Wireless Design with MATLAB

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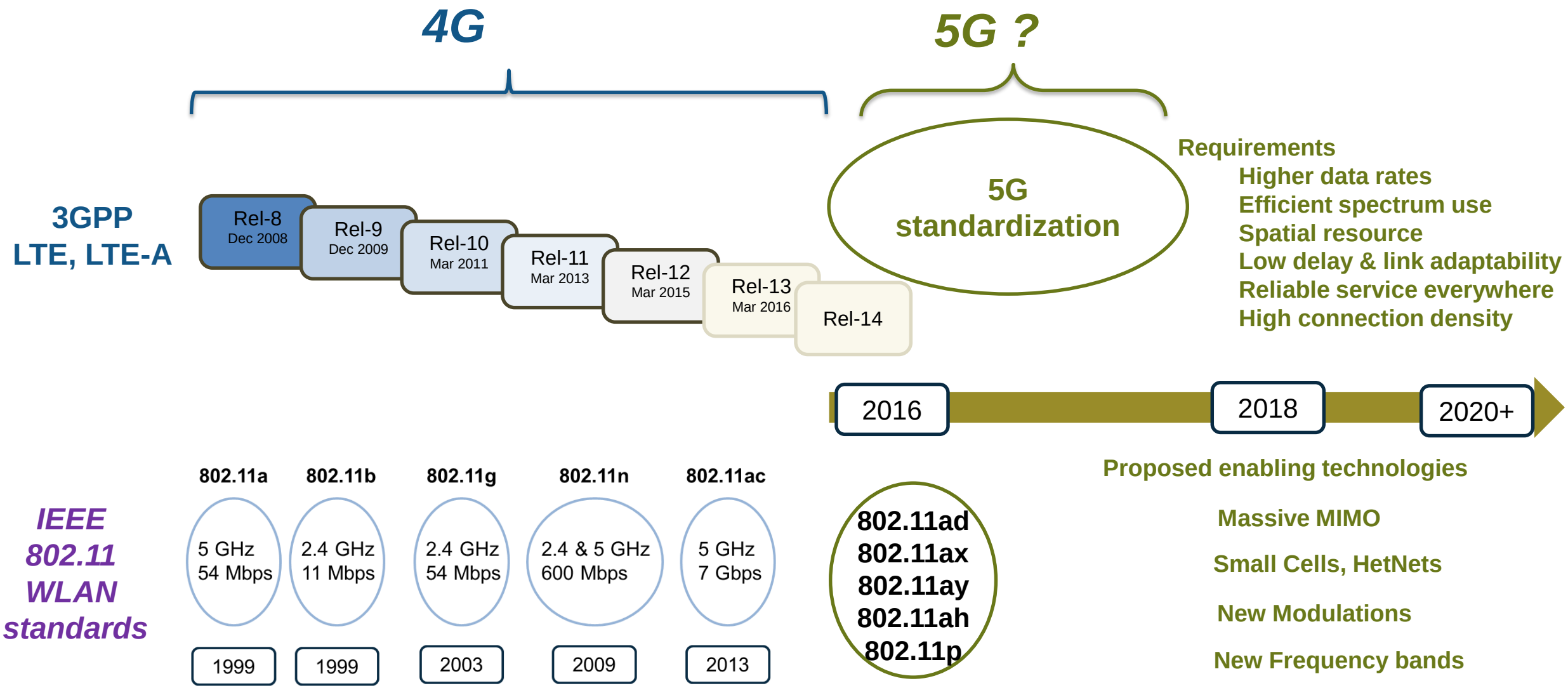
If you had a choice….

When things get social…..

AT&T

"To be future-proof IoT devices must be LTE"

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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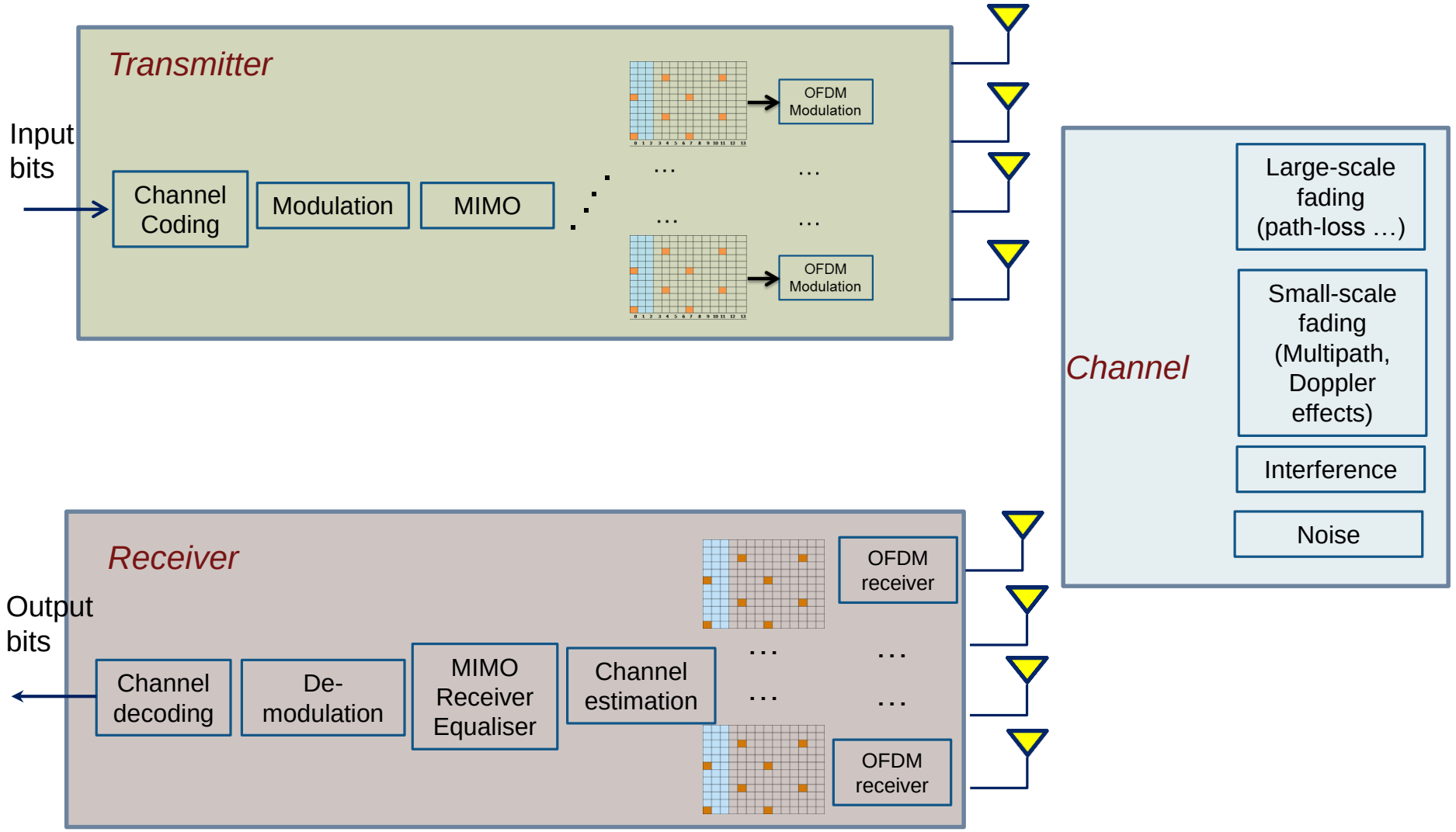
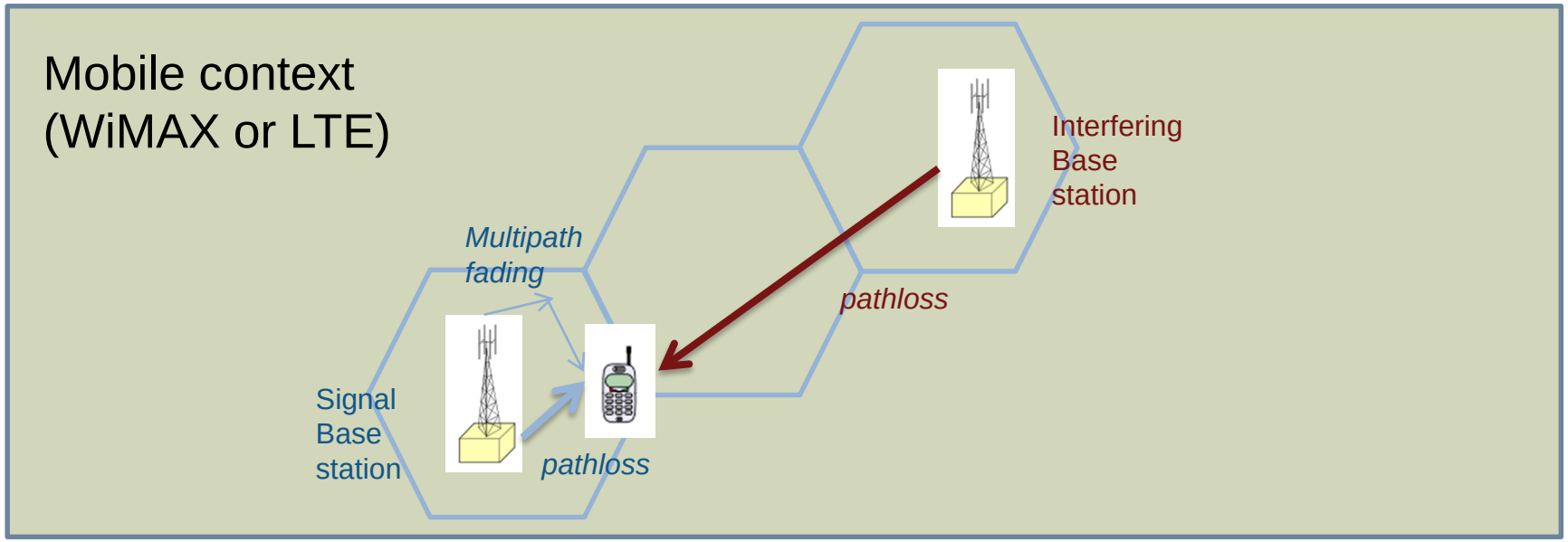
Simulate the communication system & tune the parameters

How does a Digital Communication System work?



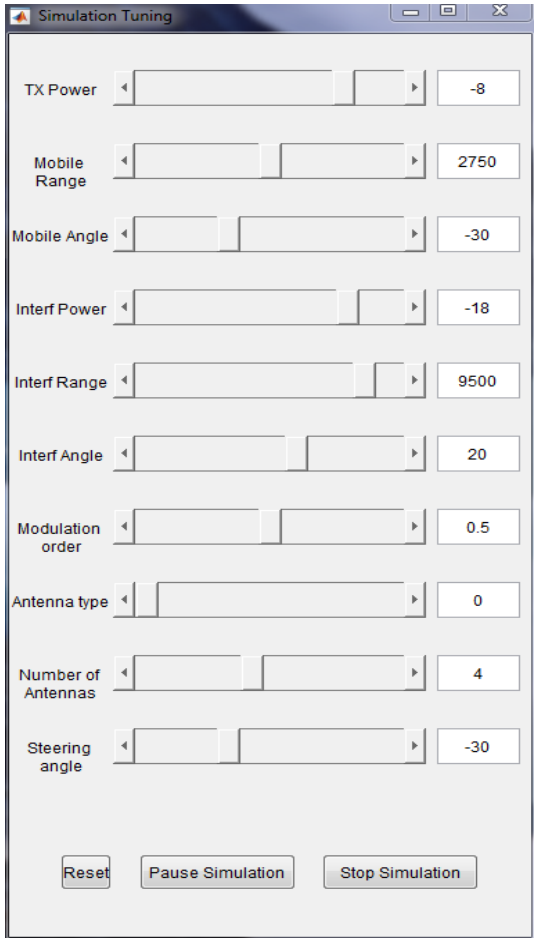
Channel modeling & propagation scenarios

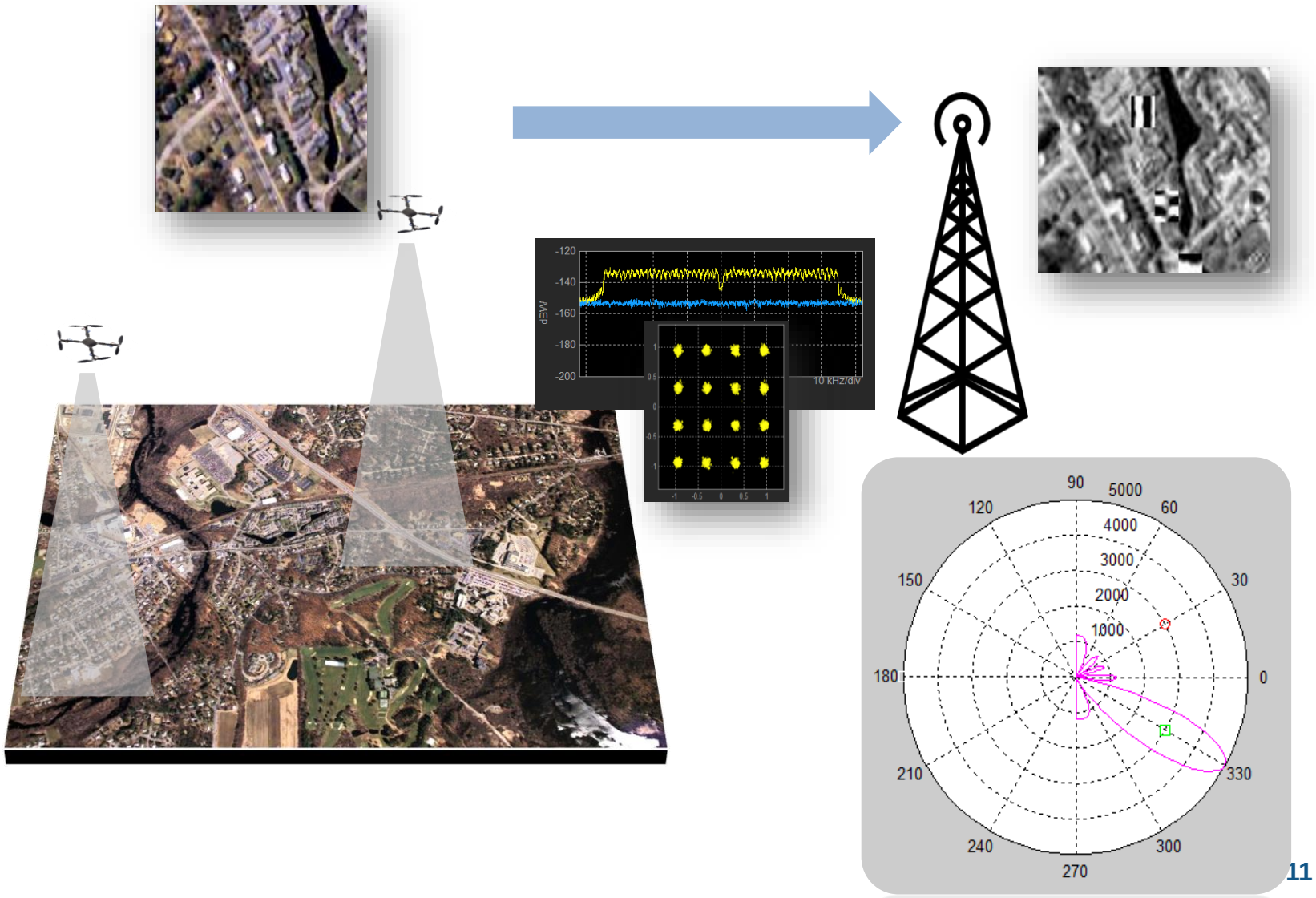


Challenges in designing and evaluating Mobile Communications (more time, earlier)

- 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
-8
Mobile Range
2750
Mobile Angle
-30
Interf Power
-18
Interf Range
9500
Interf Angle
20
Modulation order
0.5
Antenna type
0
Number of Antennas
4
Steering angle
-30
Reset
Pause Simulation
Stop Simulation


-120
-140
-160
-180
-200
dBW
10 kHz/div
90
120
60
150
30
180
0
210
330
240
300
270
5000
4000
3000
2000
1000

Why look at MIMO-OFDM systems?

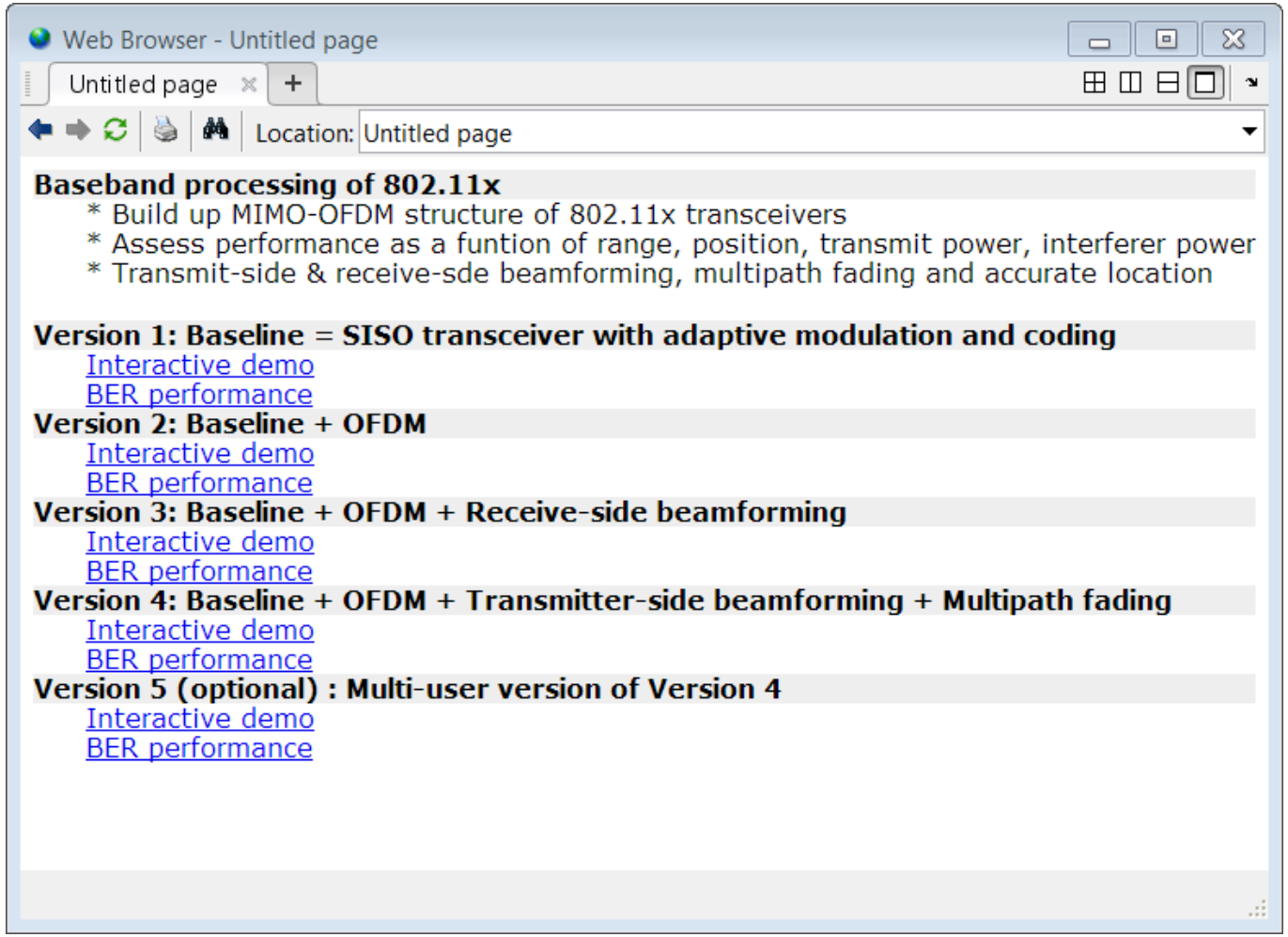
Communications Systems Toolbox

- 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

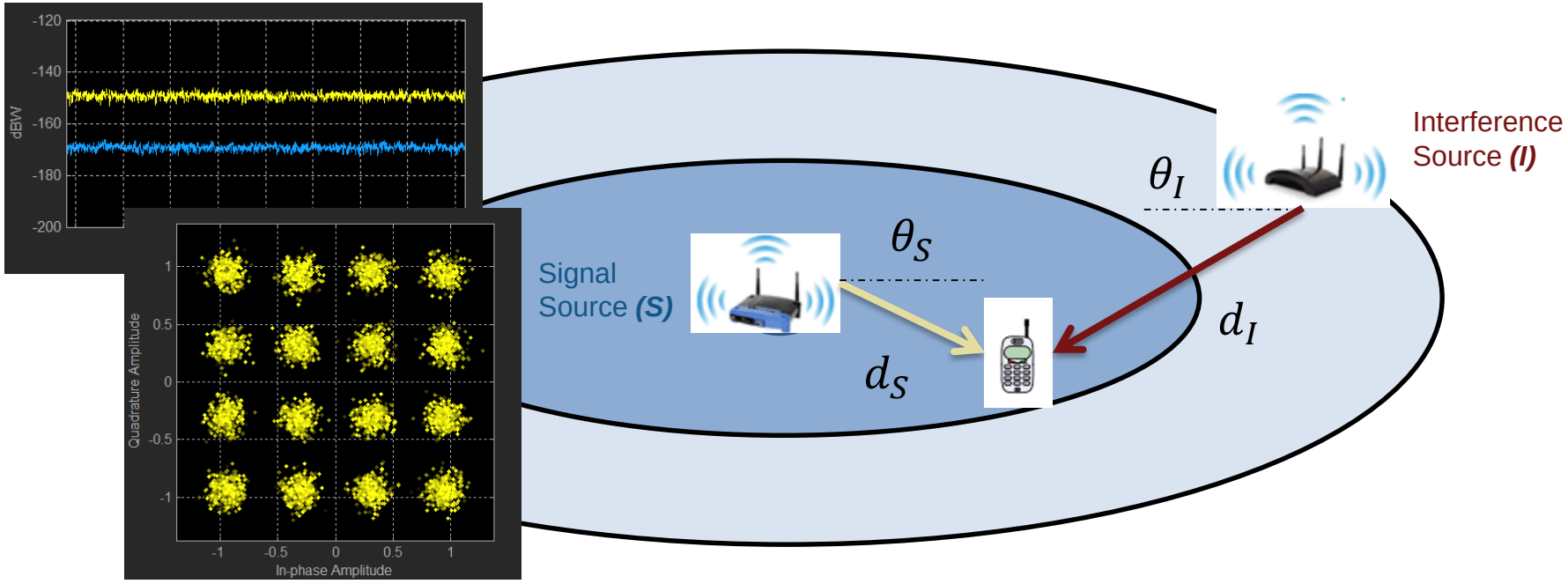
- comm.AlgebraicDeinterleaver
- comm.AlgebraicInterleaver
- comm.BlockDeinterleaver
- comm.gpu.BlockDeinterleaver
- comm.BlockInterleaver
- comm.gpu.BlockInterleaver
- comm.MatrixDeinterleaver
- comm.MatrixHelicalScanDeinterleaver
- comm.MatrixHelicalScanInterleaver
- comm.MatrixInterleaver
- comm.ConvolutionalDeinterleaver
- comm.gpu.ConvolutionalDeinterleaver
- comm.ConvolutionalInterleaver
- comm.gpu.ConvolutionalInterleaver
- comm.HelicalDeinterleaver
- comm.HelicalInterleaver
- comm.MultiplexedDeinterleaver
- comm.MultiplexedInterleaver

Baseband demo workflow



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

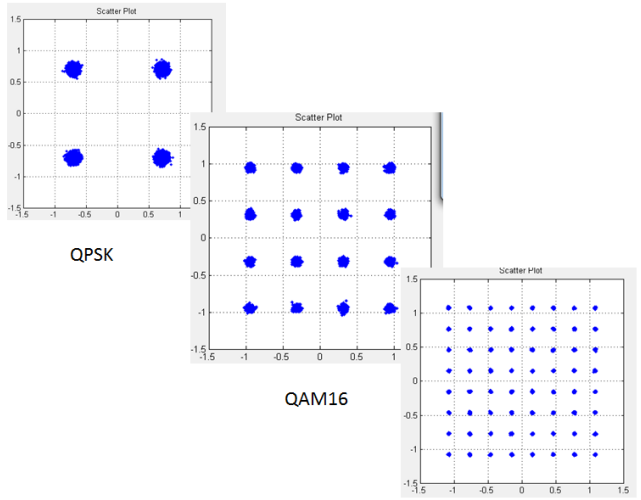
```
function tx = modulateBitstream(bits,t)

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(h
```



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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

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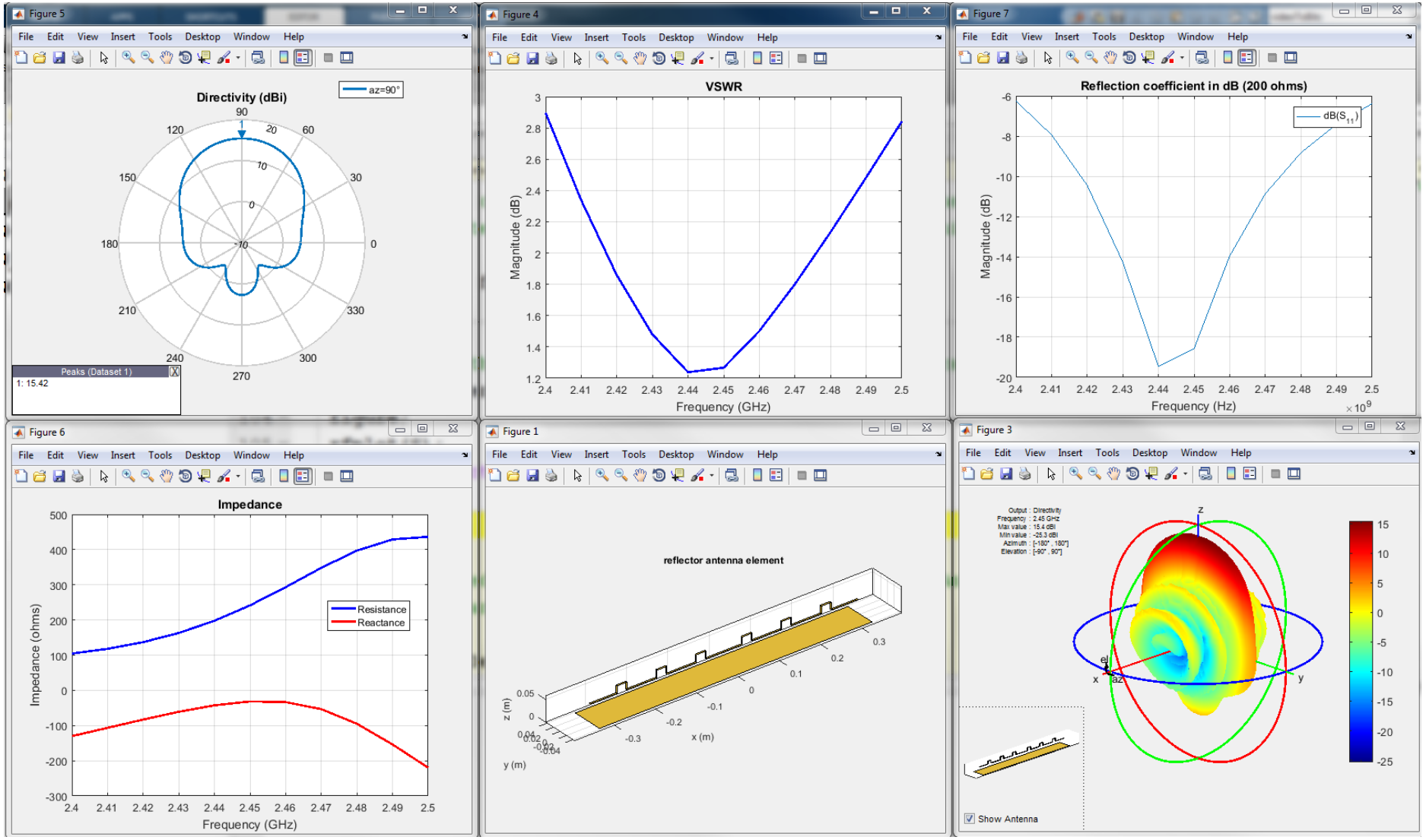
Design antennas/ arrays, visualise their parameters and test their performance

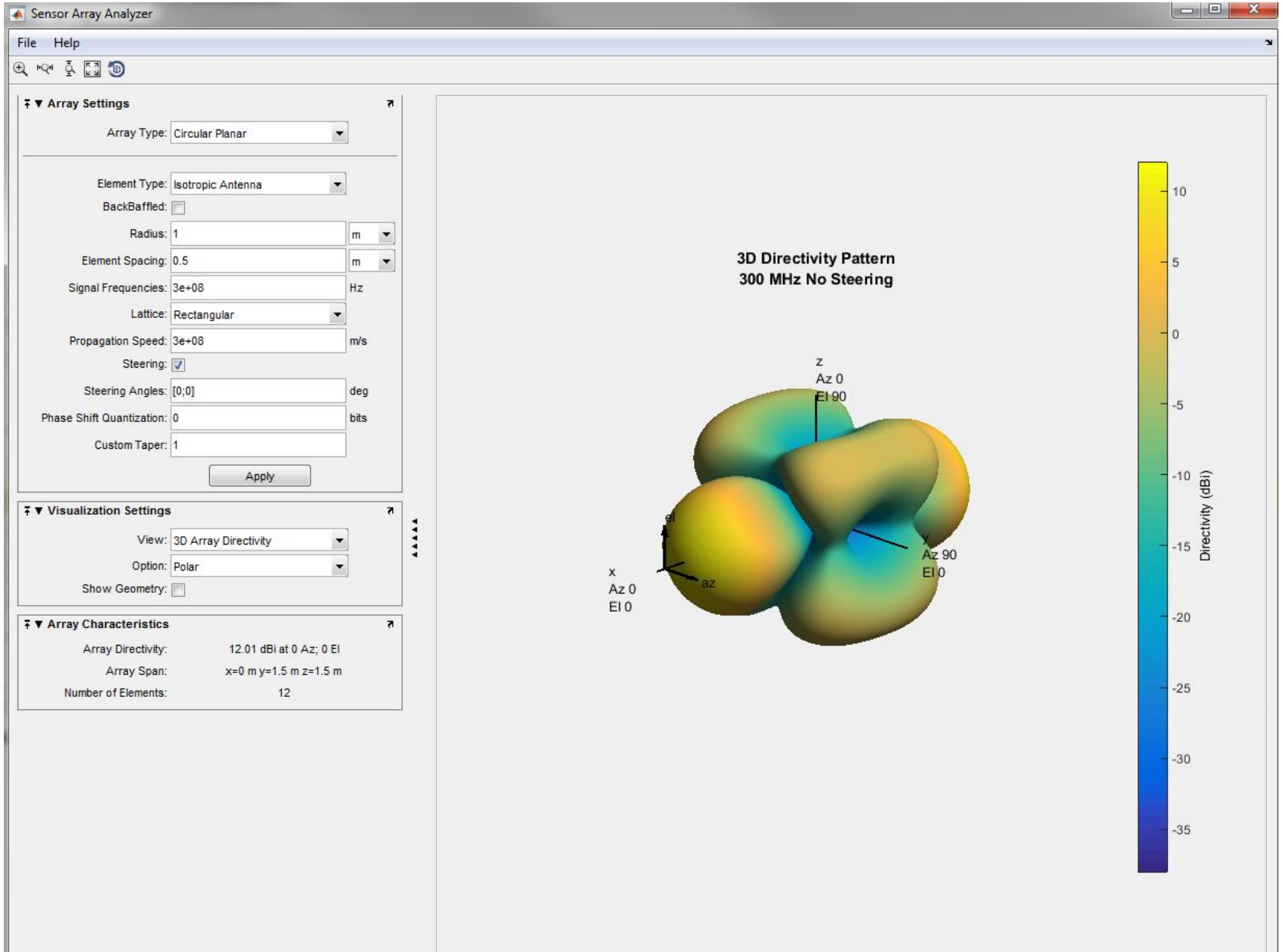
Antenna and Phase Array System toolbox

- 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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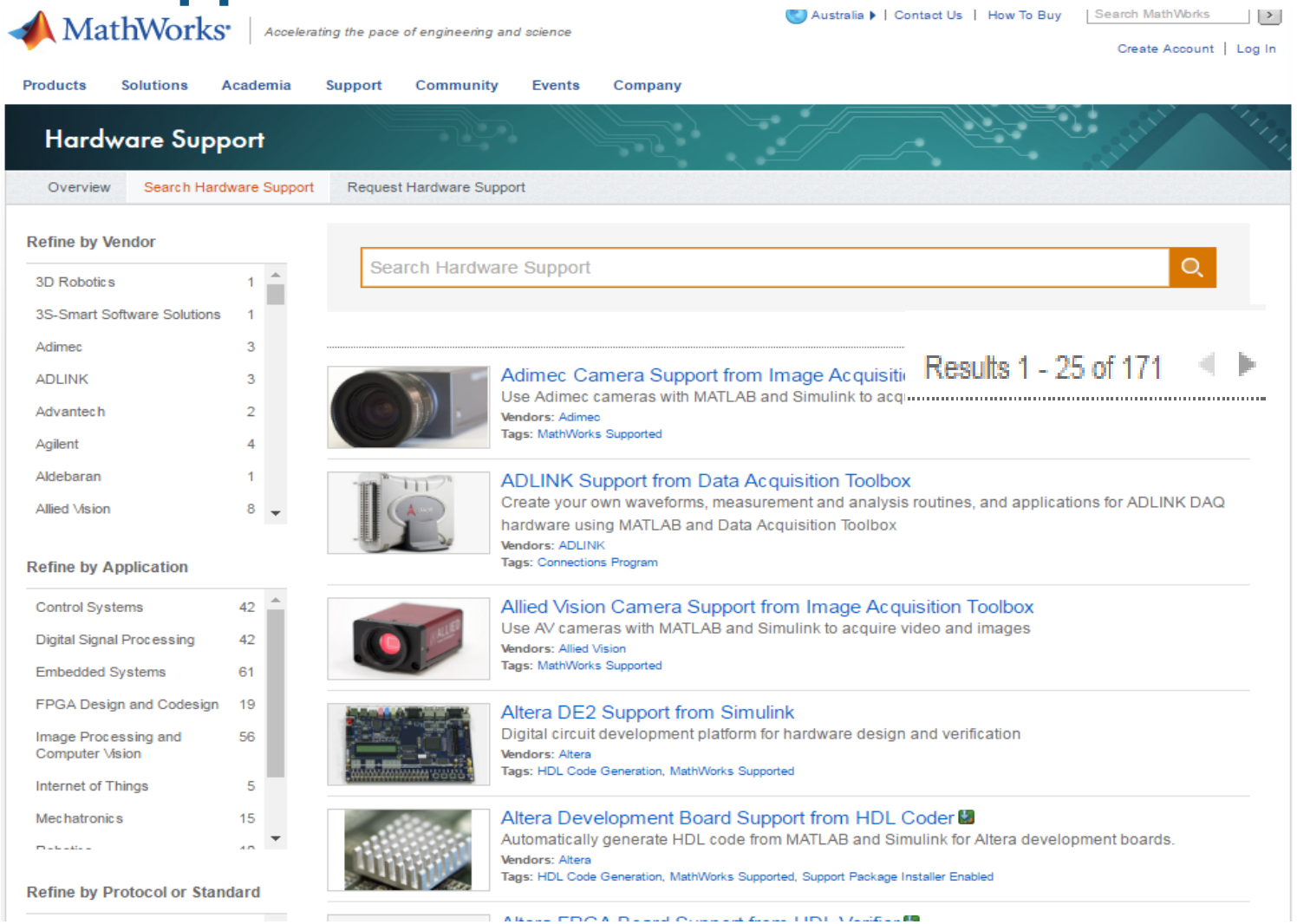
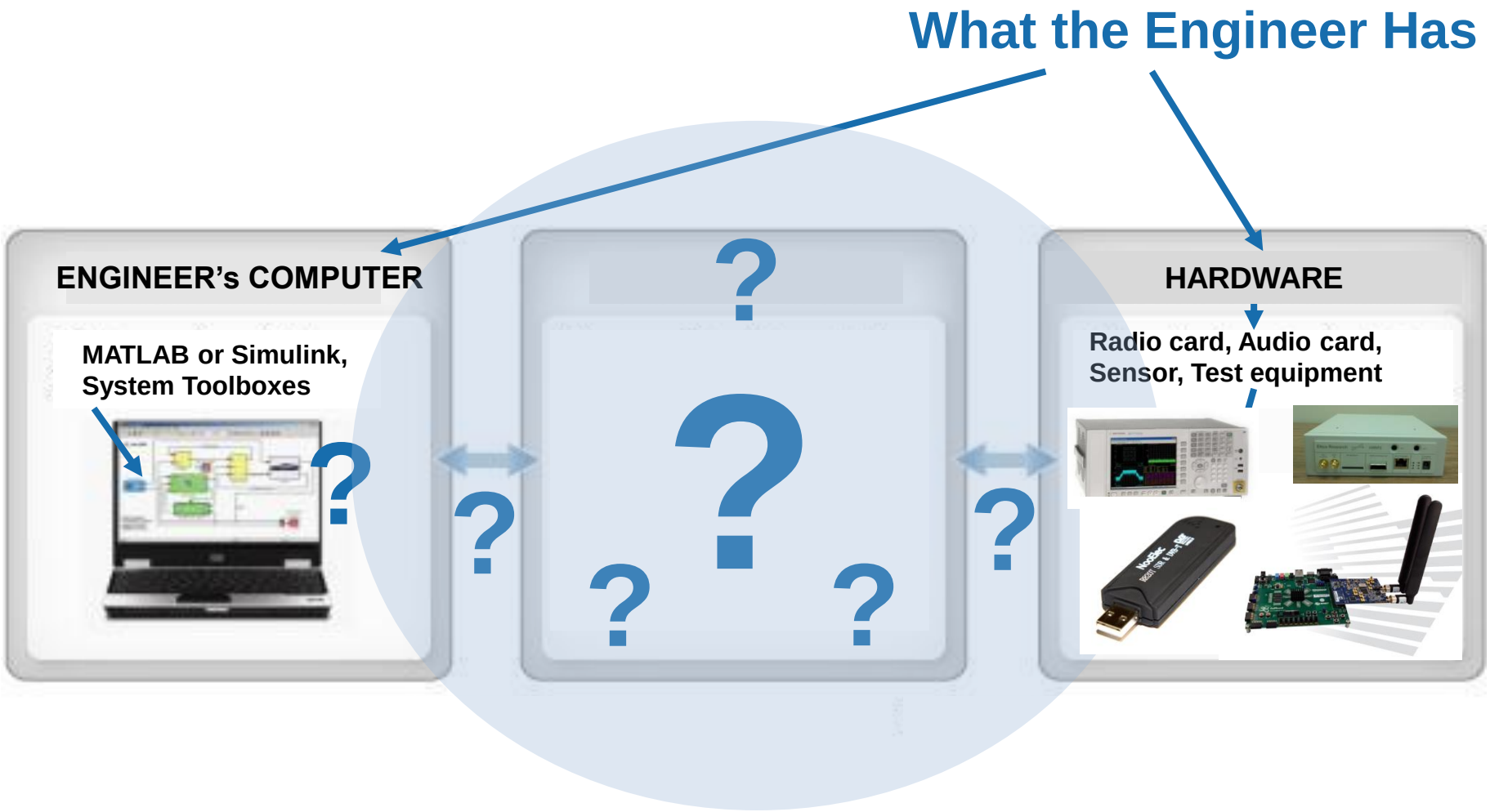
Connect to Hardware and see it happen !

MathWorks Support of Hardware

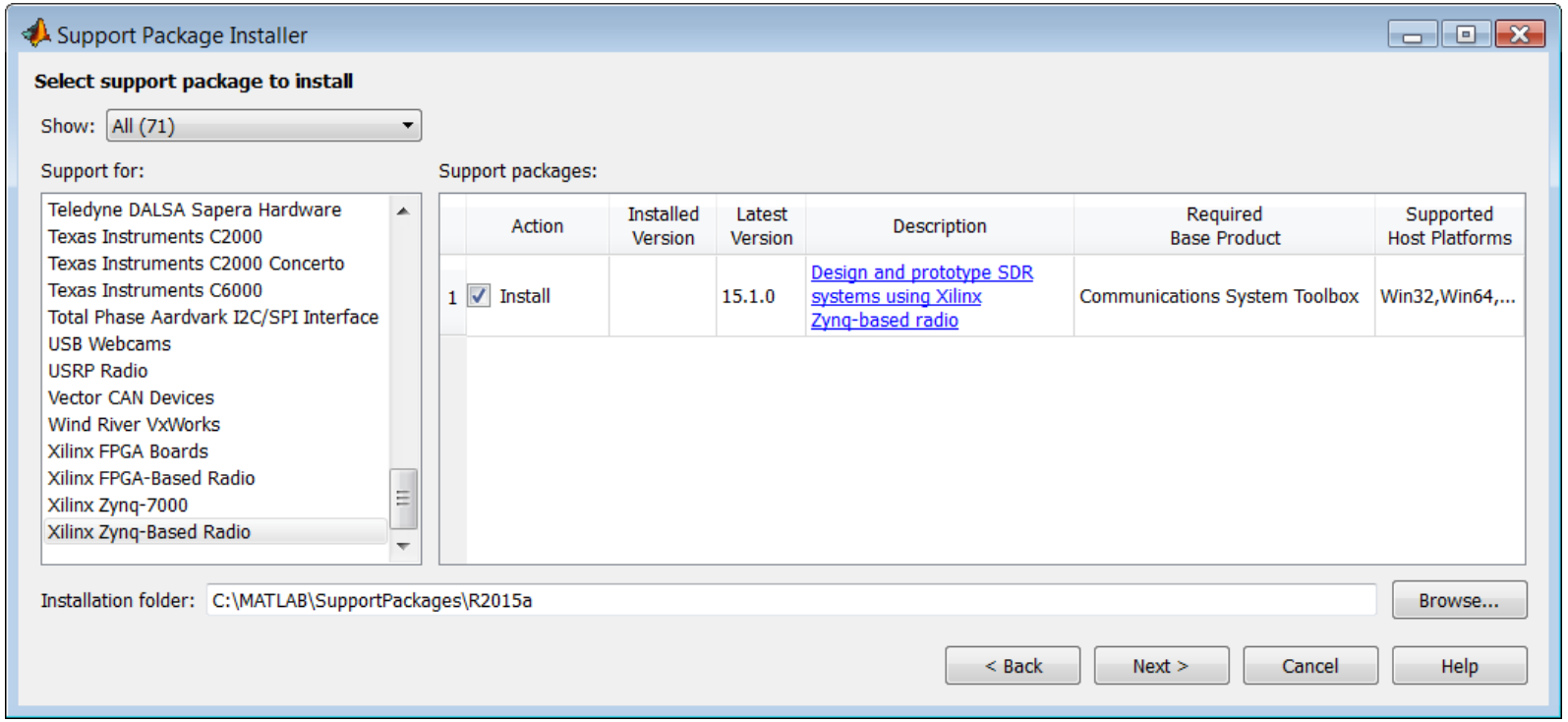


http://www.mathworks.com/hardware-support/index.html

How can we help

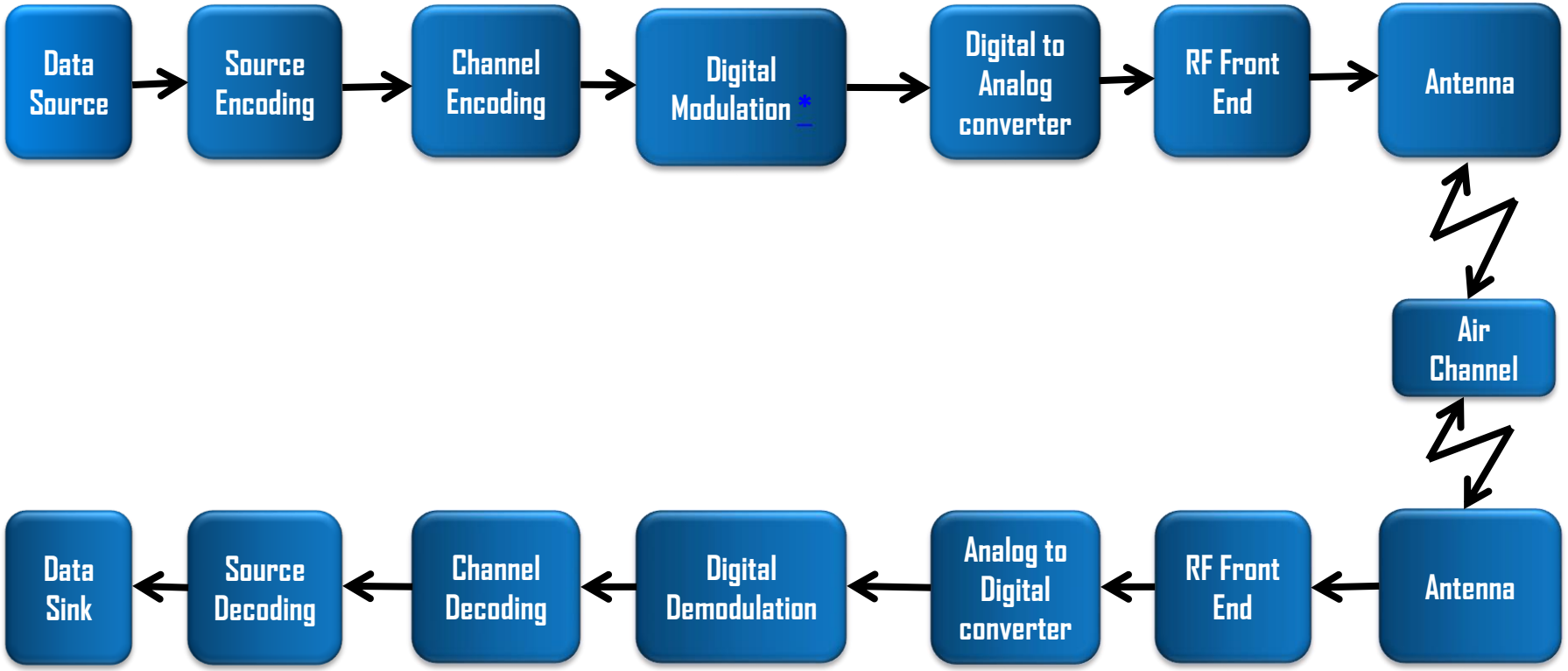


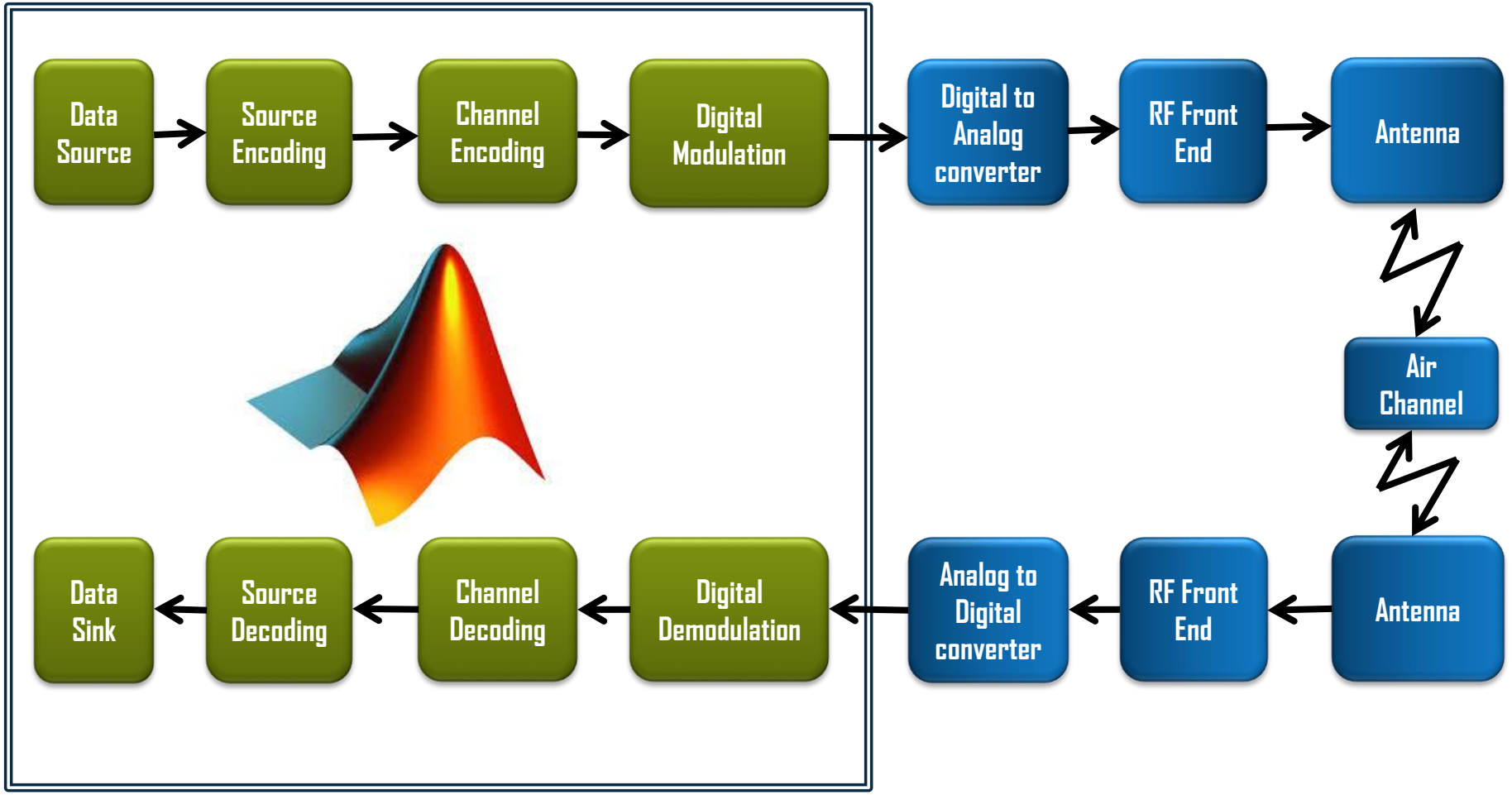
Software setup: Hardware support packages



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


Data Source
Source Encoding
Channel Encoding
Digital Modulation *
Digital to Analog converter
RF Front End
Antenna
Air Channel
Antenna
RF Front End
Analog to Digital converter
Digital Demodulation
Channel Decoding
Source Decoding
Data Sink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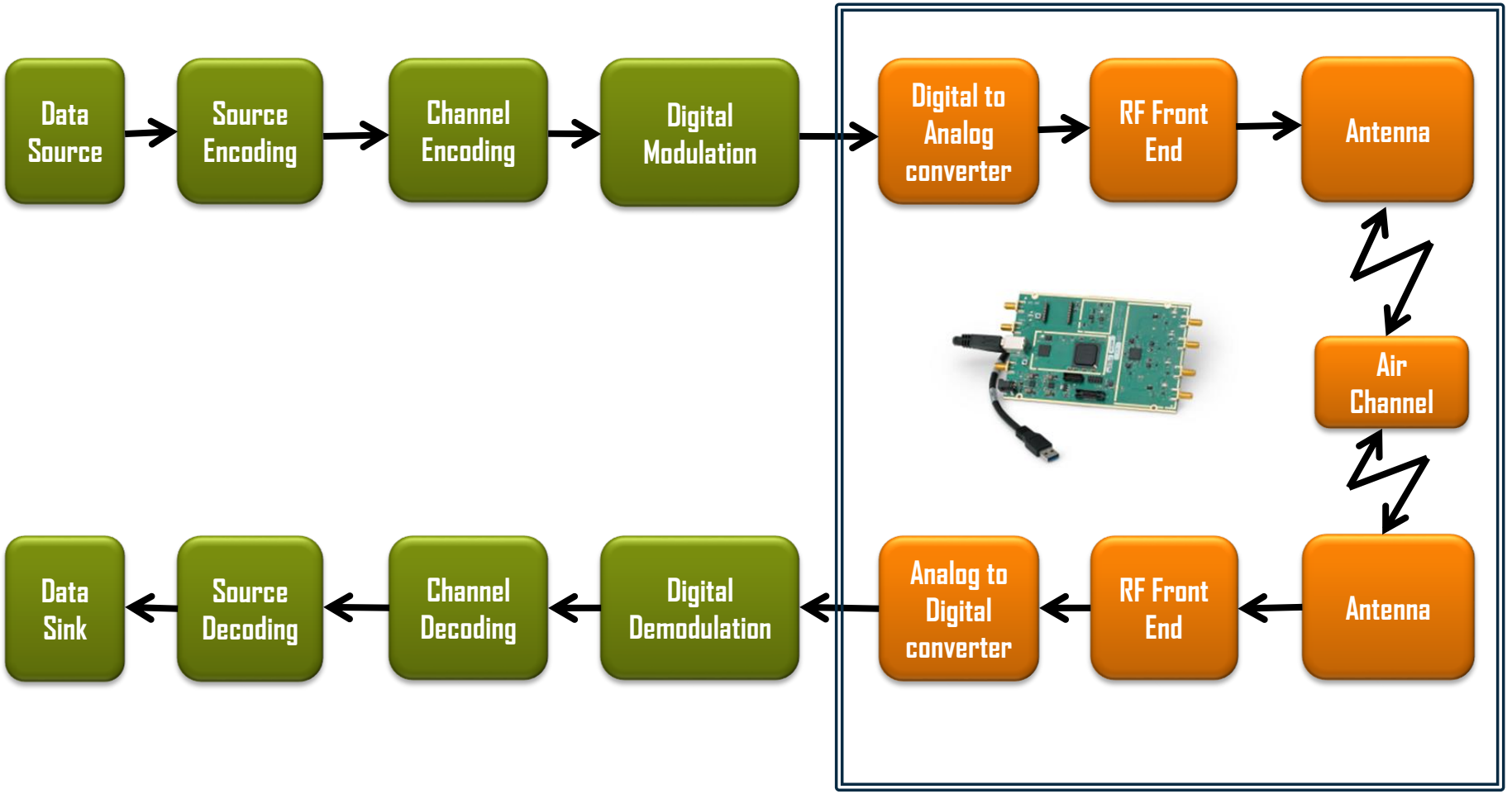
Software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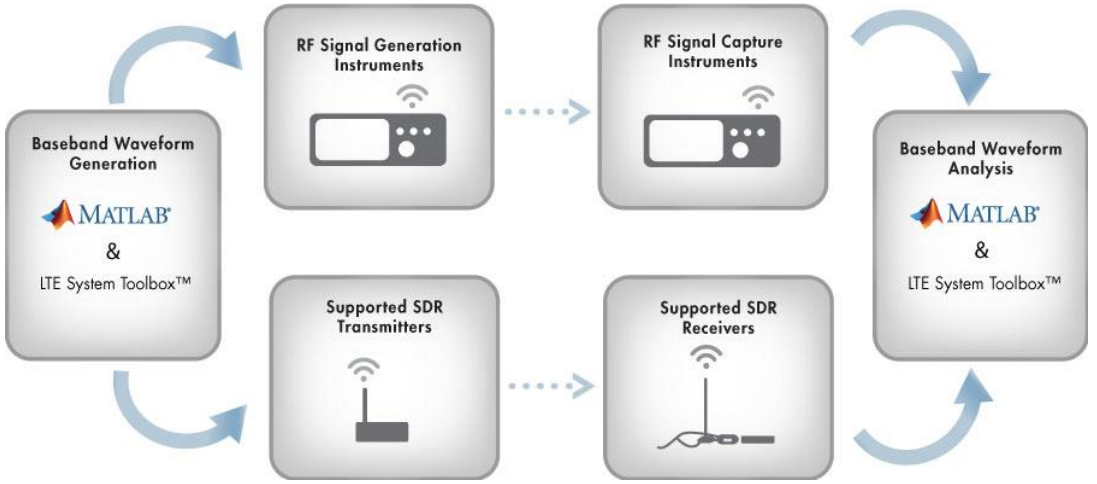
Hardware

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



Demo

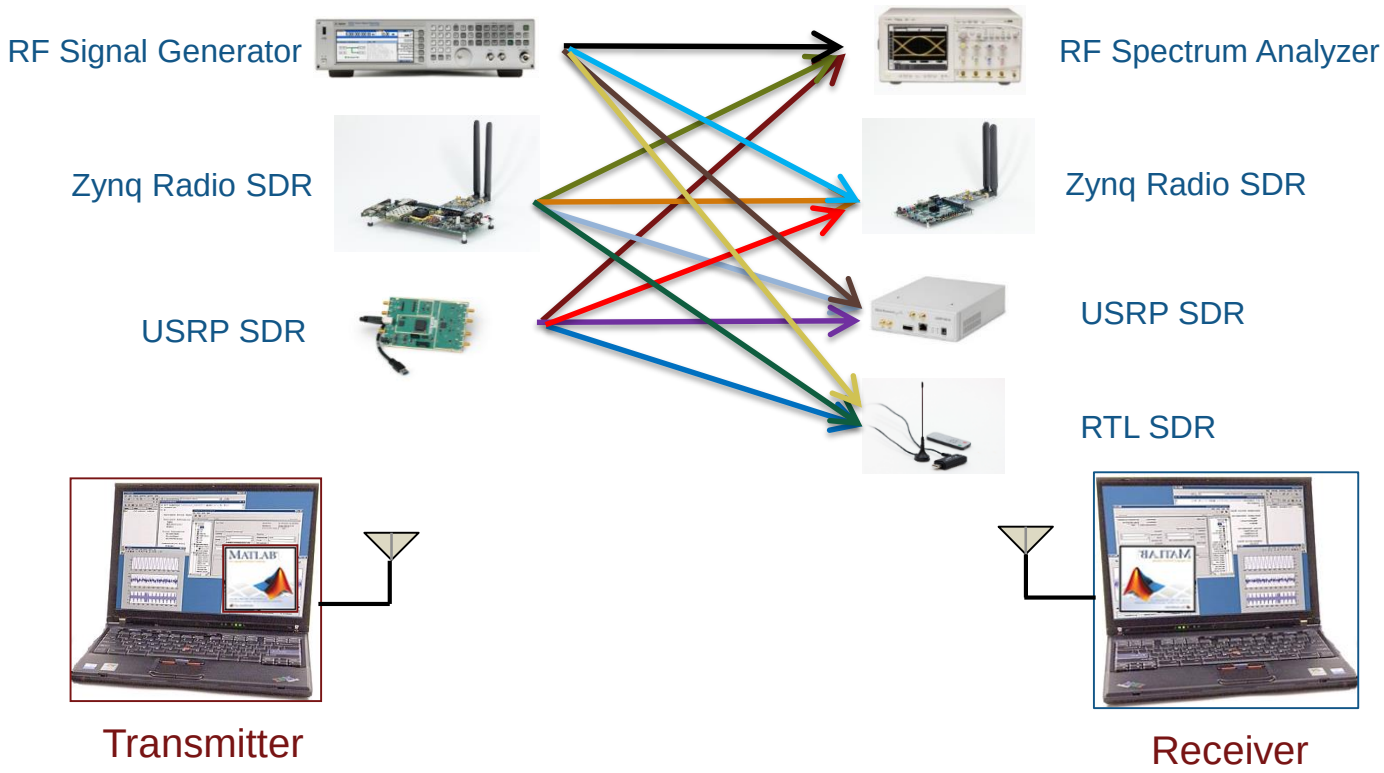
Process original data bits and generate custom digital baseband waveforms in transmitter

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)