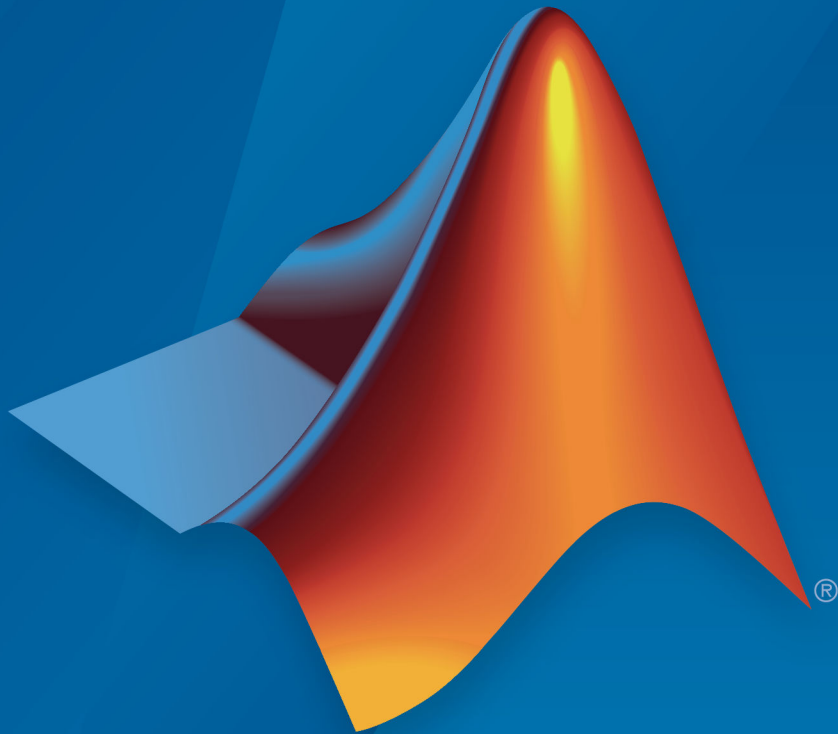


# LTE Toolbox™ Release Notes



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*LTE Toolbox™ Release Notes*

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# R2019a

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**Version: 3.1**

**New Features**

## Wireless Waveform Generator App Updates

With the **Wireless Waveform Generator** app, you can now:

- Create waveforms compliant with specific LTE uplink and downlink reference measurement channel (RMC) and E-UTRA test model (E-TM) configurations.
- Generate a waveform that you can transmit with a connected lab test instrument. The Wireless Waveform Generator app can generate waveforms for instruments supported by the `rfsiggen` function. Use of the transmit feature in the Wireless Waveform Generator app requires Instrument Control Toolbox™.

## NB-IoT Uplink Support: Perform perfect channel estimation and SC-FDMA demodulation

The `lteULPerfectChannelEstimate` and `lteSCFDMADemodulate` functions now support the narrowband Internet of Things (NB-IoT). You can perform perfect channel estimation and SC-FDMA demodulation with a subcarrier spacing of 3.75 kHz or 15 kHz.

## NB-IoT Downlink Support: Generate downlink synchronization and reference signals

You can generate narrowband reference signals with the `lteNRS` function. You can also generate primary and secondary synchronization signals and their corresponding indices with these functions: `lteNPSS`, `lteNPSSIndices`, `lteNSSS`, and `lteNSSSIndices`.

## Updated NB-IoT Examples: Perform NB-IoT NPUSCH and NPDSCH block error rate simulations

The “NB-IoT NPUSCH Block Error Rate Simulation” and “NB-IoT NPDSCH Block Error Rate Simulation” examples now model:

- A fading channel
- Perfect synchronization, perfect channel estimation, and equalization
- Codeword repetitions and performance comparisons with different repetitions

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## **Uplink Carrier Aggregation Example: Generate an aggregated uplink waveform**

The “Uplink Carrier Aggregation Waveform Generation, Demodulation, and Analysis” example shows how to:

- 1** Generate an LTE uplink waveform with carrier aggregation (CA).
- 2** Generate a modulated waveform for each component carrier (CC) configuration by calculating CA parameters.
- 3** Extract CCs by demodulating and filtering a waveform.
- 4** Measure the error vector magnitude and in-band emissions for any CC.



# R2018b

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**Version: 3.0**

**New Features**

**Bug Fixes**

## **256QAM Uplink Support: Generate and decode uplink waveforms with Release 14 256QAM modulation**

The following set of PUSCH/UL-SCH and uplink control HARQ-ACK and RI functions now support 256QAM modulation: `lteACKDecode`, `lteACKEncode`, `lteCQIEncode`, `ltePUSCH`, `ltePUSCHDecode`, `ltePUSCHIndices`, `lteRIDecode`, `lteRIEncode`, `lteRMCUL`, `lteRMCULTool`, `lteULDescramble`, `lteULSCH`, `lteULSCHDecode`, `lteULSCHDeinterleave`, `lteULSCHInfo`, and `lteULSCHInterleave`.

The `lteRMCUL` and `lteRMCULTool` waveform generation functions now support the 256QAM specific 'A17' set of fixed-reference channel (FRC) settings: 'A17-1', 'A17-2', 'A17-3', 'A17-4', 'A17-5', 'A17-6'.

## **NB-IoT Example: Model the narrowband Internet of Things (NB-IoT) transport and physical uplink shared channel**

The NB-IoT Uplink Waveform Generation example shows how to generate LTE-Advanced Pro Release 13 Narrowband IoT (NB-IoT) uplink waveforms. The waveforms consist of the Narrowband Physical Uplink Shared Channel (NPUSCH) and the associated demodulation reference signals for test and measurement applications using LTE Toolbox.

## **LTE-M Downlink Example: Model the Release 13 (Cat-M1) and Release 14 (Cat-M2) LTE-M downlink physical channels and signals**

The LTE-M Downlink Waveform Generation example shows how to create a downlink LTE-M transmission consisting of MTC Physical Downlink Control Channel (MPDCCH), the associated Physical Downlink Shared Channel (PDSCH) and the Physical Broadcast Channel (PBCH), including repetitions and frequency hopping.

## **LTE-M Uplink Example: Model the Release 13 (Cat-M1) and Release 14 (Cat-M2) LTE-M uplink shared channel and associated DM-RS**

The LTE-M Uplink Waveform Generation example shows how to create an uplink LTE-M transmission consisting of the Physical Uplink Shared Channel (PUSCH) and the



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associated demodulation reference signals (DM-RS) including repetitions and frequency hopping.

## **MU-MIMO Link Example: Simulate a MU-MIMO end-to-end link**

The PDSCH Throughput for Non-Codebook Based MU-MIMO Transmission Mode 9 (TM9) example shows how to measure the physical downlink shared channel (PDSCH) throughput performance in a multi-user multiple-input multiple-output (MU-MIMO) scenario with LTE Toolbox. The example uses non-codebook based transmission mode, TM9, with block diagonalization precoding.

## **NB-IoT Examples: NB-IoT NPUSCH block error rate simulation**

The NB-IoT NPUSCH Block Error Rate Simulation example shows how LTE Toolbox can be used to create an NB-IoT PUSCH block error rate simulation under additive white Gaussian noise.

## **NB-IoT Support: NB-IoT SC-FDMA modulation and precoding/depredcoding support added to existing functions**

This release supports NB-IoT for the following existing functions:

- `lteSCFDMAmodulate`
- `lteSCFDMAInfo`
- `lteULPrecode`
- `lteULDeprecode`

## **Functionality Being Removed or Changed**

The 5G Library for LTE System Toolbox® has been removed for R2018b. The functions and reference examples comprising this library are available in 5G Toolbox, introduced in R2018b.



# R2018a

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**Version: 2.6**

**New Features**

**Bug Fixes**

## **NB-IoT Support: Model the narrowband Internet of Things (NB-IoT) transport and physical downlink shared channel**

LTE System Toolbox now supports the narrowband transport and the physical downlink shared channel (NPDSCH) for the NB-IoT technique, according to Release 13 of the 3GPP LTE standard: `lteNRSIndices`, `lteNPDSCHIndices`, `lteNDLSCH`, `lteNDLSCHDecode`, `lteNPDSCH`, `lteNPDSCHDecode`

## **3GPP TR 36.873 3-D Channel Model: Model 3-D propagation conditions**

The toolbox now provides the 3-D channel model described in 3GPP TR 36.873. To model 3-D fading environmental conditions, use the `lte3DChannel` System object™.

## **User Equipment (UE) Detection Example: Detect UE IDs by analyzing an LTE downlink signal**

This example enables you to detect user equipment (UE) identities by analyzing either an LTE downlink signal generated with LTE System Toolbox or a real waveform recovered from the air.

## **Simulink Example: Model a physical downlink shared channel (PDSCH) throughput conformance test using Simulink**

Use the physical downlink shared channel (PDSCH) throughput simulation example to explore LTE System Toolbox capabilities in Simulink®.

## **5G Library: Simulate 3GPP 5G radio technologies with new channel coding schemes (LDPC and Polar coding) and radio waveforms with variable subcarrier spacing**

The 5G Library for LTE System Toolbox enables you to explore the behavior and performance of 3GPP 5G radio access technologies. To download it:

- 1 On the MATLAB® **Home** tab, in the **Environment** section, click **Add-Ons > Get Add-Ons**.

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- 2 In the Add-On Explorer window, browse or search for 5G.
  - 3 Select the add-on and then click **Install**.



# R2017b

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**Version: 2.5**

**New Features**

**Bug Fixes**

## **V2X Sidelink Support: Model vehicle-to-vehicle wireless communications using LTE Release 14 functionality**

LTE System Toolbox sidelink functionality has been extended to include V2X sidelink support of LTE Release 14.

The new V2X sidelink example explains how to perform block error rate simulation of the new sidelink functionality.

## **NB-IoT Example: Simulate a narrowband Internet of Things (NB-IoT) communications link over an AWGN channel model**

This example shows how to create the NB-IoT narrowband physical downlink shared channel (NPDSCH) block error rate simulation. You can test its performance over an AWGN channel model, and the NB-IoT downlink time-domain waveform containing the NPDSCH and narrowband reference signal is generated.

## **5G Library: Simulate 3GPP 5G radio technologies with new waveforms and channel models**

The 5G Library for LTE System Toolbox enables you to explore the behavior and performance of 3GPP 5G radio access technologies. To download it:

- 1 On the MATLAB **Home** tab, in the **Environment** section, click **Add-Ons > Get Add-Ons**.
- 2 In the Add-On Explorer window, browse or search for 5G.
- 3 Select the add-on and then click **Install**.

## **Additional Functions Implemented in MATLAB Code: Explore the MATLAB code of lteULSCH and ltePDSCH**

The `lteULSCH` and `ltePDSCH` functions have been implemented using MATLAB code. You can now access the underlying code of these functions to customize the algorithms and functionality.



# R2017a

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**Version: 2.4**

**New Features**

**Compatibility Considerations**

## **Sidelink Receive Functionality: Perform sidelink link-level simulations that include timing synchronization, channel estimation, and equalization for ProSe direct communications**

The following sidelink channel estimation and timing synchronization functions have been added to LTE System Toolbox: `lteSLFrameOffsetPSBCH`, `lteSLFrameOffsetPSCCH`, `lteSLFrameOffsetPSSCH`, `lteSLChannelEstimatePSBCH`, `lteSLChannelEstimatePSCCH`, and `lteSLChannelEstimatePSSCH`. For more information, see Sidelink Channels.

Sidelink PSCCH and PSSCH Throughput demonstrates using the PSCCH and PSSCH frame offset and channel estimation functions in a BLER simulation of sidelink control and shared channels.

## **TDD Configurations Support: Generate waveforms for all TDD configurations, including HARQ process mapping tables**

The uplink and downlink generators can now create waveforms for any TDD configuration. The HARQ process mapping table creation was updated to support all TDD configurations. For more information, see `lteRMCDLTool` and `lteRMCULTool`.

For TDD, `lteRMCDL` now allows parameterization using the TDD configuration when the reference configuration is not provided, specifically when the RC parameter is absent or is empty, []. When a supported reference configuration is specified, the TDD configuration defaults to 1 as specified by the RMC definitions in TS 36.101, Annex A. If scheduling is not specified via input parameters, all downlink and special subframes are assumed to be scheduled.

## **5G Library: Simulate 3GPP 5G radio technologies**

The 5G library provides MATLAB functions for simulating 3GPP 5G new radio technologies. To download these functions:

- 1 On the MATLAB **Home** tab, in the **Environment** section, click **Add-Ons > Get Add-Ons**.
- 2 In the Add-On Explorer window, browse or search for 5G.
- 3 Select the add-on and then click **Install**.

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## **Additional Functions Implemented in MATLAB Code: Explore the MATLAB code of `ltePRACH`, `ltePRACHInfo`, `lteSymbolModulate`, `lteDLSCH`, and `lteDLSCHDecode`**

These functions have been implemented using MATLAB code — `ltePRACH`, `ltePRACHInfo`, `lteSymbolModulate`, `lteDLSCH`, and `lteDLSCHDecode`.

You can now access the underlying code of these functions to customize the algorithms and functions.

## **Transmission Modes 7 to 10 Throughput Example: Evaluate the performance of non-codebook-based transmission modes 7 to 10 in FDD and TDD scenarios**

The example models throughput simulation performance for the physical downlink shared channel (PDSCH) in an FDD scenario. The 3GPP transmission modes explored include:

- TM7 — Non-codebook-based precoding for a single layer (Port 5)
- TM8 — Non-codebook-based precoding for up to two layers (Port 7-8), or single antenna port 7 or 8
- TM9 and TM10 — Non-codebook-based precoding for up to eight layers (Port 7-14), or single antenna port 7 or 8

## **Change to `CBSBuffers` representation used by `lteDLSCHDecode`**

This change makes the `CBSBuffers` format consistent across LTE System Toolbox functions. The R2017a release changes the representation of the `CBSBuffers` field of the `statein` input and `stateout` output structure arrays. This change makes `lteDLSCHDecode` consistent with the format used by the other LTE System Toolbox low-level coding chain functions, such as `lteRateRecoverTurbo` and `lteULSCHDecode`.

## **Compatibility Considerations**

Up to R2016b, the `CBSBuffers` field for `lteDLSCHDecode` contains the LLR soft buffer states ordered with the systematic (S) and parity (P) bits interleaved, such as `[S P1 P2 S P1 P2...]`, where P1 is a parity bit from the first encoder, and P2 is a parity bit from the second encoder.

In R2017a, these LLR soft buffer states are ordered in separate consecutive blocks, such as [*block of S, block of P1, block of P2*].

# R2016b

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**Version: 2.3**

**New Features**

**Bug Fixes**

## **Sidelink Functionality: Model sidelink transmission and reception for ProSe direct communications**

In this release, LTE System Toolbox adds proximity services (ProSe) transmission and reception components to support sidelink communication. Release 12 of the 3GPP LTE standard introduced this new device-to-device (D2D) interface, primarily allowing LTE to support public safety communication systems.

LTE System Toolbox sidelink transmission and reception functions have been added for broadcast, control, and shared channels. ProSe direct communication enables direct UE to multiple UE communication (group communication) without data transmission on the uplink or downlink. ProSe direct communication is allowed for public safety applications only and supports one or more UEs being out of network or out of frequency coverage.

For a list of sidelink functions and further details, see Sidelink Channels.

## **EPDCCH Receiver: Perform end-to-end EPDCCH BLER simulation**

This release adds enhanced physical downlink control channel (EPDCCH) receiver support including search space creation, physical channel demodulation, and blind search. For further details, see Enhanced Physical Downlink Control Channel (EPDCCH) Conformance Test.

## **Transmission Modes 7 to 10 Throughput Example: Evaluate the performance of non-codebook-based transmission modes 7 to 10**

The PDSCH TDD Throughput for Non-Codebook Based Precoding Schemes: Port 5 (TM7), Port 7 or 8 or Port 7-8 (TM8), Port 7-14 (TM9 and TM10) example models throughput simulation performance for the physical downlink shared channel (PDSCH) in a TDD scenario. The 3GPP transmission modes explored include:

- TM7 — Non-codebook-based precoding for a single layer (Port 5)
- TM8 — Non-codebook-based precoding for up to two layers (dual layer Port 7-8, or single antenna port 7 or 8)

- 
- TM9 and TM10 — Non-codebook based precoding for up to eight layers (up to eight layers Port 7-14 or single antenna port 7 or 8)

## **Waveform Generation Enhancements: Generate sustained data rate waveforms and directly control the code rate**

This release adds several enhancements for waveform generation and analysis:

- Previously, the only subframe 5 data that could be generated was OCNG. Now you can transmit reference PDSCH data in subframe 5. For details, see `lteRMCDLTool` and `lteRMCDL`.
- Support for generating sustained data rate RMC waveforms. For details, see `lteRMCDLTool` and `lteRMCDL`.
- Direct control over target code rate. For details, see `lteRMCDL` and `lteRMCUL`.
- Simulation support added to `lteDLConformanceTestTool` for Transmission modes 7-10. Transmission modes 7-10 include demodulation reference signals (DM-RS) for channel estimation when demodulating PDSCH.
- The LTE Parameterization for Waveform Generation and Simulation example shows the steps involved and the different ways to parameterize end-to-end simulations and static waveform generation using LTE System Toolbox.

## **Functions now implemented in MATLAB Code**

The `lteOFDMModulate` and `lteSCFDMAModulate` functions are now implemented in MATLAB code. You can access the underlying code to customize the algorithms and functions.





# R2016a

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**Version: 2.2**

**New Features**

**Bug Fixes**

## **Release 12 Alternative Codebook: Model CSI reporting with Release 12 alternative codebook, optimized for Multiuser-MIMO applications**

These functions now support Release 12 alternative codebook (four-antenna downlink), as specified in TS 36.213, Table 7.2.4-0A to Table 7.2.4-0D:

- `lteCSICodebook`
- `ltePMIInfo`
- `ltePMISelect`
- `lteRISelect`
- `lteCQISelect`

## **Release 10 and 11 DCI Message Enhancements: Create, decode, and search for all DCI messages for LTE Releases 10 and 11**

These functions now fully support 3GPP Release 10 and 11 DCI message creation, manipulation, and decoding:

- `lteDCI`
- `lteDCIDecode`
- `lteDCIInfo`
- `ltePDCCHSearch`

## **Fixed Reference Channel A.11-1 Waveform Generation: Create waveforms with TTI bundling and Release 12 enhanced HARQ patterns for VoIP applications**

The `lteRMCUL` and `lteRMCULTool` functions now support 3GPP Release 12 uplink fixed reference channel A11-1. The FRC A11-1 specifies waveform generation of PUSCH with TTI bundling and the enhanced HARQ pattern.

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## **EPDCCH Channel Estimation: Estimate the channel for EPDCCH equalization and reception**

The `lteDLChannelEstimate` function now supports EPDCCH DM-RS channel estimation, which can be used for equalization and reception of EPDCCH.



# R2015b

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**Version: 2.1**

**New Features**

**Bug Fixes**

**Compatibility Considerations**

## Release 12 256QAM: Simulate small cell PDSCH 256QAM modulation and coding schemes

`lteTBS`, `lteMCS`, and all PDSCH/DL-SCH related functions have been updated adding support for 256QAM modulation. These functions extend TBS tables and add the alternative PDSCH MCS table for Release 12 MCS determination.

## Release 11 Multiple Zero Power CSI-RS Bitmaps: Model multicell ZP CSI-RS patterns

`lteCSIRS`, `lteCSIRSIndices`, `lteEPDCCHIndices`, and `ltePDSCHIndices` functions now support multiple zero-power CSI-RS resources. Using these functions when assigning resource elements, a transmitting cell can now avoid assigning resource elements used by other cells for CSI-RS transmission.

## Release 11 PUSCH/PUCCH DRS Virtual Identities: Model uplink Release 11 Coordinated Multipoint (CoMP) scenarios

The following functions now support virtual cell identities and alternative scrambling, enabling modeling of uplink Release 11 Coordinated Multipoint (CoMP) scenarios with the LTE System Toolbox:

<code>ltePUSCHDRS</code>	<code>lteULChannelEstimate</code>	<code>lteULChannelEstimatePUCCH2</code>
<code>ltePUCCH1DRS</code>	<code>lteULFrameOffset</code>	<code>lteULFrameOffsetPUCCH2</code>
<code>ltePUCCH2DRS</code>	<code>lteULChannelEstimatePUCCH1</code>	<code>lteULChannelEstimatePUCCH3</code>
<code>ltePUCCH3DRS</code>	<code>lteULFrameOffsetPUCCH1</code>	<code>lteULFrameOffsetPUCCH3</code>
<code>lteRMCULTool</code>	<code>ltePUCCH2DRSDecode</code>	

## Cell Search Enhancements: Detect multiple cells in an LTE downlink waveform

The `lteCellSearch` now enables you to:

- Detect multiple cells

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- Perform post-FFT-based SSS detection
  - Compare the strength of detected cells

The following feature examples show the cell search enhancements:

- Reference Signal Measurements (RSRP, RSSI, RSRQ) for Cell Reselection determines the quality of the detected cells. The cell reselection test environment, described in TS 36.133 Annex A.4.2.2.1, is configured in this example.
- Cell Search, MIB and SIB1 Recovery fully synchronizes, demodulates and decodes live eNodeB signal.
- Time Difference Of Arrival Positioning Using PRS calculates the position of a User Equipment (UE) within a network of eNodeBs via the Time Difference Of Arrival (TDOA) positioning approach in conjunction with the Release 9 Positioning Reference Signal (PRS).

## **Waveform Generation: Improved control of PDCCH, DCI, and OCNG for test and measurement**

The uplink and downlink waveform generator functions (`lteRMCDLTool`, `lteRMCDL`, `lteRMCULTool`, and `lteRMCUL`) now enable:

- Uplink waveform generator control of the bandwidth associated with each RMC
- Downlink waveform generator control of the DCI format, the PDCCH format, and PDCCH power. OCNG generation for PDSCH and PDCCH, has been enhanced as follows:
  - New parameters to enable or disable the PDSCH and PDCCH OCNG
  - OCNG power control
  - Control over the RNTI of the PDSCH OCNG, modulation scheme, and the transmission scheme

The PDCCH Conformance Test feature example demonstrates some of the enhanced waveform generation controls.

## **LTE Obsolete Interface Support**

This interface is provided for backwards compatibility. It will now result in runtime errors indicating which new functions to use.

## **Compatibility Considerations**

Previous versions of the LTE System Toolbox product contained a different set of function names. The term Obsolete LTE Toolbox interface refers to these previous versions, prior to version 1.0. If you wrote scripts using any of the old function names used in previous versions, you should modify the scripts to use the new function names. Also, you should modify many of the scripts to expect column vectors for output arguments where row vectors were previously returned.



# R2015a

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**Version: 2.0**

**New Features**

**Bug Fixes**

## **UMTS Downlink and Uplink Waveform Generation Functions: Generate standard-compliant W-CDMA, HSPA and HSPA+ signals**

This release adds UMTS (W-CDMA, HSPA and HSPA+) waveform generation functions, `umtsDownlinkWaveformGenerator` and `umtsUplinkWaveformGenerator`. Additionally reference channel functions, `umtsDownlinkReferenceChannels` and `umtsUplinkReferenceChannels`, are provided so that you can readily produce a configuration structure initialized to define RMC, FRC H-Set and test models defined in 3GPP standards. The reference channel function output configuration structure serves as input to the associated waveform generation function.

## **Coordinated Multipoint (CoMP) Transmission and Reception Simulation: Mitigate interference and improve performance at the edge of an LTE cell**

This release features an example demonstrating CoMP dynamic interference mitigation cooperation between multiple base stations.

- CoMP Dynamic Point Selection with Multiple CSI Processes

## **SIB1 Message PDSCH Support: Generate and receive LTE downlink waveforms carrying SIB1 for cell search and network access**

This release enables you to generate LTE waveforms carrying SIB1 message using the `lteRMCDLTool` function.

## **TM9/TM10 RMC waveform generation: Create TM9/TM10 waveforms containing CSI-RS for channel quality measurements**

The `lteRMCDL` function now returns the 3GPP standard defined CSI-RS RMC configurations and the `lteRMCDLTool` can now generate these waveforms containing CSI-RS. New RMCs added to `lteRMCDL` and the `lteRMCDLTool` GUI in this release are 'R.43', 'R.44', 'R.45', 'R.45-1', 'R.48', 'R.50', and 'R.51'.

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## **Additional Featured Examples: SIB1, EPDCCH, working with live LTE signals, multicell interference, EVM measurement, HDL verification, UMTS**

This release adds and/or enhances several examples

- Cell Search, MIB and SIB1 Recovery
- Enhanced Physical Downlink Control Channel (EPDCCH) Generation
- Working with Live LTE Signals using Software-Defined Radio (SDR)
- Effect of Inter-Cell Interference on PDSCH Throughput
- PDSCH Error Vector Magnitude (EVM) Measurement
- Verification of HDL Implementation of LTE OFDM Modulator and Detector
- UMTS Downlink Waveform Generation
- UMTS Uplink Waveform Generation



# R2014b

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**Version: 1.2**

**New Features**

**Bug Fixes**

## **Enhanced physical downlink control channel (EPDCCH) and its demodulation reference signal (DM-RS) generation functions in support of 3GPP Release 11**

R2014b adds support for the creation of Release 11 compliant enhanced physical downlink control channel (EPDCCH) transmissions. For details, see the command line help for `lteEPDCCH` and `lteEPDCCHIndices`. Additionally, `lteEPDCCHDMRS` and `lteEPDCCHDMRSIndices` allow you to generate the associated demodulation reference signals (DM-RS).

## **Channel quality indicator (CQI) and rank indicator (RI) estimation functions for modulation and coding scheme (MCS) selection**

R2014b adds support for adaptive modulation and coding scheme (MCS) selection. `lteCQISelect` performs channel quality indicator (CQI) estimation, `lteRISelect` performs rank indicator (RI) estimation, and `lteMCS` provides a lookup between MCS values and the corresponding transport block size (TBS) and modulation order.

## **Unifying function for extracting physical channel symbols and signals from a resource grid**

R2014b adds support for extracting physical channel symbols and signals from a resource grid. For details, see the command-line help for `lteExtractResources`.

## **Zero-power channel state information reference signals (CSI-RS) generation functions in support of 3GPP Release 10**

R2014b adds support for zero-power CSI-RS. New parameters added to `lteCSIRS`, `lteCSIRSIndices`, and `ltePDSCHIndices` allow you to define zero-power CSI-RS via the standardized 16-bit bitmap representation.

# R2014a

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**Version: 1.1**

**New Features**

**Compatibility Considerations**

## **Standard-compliant models for LTE and LTE-Advanced (Releases 8, 9, and 10)**

The LTE System Toolbox product provides standard-compliant functions and tools for the design, simulation, and verification of long-term evolution (LTE) and LTE-Advanced communications systems. LTE-Advanced comprises changes made to releases 9 and 10 of the LTE Standard.

## **End-to-end physical layer transmit and receive processing functions, including OFDM (downlink) and SC-FDMA (uplink)**

The LTE System Toolbox product provides standard-compliant functions for end-to-end physical layer transmit and receive processing. These functions include OFDM modulation for downlink and SC-FDMA modulation for uplink.

## **MIMO antenna transmission and UE-specific beamforming functions**

The LTE System Toolbox product provides standard-compliant functions for multiple-input, multiple-output (MIMO) antenna transmission and user equipment (UE)-specific beamforming.

## **Channel estimation, synchronization, and MIMO receiver functions**

The LTE System Toolbox product provides standard-compliant MIMO receiver functions for synchronization, channel estimation, equalization, and signal recovery procedures.

## **Standard-compliant propagation channel models**

The LTE System Toolbox product provides standard-compliant functions for modeling propagation channels. These functions include models for MIMO fading channel, EPA, EVA, and ETU, moving propagation channel, and high-speed train MIMO channel.



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## Test models and reference measurement channel (RMC) waveform generators

The LTE System Toolbox product provides standard-compliant functions and tools for generating E-UTRA test models (E-TM) and reference measurement channel (RMC) waveforms.

## Interactive tools for conformance and BER testing

The LTE System Toolbox product provides interactive tools for conformance and BER testing. You can create and reuse a conformance test bench to verify that your designs, prototypes, and implementations comply with the LTE standard.

## Recovery of low-level parameters, such as cell identity

The LTE System Toolbox product provides for the recovery of low-level parameters, such as cell identity.

## Apps for generating waveforms and analyzing throughput

This release adds the following four new apps to the MATLAB apps gallery.

- **LTE Downlink RMC Generator** — used for selection of parameters for and generation of downlink reference measurement channel (RMC) waveforms. For more information, see `lteRMCDLTool`
- **LTE Uplink RMC Generator** — used for selection of parameters for and generation of uplink reference measurement channel (RMC) waveforms. For more information, see `lteRMCULTool`
- **LTE Test Model Generator** — used for selection of parameters for and generation of E-UTRA test model (E-TM) waveforms. For more information, see `lteTestModelTool`
- **LTE Throughput Analyzer** — used to perform the PDSCH demodulation performance test and plot throughput performance graphs. For more information, see `lteDLConformanceTestTool`

## Function names and output behavior changed

Previous versions of the LTE System Toolbox product used different function names. In version 1.0, the LTE System Toolbox product contains an entirely new set of function

names. Also, many functions in previous versions of the LTE System Toolbox product returned row vectors for output arguments. In version 1.0, many of the new equivalent functions return column vectors for output arguments.

## Compatibility Considerations

If you wrote scripts using any of the old function names used in previous versions, you must modify the scripts to use the new function names in the LTE System Toolbox product, version 1.0. Also, you must modify many of the scripts to expect column vectors for output arguments where row vectors were previously returned. Refer to the following table for a mapping of the previous function names to their new equivalent function names.

In R2014a, by default, all the functions listed in the **Previous Function Name** column are on the MATLAB path. To remove these functions from the path, call the `rmlteobsolete` function. To add these functions to the path again, call the `addlteobsolete` function.

Previous Function Name	New Function Name
LteACKDecode	lteACKDecode
LteACKEncode	lteACKEncode
LteBCH	lteBCH
LteBCHDecode	lteBCHDecode
LteCFI	lteCFI
LteCFIDecode	lteCFIDecode
LteCQIDecode	lteCQIDecode
LteCQIEncode	lteCQIEncode
LteCRC	lteCRCEncode
LteCRCDecode	lteCRCDecode
LteCSICodebook	lteCSICodebook
LteCSIRS	lteCSIRS
LteCSIRSIndices	lteCSIRSIndices
LteCellRS	lteCellRS
LteCellRSIndices	lteCellRSIndices

Previous Function Name	New Function Name
LteCellSearch	lteCellSearch
LteCodeBlkDeseg	lteCodeBlockDesegment
LteCodeBlkSeg	lteCodeBlockSegment
LteConvCode	lteConvolutionalEncode
LteConvDecode	lteConvolutionalDecode
LteDCI	lteDCI
LteDCIDecode	lteDCIDecode
LteDCIDims	lteDCIInfo
LteDCIEncode	lteDCIEncode
LteDLChannelEstimation	lteDLChannelEstimate
LteDLConformanceTestBench	lteDLConformanceTestTool
LteDLDeprecoder	lteDLDeprecode
LteDLFrameOffset	lteDLFrameOffset
LteDLPerfectChannelEstimation	lteDLPerfectChannelEstimate
LteDLPrecoder	lteDLPrecode
LteDLResourceGrid	lteDLResourceGrid
LteDLResourceGridDims	lteDLResourceGridSize
LteDLSCH	lteDLSCH
LteDLSCHDecode	lteDLSCHDecode
LteDLSCHDims	lteDLSCHInfo
LteDMRS	lteDMRS
LteDMRSIndices	lteDMRSIndices
LteDuplexDims	lteDuplexingInfo
LteEVM	lteEVM
LteEqualizeMIMO	lteEqualizeMIMO
LteEqualizeMMSE	lteEqualizeMMSE
LteEqualizeULMIMO	lteEqualizeULMIMO
LteEqualizeZF	lteEqualizeZF

Previous Function Name	New Function Name
LteFadingChan	lteFadingChannel
LteFreqCorrect	lteFrequencyCorrect
LteFreqOffset	lteFrequencyOffset
LteHSTChan	lteHSTChannel
LteLayerDemapper	lteLayerDemap
LteLayerMapper	lteLayerMap
LteMIB	lteMIB
LteMovingChan	lteMovingChannel
LteOFDM	lteOFDMModulate
LteOFDMDemod	lteOFDMDemodulate
LteOFDMDims	lteOFDMInfo
LtePBCH	ltePBCH
LtePBCHDecode	ltePBCHDecode
LtePBCHIndices	ltePBCHIndices
LtePBCHPRBS	ltePBCHPRBS
LtePCFICH	ltePCFICH
LtePCFICHDecode	ltePCFICHDecode
LtePCFICHDims	ltePCFICHInfo
LtePCFICHIndices	ltePCFICHIndices
LtePCFICHPRBS	ltePCFICHPRBS
LtePDCCH	ltePDCCH
LtePDCCHDecode	ltePDCCHDecode
LtePDCCHDeinterleave	ltePDCCHDeinterleave
LtePDCCHDims	ltePDCCHInfo
LtePDCCHIndices	ltePDCCHIndices
LtePDCCHInterleave	ltePDCCHInterleave
LtePDCCHPRBS	ltePDCCHPRBS
LtePDCCHSearch	ltePDCCHSearch

Previous Function Name	New Function Name
LtePDCCHSpace	ltePDCCHSpace
LtePDSCH	ltePDSCH
LtePDSCHDecode	ltePDSCHDecode
LtePDSCHIndices	ltePDSCHIndices
LtePDSCHPRBS	ltePDSCHPRBS
LtePHICH	ltePHICH
LtePHICHDecode	ltePHICHDecode
LtePHICHDeprecoder	ltePHICHDeprecode
LtePHICHDims	ltePHICHInfo
LtePHICHIndices	ltePHICHIndices
LtePHICHPRBS	ltePHICHPRBS
LtePHICHPrecoder	ltePHICHPrecode
LtePHICHTxDivDecode	ltePHICHTransmitDiversityDecode
LtePMIDims	ltePMIInfo
LtePMISelection	ltePMISelect
LtePRACH	ltePRACH
LtePRACHDetect	ltePRACHDetect
LtePRACHDims	ltePRACHInfo
LtePRBFfromDCI	lteDCIResourceAllocation
LtePRBS	ltePRBS
LtePRS	ltePRS
LtePRSIndices	ltePRSIndices
LtePSS	ltePSS
LtePSSIndices	ltePSSIndices
LtePUCCH1	ltePUCCH1
LtePUCCH1DRS	ltePUCCH1DRS
LtePUCCH1DRSIndices	ltePUCCH1DRSIndices
LtePUCCH1Decode	ltePUCCH1Decode

Previous Function Name	New Function Name
LtePUCCH1Indices	ltePUCCH1Indices
LtePUCCH2	ltePUCCH2
LtePUCCH2DRS	ltePUCCH2DRS
LtePUCCH2DRSDecode	ltePUCCH2DRSDecode
LtePUCCH2DRSIndices	ltePUCCH2DRSIndices
LtePUCCH2Decode	ltePUCCH2Decode
LtePUCCH2Indices	ltePUCCH2Indices
LtePUCCH2PRBS	ltePUCCH2PRBS
LtePUCCH3	ltePUCCH3
LtePUCCH3DRS	ltePUCCH3DRS
LtePUCCH3DRSIndices	ltePUCCH3DRSIndices
LtePUCCH3Decode	ltePUCCH3Decode
LtePUCCH3Indices	ltePUCCH3Indices
LtePUCCH3PRBS	ltePUCCH3PRBS
LtePUSCH	ltePUSCH
LtePUSCHDRS	ltePUSCHDRS
LtePUSCHDRSIndices	ltePUSCHDRSIndices
LtePUSCHDecode	ltePUSCHDecode
LtePUSCHDeprecoder	ltePUSCHDeprecode
LtePUSCHIndices	ltePUSCHIndices
LtePUSCHPrecoder	ltePUSCHPrecode
LteRIDecode	lteRIDecode
LteRIEncode	lteRIEncode
LteRMCDL	lteRMCDL
LteRMCDLTool	lteRMCDLTool
LteRMCUL	lteRMCUL
LteRMCULTool	lteRMCULTool
LteRateMatchConv	lteRateMatchConvolutional

Previous Function Name	New Function Name
LteRateMatchTurbo	lteRateMatchTurbo
LteRateRecoverConv	lteRateRecoverConvolutional
LteRateRecoverTurbo	lteRateRecoverTurbo
LteResourceGrid	lteResourceGrid
LteResourceGridDims	lteResourceGridSize
LteSCFDMA	lteSCFDMAModulate
LteSCFDMADemod	lteSCFDMADemodulate
LteSCFDMADims	lteSCFDMAInfo
LteSRS	lteSRS
LteSRSDims	lteSRSInfo
LteSRSIndices	lteSRSIndices
LteSSS	lteSSS
LteSSSIndices	lteSSSIndices
LteSymbolDemod	lteSymbolDemodulate
LteSymbolMod	lteSymbolModulate
LteTBS	lteTBS
LteTestModel	lteTestModel
LteTestModelTool	lteTestModelTool
LteTurboCode	lteTurboEncode
LteTurboDecode	lteTurboDecode
LteTxDiversityDecode	lteTransmitDiversityDecode
LteUCI3Decode	lteUCI3Decode
LteUCI3Encode	lteUCI3Encode
LteUCIDeCode	lteUCIDeCode
LteUCIEncode	lteUCIEncode
LteUeRS	Removed. Use lteDMRS instead.
LteUeRSIndices	Removed. Use lteDMRSIndices instead.
LteULChannelEstimation	lteULChannelEstimate

Previous Function Name	New Function Name
LteULChannelEstimationPUCCH1	lteULChannelEstimatePUCCH1
LteULChannelEstimationPUCCH2	lteULChannelEstimatePUCCH2
LteULChannelEstimationPUCCH3	lteULChannelEstimatePUCCH3
LteULDeprecoder	lteULDeprecode
LteULDescrambler	lteULDescramble
LteULFrameOffset	lteULFrameOffset
LteULFrameOffsetPUCCH1	lteULFrameOffsetPUCCH1
LteULFrameOffsetPUCCH2	lteULFrameOffsetPUCCH2
LteULFrameOffsetPUCCH3	lteULFrameOffsetPUCCH3
LteULPMIDims	lteULPMIInfo
LteULPMISelection	lteULPMISelect
LteULPerfectChannelEstimation	lteULPerfectChannelEstimate
LteULPrecoder	lteULPrecode
LteULResourceGrid	lteULResourceGrid
LteULResourceGridDims	lteULResourceGridSize
LteULSCH	lteULSCH
LteULSCHDecode	lteULSCHDecode
LteULSCHDeinterleave	lteULSCHDeinterleave
LteULSCHDims	lteULSCHInfo
LteULSCHInterleave	lteULSCHInterleave
LteULScrambler	lteULScramble
LteVersion	Removed. Use the MATLAB version function instead.
LteWarning	lteWarning
LteZadoffChu	Removed. Use lteZadoffChuSeq in the Communications Toolbox™ product instead.