5G Toolbox™

Model, simulate, design and test 5G systems with MATLAB®

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Product Manager
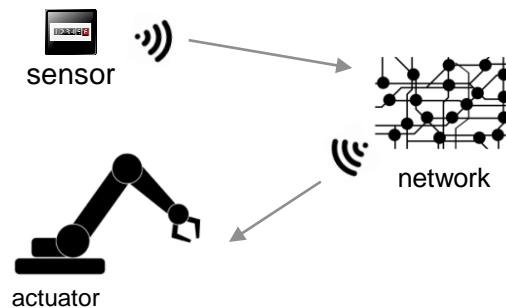
5G, Communications, LTE and WLAN Toolboxes

Signal Processing & Communications

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5G Technology use cases

- eMBB (enhanced Mobile Broadband)

- mMTC (massive Machine Type Communications)

- URLLC (Ultra-Reliable and Low Latency Communications)
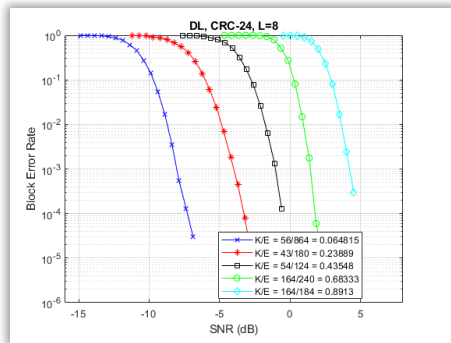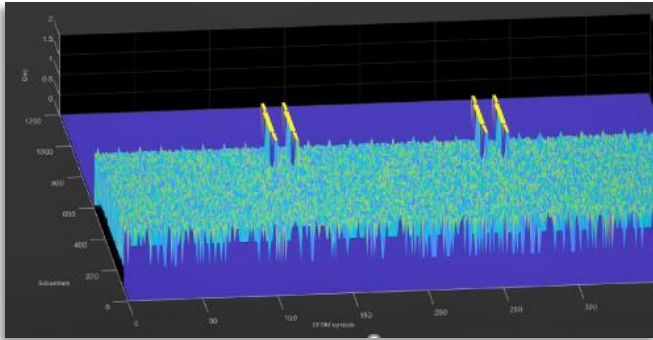
sensor

actuator

network

5G Toolbox is here!

Available as of **R2018b**

Supports 3GPP Rel. 15

Based on Version 15.2.0 (June 2018)

5G Toolbox applications & use-cases

Waveform Generation and Analysis

- New Radio (NR) subcarrier spacings and frame numerologies

**End-to-End Link-Level Simulation**

- Transmitter, channel model, and receiver
- Analyze bit error rate (BER), and throughput

Golden Reference Design Verification

- Customizable and editable algorithms as golden reference for implementation

5G Toolbox

- Waveform generation
- Downlink processing - Transmit and receive
- TDL and CDL channel models
- Physical channels and signals
- Link-level simulation & throughput measurements
- Synchronization Bursts
- Cell search procedures
- Reference designs as detailed examples
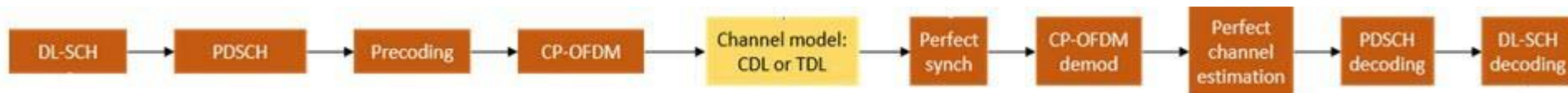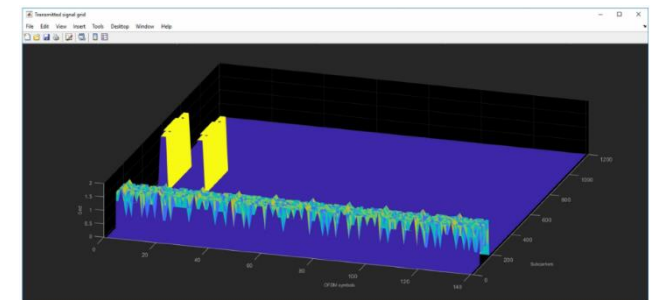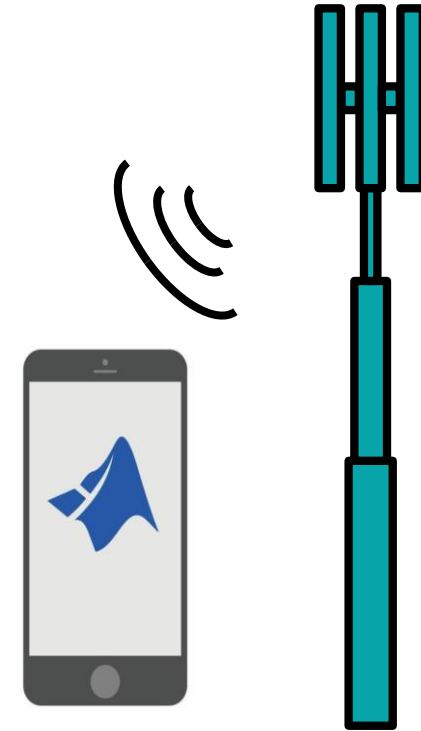
Waveform Generation and Analysis

5G waveform generation

Demo

- 5G Toolbox supports Downlink waveform generation
- OFDM Waveform with cyclic prefix: CP-OFDM

- Generated waveforms feature:
  - mixed frame numerology
  - multiple bandwidth parts
  - multiple PDSCHs
  - fully parameterizable SS bursts
 - multiple CORESETS and search spaces
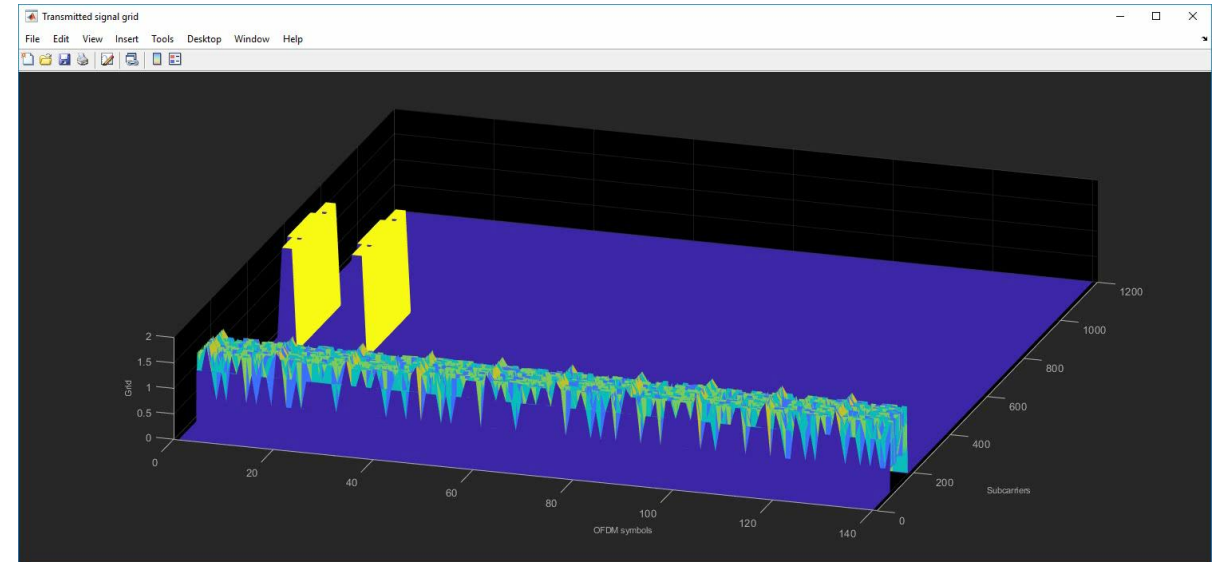
Power levels have been modified to improve visualization

Numerology and Subcarrier Spacing

- Subcarrier spacing can be a power-of-two multiple of 15kHz
- Toolbox supports variable subcarrier spacings
- Waveforms generated by Toolbox can contain a mix of subcarrier spacings

m	$Df = 2^m * 15kHz$	Slots / ms
0	15	1
1	30	2
2	60	4
3	120	8
4	240	16
5	480	32
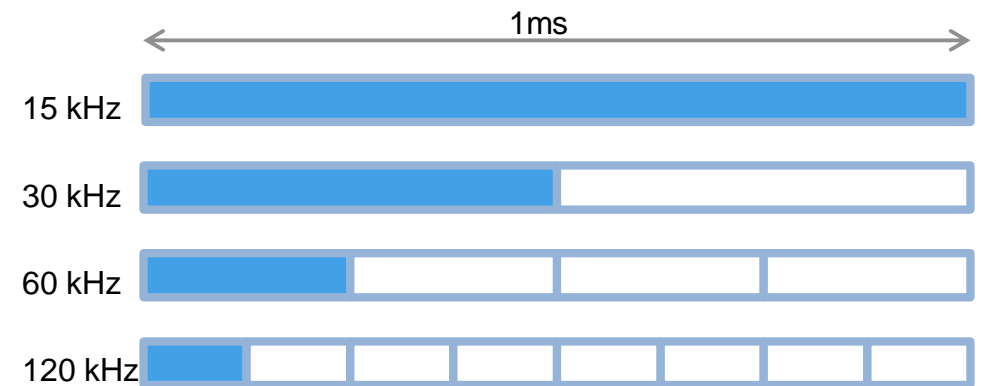
Maximum Supported Bandwidth

| μ	$\Delta f = 2^\mu *$ 15kHz	Max NDLRB	nrREs	nrREs $* \Delta f$ (MHz)
0	15	275	3300	49.50
1	30	275	3300	99
2	60	275	3300	198
3	120	275	3300	396
4	240	138	1656	397.44
5	480	69	828	397.44

Bandwidth Parts and Mixed Numerology

- Bandwidth divided into Carrier Bandwidth Parts (CBP)
  - Consecutive resource blocks
- Each CBP has its own subcarrier spacing
- Each UE can be associated with up to 4 CBPs in DL

- Toolbox supports different CBPs
- Waveforms generated by Toolbox can contain multiple CBPs
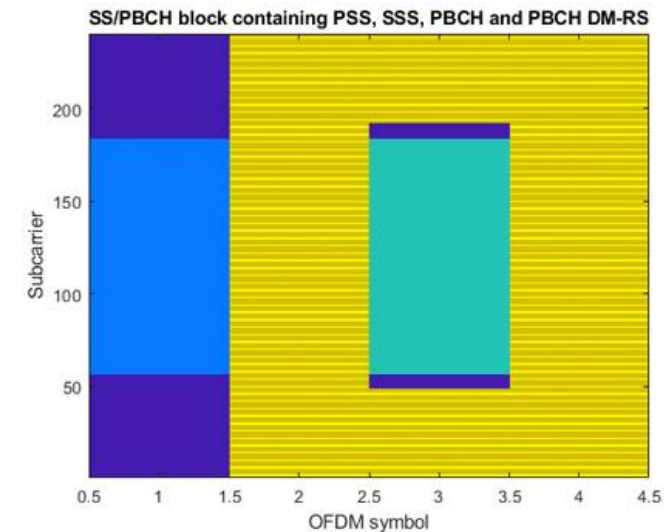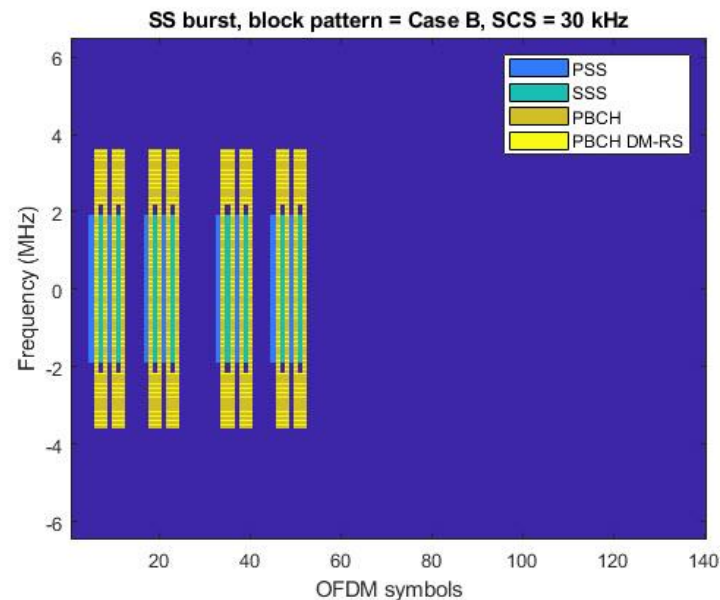
60 kHz

30 kHz

15 kHz
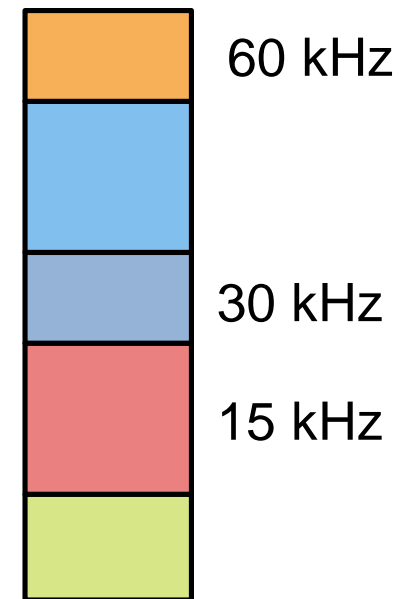
CORESET and Search Space Configuration

- Toolbox allows you to specify Control resource set (CORESET)
  - Possible locations (in time and frequency) of the control channel for a given numerology
  - Allocated OFDM symbols in a slot
  - The allocated slots within a period
  - Periodicity of the allocation.
  - CORESET duration in symbols, either 1, 2 or 3.
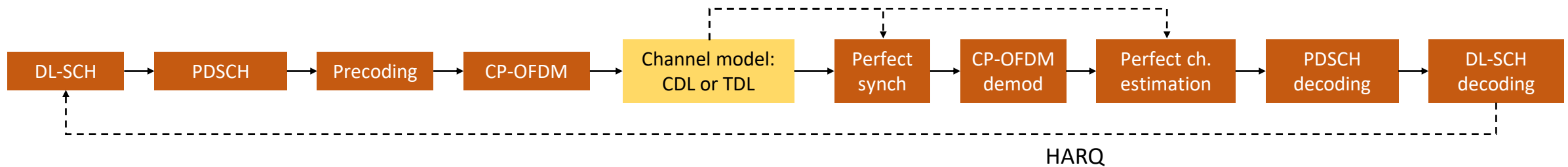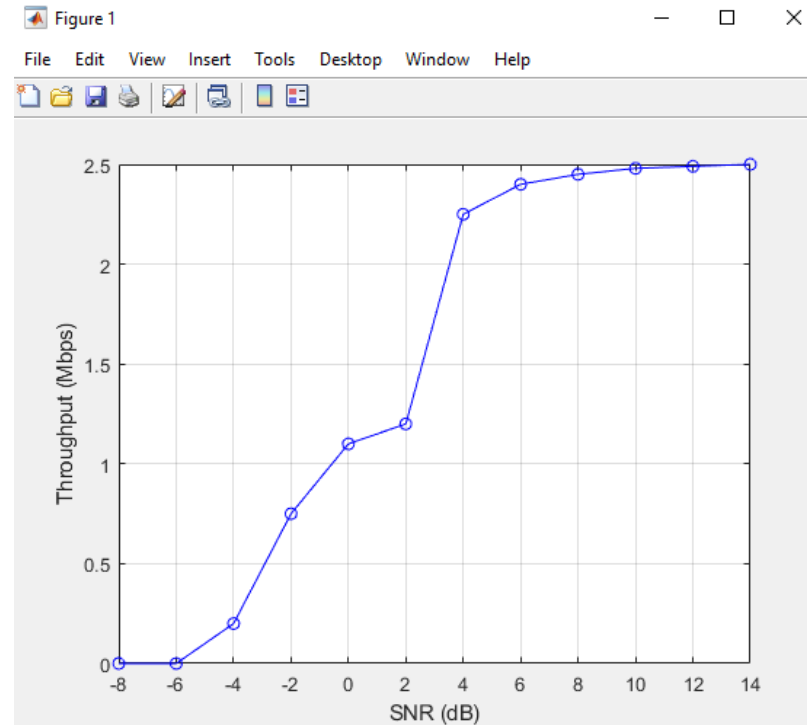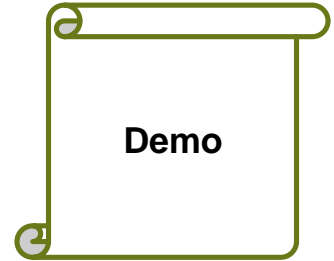 - The first PRB of the allocation
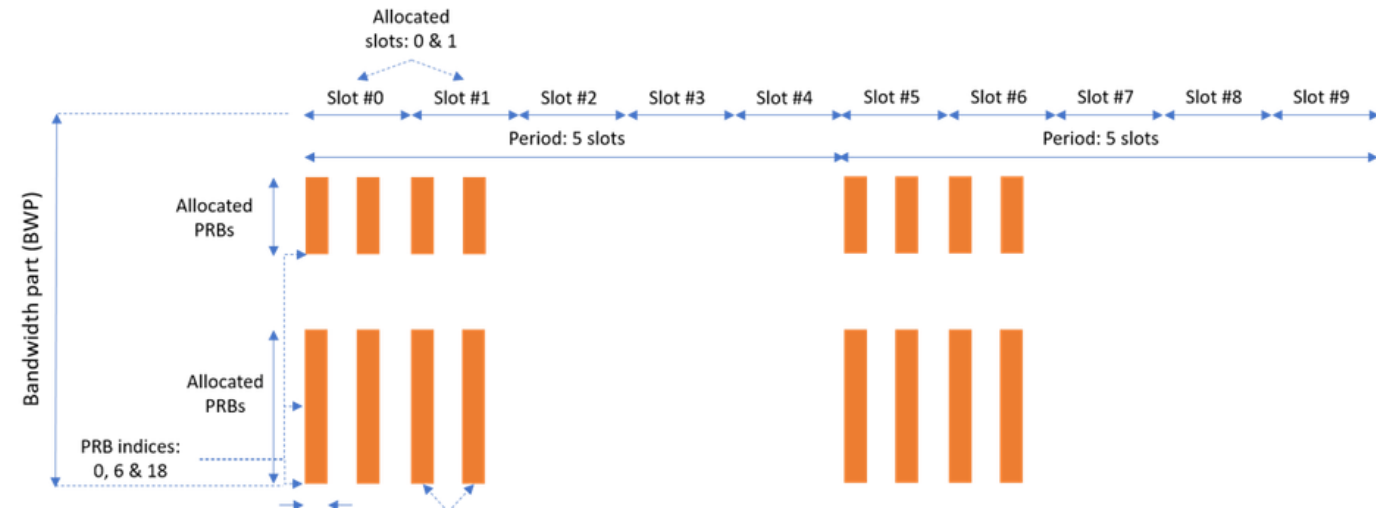
Downlink Physical layer channels and signals

- **Shared, control and broadcast channels**
  - PDSCH, PDCCH, PBCH
- **Synchronization and reference signals**
 - PSS, SSS, DM-RS

SS/PBCH block containing PSS, SSS, PBCH and PBCH DM-RS

SS burst, block pattern = Case B, SCS = 30 kHz

End-to-End Link-Level Simulation

Full 5G processing chain (end to end) link level simulation

Demo

DL-SCH → PDSCH → Precoding → CP-OFDM → Channel model: CDL or TDL → Perfect synch → CP-OFDM demod → Perfect ch. estimation → PDSCH decoding → DL-SCH decoding

HARQ

5G Channel Models

- Implementation of 5G channel models TR 38.901

- These include control of:
  - Delay profile: TDL and CDL profiles: A, B, C, D, E or custom
  - Channel delay spread
  - Doppler shift
  - MIMO correlation
  - CDL: spatial channel model, includes also:
    - Antenna array geometry [M, N, P, Mg, Ng]
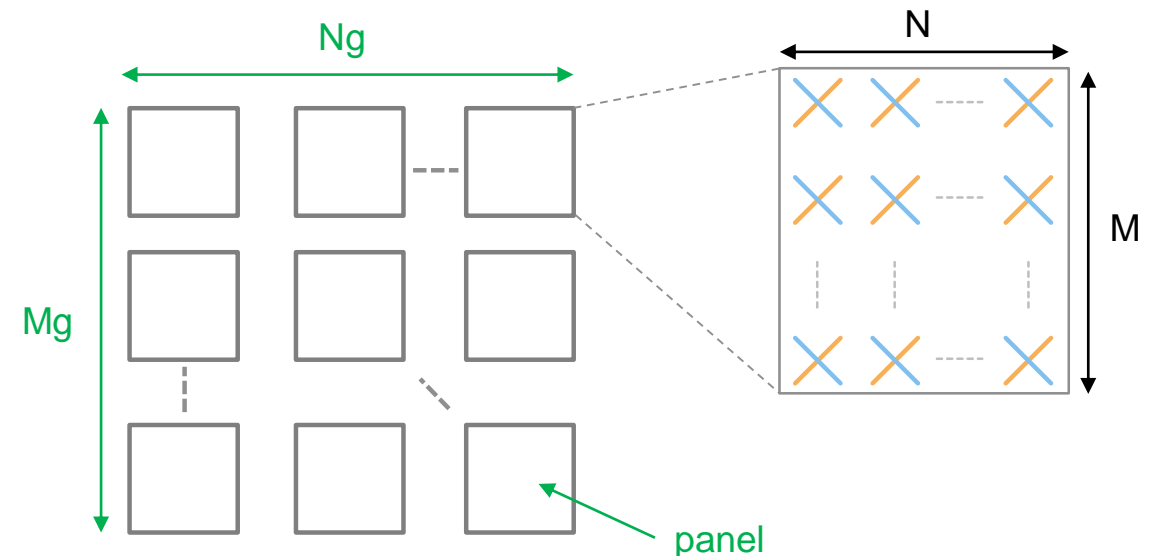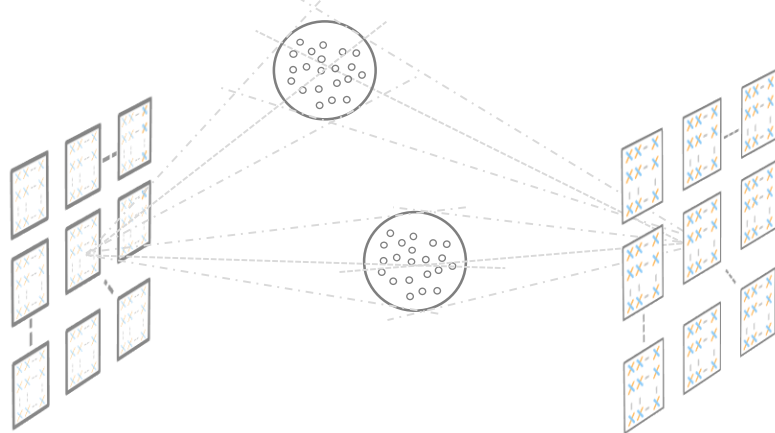
Transport Channel Processing

- Cyclic redundancy check (CRC) encoding and decoding

- DL-SCH: Low-density parity-check (LDPC) encoding, decoding, rate matching, and rate recovery.

- LDPC code block segmentation and de-segmentation

- DCI and BCH: Polar encoding, decoding, rate matching, and rate recovery.
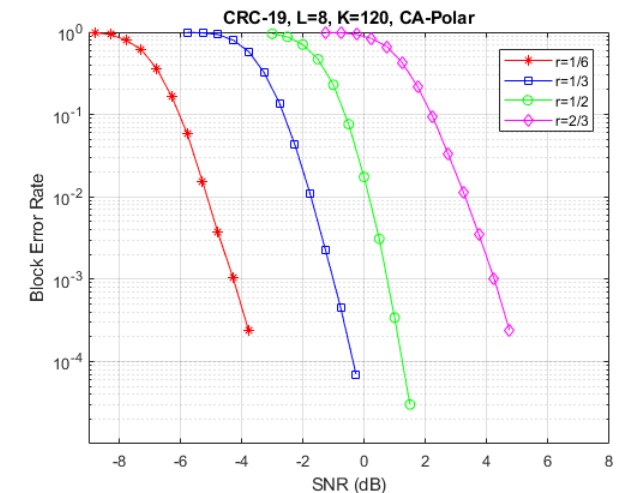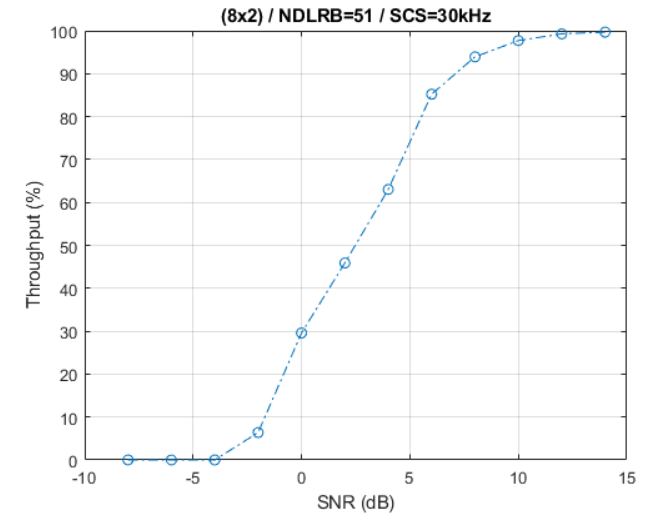
# Cell search and selection procedures

- Obtain cell ID and initial system information including Master Information Block (MIB)

- Perform the following steps:
  - Burst generation
  - Beam sweep
  - TDL propagation channel model and AWGN
  - Receiver synchronization and demodulation

PSS Correlations (time domain)
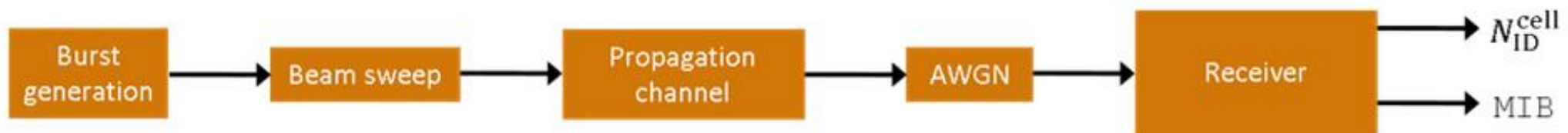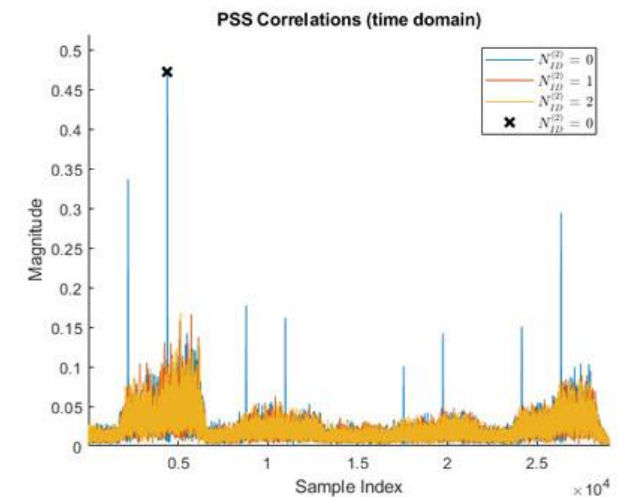
# Synchronization
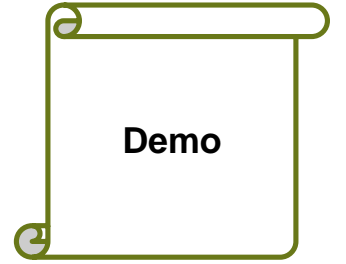
Demo

- Construct synchronization signal (SS) bursts

- Pass waveform through fading channel

- Synchronize to receive waveform using
  - Primary synchronization signal (PSS)
  - Secondary synchronization signal (SSS)
  - PBCH demodulation reference signal
  (PBCH DM-RS)

- Perform PBCH decoding and parsing

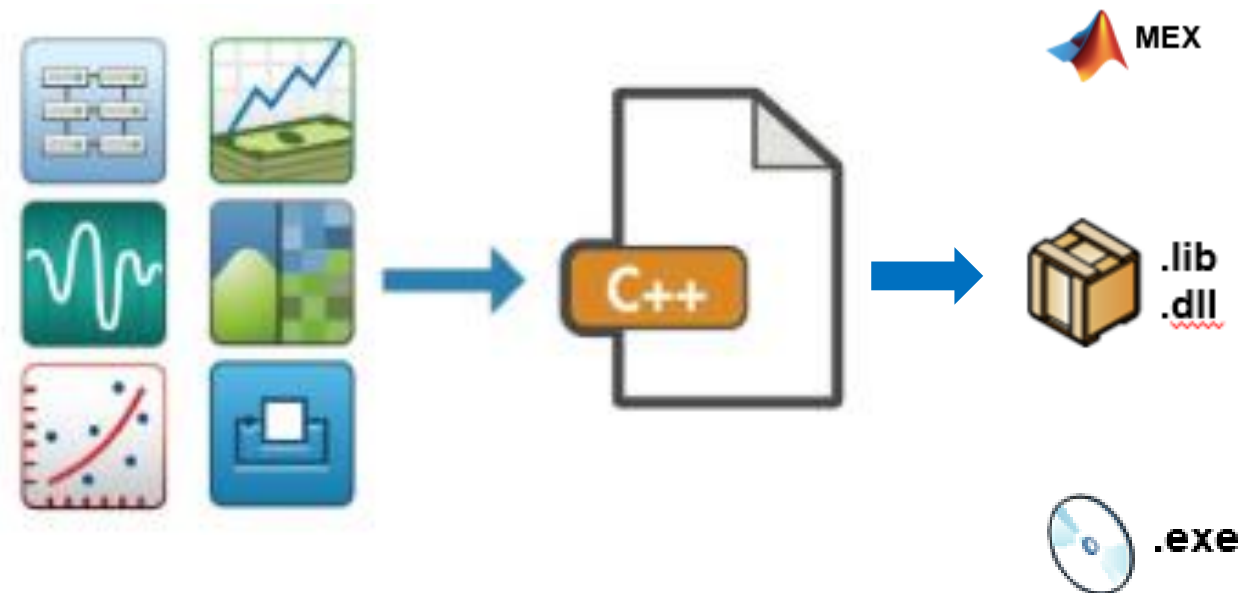SS burst, block pattern = Case B, SCS = 30 kHz
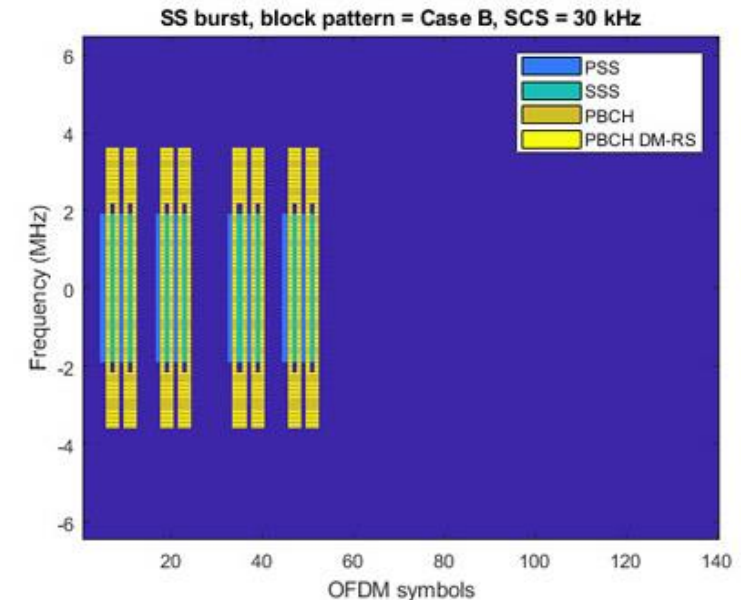
Golden Reference Design Verification

5G Toolbox has open customizable algorithms

- All functions are

Open, editable, customizable MATLAB code
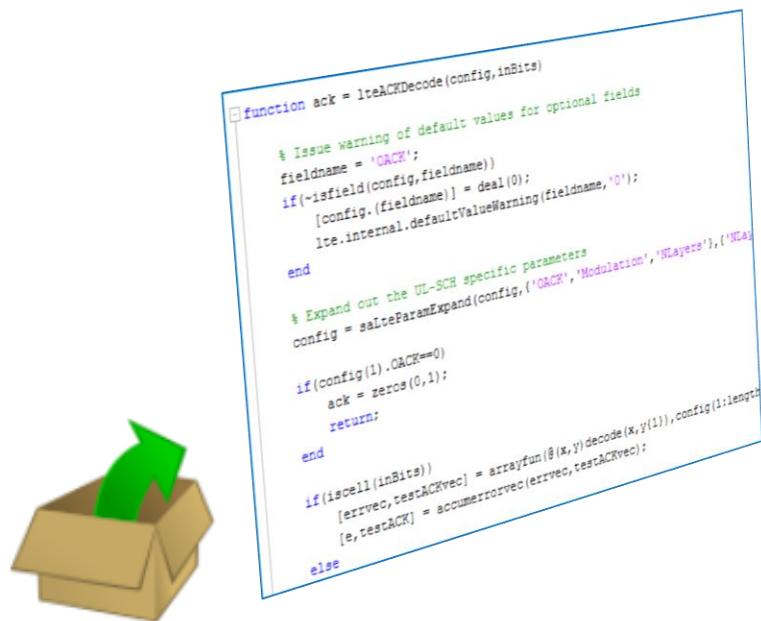
- C/C++ code generation:

Supported with MATLAB Coder

How to learn more

- Go to 5G Toolbox product page
  mathworks.com/products/5g

- Watch the 5G Toolbox video
  – On YouTube
  – On 5G Toolbox product page

- Go to 5G Toolbox documentation page

- Consult 'MATLAB for 5G' page
  mathworks.com/solutions/wireless-communications/5g.html

Summary

- 5G Toolbox enables you to simulate, analyse, test 5G wireless communications systems
- Standard-compliant MATLAB functions based on Rel.15 of 3GPP 5G NR standard
  - Waveform generation
  - Downlink Physical Channels and Signals including PDSCH, PDCCH, PBCH, PSS, SSS, and DM-RS
  - Link-level simulation including PDSCH Throughput Simulation
  - Cell search procedure with MIB decoding
  - LDPC and Polar Coding algorithms
  - TR 38.901 CDL and TDL Propagation Channels