MATLAB EXPO 2016

The Road to 5G: Simulating and Prototyping Wireless Systems

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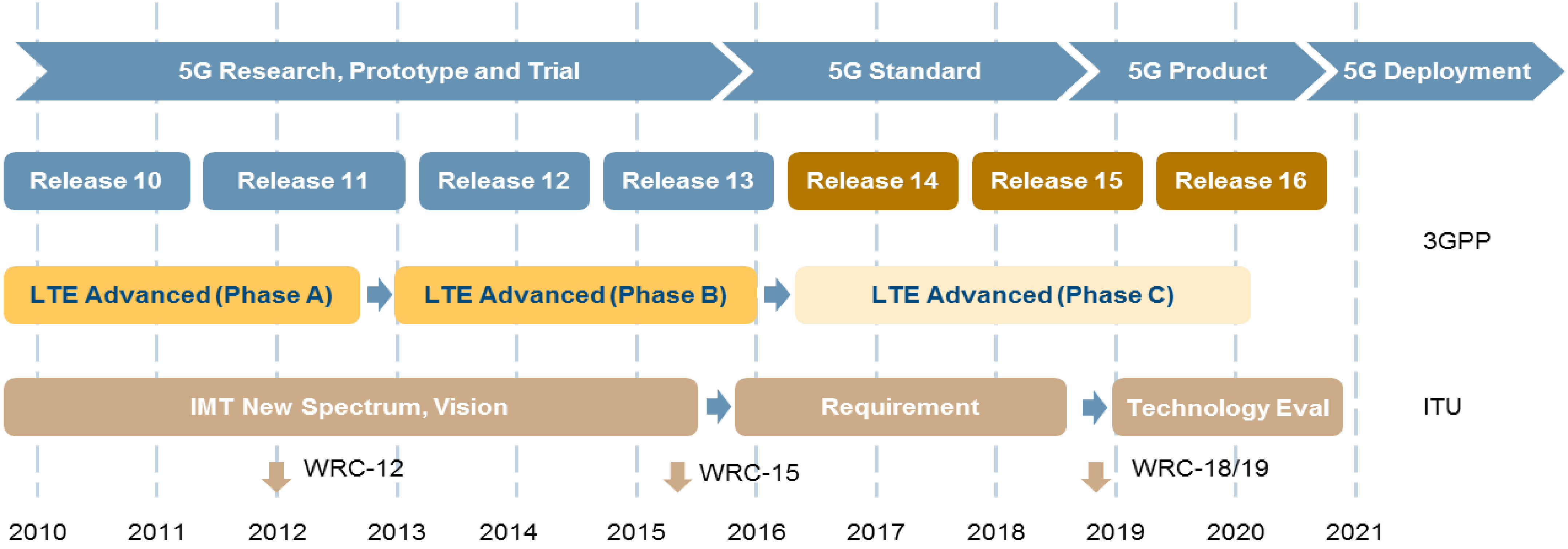
Industry Manager, MathWorks

Agenda

- Introduction
- Algorithm-to-Antenna Design
- Over-the-Air Testing
- Prototyping and Implementation
- Summary

A 5G Timeline
- Fifth Generation mobile networks (wireless systems)



- LTE: Long Term Evolution
  - Long Term Employment
- 5G: NR: New Radio
  - Never Retirement

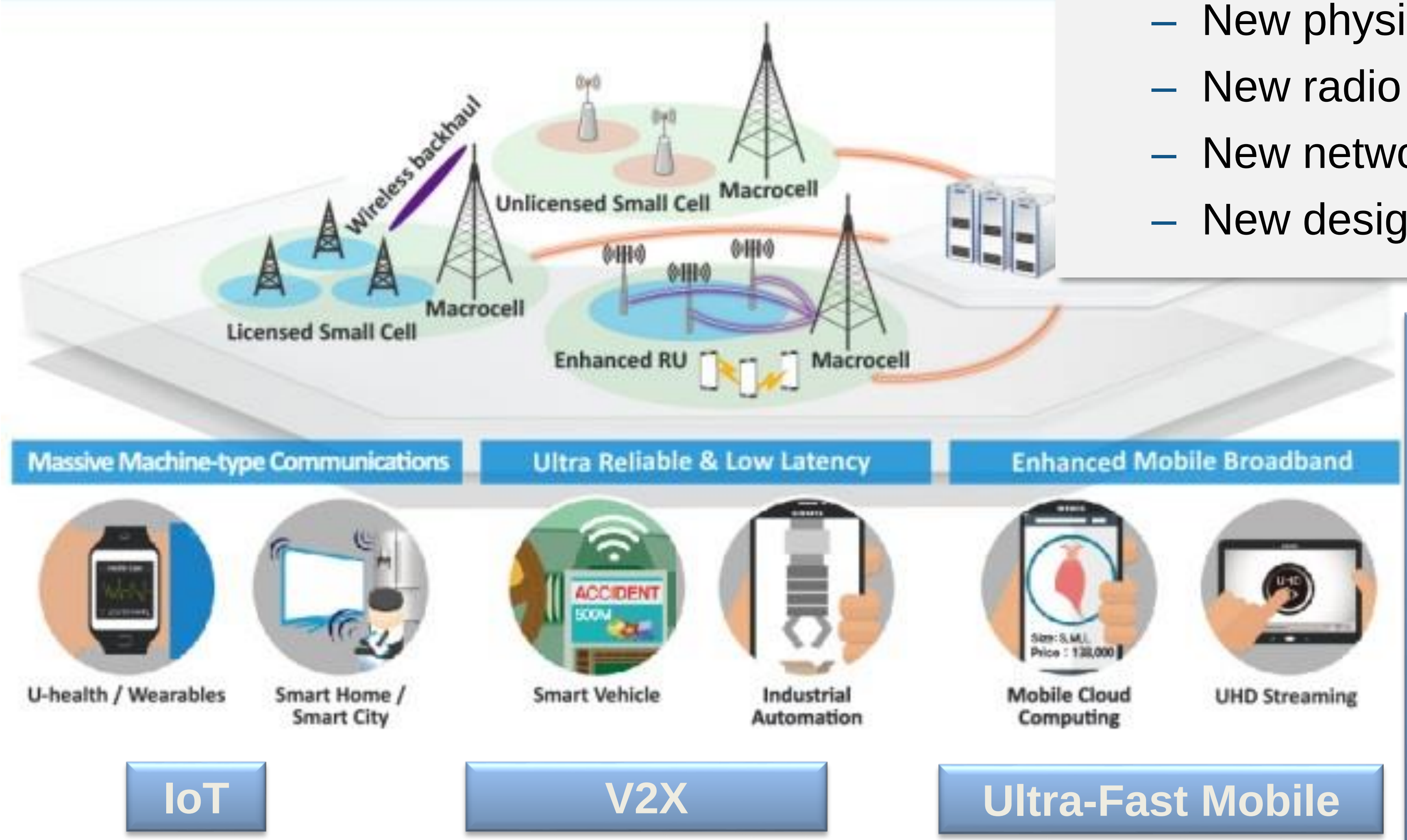
PyeongChang 2018

TOKYO 2020

Source: 3GPP

5G Vision and Use Cases

Not just towers and mobile phones



Source: 3GPP

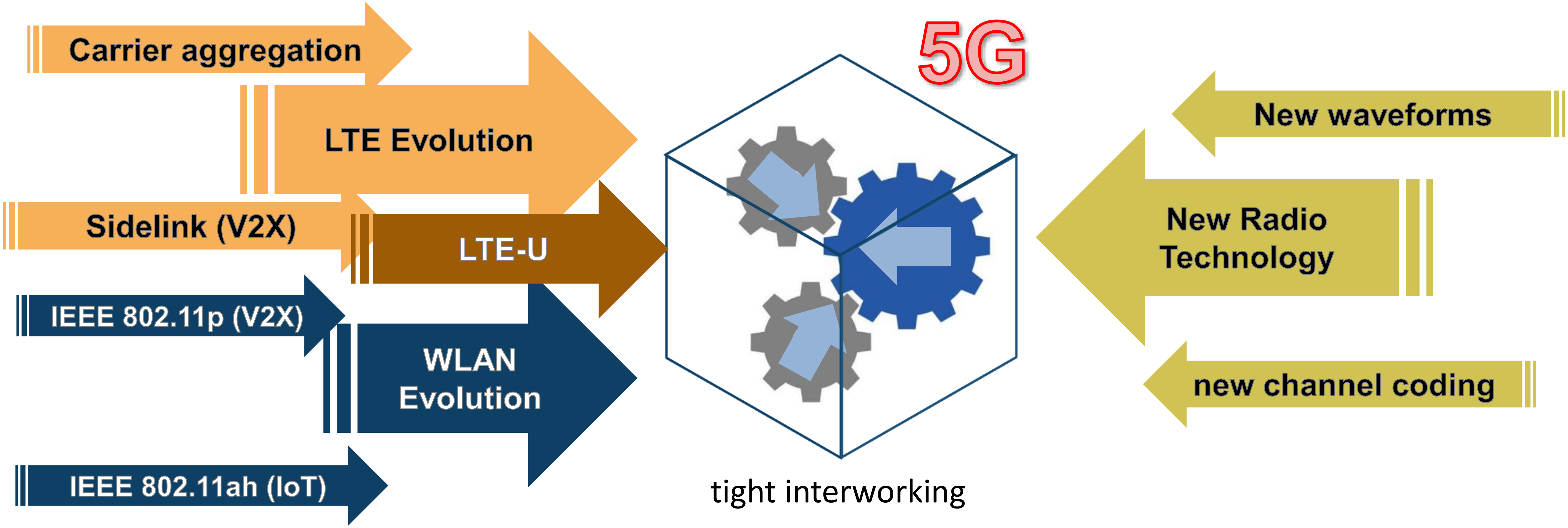
To do all of this, 5G will require:

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

Challenges

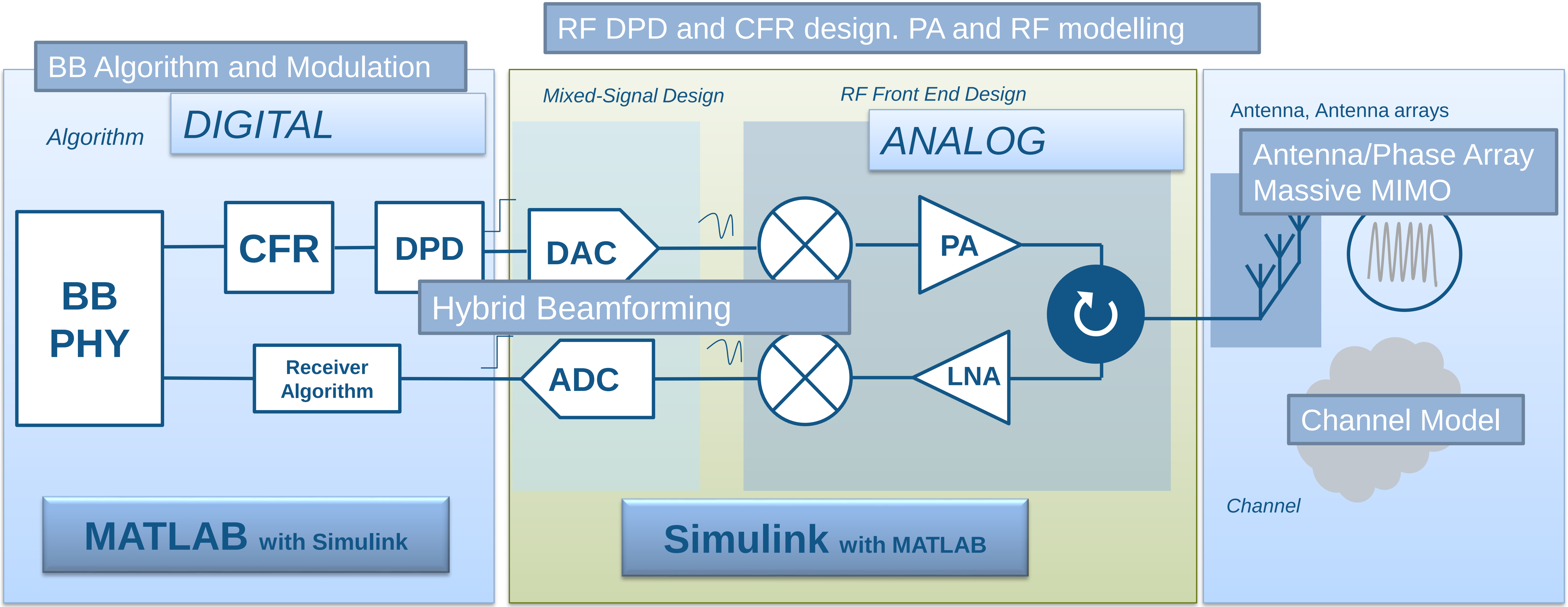
- **RF Design and mmWave**
- **Channel models (>6GHz)**
- **New Channel Coding**
- **New waveforms**
- **Massive MIMO**
- **Advanced receivers**
- **Quick Prototyping**

Towards 5G: LTE and WLAN will Continue to Play a Key Role

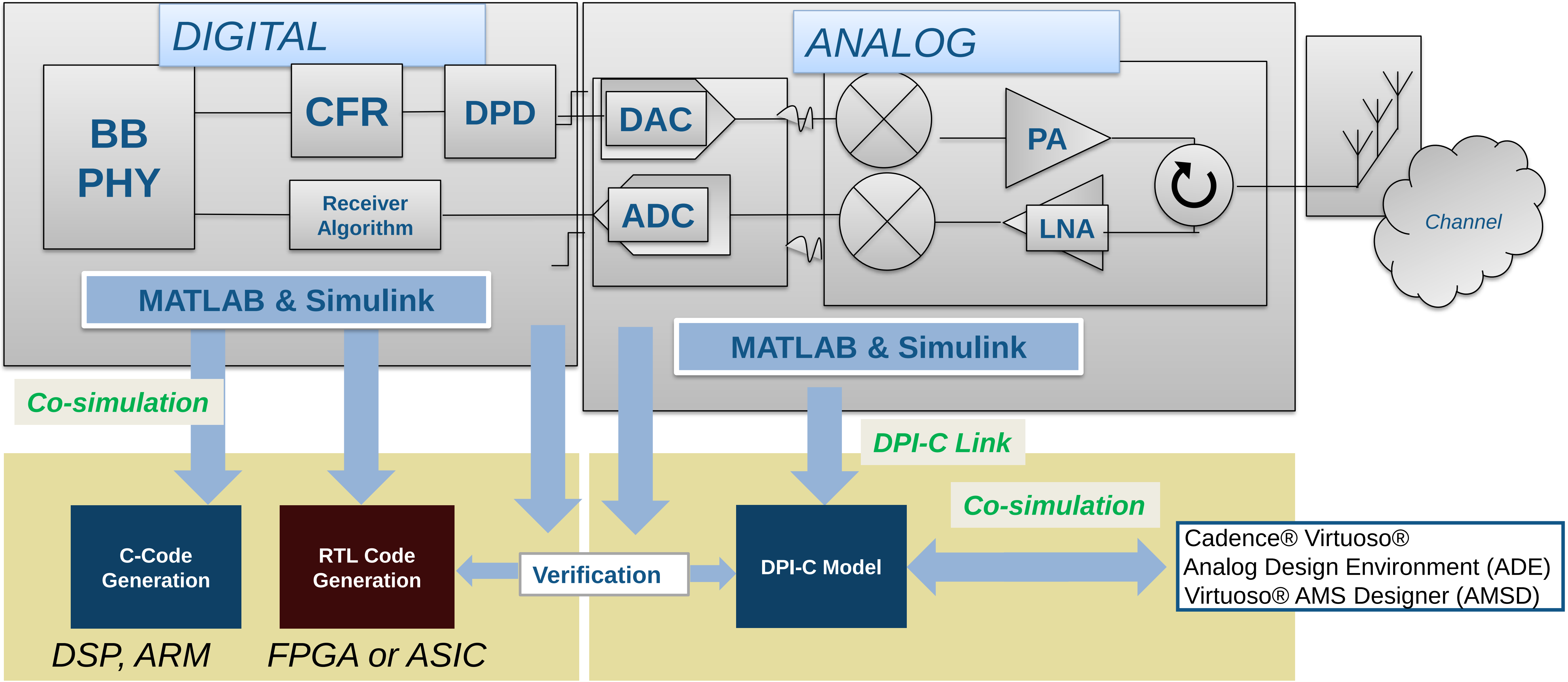


LTE and WLAN will likely remain the baseline with new radio technology

5G: From Algorithm to Antenna



5G: From Algorithm to Implementation



Quick Hardware Testbed Prototyping and Early Verification

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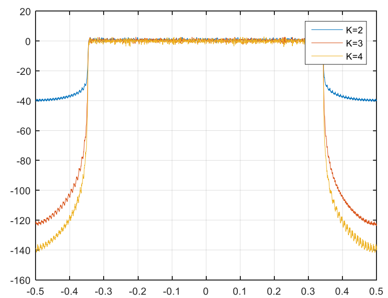
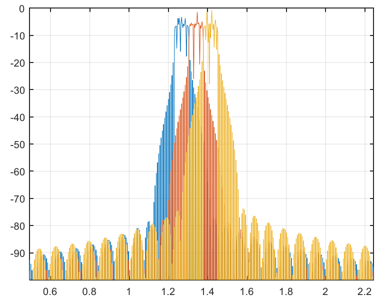
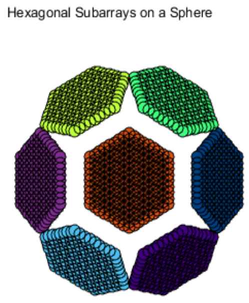
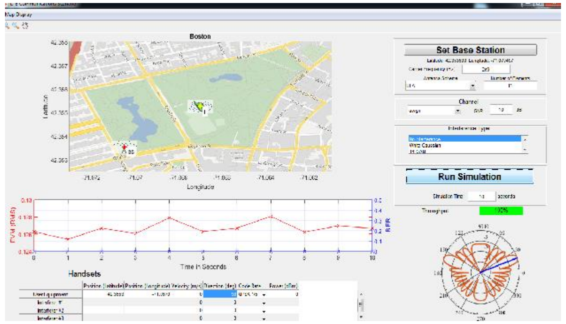
5G Challenges and Solutions

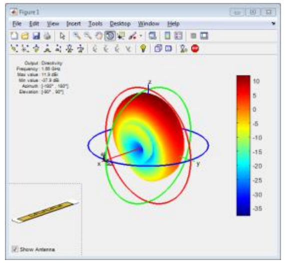
- **New Waveforms**
  - Performance of f-OFMD, FBMC, UFMC, etc.
- **Massive MIMO and mmWave**
  - Antenna arrays, Beamforming and RF architectures
- **Channel Model**
  - WINNER II model and 3GPP
- **Advanced Receivers Design**
  - LDPC and Turbo
- **Real Hardware Verification and Prototyping**
  - Hardware testbed and Quick prototyping on FPGA
- **LTE and WLAN Evolution**
- **V2X (LTE based and DSRC based, 802.11p)**

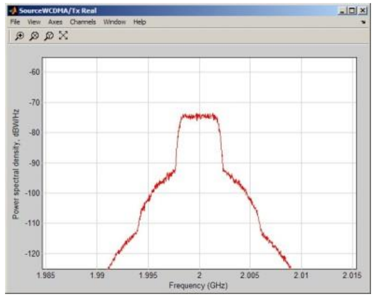






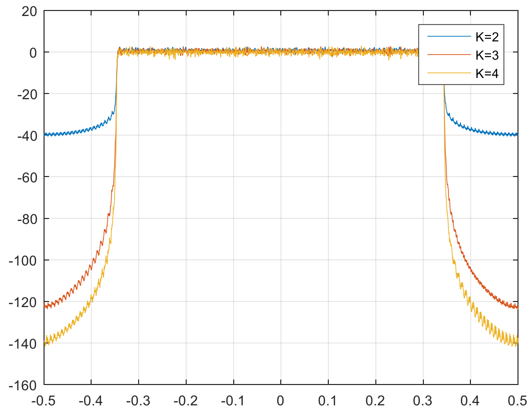




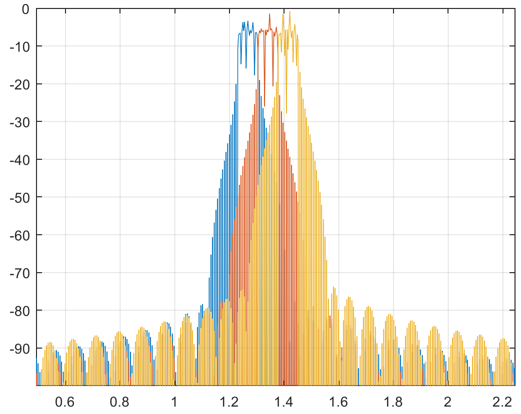


Example: New Waveforms Evaluation:
- Universal Filtered Multi-carrier (UFMC)

- Filtering applied per <u>sub-bands</u> (not per sub-carrier as in FBMC)
  - Filtering parameterized by side-lobe attenuation
  - Reduced filter length (compared to FBMC)
  - Good for short bursts, suited for uplink with multiple users



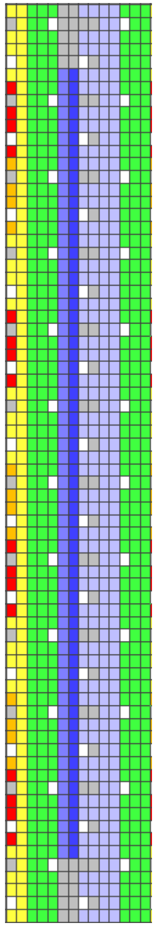
- Orthogonal in the complex plane
  - use QAM symbols, reapply MIMO schemes



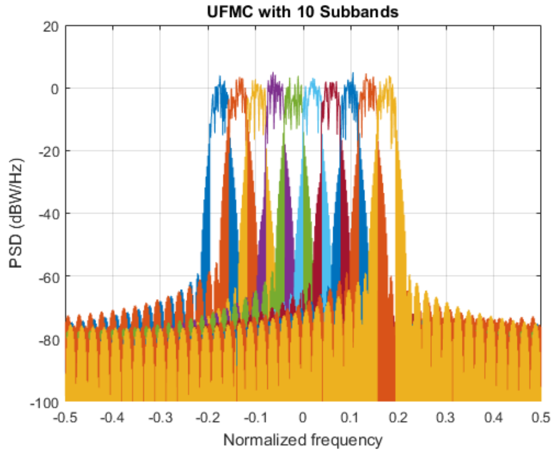
- Receiver complexity
  - Similar to OFDM, use per subcarrier equalization

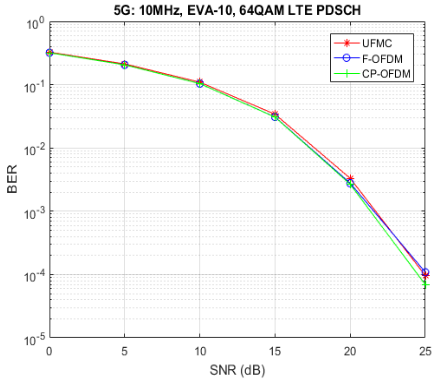
Evaluating the Performance of new Modulation Schemes

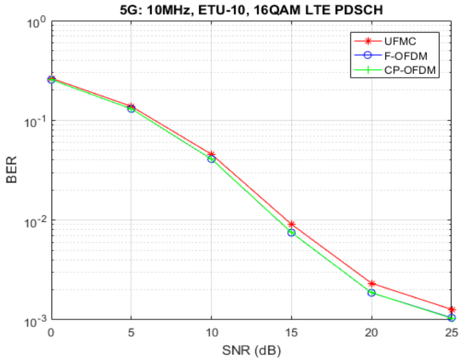
LTE System Toolbox



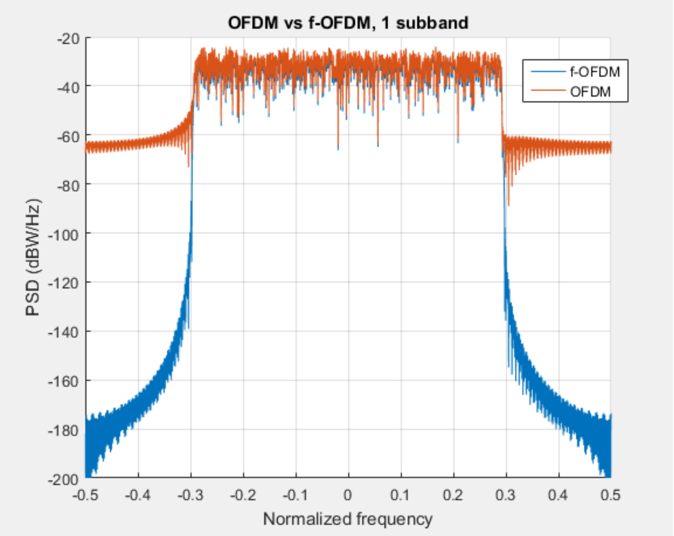
LTE resource grid







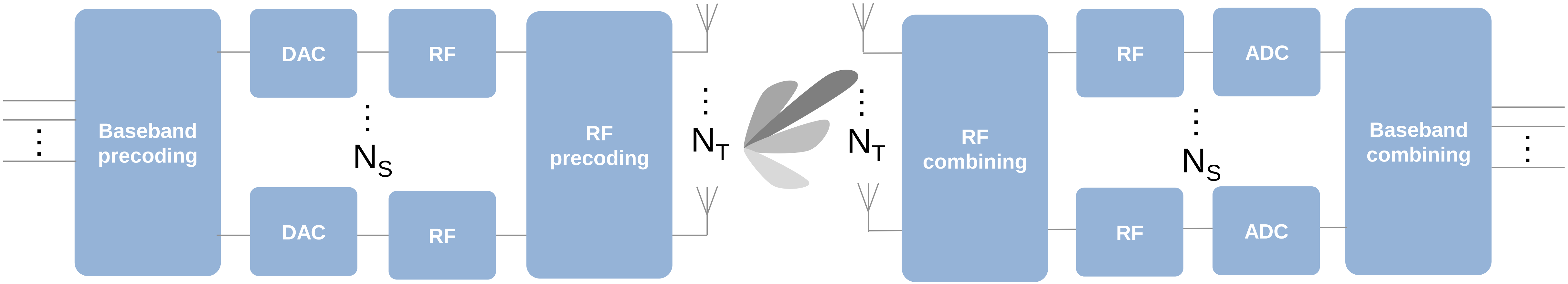
UFMC modulation → Channel → UFMC demodulation → Channel estimation & equalization →



- Need reference symbols
- Need a realistic signal structure

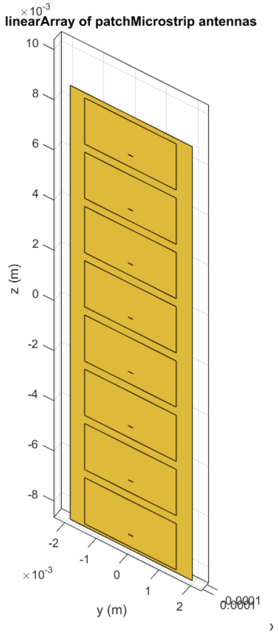
Example: Hybrid Beamforming Design

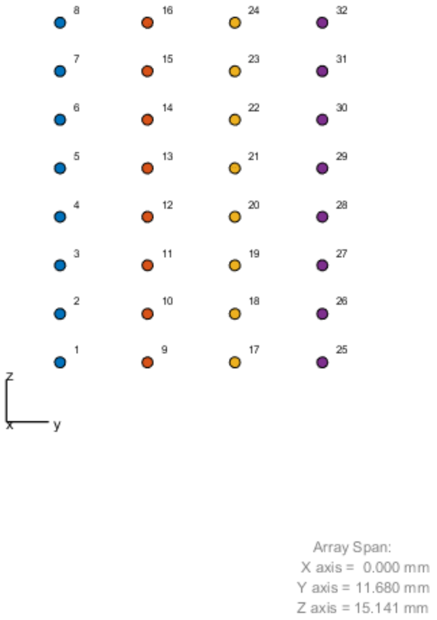
- Beamforming implemented part in the digital and part in the RF domain
  – Trade-off performance, power dissipation, implementation complexity
- Different possible analog implementations
  – Phase shifters vs. Switching networks
- Different possible analog architectures
  – RF chains fully connected to each antenna vs. Subarrays



Example: Hybrid Beamforming Transmitter Array

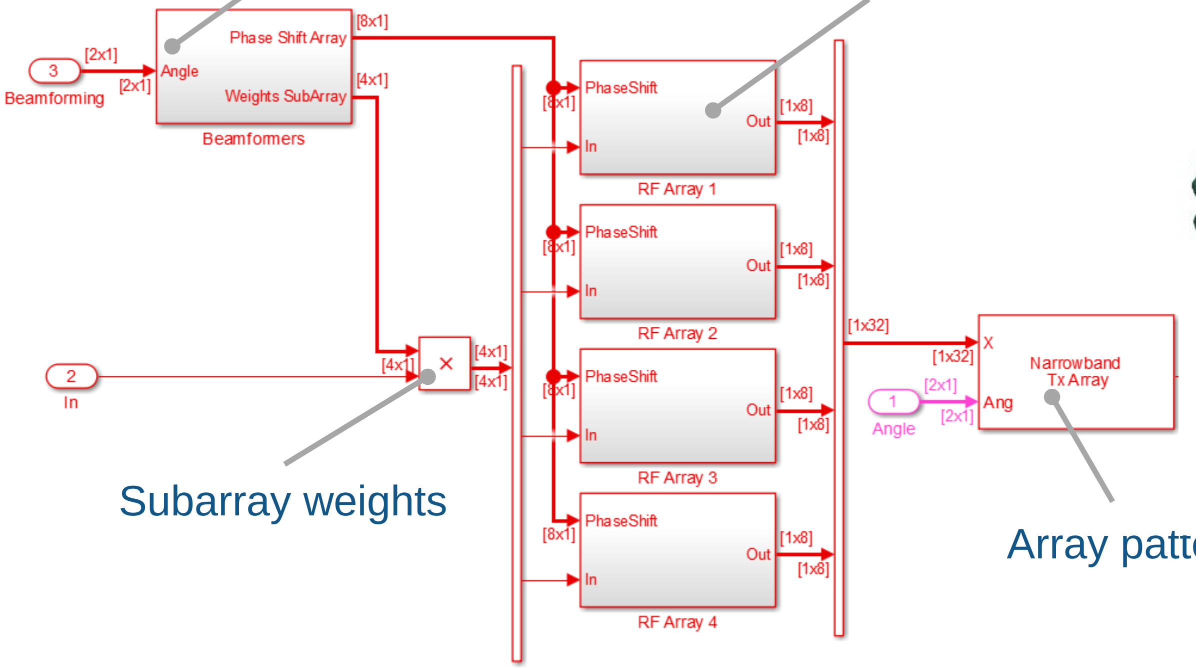
- 4 subarrays of 8 patch antennas operating at 66GHz → 8x4 = 32 antennas
- Digital beamforming applied to the 4 subarrays (azimuth steering)
- RF beamforming (phase shifters) applied to the 8 antennas (elevation steering)



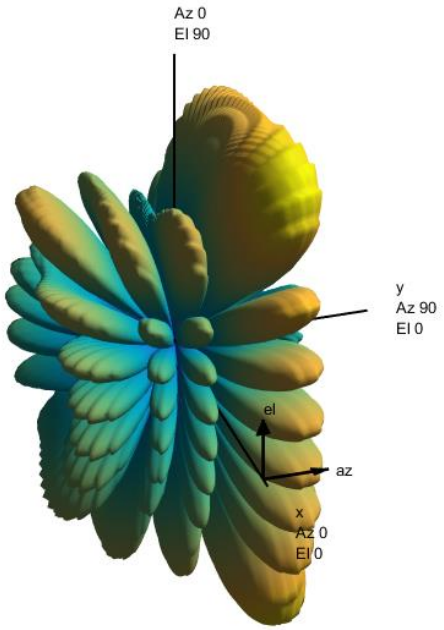


Beamformers (array and subarray)

4 subarrays



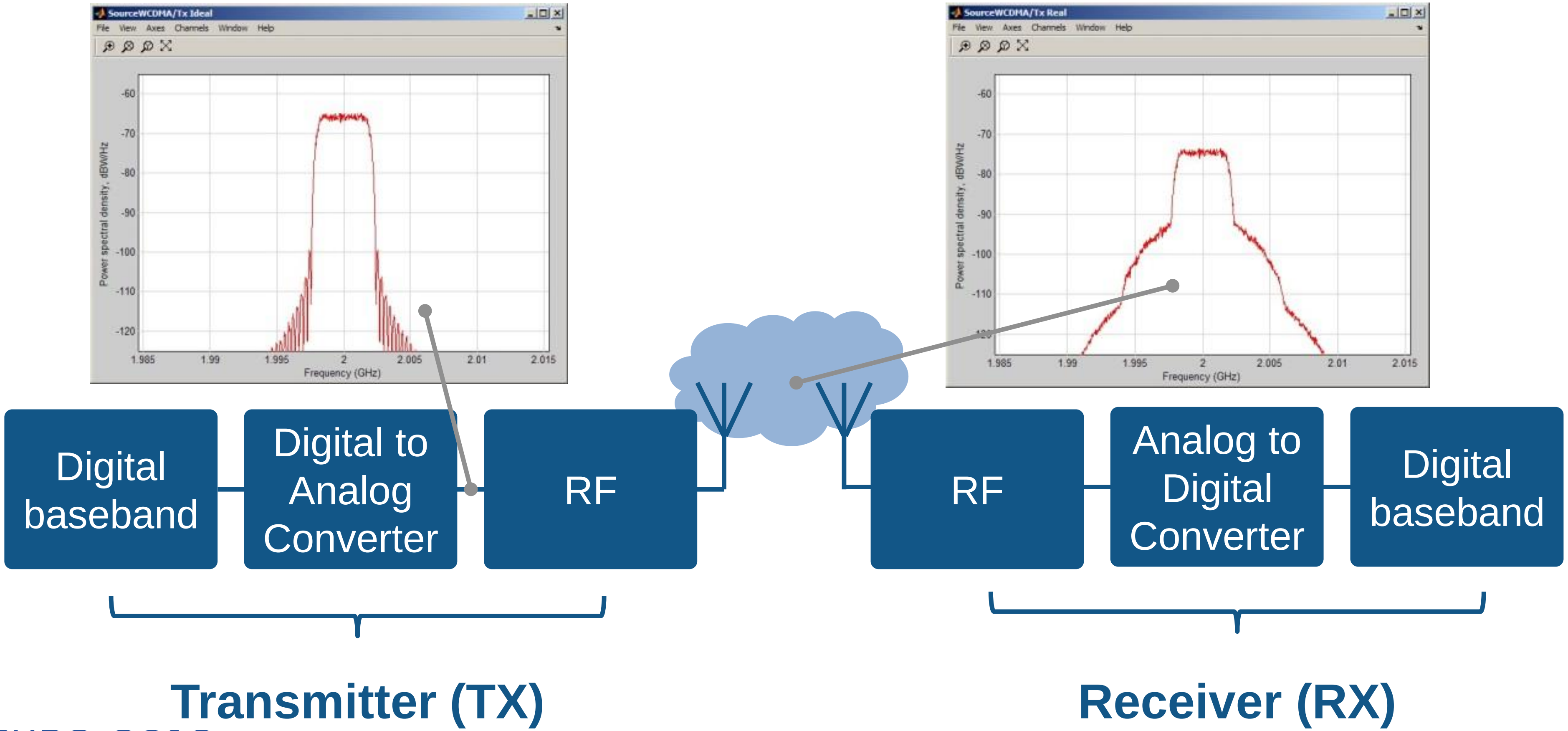
Subarray weights



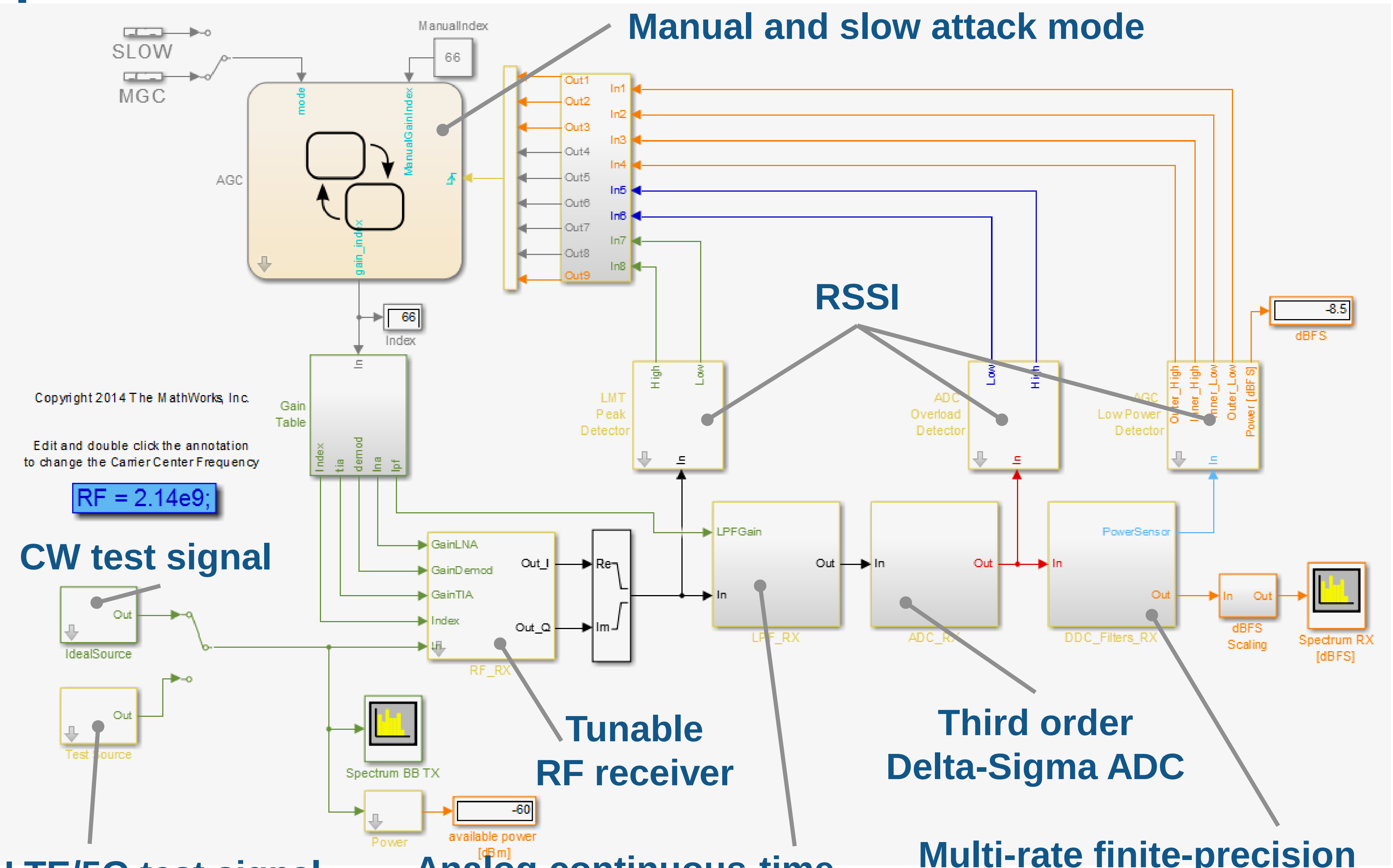
Array pattern

Why Consider RF in 5G System-Level Simulation?

- RF imperfections that cannot be neglected, especially in 5G with higher frequency
- There will be a need for greater integration between RF and baseband



Example: AD9361 RF Transceiver



AGC

Manual and slow attack mode

RSSI

CW test signal

Tunable RF receiver

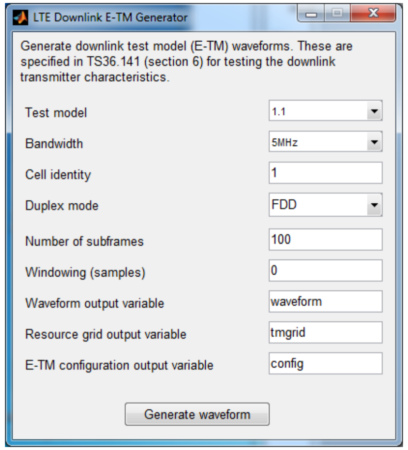
Third order Delta-Sigma ADC

Custom LTE/5G test signal

Analog continuous-time programmable filters

Multi-rate finite-precision programmable decimation filters

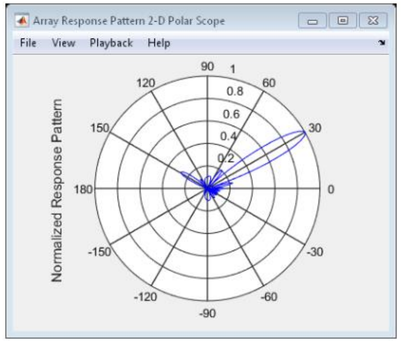
5G End-to End Simulation Platform



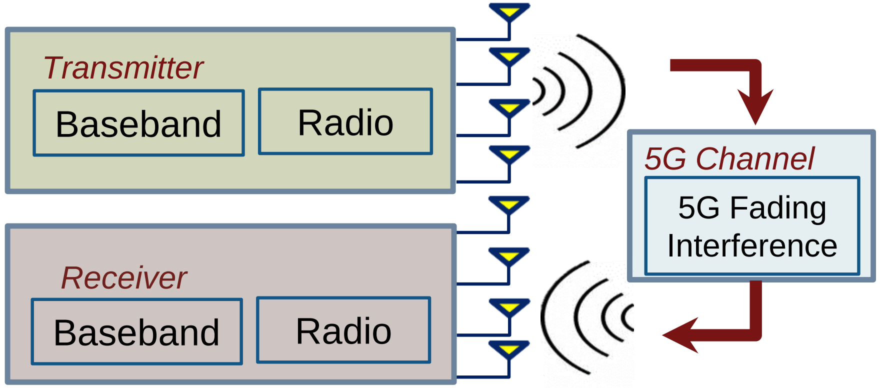
Testing Waveforms

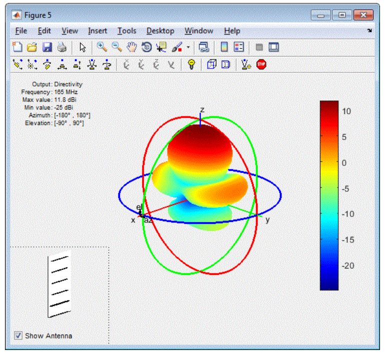
```
% Construct Modulator
hDataMod = comm.OFDMModulator(...
  'FFTLength' ,              c.FFTLength,...
  'NumGuardBandCarriers', c.NumGuardBandCarriers,...
  'InsertDCNull',            true, ...
  'PilotInputPort',          true,...
  'PilotCarrierIndices',     c.PilotCarrierIndices,...
  'CyclicPrefixLength',      c.CyclicPrefixLength,...
  'NumSymbols',              numDataSymbols);
```

5G Baseband algorithms

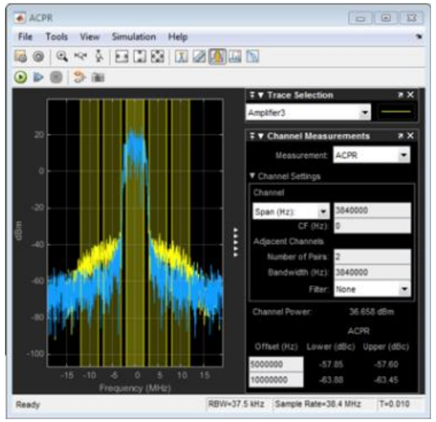


Beamforming

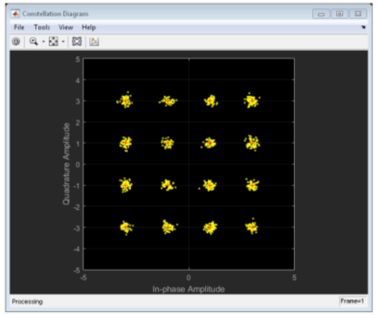




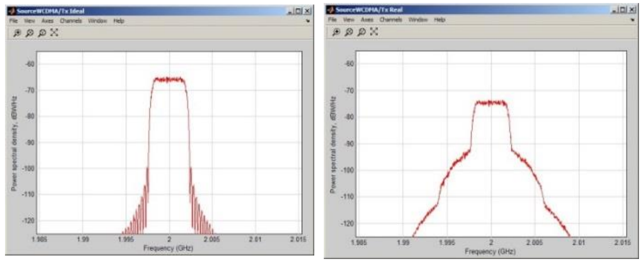
Antenna modeling



Signal analysis



5G Receiver design



RF and channel impairments

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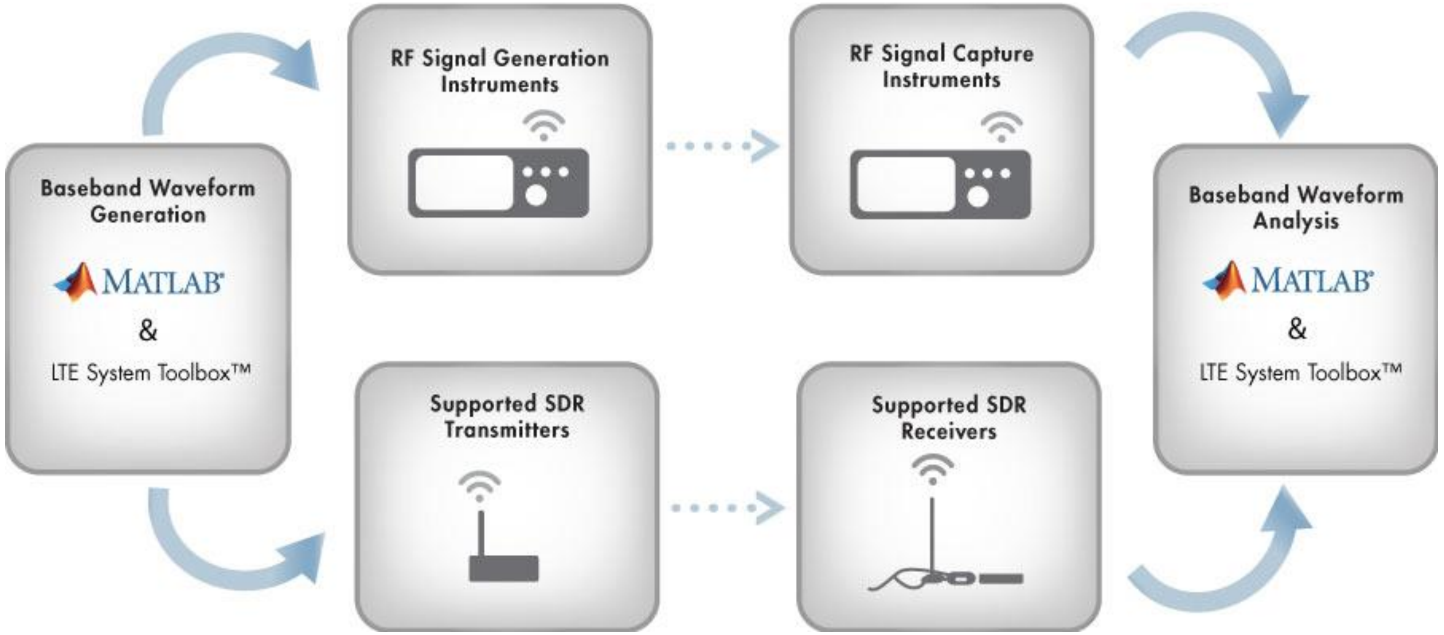
5G - Over-the-Air Testing with SDRs & RF instruments



Generate custom waveforms

Transmit with SDR devices or RF instruments

Capture signals with SDR or instruments

Recover original data

Range of supported hardware

RF Signal Generator

Spectrum Analyzer

Zynq Radio SDR

USRP SDR

LTE/WLAN Standard-Compliant Signals: Signal Generation and Transmission

LAN/USB/GPIB

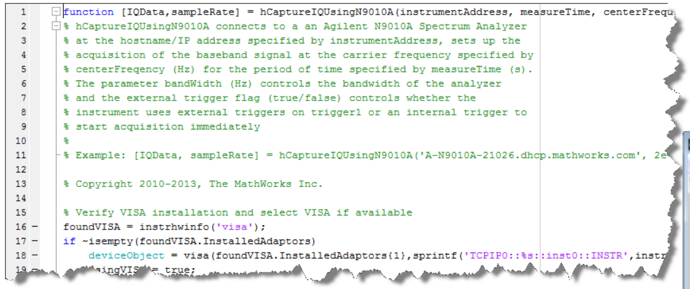
hDownloadAndPlayWaveformUsingN5172B.m

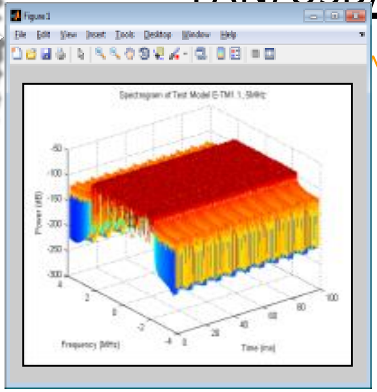
RF Signal Generator

- Generate LTE baseband signal in MATLAB
- Download to Signal Generator

- Configure and control generation parameters using
- Upconvert IQ waveform to RF and play back over the air

LTE/WLAN Standard-Compliant Signals: Signal Acquisition and Analysis

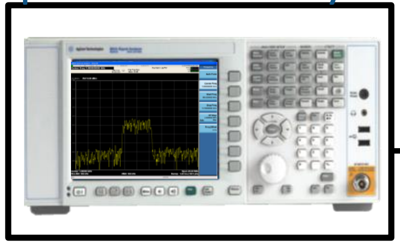




LAN/USB/GPIB

N9010A.m

Spectrum Analyzer



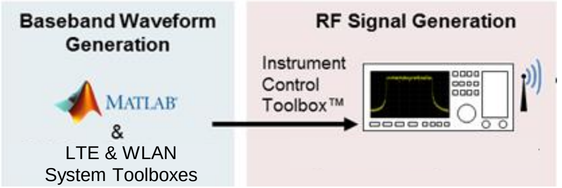
- Retrieve IQ data into MATLAB for analysis
- Perform visualization and analysis in MATLAB

- Programmatically configure acquisition parameters
- Downconvert RF Signal to baseband in hardware

Typical Use Cases for LTE & WLAN System Toolboxes

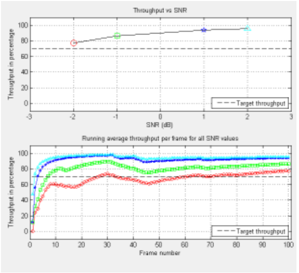
Golden Reference for Verification

Does my design work as it should?



Signal Generation/Analysis

Test with live data



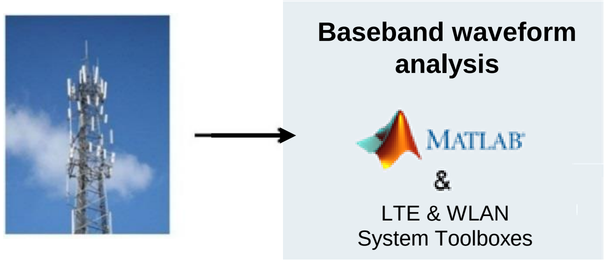
Throughput?

Quality?

End-To-End Simulation

How do design choices affect system performance?

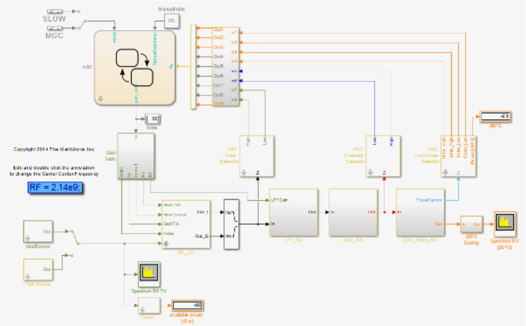
Does my system conform to the standard?



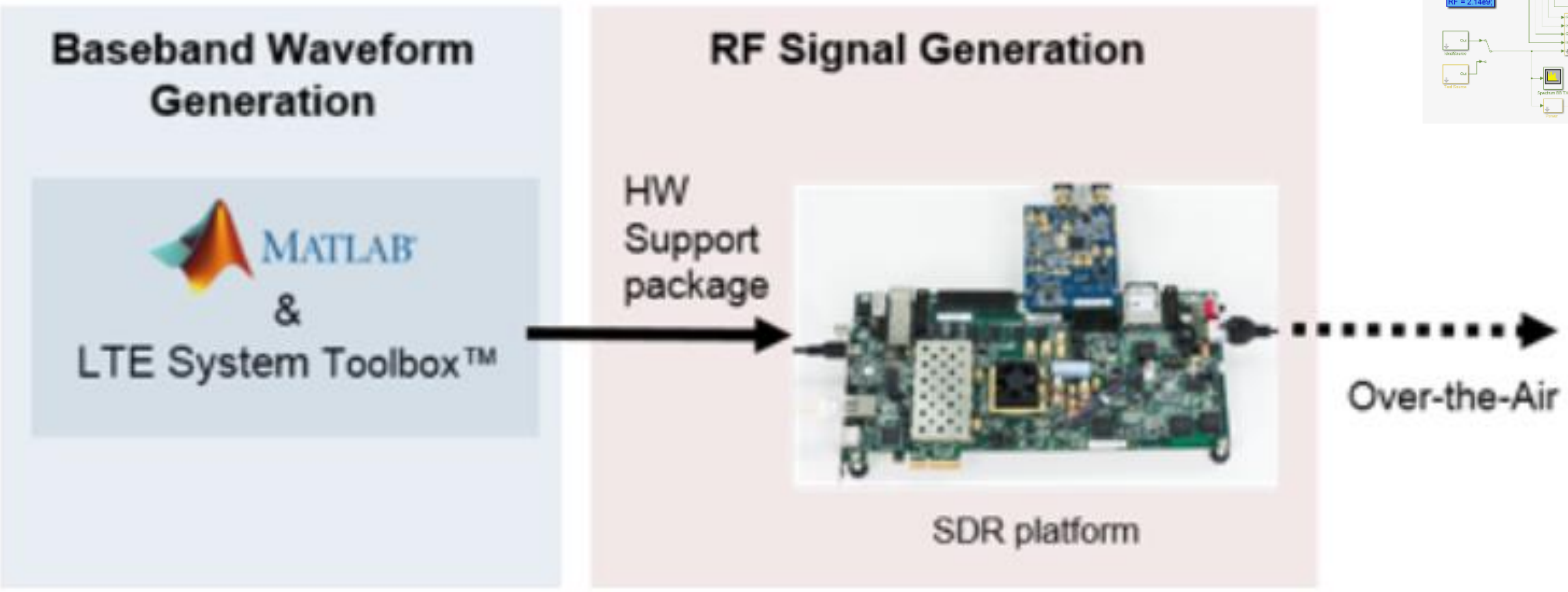
Signal Information Recovery

Decode real-world signals

Example: MATLAB Connects with SDR and AD9361



AD9361 RF Transceiver



Zynq ZC706 Board

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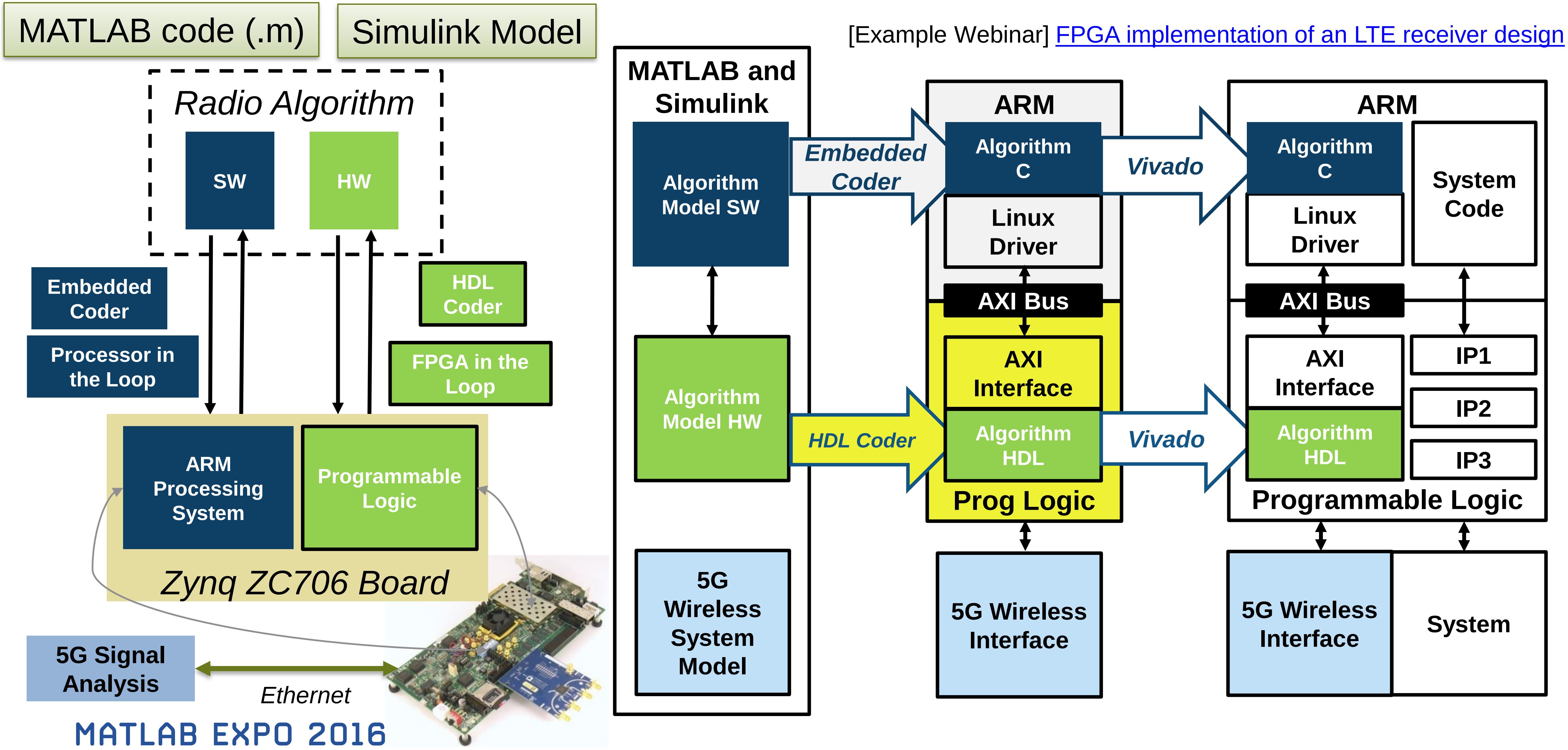
From Simulation to Prototyping: Xilinx Zynq + AD9361 SDR

[Example Webinar] FPGA implementation of an LTE receiver design



Ericsson – Radio Testbed Design Using HDL Coder

Radio Testbed Design Using HDL Coder

Systems & Technology (S&T) is the department at Ericsson responsible for securing technology leadership for Development Unit Radio. S&T is involved in standardization, concept development, and pre-pre-studies of new features, standards, and concepts, and acts as a driver for radio technology strategic work. An important part of this work is the development of test beds to validate and demonstrate new technology. In this session, Tomas shares his experiences incorporating HDL Coder™ into the design workflow of a new test bed radio. He highlights how it has been a key factor in managing the rapid development of a complex FPGA application and how it has enabled the design to quickly adapt to changes in specifications.

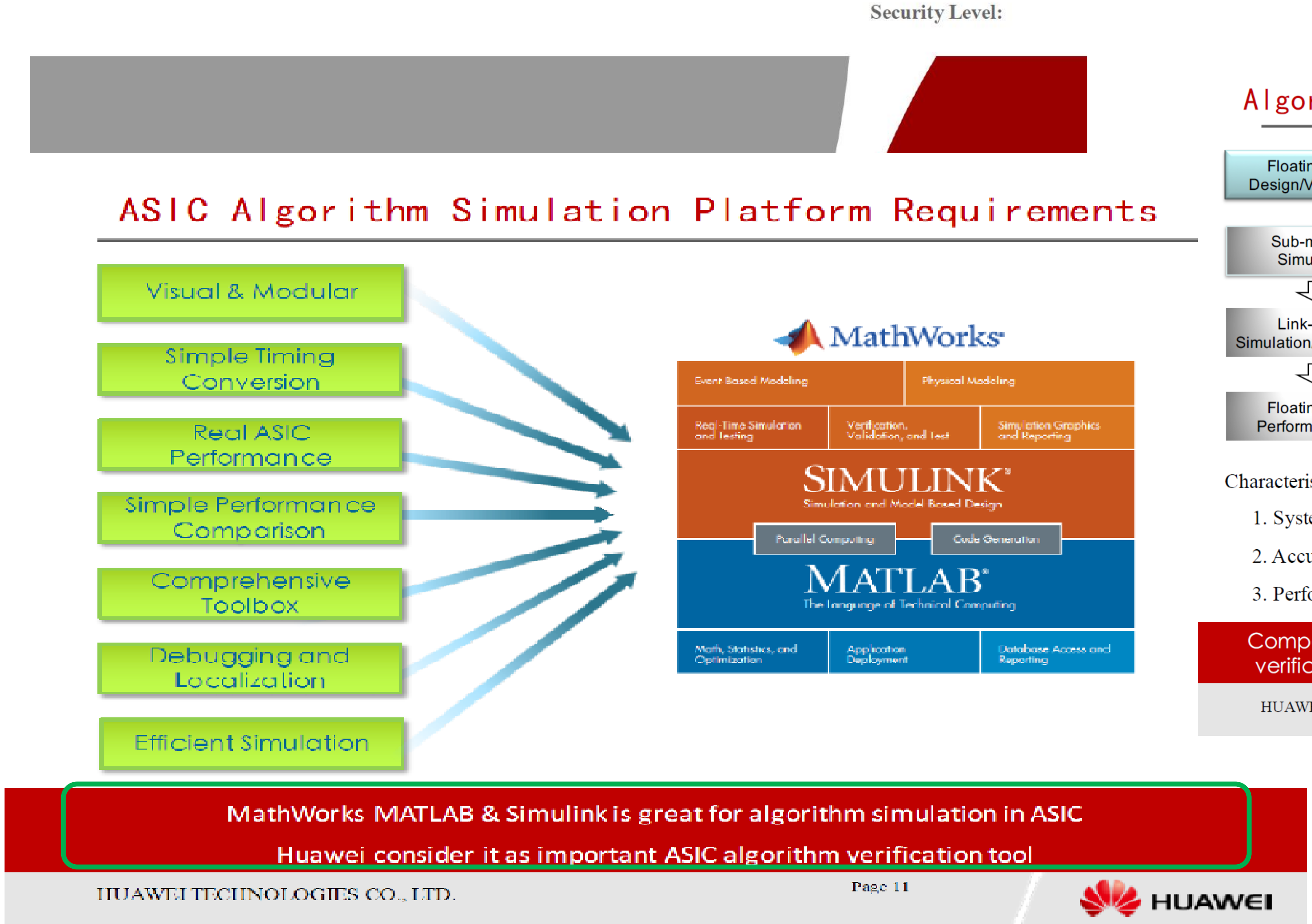
View video online here

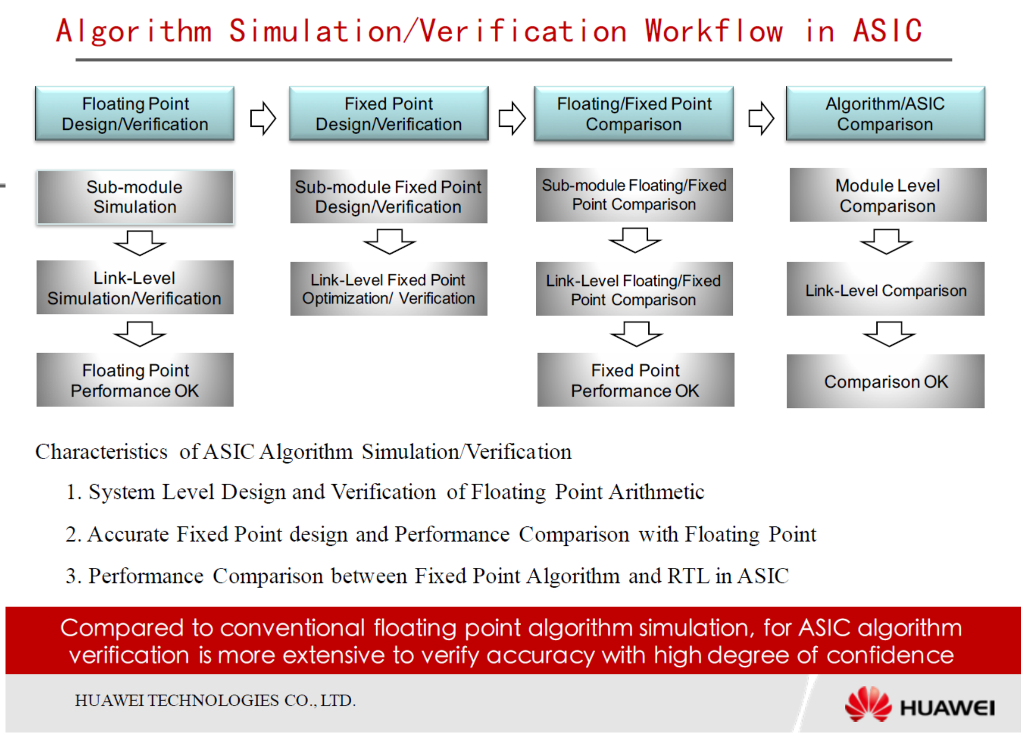
Accelerating 5G Wireless System Development with Hardware Testbeds

Download the white paper "Accelerating 5G Wireless System Development with Hardware Testbeds." The paper explores an integrated methodology and workflow for the development of advanced algorithms and rapid deployment to hardware testbeds. It discusses their usage in engineering the next generation of wireless communication systems.

Download our white paper here

Huawei: System-Level ASIC Algorithm Platform using MATLAB and Simulink





View slides online at:

System Level ASIC Algorithm Simulation Platform using Simulink

Broadcom – NFC ASIC Chip System and Implementation

Modelling Near Field Communication Systems and Implementation on ASIC

Rob Castle, Broadcom

Read abstract

Near field communication (NFC) technology is attracting a lot of interest for mobile payment and ticketing applications. Behind the simple "swipe and go" operation is a complex system spanning many different standards and presenting challenges from the RF interface to the digital processing. Broadcom is currently developing chips to provide NFC solutions for handset manufacturers, and MATLAB and Simulink are an important part of both the system modelling and, through HDL Coder, generation of the actual digital hardware. This session will begin with an overview of NFC and its relevant standards. This will be followed by a discussion on how MATLAB and Simulink are used for both simulation and FPGA emulation, as the design evolves towards production.

View video online at:
http://www.matlabexpo.com/uk/2012/proceedings/modelling-near-field-communication-systems-and-implementation-on-asic.html

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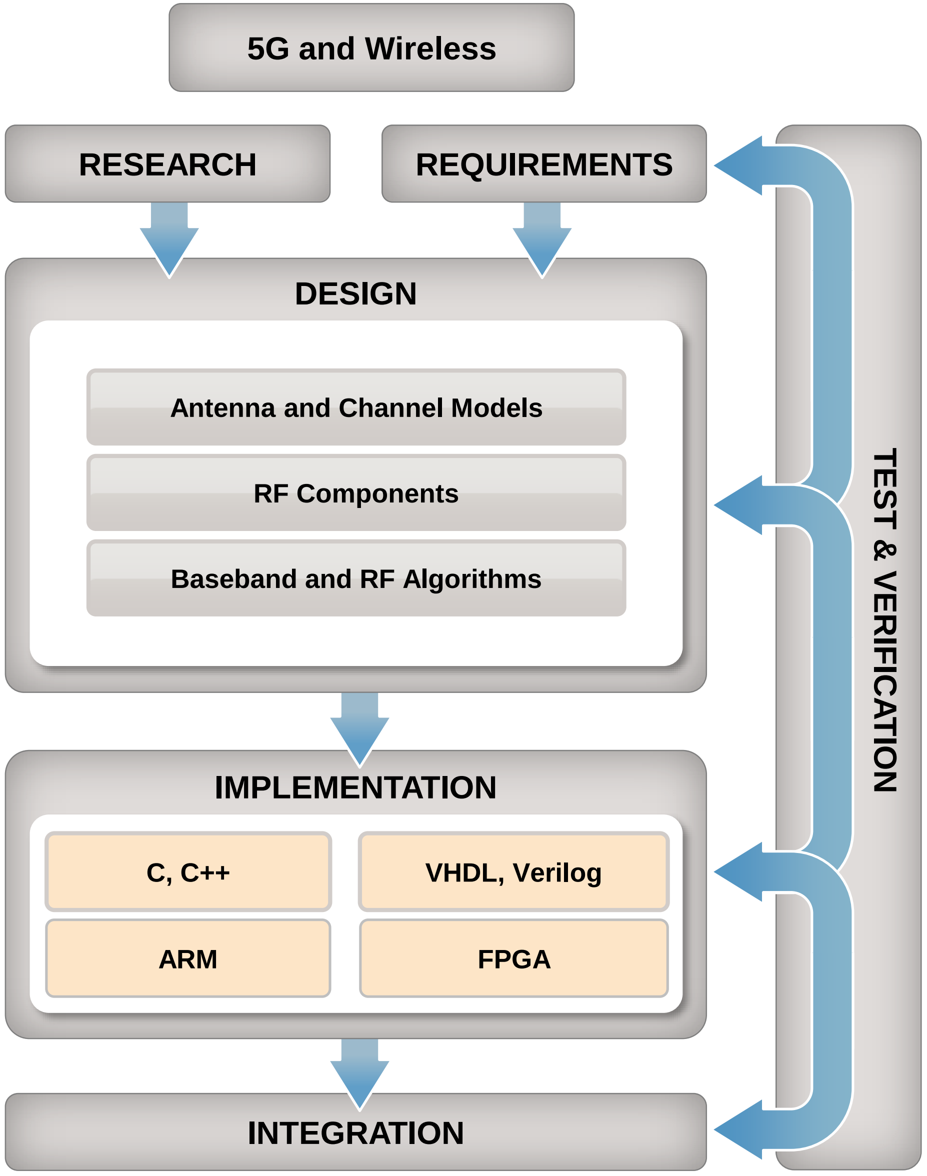
Summary:

- Algorithm-to-Antenna Design and Verification
  - Waveforms, Beamforming, RF and Antenna
  - End-to-End Simulation
- Over-the Air Testing
  - LTE and WLAN standards compliant
- Prototyping and Implementation
  - C-Code and RTL Code Generation
  - Quick FPGA Prototyping and ASIC Implementation



For more information

- Website
  - https://www.mathworks.com/discovery/5g-wireless-technology.html

- Web Search
  - **“5G, MATLAB”**

Questions