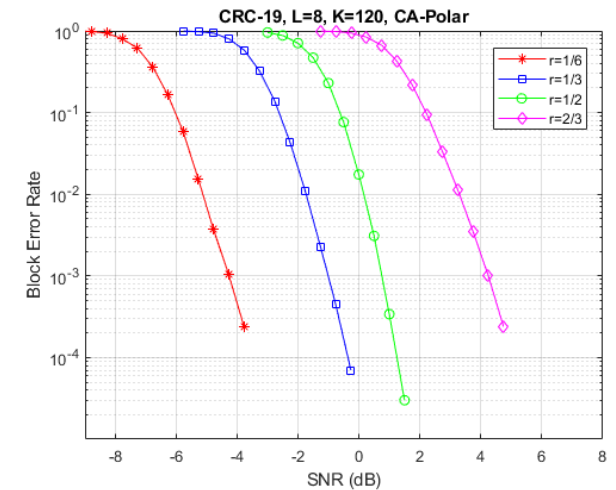
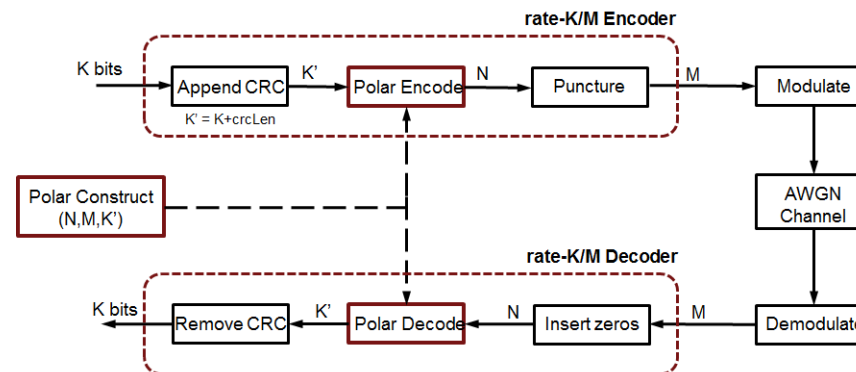
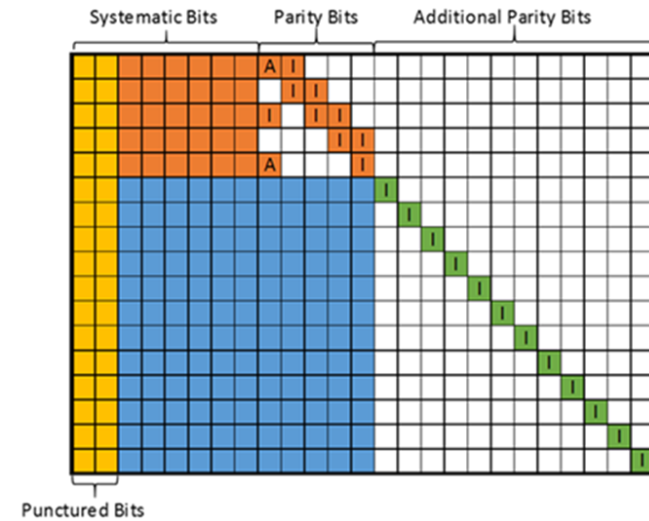


# Baseband DSP Development

- LDPC code for user data channels
  - Flexible for all block sizes
  - Memoryless Block Coding

- Polar codes for control channels

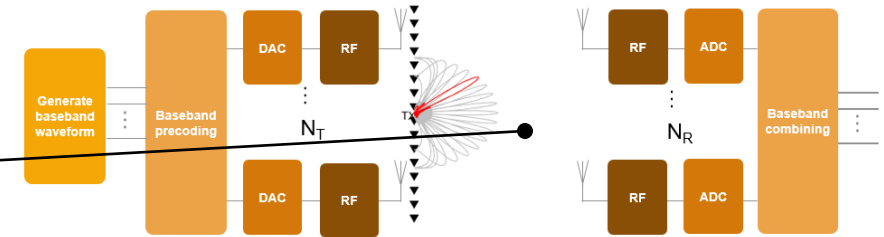
- Capacity achieving as opposed to just capacity approaching.
- CRC-aided Successive Cancellation List Decoding (CA-SCL)
- Downlink and uplink control information (DCI/UCI) and PBCH



# Channel and Interference

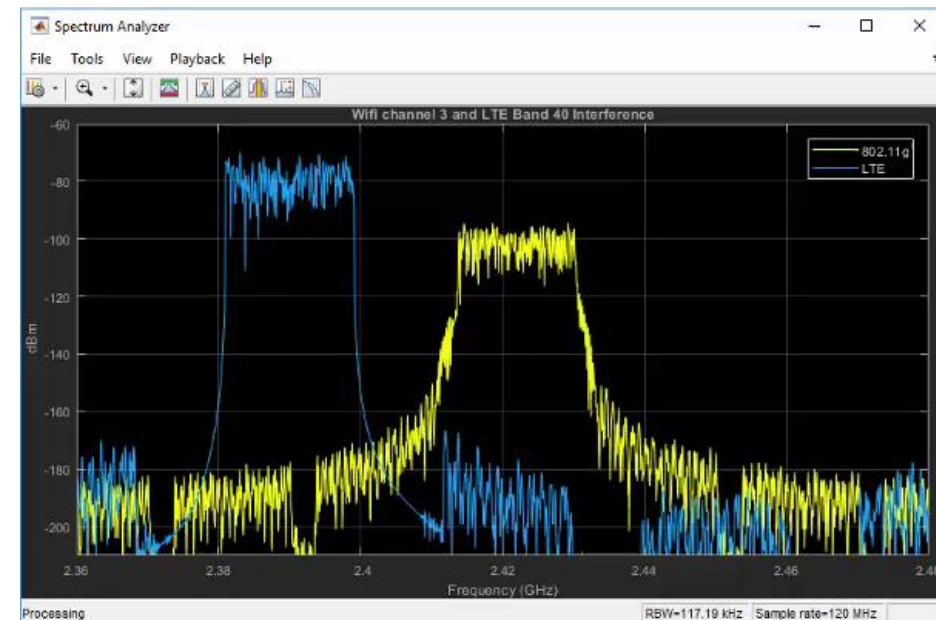
## Channel and Interference

- Multiple UEs/Stations
- 3D propagation channel



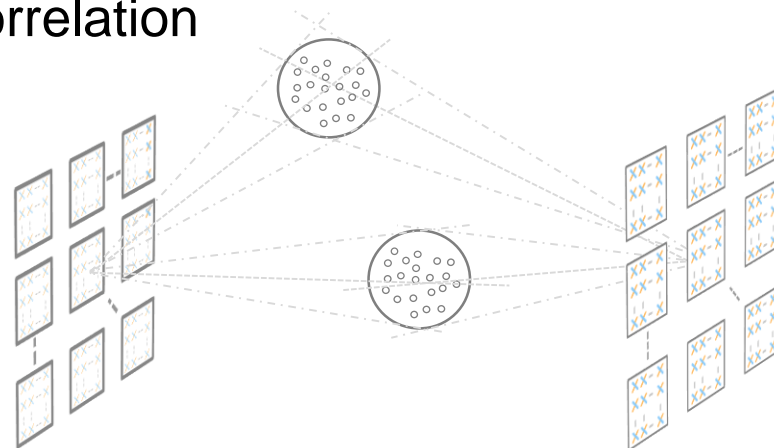
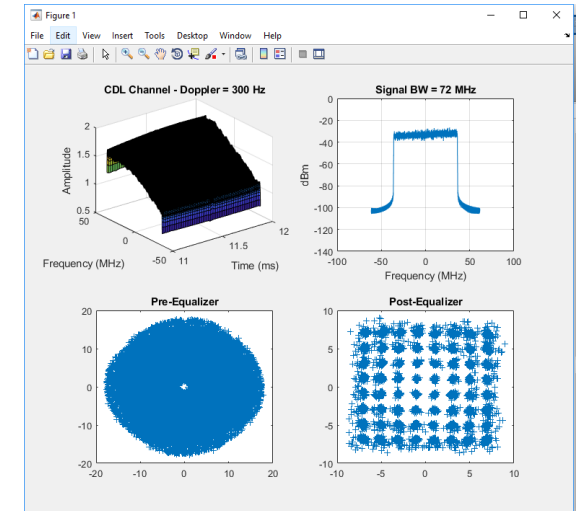
- Interference
  - Multiple standards: LTE/WLAN
  - Multi-cell / Multiple UEs
- Propagation channels
  - LTE
  - 5G
  - Custom

LTE      WLAN

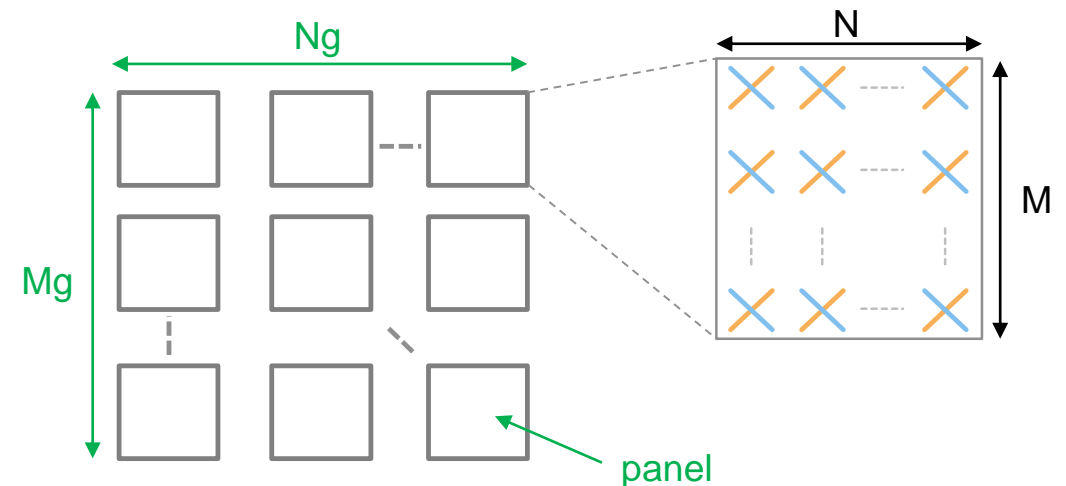


# Channel and Interference

- 5G channel models TR 38.901: 0.5 - 100 GHz
- Control of:
  - Delay profile: TDL and CDL profiles: A, B, C, D, E or custom
  - Channel delay spread
  - Doppler shift
  - MIMO correlation



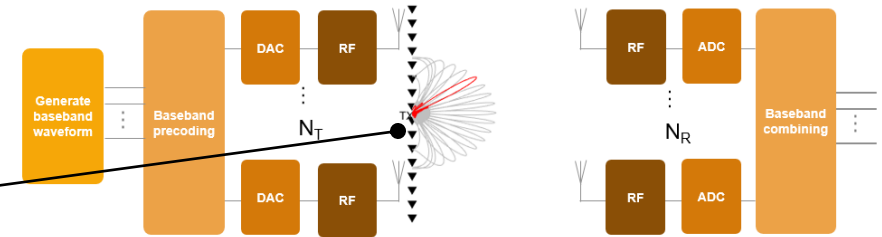
Cluster Delay Line: 3D model



# Antenna Array Design and Evaluation

## Antenna array design and evaluation

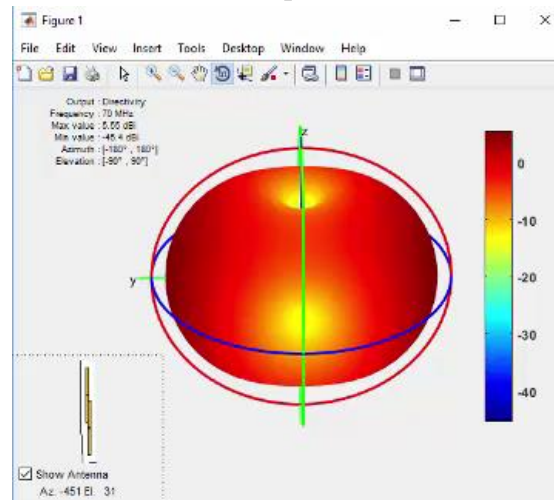
- Element coupling
- Edge effects
- Imperfections



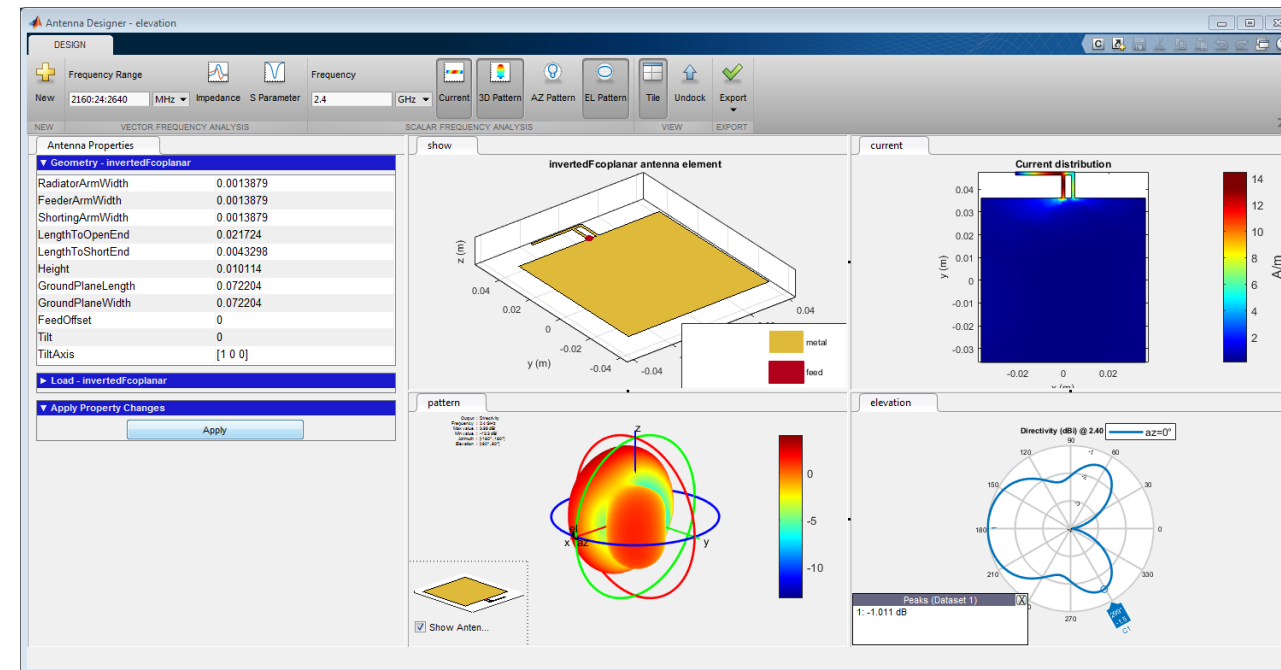
## Design custom elements

- Predefined or custom shape
- Polarization support

### Dipole



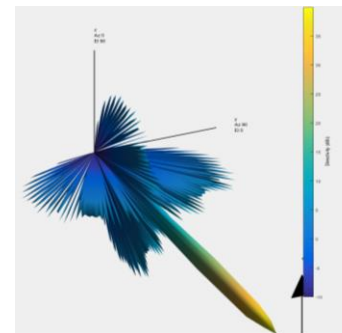
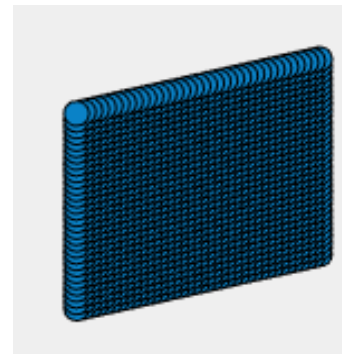
### Inverted F



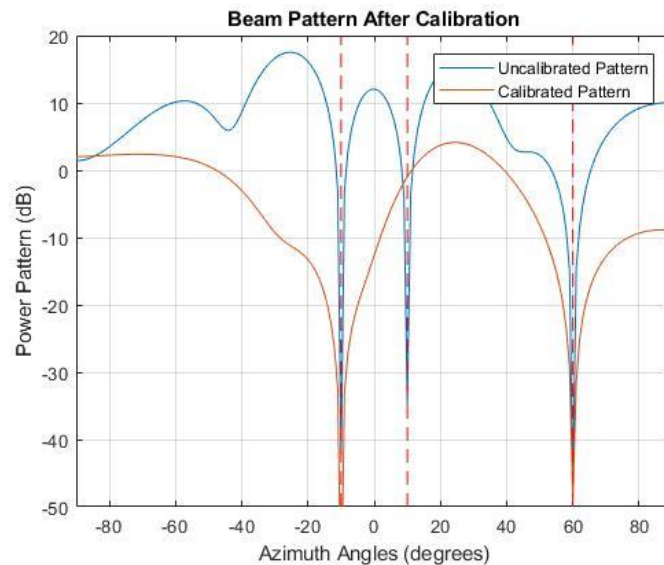
# Antenna Array Design and Evaluation

- Advanced algorithms and imperfection mitigation
  - For ULA, URA, conformal arrays

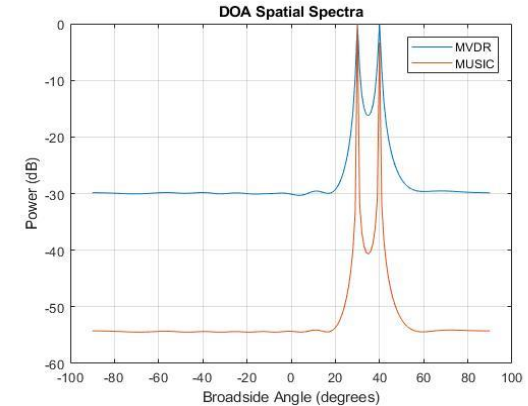
## Design 32x32 Array



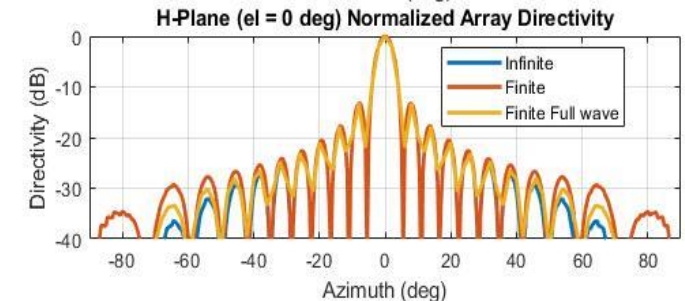
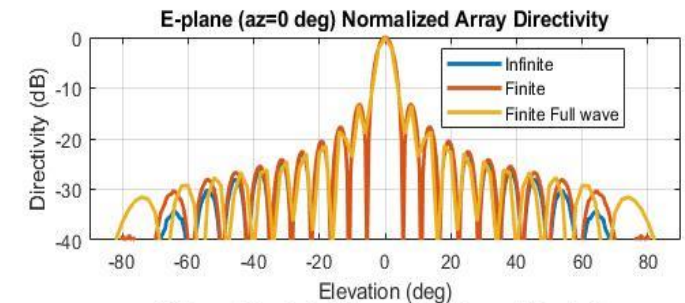
## Calibration



## Direction of Arrival



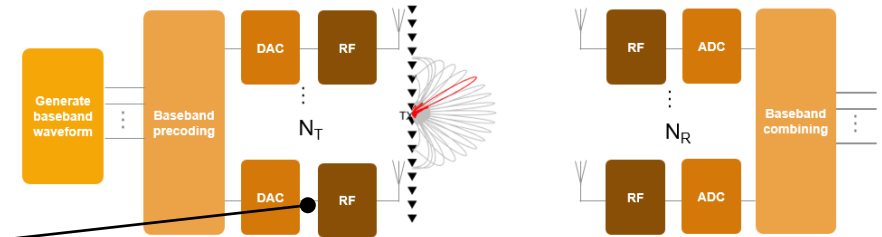
## Mutual Coupling



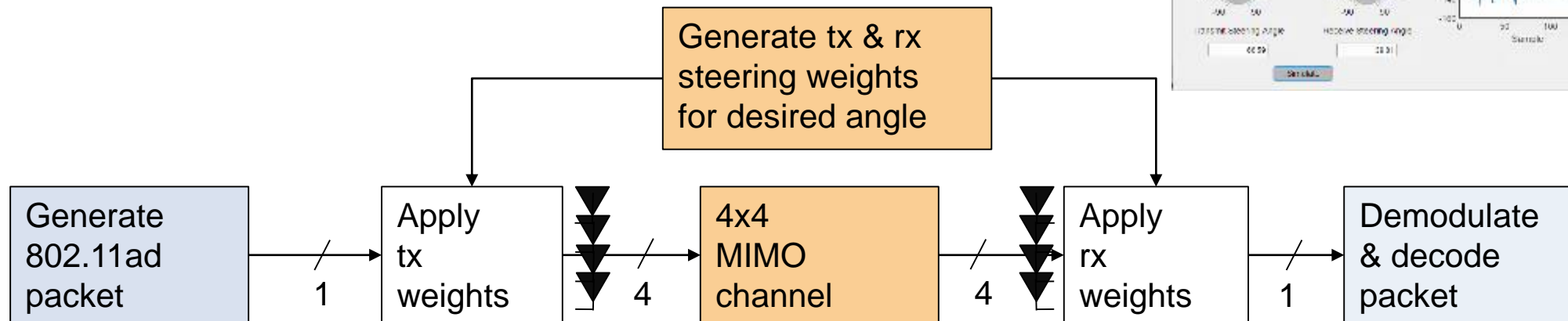
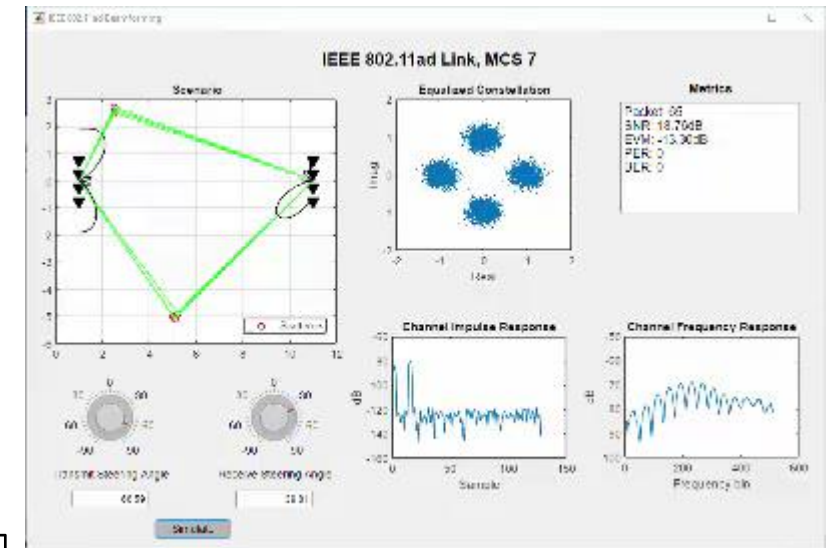
# Explore Beamforming Trade-Offs

## Explore beamforming trade-offs

- Baseband, analog or hybrid beamforming?
- Simulate capabilities and limitations
- Analog/Digital/RF components trade-off

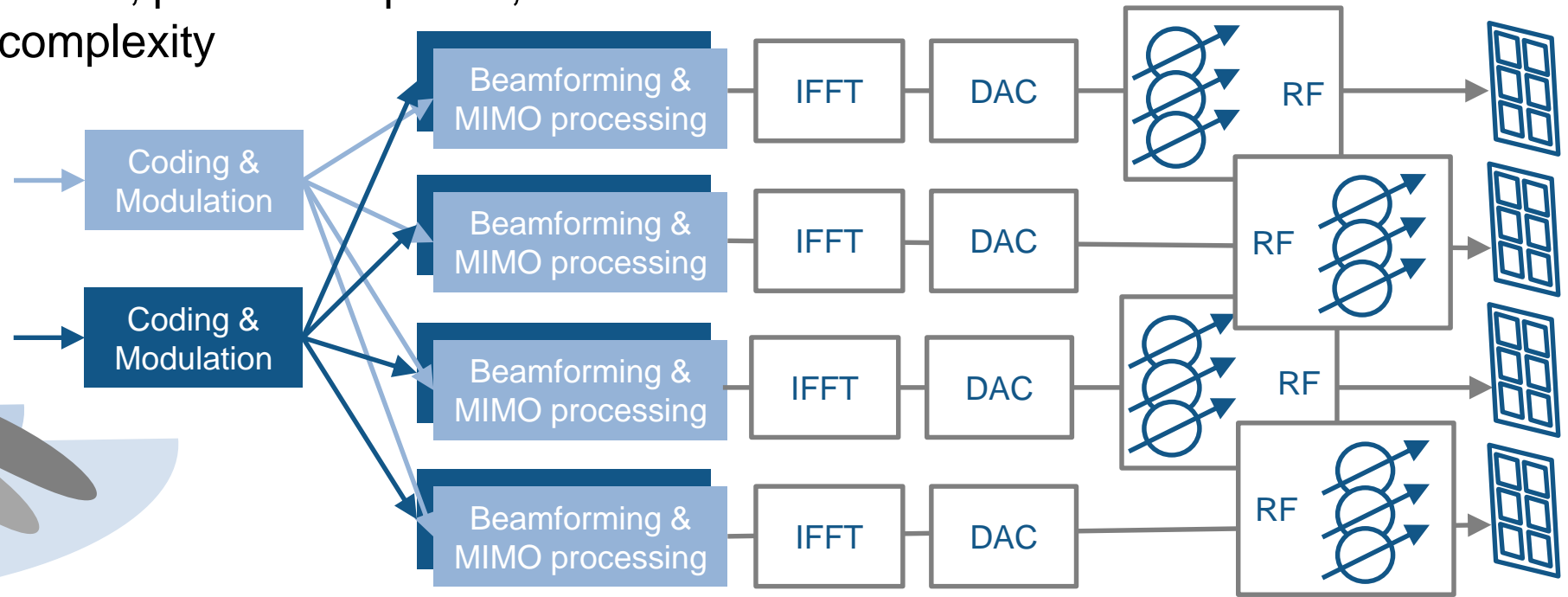
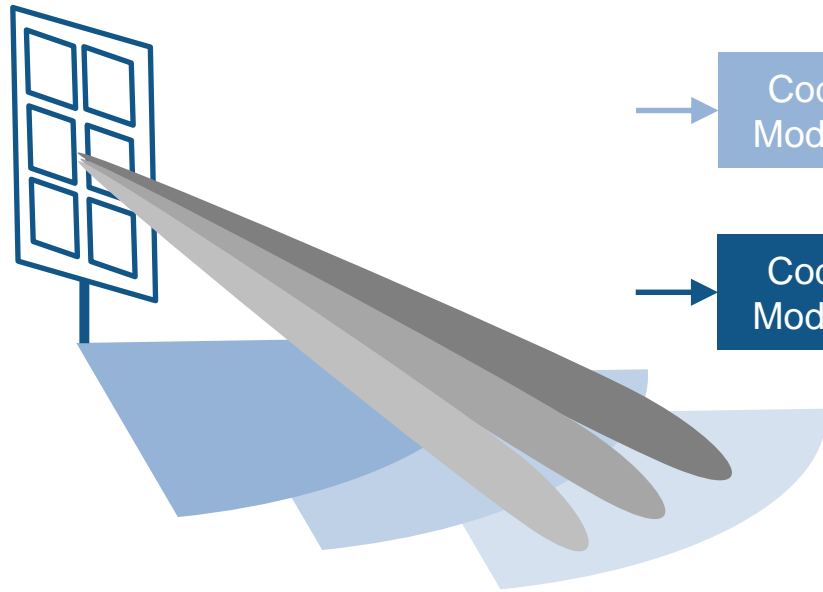


- Generate steering vectors
- Place null in direction of interferer



# Explore Beamforming Trade-Offs

- Hybrid beamforming
  - Phase resolution
  - DAC/ADC resolution
  - Trade-off performance, power dissipation, implementation complexity

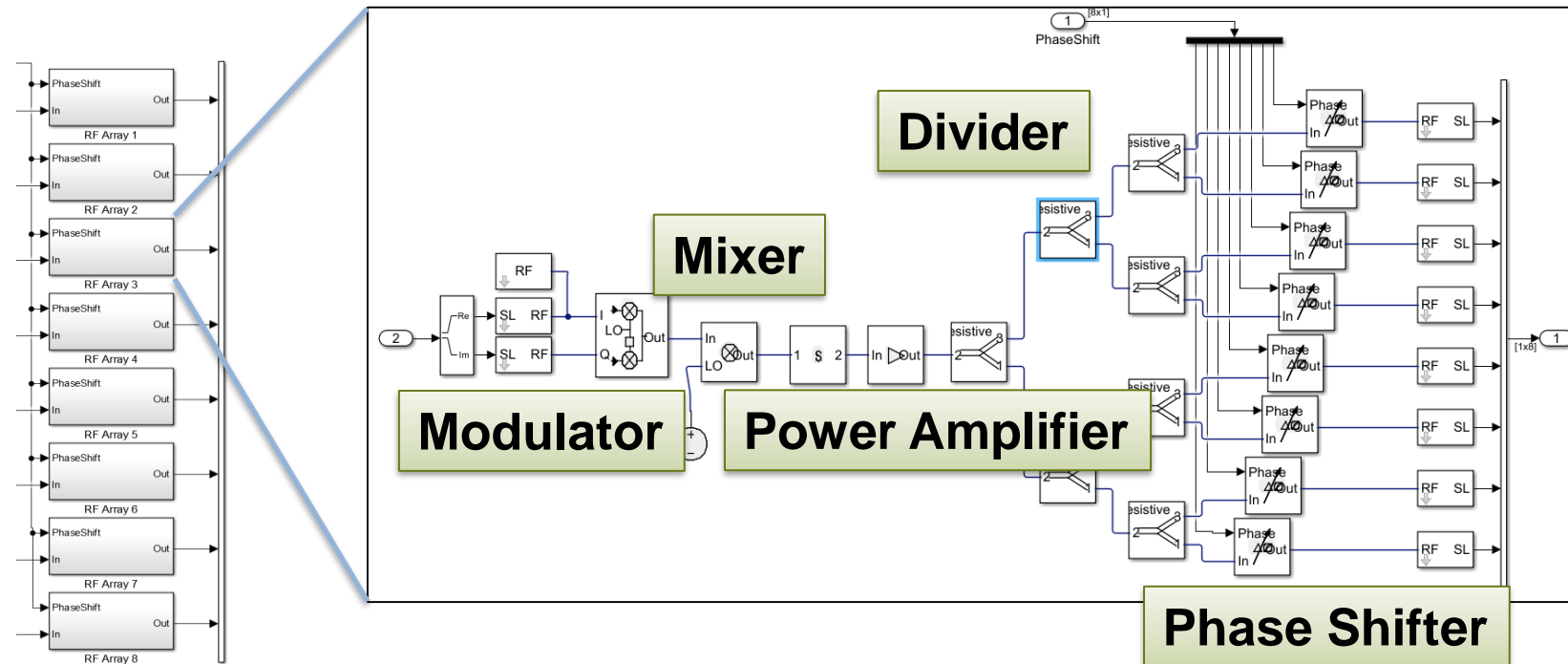
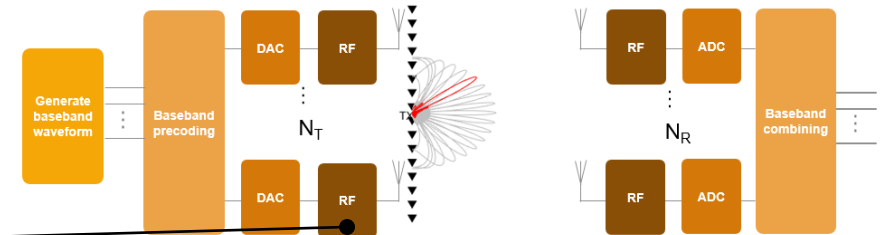




# Investigate the Impact of RF Impairments

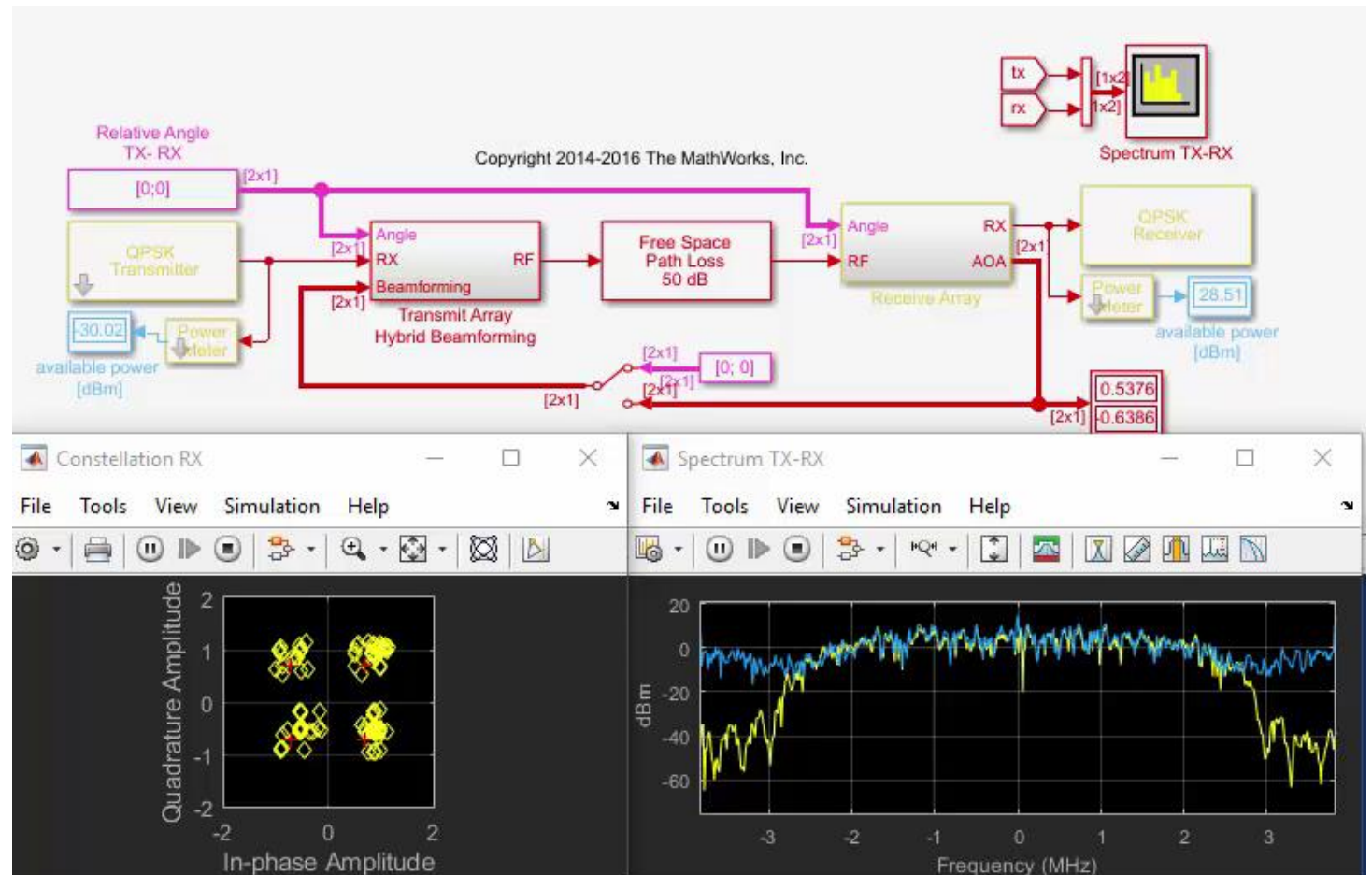
## Investigate the impact of RF impairments

- Frequency dependency
- Non-linearities
- Mismatches and coupling



# Investigate the Impact of RF Impairments

- Non-linear amplifier with memory
- S-Parameters
- Intermodulation distortion



## Products of Interest

LTE System Toolbox

WLAN System Toolbox

Antenna Toolbox

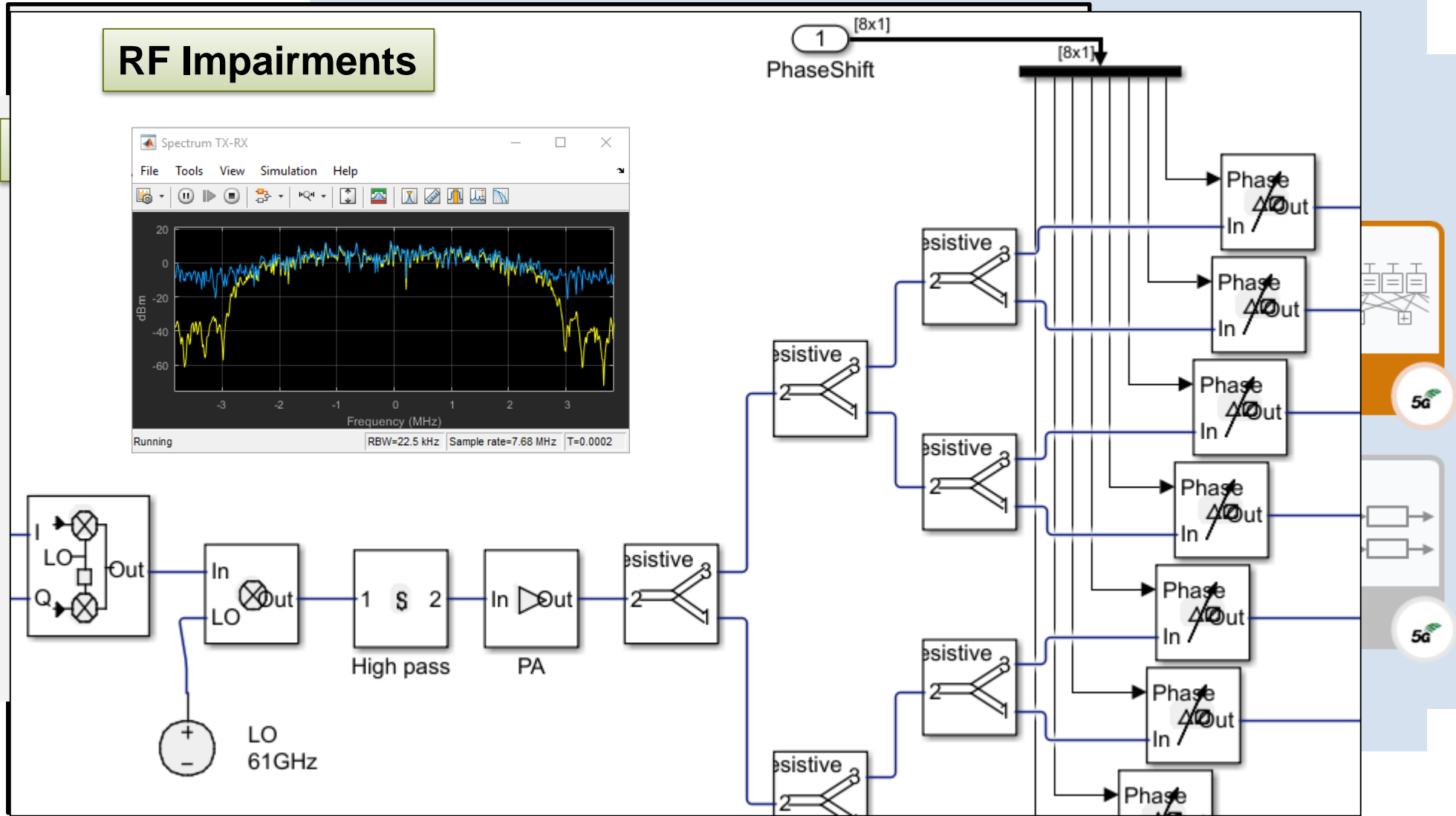
Phased Array System Toolbox

RF Blockset

Communications System Toolbox

# Addressing Wireless Engineering Challenges

Generate baseband waveform



## Resources – Links in PDF Document

- [MATLAB and Simulink for 5G Technology Development](#)
- [Download the 5G Library](#)
- [Introduction to 5G Library](#) (4:54 video)
- [Evaluating 5G Waveforms Over 3D Propagation Channels with the 5G Library](#) (white paper)
- [Wireless Suite](#) (US only): package set of 10 wireless products
- [Hybrid Beamforming for Massive MIMO Phased Array Systems](#) (white paper)
- [LTE System Toolbox](#)
- [WLAN System Toolbox](#)

# Thank You!