From Antenna to Bits:

Wireless System Design with MATLAB and Simulink

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Innovations in the World of Wireless

- Everything is mobile
- Everything is connected to internet

→ Everything needs signal processing & wireless communications
Challenges in Next Generation Wireless Systems

- **Innovation drivers**
  - Ultra-high throughput
  - Massive connectivity for IoT
  - Device integration

- **Challenges**
  - Changing demands on engineering roles and skills
  - Accelerating product cycles
  - Cost of verification
Next Generation Wireless Design

Requires 7 different skills to be successful!

\(^{\land}\) at least

- System Architecture
- DSP Algorithms
- Software Development
- Digital Hardware
- Mixed-Signal Hardware
- RF Design
- Antenna Design

TRANSMITTER

Baseband \rightarrow Digital Front End \rightarrow DAC \rightarrow PA \rightarrow Antenna

Digital PHY

RECEIVER

Baseband \rightarrow Digital Front End \rightarrow ADC \rightarrow LNA

RF Front End

Channel
Next Generation Wireless Design

MATLAB

SIMULINK
1. Antenna to Bits Simulation
2. Smart RF Design
3. Over-the-air testing
4. LTE, LTE-Advanced & WLAN
Antenna-to-Bits Simulation

Simulate a complete wireless link

- Design modern wireless systems with components such as MIMO, OFDM, and adaptive beamforming
- Analyze signals and make measurements such as EVM, ACLR, BLER, Throughput
- Generate waveforms and create verification references for downstream implementation
- New Antenna Design capabilities using full wave EM simulation

Is this for me?
- Do you work on wireless physical layer?
- Do you simulate and measure system performance?
Example: MIMO-OFDM systems
Example: 802.11a/g/n/ac MIMO-OFDM system

- Interactive MATLAB demo
  - OFDM as the air interface technology
  - Adaptive Beam-forming (up to 8 antenna)
- Easy-to-follow end-to-end simulation
- Graphical test bench
- Tune system parameters on-the-fly
Baseband processing of 802.11x

* Build up MIMO-OFDM structure of 802.11x transceivers
* Assess performance as a function of range, angle of arrival, transmit power, interferer power
* Introduce Transmit-side beamforming, multipath fading, channel estimation and equalization

Great Demo = Full transceiver used in telemetry

Version 1: Baseline = SISO transceiver with adaptive modulation and coding
    Interactive demo

Version 2: Baseline + OFDM
    Interactive demo
    Look at MATLAB code

Version 3: Baseline + OFDM + Transmitter-side beamforming
    Interactive demo
    Look at MATLAB code

Version 4: Baseline + OFDM + Transmitter-side beamforming + Multipath fading
    Interactive demo
    Look at MATLAB code

Version 5 (optional): Multi-user version of Version 4
    Interactive demo
    Look at MATLAB code
MATLAB and Simulink

- **Easy** setup of MIMO-OFDM system components
- Parameter **tuning** and measurements
- (Optionally) Providing **live** data feeds of telemetry data as transmitted bit stream
1. Antenna to Bits Simulation

2. Smart RF Design

3. Over-the-air testing

4. LTE, LTE-Advanced & WLAN
Smart RF = Digitally Assisted RF Transceivers

Fast behavioral RF modeling & simulation

- Model and simulate RF transceiver together with baseband algorithms
- Develop calibration and control algorithms such as DPD or AGC to mitigate impairments and interferers
- Add measured RF component characteristics
- Use circuit envelope techniques to accelerate simulation of RF transceivers

Is this for me?
- Are you an RF system designer?
- Do you jointly model RF and digital components?
System-Level Model of SDR Tunable RF Receiver

- Model of a real off-the-shelf component
  - Analog Devices Agile Transceiver AD9361
- Based on data-sheet parameters
- Integrating digital + mixed-signal + RF + Control Logic
- Validated in the lab

Test Your System by Simulation

AD9361
RF Agile Transceiver™
70 MHz – 6000 MHz Turning range
200kHz – 56 MHz RF channel Bandwidth
Multi-Domain Executable Specifications
What Can You Do With the System-Level Model?

- Test the RF front-end **before** going in the lab
- Test **with** your digital baseband algorithms
- **Program** the agile transceiver
1. Antenna to Bits Simulation
2. Smart RF Design
3. Over-the-air testing
4. LTE, LTE-Advanced and WLAN
Over-the-air Testing with Radio Hardware

Transmit and receive live radio signals

- Transmit and receive generated waveforms
- Configure hardware parameters from MATLAB/Simulink for a range of center frequencies and sampling rates
- Analyze acquired I/Q baseband signal with configurable measurement tools
- Verify and validate your designs based on live radio signals

Is this for me?
- Do you have a wireless lab?
- Do you need to validate your design with live signals?
MathWorks Support of Hardware

Refine by Vendor
- Agilent: 2
- Allied Vision: 1
- Altera: 2
- Analog Devices: 3
- Amatsu: 1
- Amnet: 5
- Bastyr: 1
- Baumer: 1

Refine by Application
- Control Systems: 4
- Digital Signal Processing: 10
- Embedded Systems: 7
- FPGA Design and Codesign: 10
- Image Processing and Computer Vision: 8
- Mechatronics: 2
- Test and Measurement: 3

Refine by Protocol or Standard
- Ethernet: 2
- I2C/SPI: 2
- Serial: 2
- USB: 1
- Video Standards: 2

Refine by Product Family

**USRPR® Support from Communications System Toolbox**
support package, Communications System Toolbox™, and a USRP® radio, you can design and verify practical SDR systems. MATLAB and Simulink Support Package for USRP® Radio includes: Use of USRPR®

**RTL-SDR Support from Communications System Toolbox**
Capabilities and Features With Communications System Toolbox™ Support Package for RTL-SDR Radio, you can use MATLAB® and Simulink® to design and prototype systems that process real time WIRELESS...

**Zynq SDR Support from Communications System Toolbox**
Capabilities and Features Communications System Toolbox™ Support Package for Xilinx® Zynq®-Based Radios enables you to use MATLAB® and Simulink® to prototype and verify practical wireless systems...

**FPGA Radio Support from Communications System Toolbox**
The Xilinx® FPGA radio support package enables you to design and verify practical wireless communications systems. Using Communications System Toolbox™ in conjunction with a Xilinx ...

**Altera Stratix V DSP Kit Support from Simulink**
Altera, The Stratix® V DSP Kit is optimized for implementation of signal processing and communications designs. You can also use HDL Coder and HDL Verifier with the Stratix V DSP Kit to design...

**Altera DE2 Support from Simulink**
video ports. You can explore concepts in signal processing, communications, and embedded systems as you develop real-world audio and video applications using this turnkey FPGA workflow: Create...
Demo: Airplane Tracking Using ADS-B Signals

RTL-SDR

Mix to baseband, stream digital IQ samples

Retrieve data and process samples using MATLAB or Simulink
Tracking Airplanes Using ADS-B Signals

Double click Signal Source Selector block to select signal source.

If you select RTL-SDR radio, set the radio address in the block to the address of the radio connected to your computer.
1. Antenna to Bits Simulation
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LTE, LTE-Advanced and WLAN

Design, simulate, and test LTE, LTE-Advanced and WLAN systems

- Specify your PHY systems covering all transmission modes, channels, and signals
- Combine your LTE/WLAN baseband models with RF modeling for a combined digital-RF design

Is this for me?
- Are you working on LTE or WLAN Physical layer?
Typical Use Cases for LTE and WLAN in MATLAB

Golden Reference

My PDSCH $= ?$ LTE PDSCH

Signal Information Recovery

MATLAB

- Cell ID
- Positioning Info...

Decoding SIB1...
SIB1 CRC: 0
Successful SIB1 recovery.

Signal Detection

Packet detected
Packet successfully decoded!
VHT-SIGA Decoded

Signal Generation & Analysis

Transmitter

Test Waveform Generation

RF Signal

Measurements

Spectral Mask, Antenna 1

Packet successfully decoded!
LTE and WLAN standards in MATLAB

- **Comprehensive** set of PHY models and extensible examples

- **Open** environment, link to test and measurement instruments, RF, SDRs

- **Versatile**: detailed behavior for LTE experts, quick access to LTE waveforms for verification
Key Takeaways
Wireless Design Environment

• Rapid and flexible algorithm exploration, design, and analysis
• Unified simulation of digital, RF, and antenna elements
**Accelerate System Development**

- **HDL and C code generation** for FPGAs, processors, and ASICs
- **Multi-vendor hardware and software** support for verification and prototyping

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**Diagram:**

- **Algorithms**
- **Component Model**
- **Development Board**
- **RF Signal Generator**
- **RF Spectrum Analyzer**
- **Software-Defined Radio**
- **Transmitter**
- **Receiver**
- **Channel**
Web Resources

New Product Pages

New Solution Page

MATLAB® and Simulink® products help engineers design and simulate communications systems with greater speed and accuracy. Using both detailed low-level models as well as higher-level behavioral abstractions, communications engineers can implement the desired level of model fidelity and run-time performance from within a single environment. MATLAB and Simulink streamline design flows by helping engineers to:

- Design and simulate communications algorithms and systems using top-down design methodologies
- Combine digital, analog/mixed-signal, and RF domains in a single system model
- Design, simulate, and verify complex systems using standards such as LTE
- Prototype designs with connections to hardware such as USRP® to enable radio-in-the-loop design
Merci pour votre participation !

Questions ?