MATLAB EXPO 2016
The Road to 5G: Simulating and Prototyping Wireless Systems

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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

Source: 3GPP

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5G Vision and Use Cases
*Not just towers and 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

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

Source: 3GPP
Towards 5G: LTE and WLAN will Continue to Play a Key Role

- Carrier aggregation
- LTE Evolution
- Sidelink (V2X)
- LTE-U
- IEEE 802.11p (V2X)
- WLAN Evolution
- IEEE 802.11ah (IoT)

New waveforms
New Radio Technology
new channel coding

5G

tight interworking

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

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5G: From Algorithm to Antenna

- **BB Algorithm and Modulation**
  - Algorithm
  - **DIGITAL**
    - BB PHY
    - CFR
    - DPD
    - Receiver Algorithm

- **Mixed-Signal Design**
  - DAC
  - **ANALOG**
    - PA
    - LNA

- **RF Front End Design**
  - RF DPD and CFR design. PA and RF modelling

- **Hybrid Beamforming**
  - ADC

- **MATLAB with Simulink**

- **Simulink with MATLAB**

- **Antenna, Antenna arrays**
  - Antenna/Phase Array
  - Massive MIMO

- **Channel Model**

- **Channel**

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5G: From Algorithm to Implementation

DIGITAL

BB PHY

CFR

DPD

Receiver Algorithm

MATLAB & Simulink

ANALOG

DAC

ADC

PA

LNA

MATLAB & Simulink

Co-simulation

DPI-C Link

C-Code Generation

RTL Code Generation

Verification

DPI-C Model

Co-simulation

Cadence® Virtuoso® Analog Design Environment (ADE)
Virtuoso® AMS Designer (AMSD)

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 **sub-bands** (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

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)
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

CW test signal

Custom LTE/5G test signal

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AGC

Manual and slow attack mode

RSSI

Tunable RF receiver

Third order Delta-Sigma ADC

Multi-rate finite-precision programmable decimation filters

Analog continuous-time programmable filters
5G End-to-End Simulation Platform

5G Baseband algorithms

Testing Waveforms

Signal analysis

5G Receiver design

Beamforming

Antenna modeling

RF and channel impairments

Beamforming

5G Fading Interference

Testing Waveforms

Beamforming

Antenna modeling

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**

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

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

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

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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*

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

- **Baseband Waveform Generation**
  - MATLAB & LTE System Toolbox™

- **RF Signal Generation**
  - HW Support package
  - SDR platform

- **Over-the-Air**

- **AD9361 RF Transceiver**

- **Zynq ZC706 Board**
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From Simulation to Prototyping: Xilinx Zynq + AD9361 SDR

MATLAB code (.m) Simulink Model

Radio Algorithm

ARM

Simulink Model

5G Wireless System Model

Zynq ZC706 Board

5G Signal Analysis

Ethernet

FPGA implementation of an LTE receiver design
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

ASIC Algorithm Simulation Platform Requirements

- Visual & Modular
- Simple Timing Conversion
- Real ASIC Performance
- Simple Performance Comparison
- Comprehensive Toolbox
- Debugging and Localization
- Efficient Simulation

Algorithm Simulation/Verification Workflow in ASIC

1. System Level Design and Verification of Floating Point Arithmetic
2. Accurate Fixed Point design and Performance Comparison with Floating Point
3. Performance Comparison between Fixed Point Algorithm and RTL in ASIC

Compared to conventional floating point algorithm simulation, for ASIC algorithm verification, it is more extensive to verify accuracy with high degree of confidence.

MathWorks MATLAB & Simulink is great for algorithm simulation in ASIC
Huawei consider it as important ASIC algorithm verification tool

View slides online at:
System Level ASIC Algorithm Simulation Platform using Simulink
Broadcom – NFC ASIC Chip System and Implementation

View video online at:
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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”