

Wireless Design with MATLAB

Mandar Gujrathi

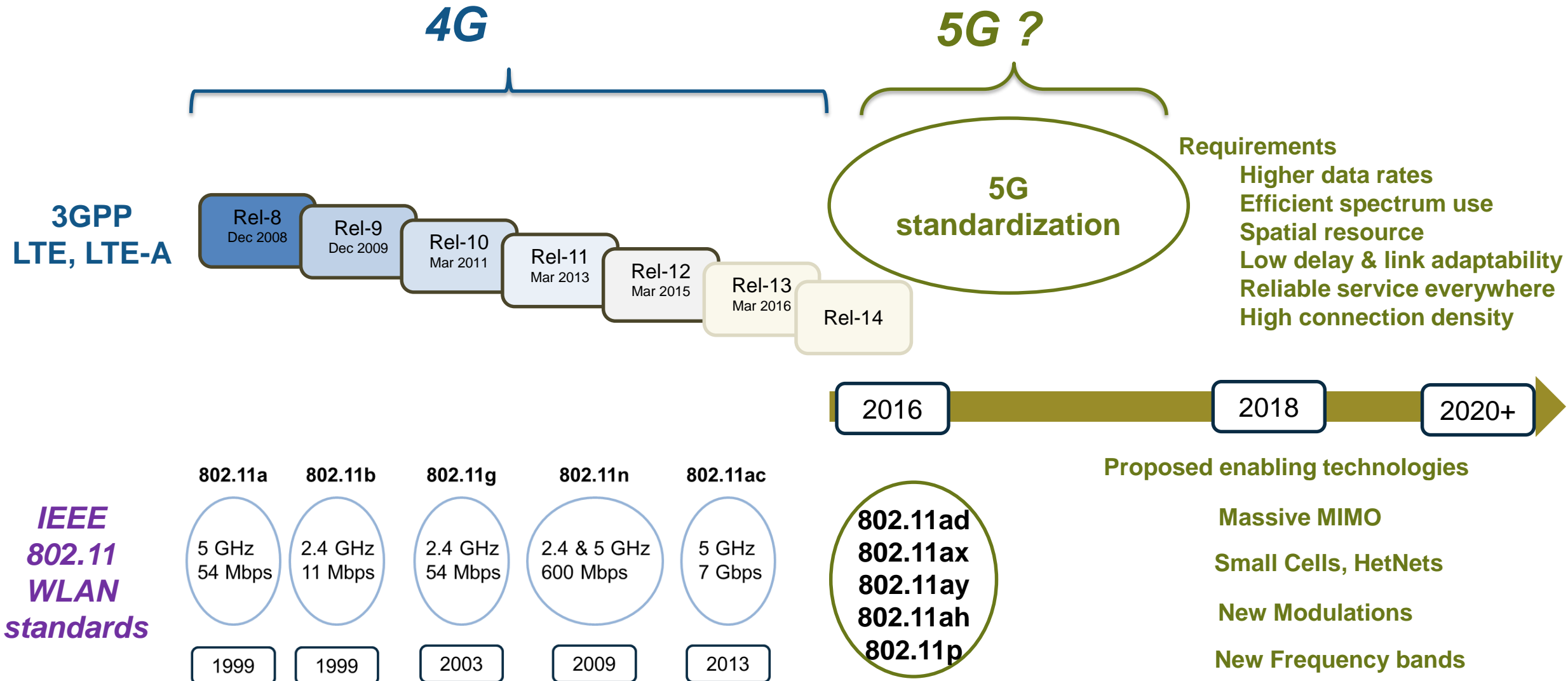
Applications Engineer

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If you had a choice....



Evolution of Air Interface Technologies



While this is all true.....

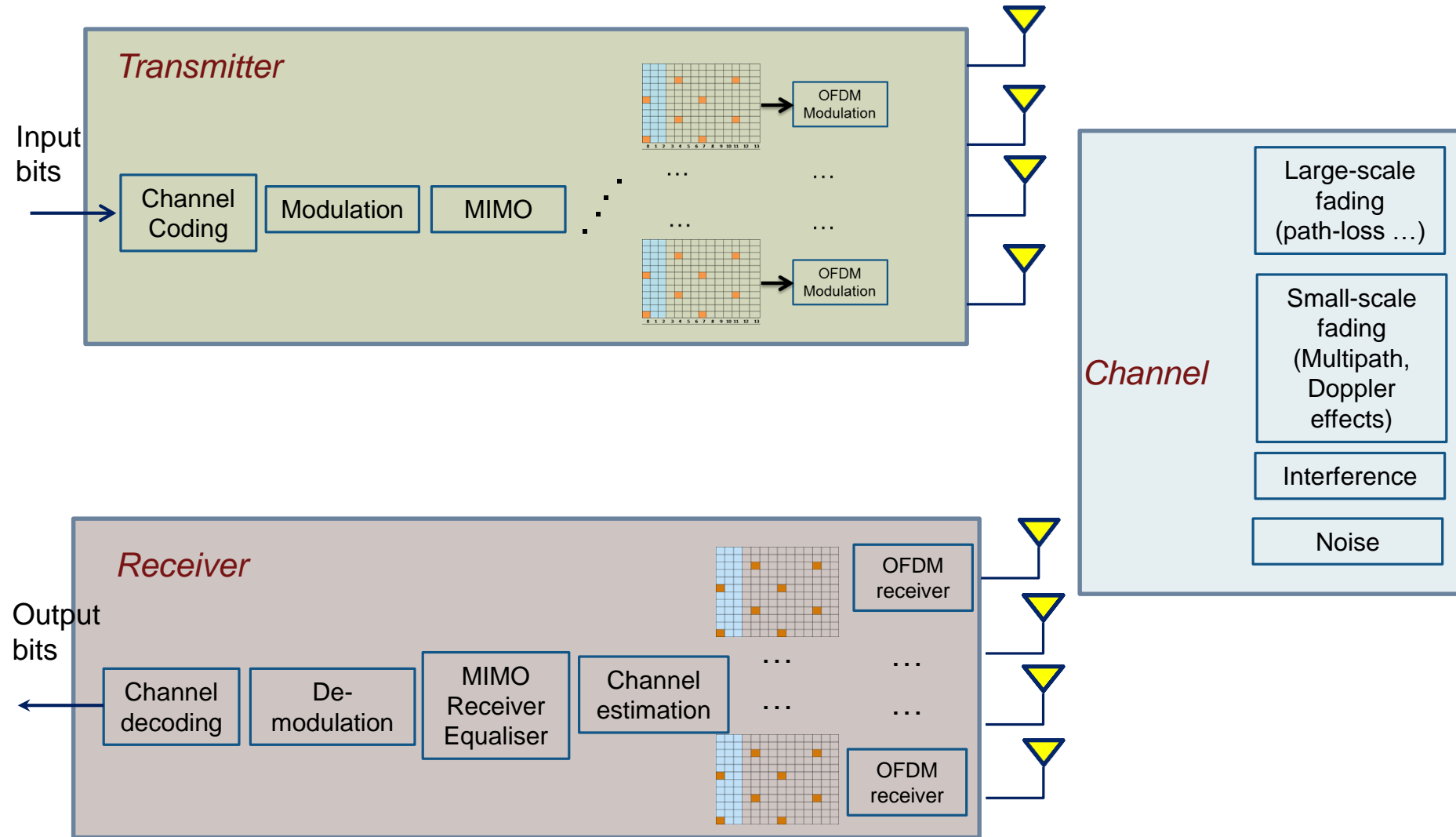
- I would like to simulate my communication system to see the effect of various parameters
- It would be good if there are ready to use channel models
- Our project demands design of antennas, visualise their parameters and test their performance.
- While I do all this I would also like to connect & test this on a hardware

Agenda

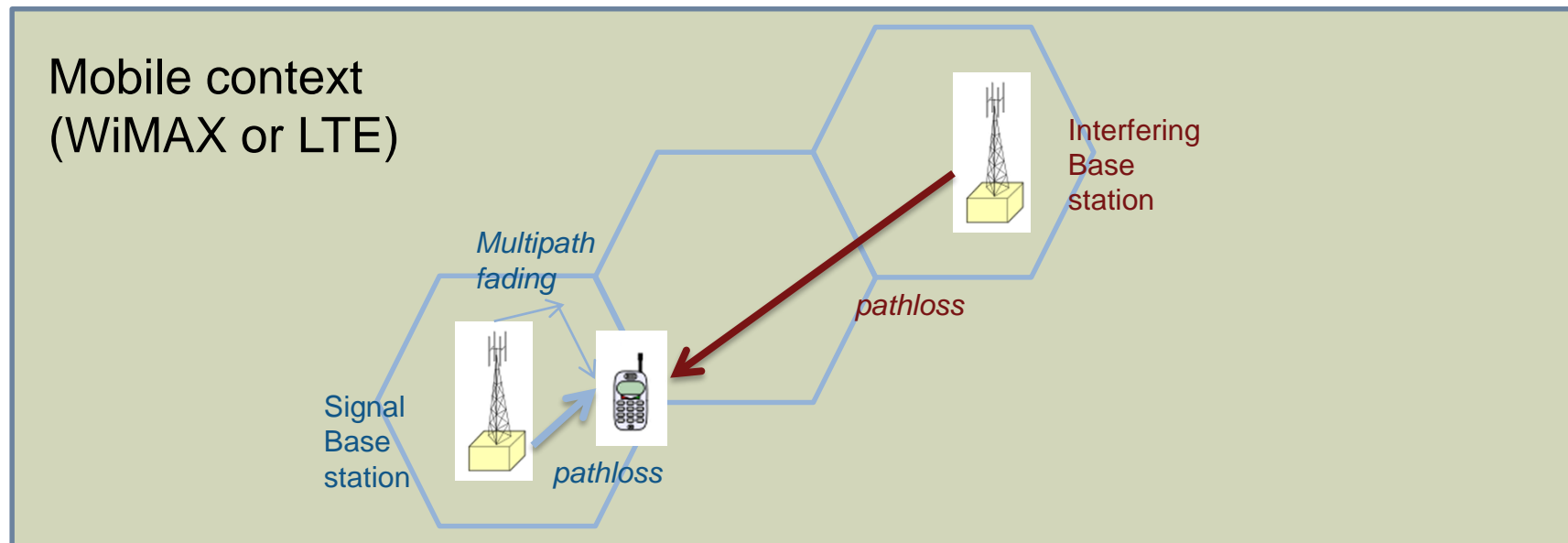
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Simulate the communication system & tune the parameters

How does a Digital Communication System work?



Channel modeling & propagation scenarios



Challenges in designing and evaluating Mobile Communications (more time, earlier)

- Performance evaluation with realistic channel models
- Transceiver system responding to dynamic channel conditions
- Evaluating the combined effects of
 - Fading channels
 - Interfering signals
 - Non-linearity of front-end receivers
 - Phase noise, Frequency offset, Timing mismatch, IQ imbalance
 - Channel estimation & Equalization
 - Antenna arrays & directional propagation
 - Beamforming & beam steering
 - ...

Telemetry

Simulation Tuning

TX Power

Mobile Range

Mobile Angle

Interf Power

Interf Range

Interf Angle

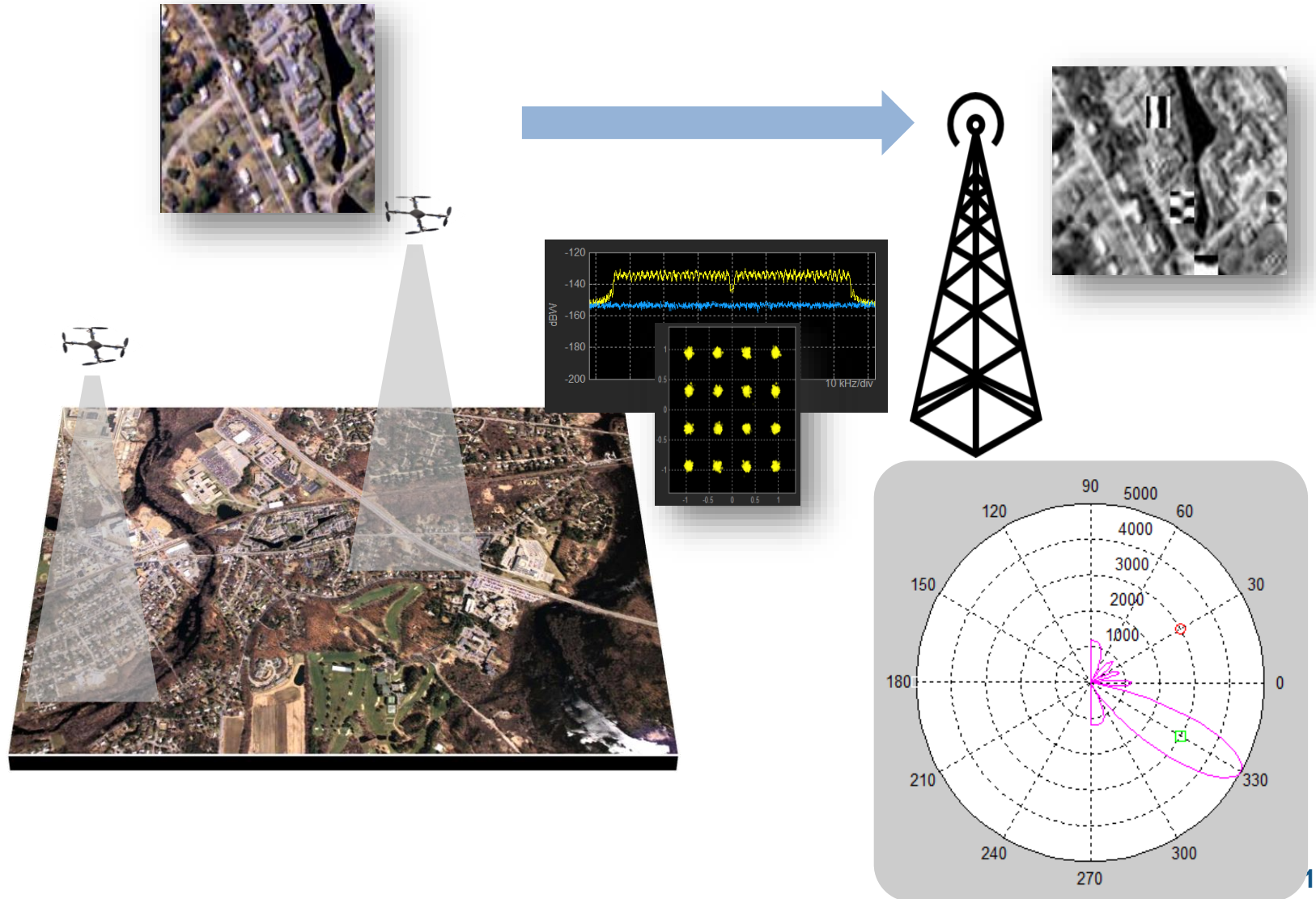
Modulation order

Antenna type

Number of Antennas

Steering angle

Reset Pause Simulation Stop Simulation



Why look at MIMO-OFDM systems?



Communications Systems Toolbox

`comm.GeneralQAMDemodulator`

`comm.GeneralQAMModulator`

`comm.PAMDemodulator`

`comm.PAMModulator`

`comm.RectangularQAMDemodulator`

`comm.RectangularQAMModulator`

`comm.AWGNChannel`

`comm.gpu.AWGNChannel`

`comm.BinarySymmetricChannel`

`comm.LTEMIMOChannel`

`comm.MemorylessNonlinearity`

`comm.MIMOChannel`

`comm.PhaseFrequencyOffset`

`comm.PhaseNoise`

`comm.RayleighChannel`

`comm.RicianChannel`

`comm.ThermalNoise`

`comm.APPDecoder`

`comm.ConvolutionalEncoder`

`comm.gpu.ConvolutionalEncoder`

`comm.TurboDecoder`

`comm.gpu.TurboDecoder`

`comm.TurboEncoder`

`comm.ViterbiDecoder`

`comm.gpu.ViterbiDecoder`

`comm.MLSEEqualizer`

`cma`

`dfe`

`equalize`

`lineareq`

`lms`

`mlseeq`

`normlms`

`reset (equalizer)`

`rls`

`signlms`

`varlms`

`comm.AlgebraicDeinterleaver`

`comm.AlgebraicInterleaver`

`comm.BlockDeinterleaver`

`comm.gpu.BlockDeinterleaver`

`comm.BlockInterleaver`

`comm.gpu.BlockInterleaver`

`comm.MatrixDeinterleaver`

`comm.MatrixHelicalScanDeinterleaver`

`comm.MatrixHelicalScanInterleaver`

`comm.MatrixInterleaver`

`comm.ConvolutionalDeinterleaver`

`comm.gpu.ConvolutionalDeinterleaver`

`comm.ConvolutionalInterleaver`

`comm.gpu.ConvolutionalInterleaver`

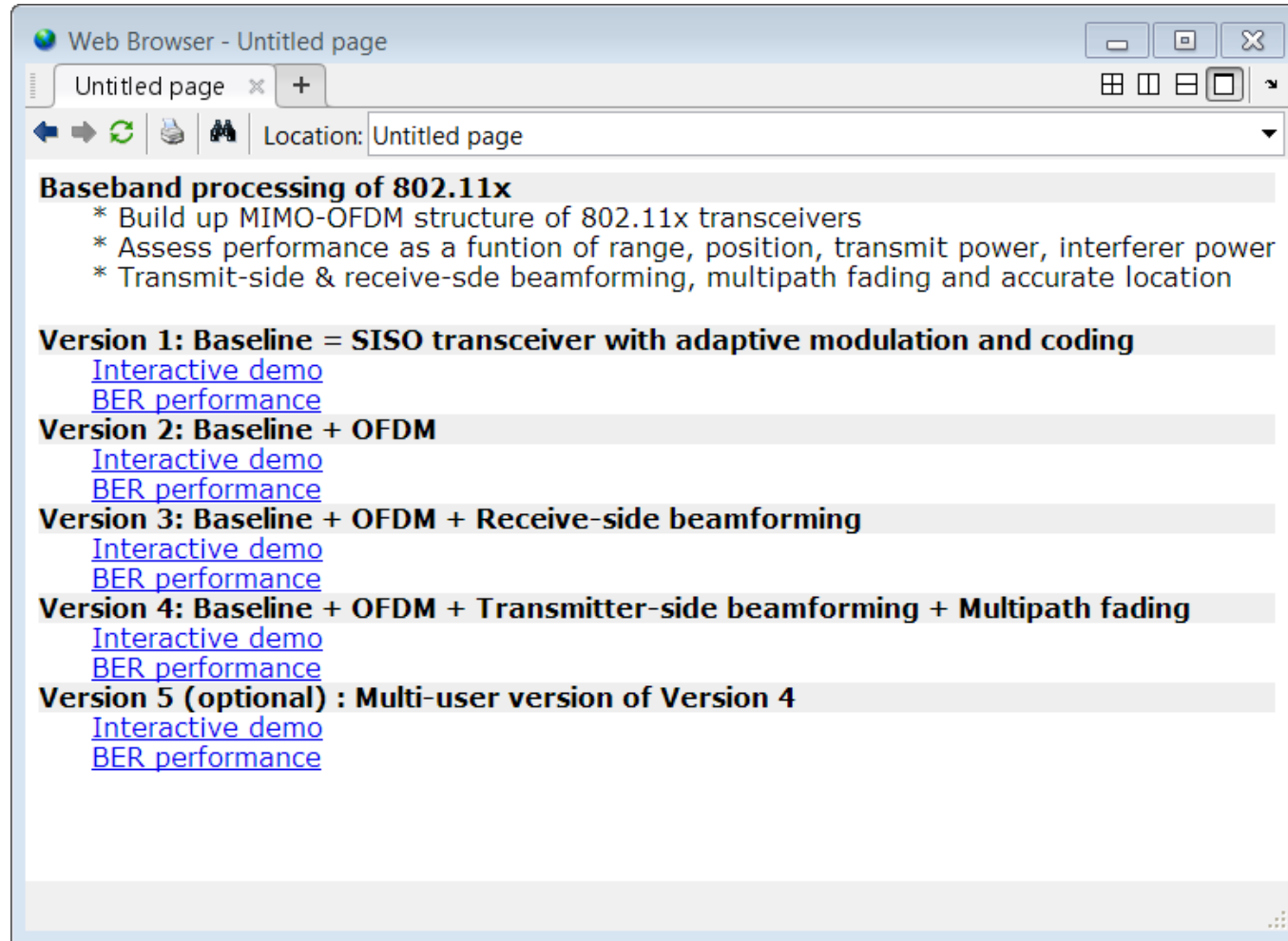
`comm.HelicalDeinterleaver`

`comm.HelicalInterleaver`

`comm.MultiplexedDeinterleaver`

`comm.MultiplexedInterleaver`

Baseband demo workflow



The screenshot shows a web browser window titled "Web Browser - Untitled page". The address bar contains "Location: Untitled page". The main content area displays the following text:

Baseband processing of 802.11x

- * Build up MIMO-OFDM structure of 802.11x transceivers
- * Assess performance as a function of range, position, transmit power, interferer power
- * Transmit-side & receive-side beamforming, multipath fading and accurate location

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

- [Interactive demo](#)
- [BER performance](#)

Version 2: Baseline + OFDM

- [Interactive demo](#)
- [BER performance](#)

Version 3: Baseline + OFDM + Receive-side beamforming

- [Interactive demo](#)
- [BER performance](#)

Version 4: Baseline + OFDM + Transmitter-side beamforming + Multipath fading

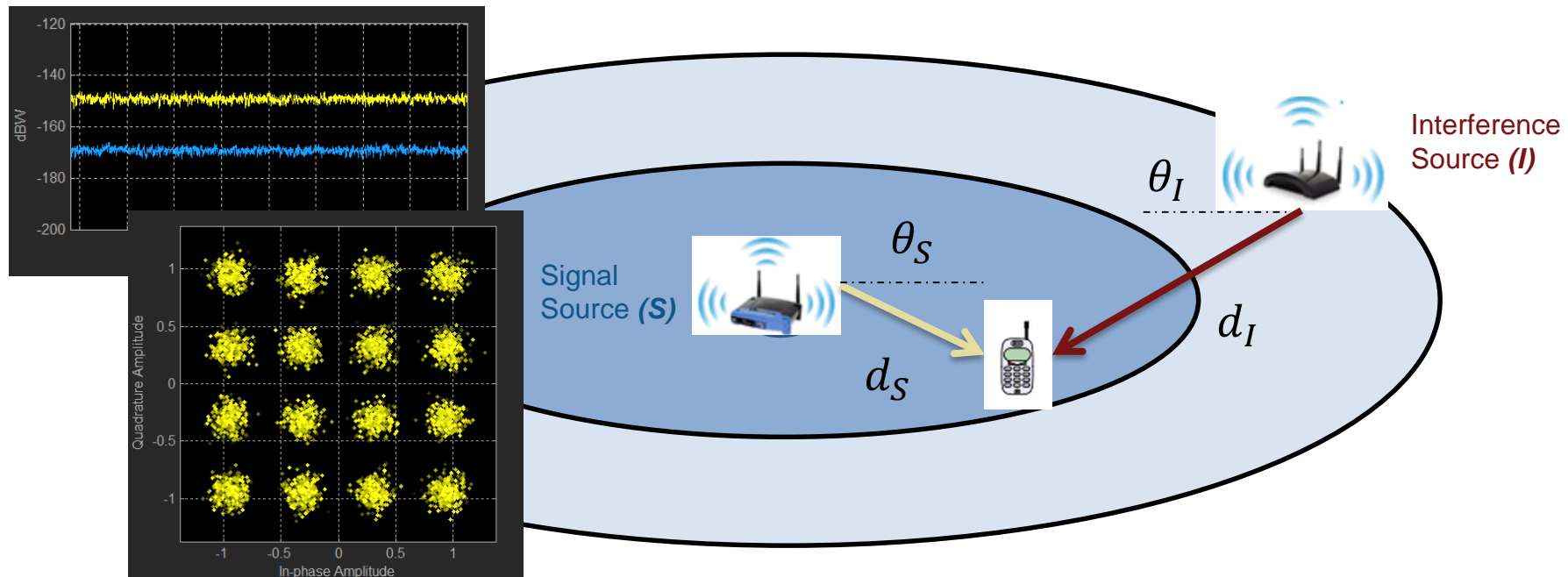
- [Interactive demo](#)
- [BER performance](#)

Version 5 (optional) : Multi-user version of Version 4

- [Interactive demo](#)
- [BER performance](#)

Version 1: Baseline - Modulation and Coding

- Start with a SISO transceiver with modulation, coding, scrambling
- Channel modeling (Interferer + path loss)
- No multipath fading yet
- Isotropic (non-directional) antennas (1x1)



MATLAB tools for modeling of adaptive modulation and coding

- Use algorithms in Communications System Toolbox
- Quickly build and run fast & reliable simulations
- Simulate dynamic changes of systems (such as modulation scheme)
- Perform measurements and examine performance metrics during simulation

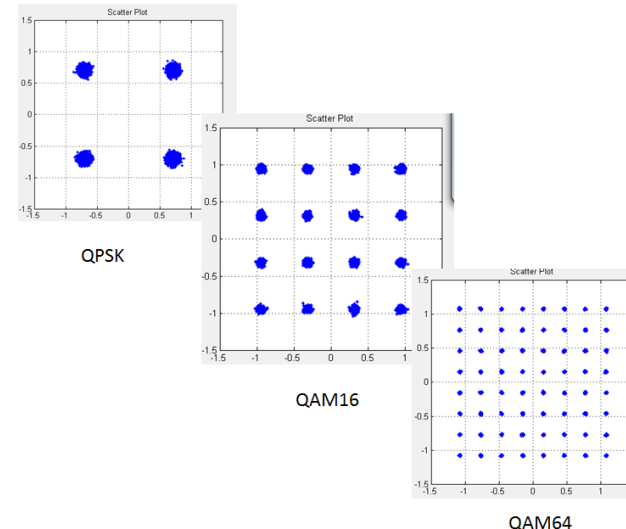
```
function tx = modulateBitstream(bits,t)

hMod = comm.RectangularQAMModulator(...
    'ModulationOrder',t.modMode,'BitInput',true,'NormalizationMethod','Average power');
hScrambler = comm.Scrambler(2, [1 0 1 1 0 1 0 1], [1 1 1 1 1 1 0]);
hConv = comm.ConvolutionalEncoder(...
    'TrellisStructure',poly2trellis(7, [133 171 165]), 'TerminationMethod', 'Terminated');

% Convolutional Encoder
coded = step(hConv,bits);

% Scramble coded input
bitsS = step(hScrambler, coded);

% Baseband QAM modulation
tx = step(hl
```



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Are there any ready to use channel models?

Supported IEEE 802.11 Standards + heaps other

Standard	Bandwidth (MHz)	MIMO	Designation
802.11ac	20,40,80,160	Up to 8 spatial streams, MU-MIMO	VHT Very High Throughput
802.11n	20,40	Up to 4 spatial streams	HT High Throughput
802.11g	20	N/A	Non-HT
802.11a	5,10,20	N/A	
802.11b	20	N/A	
802.11p	5,10	N/A	
802.11j	10	N/A	

As of R2016a

Urban, Rural, Indoor, Outdoor, etc. models in Communications Tbx

Agenda

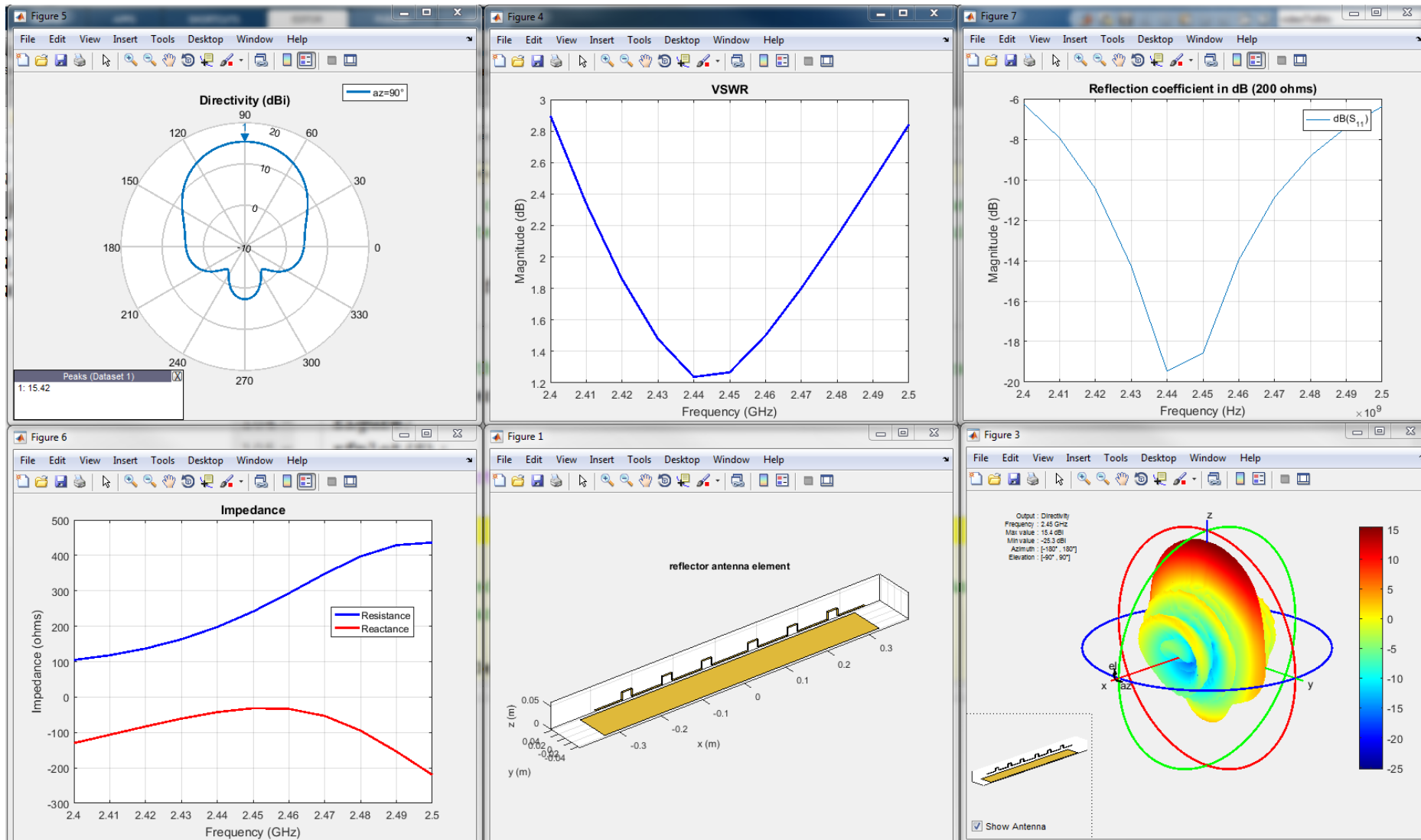
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Design antennas/ arrays, visualise their parameters and test their performance

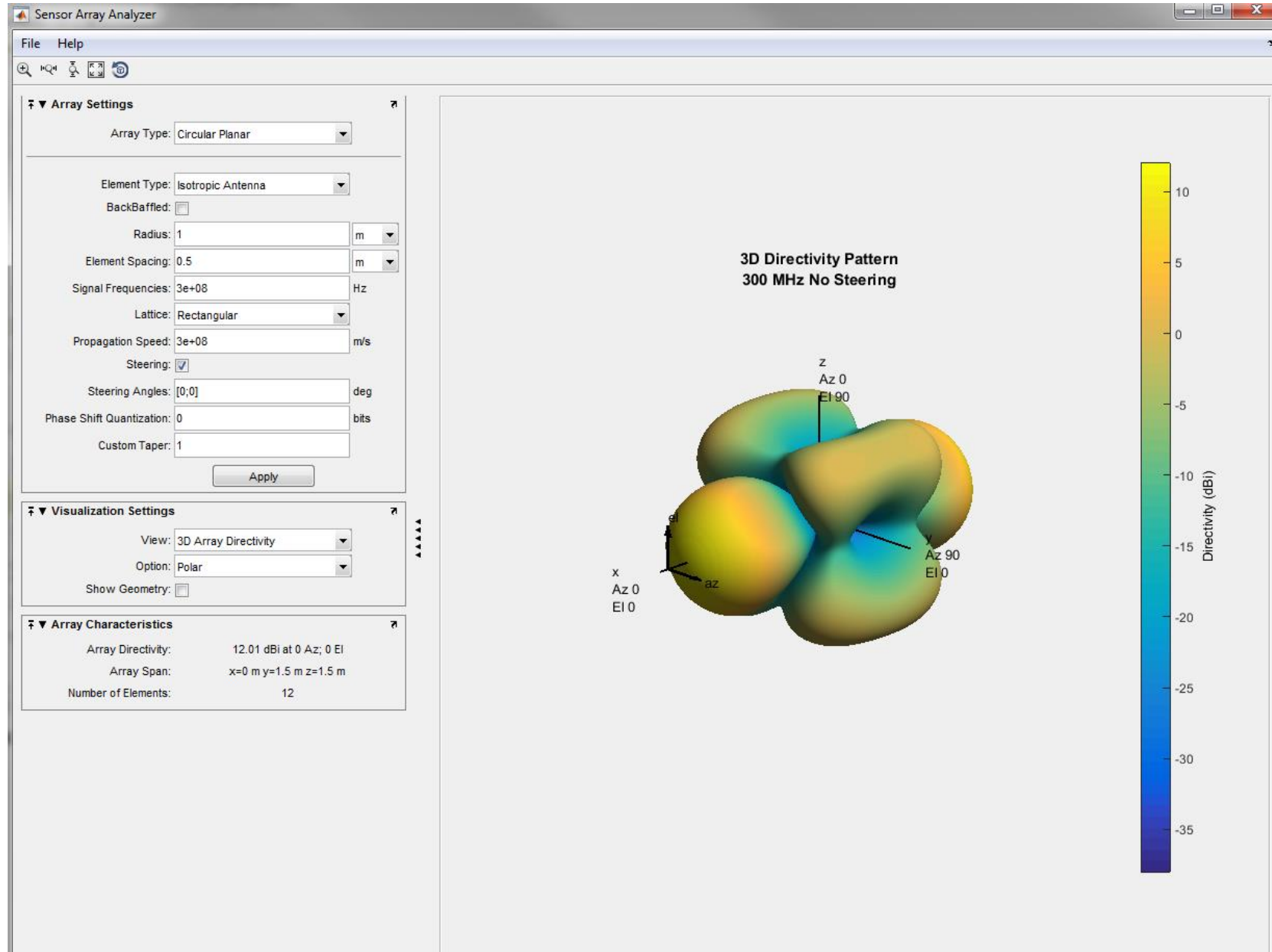
Antenna and Phase Array System toolbox

- Design, analyse, and visualise of antenna elements and arrays.
- Compute port properties such as impedance, surface properties such as current and charge distribution, and field properties such as the near-field and far-field radiation pattern.
- Integrate antennas and arrays into wireless systems, and use impedance analysis to design matching networks.

Design Antenna and Analyse Performance over Wi-Fi band.



Sensor Array Analyser: Analyse sensor array configurations



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Connect to Hardware and see it happen !

MathWorks Support of Hardware



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Refine by Vendor

- 3D Robotics 1
- 3S-Smart Software Solutions 1
- Adimec 3
- ADLINK 3
- Advantech 2
- Agilent 4
- Aldebaran 1
- Allied Vision 8

Refine by Application

- Control Systems 42
- Digital Signal Processing 42
- Embedded Systems 61
- FPGA Design and Codesign 19
- Image Processing and Computer Vision 56
- Internet of Things 5
- Mechatronics 15

Refine by Protocol or Standard

🔍

Results 1 - 25 of 171

Adimec Camera Support from Image Acquisition

Use Adimec cameras with MATLAB and Simulink to acquire video and images

Vendors: Adimec
Tags: MathWorks Supported

ADLINK Support from Data Acquisition Toolbox

Create your own waveforms, measurement and analysis routines, and applications for ADLINK DAQ hardware using MATLAB and Data Acquisition Toolbox

Vendors: ADLINK
Tags: Connections Program

Allied Vision Camera Support from Image Acquisition Toolbox

Use AV cameras with MATLAB and Simulink to acquire video and images

Vendors: Allied Vision
Tags: MathWorks Supported

Altera DE2 Support from Simulink

Digital circuit development platform for hardware design and verification

Vendors: Altera
Tags: HDL Code Generation, MathWorks Supported

Altera Development Board Support from HDL Coder

Automatically generate HDL code from MATLAB and Simulink for Altera development boards.

Vendors: Altera
Tags: HDL Code Generation, MathWorks Supported, Support Package Installer Enabled

<http://www.mathworks.com/hardware-support/index.html>

How can we help

What the Engineer Has



Software setup: Hardware support packages

Support Package Installer

Select support package to install

Show: All (71)

Support for:

- Teledyne DALSA Sopera Hardware
- Texas Instruments C2000
- Texas Instruments C2000 Concerto
- Texas Instruments C6000
- Total Phase Aardvark I2C/SPI Interface
- USB Webcams
- USRP Radio
- Vector CAN Devices
- Wind River VxWorks
- Xilinx FPGA Boards
- Xilinx FPGA-Based Radio
- Xilinx Zynq-7000
- Xilinx Zynq-Based Radio

Support packages:

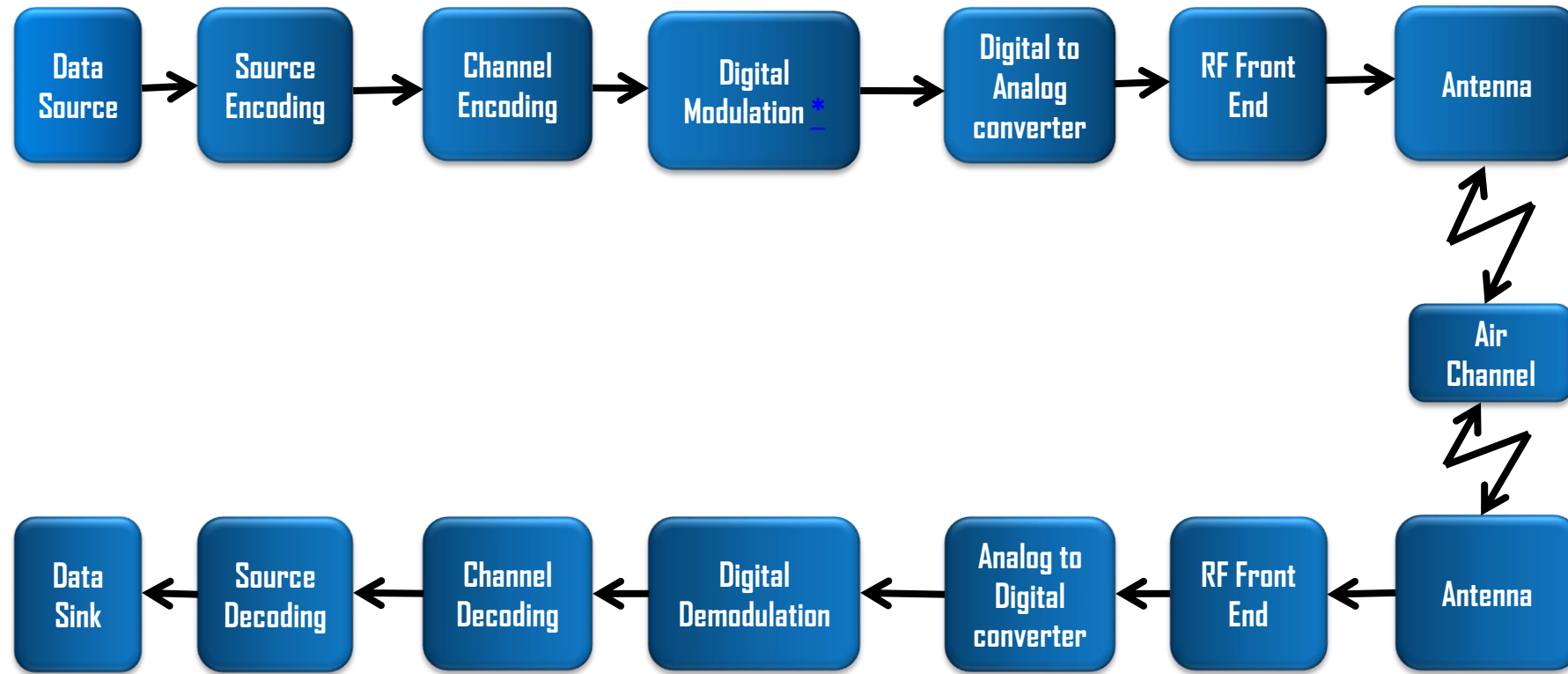
	Action	Installed Version	Latest Version	Description	Required Base Product	Supported Host Platforms
1	<input checked="" type="checkbox"/> Install		15.1.0	Design and prototype SDR systems using Xilinx Zynq-based radio	Communications System Toolbox	Win32,Win64,...

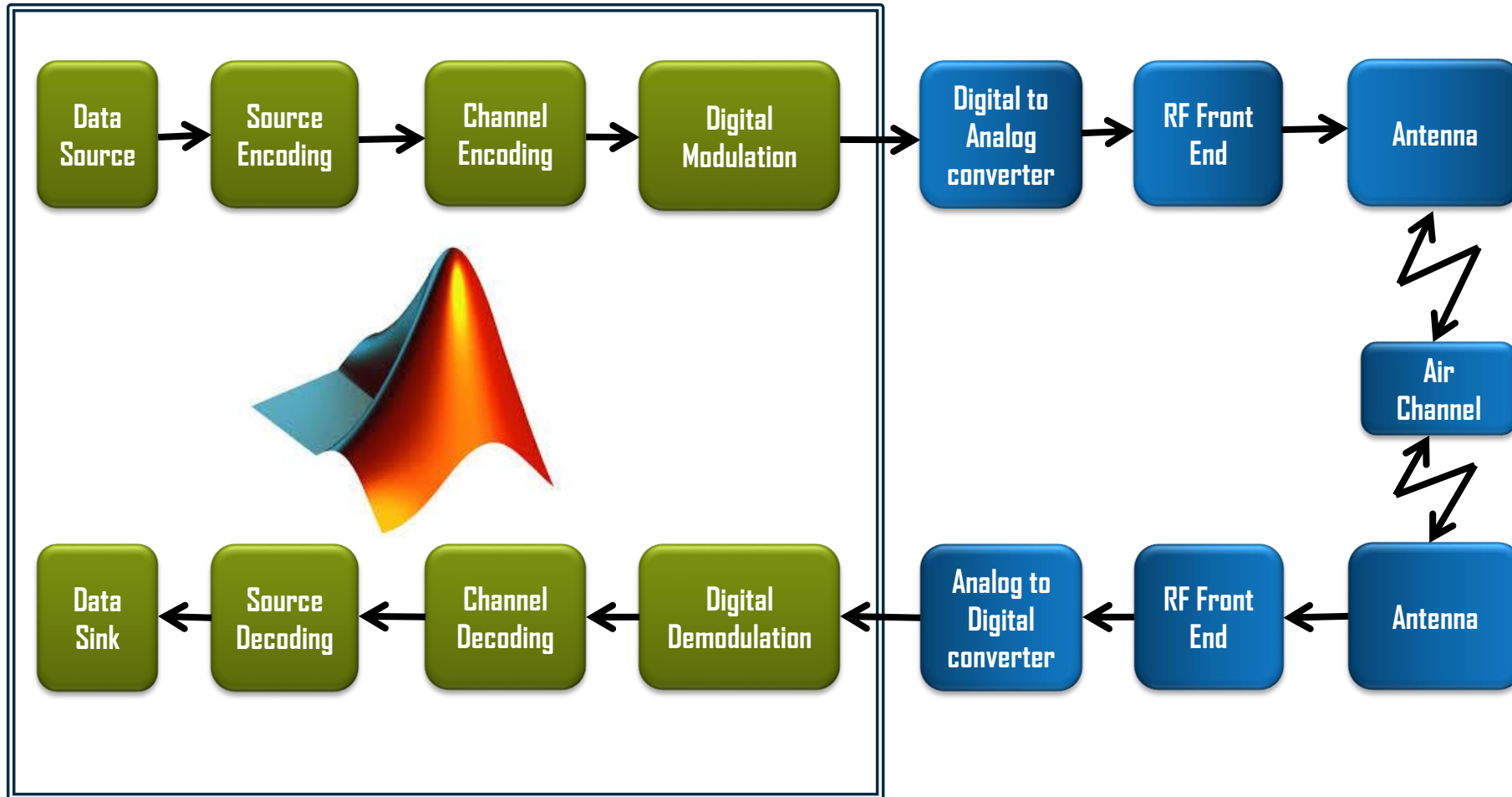
Installation folder: C:\MATLAB\SupportPackages\R2015a Browse...

< Back
Next >
Cancel
Help

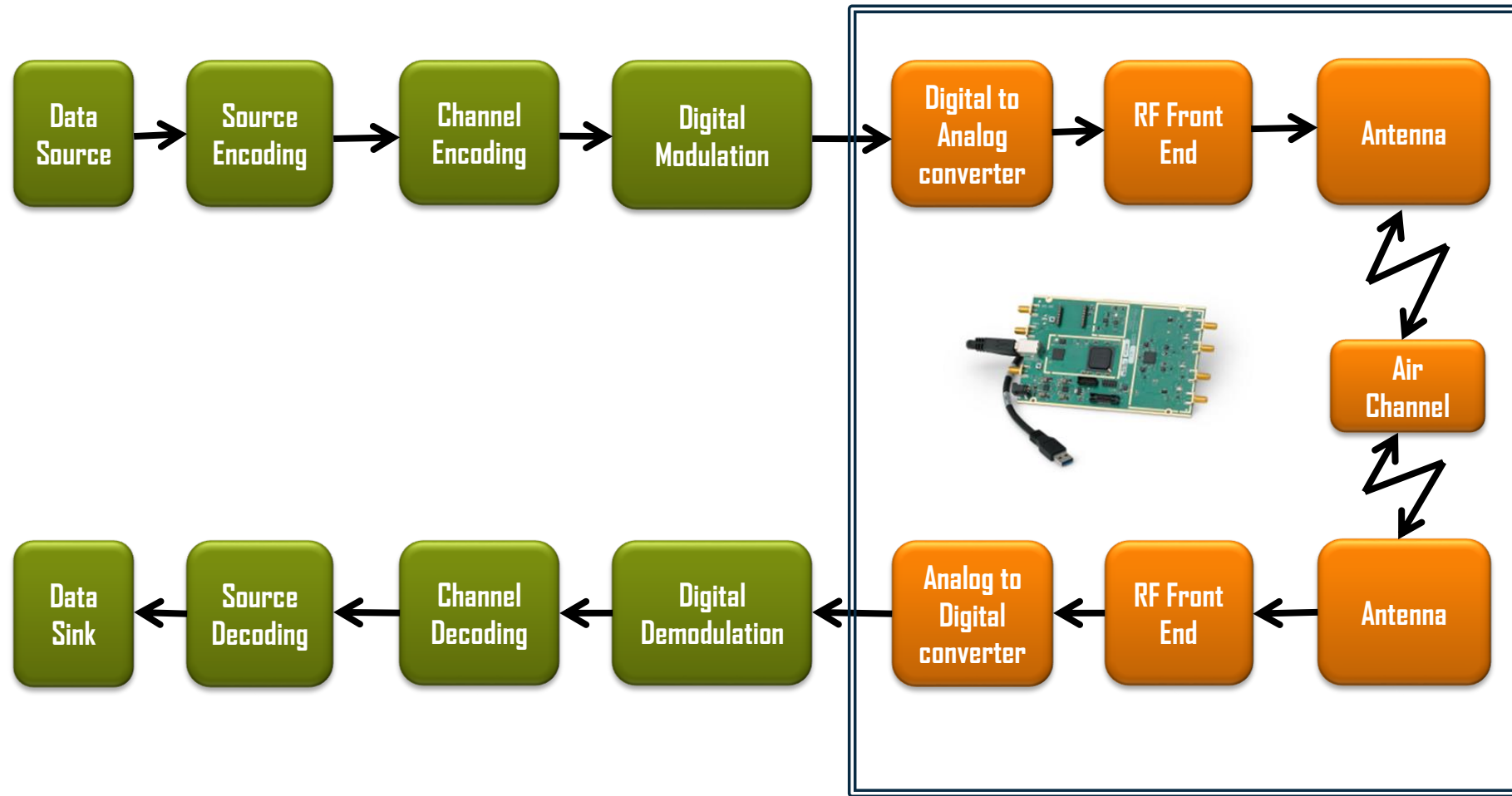
Supported hardware for radio connectivity

- [RTL-SDR](#) (US\$25)
 - Ultra low-cost, low-bandwidth
 - RX Only
- [USRP](#) (\$1800)
 - Customizable RF front-end
- [Xilinx FPGA-based radio](#) (\$2500)
 - High bandwidth (~25MHz)
 - Possible FPGA target



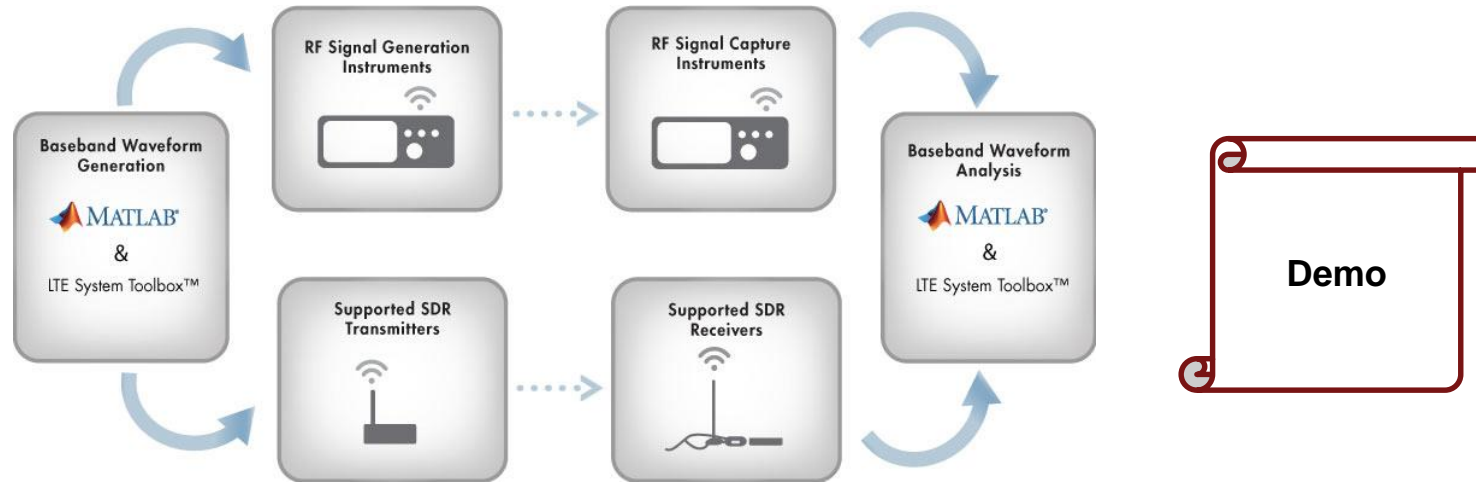


Software



Hardware

Example: Over-the-air testing with SDRs & RF instruments



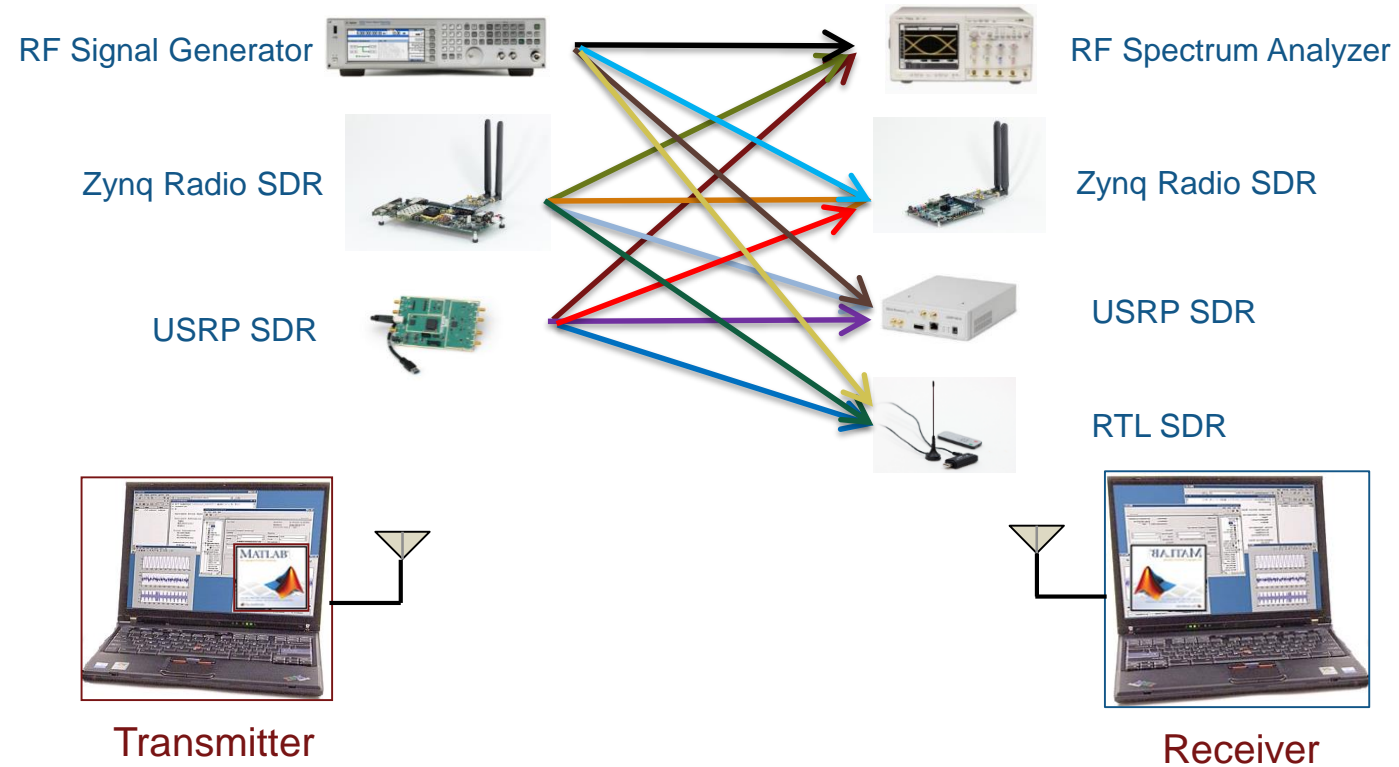
Process original data bits and generate custom digital baseband waveforms in transmitter

Transmit waveform using SDR devices or RF instruments

Capture received samples with SDR devices or RF instruments

Process received samples in receiver. Decode/recover original data

Supported SDRs & RF instruments



Key takeaways

Simulation



Design and Verification

*Simulate baseband and RF systems
Including LTE & WLAN standards*



Testing



Over-the-air testing

*Validate models with SDR, RF instruments and other
low-cost hardware*



Production



Prototyping and Implementation

Deploy algorithms onto target system



MathWorks Resources

- [Resources for Wireless Communications](#)
 - Webinars, White papers, Resource kits, etc.

- [Training on Signal Processing, Communications](#)
 - LTE, Communications, DSP, RF Systems, etc.

- Talk to us,
 - Mandar.Gujrathi@mathworks.com.au
 - Jonathan.Koay@mathworks.com.au (Education Account Manager)