

Verifying LTE Designs Using Live LTE Signals and Test and Measurement Equipment

- Verify LTE designs using live LTE signals with LTE System Toolbox and test and measurement equipment
- Generate and transmit standard and custom LTE waveforms
- Capture, analyze, and visualize live waveforms using MATLAB

A key requirement for LTE or LTE-Advanced system design and verification is the ability to work with live LTE signals. Engineers require software that provides the ability to interface designs or algorithms with live signals using test and measurement equipment for evaluation and verification.

Together with Instrument Control Toolbox™ and LTE System Toolbox™, MATLAB® can design LTE algorithms and systems, and analyze or visualize live LTE signals. LTE System Toolbox includes LTE standard-compliant functions and tools that help to design, simulate, and verify LTE communications systems. Instrument Control Toolbox connects MATLAB to test equipment in order to generate and analyze live LTE signals.

This example demonstrates a signal generation and capture using a radio frequency (RF) signal generator and analyzer as part of an LTE system design verification process (Figure 1). We download a baseband waveform, synthesized in MATLAB using LTE System Toolbox, to a signal generator for over-the-air transmission. A signal analyzer is then used to capture the over-the-air signal, which is analyzed in MATLAB.

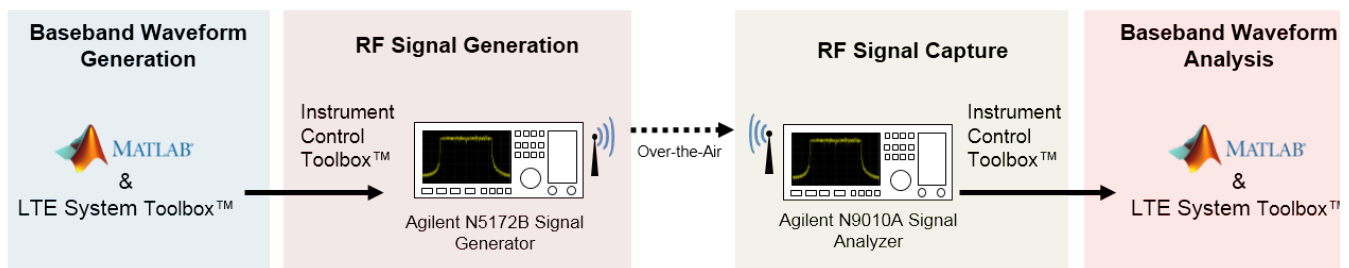


Figure 1. LTE signal generation and capture using an RF signal generator and analyzer.

Creating a Baseband Waveform

We use LTE System Toolbox to generate standard baseband IQ downlink test model (E-TM) waveforms along with uplink and downlink reference measurement channel (RMC) waveforms. The waveforms are generated from a parameter-driven interface (Figure 2).

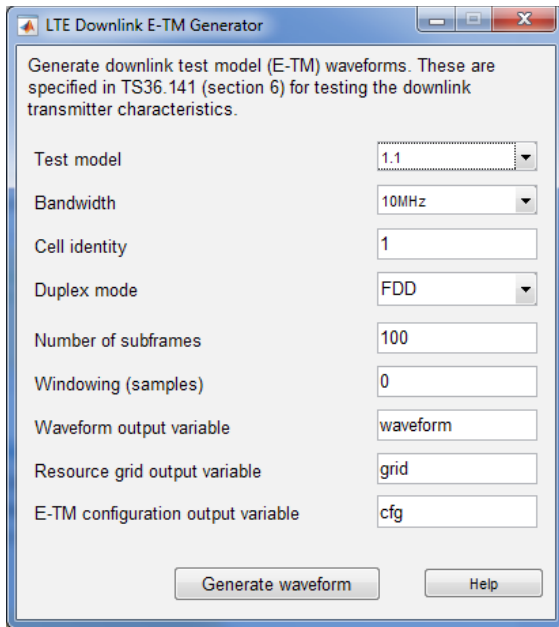


Figure 2. Parameter-driven interface for LTE downlink E-TM waveform generation.

An alternative approach includes using the functions `lteTestModel` and `lteTestModelTool`, which allow programmatic configuration and generation of LTE test models and baseband IQ waveforms.

```
cfg = lteTestModel('1.1','10MHz'); % Test Model 1.1, 10 MHz bandwidth
cfg.TotSubframes = 100;           % Generate 100 subframes

[waveform, tmgrid, cfg] = lteTestModelTool(cfg); % Generate waveform
```

Generating an Over-the-Air Signal Using an RF Signal Generator

We use Instrument Control Toolbox to download and play the test model waveform created by MATLAB and LTE System Toolbox using a signal generator. The LTE System Toolbox helper function `hDownloadAndPlayWaveformUsingN5172B.m` is used to interface with an Agilent Technologies® N5172B Signal Generator.

```
txaddress = '192.168.10.1'; % Instrument address
iq = waveform;              % IQ data
sr = cfg.SamplingRate;      % Sampling rate (Hz)
fc = 1e9;                   % Center frequency (Hz)
power = 0;                  % Output power (dBm)

hDownloadAndPlayWaveformUsingN5172B(txaddress,iq,sr,fc,power);
```

Acquiring the Baseband Signal in MATLAB from a Signal Analyzer

To analyze an over-the-air transmission in MATLAB, we use Instrument Control Toolbox to configure the signal analyzer and capture baseband IQ data. The helper function `hCaptureIQUsingN9010A.m` is an example of a function that can be used with an Agilent Technologies N9010A signal analyzer. This function retrieves the baseband IQ data `rxwaveform` and the sample rate `capsr` from the signal analyzer. This data, which is ready for analysis, is imported into MATLAB using the following code:

```
rxaddress = '192.168.10.2'; % Instrument address
t = cfg.TotSubframes*1e-3; % Capture time (s), one subframe is 1 ms
fc = 1e9; % Center frequency (Hz)
bw = 10e6; % Bandwidth (Hz)
trig = false; % External trigger

[rxwaveform, capsr] = hCaptureIQUsingN9010A(rxaddress,t,fc,bw,trig);
```

The DSP System Toolbox™ spectrum analyzer plots the frequency spectrum of the retrieved time-domain baseband waveform (Figure 3) using the code shown below that figure. The plot shows the expected 10 MHz occupied bandwidth and the impairments due to RF transmission and reception.

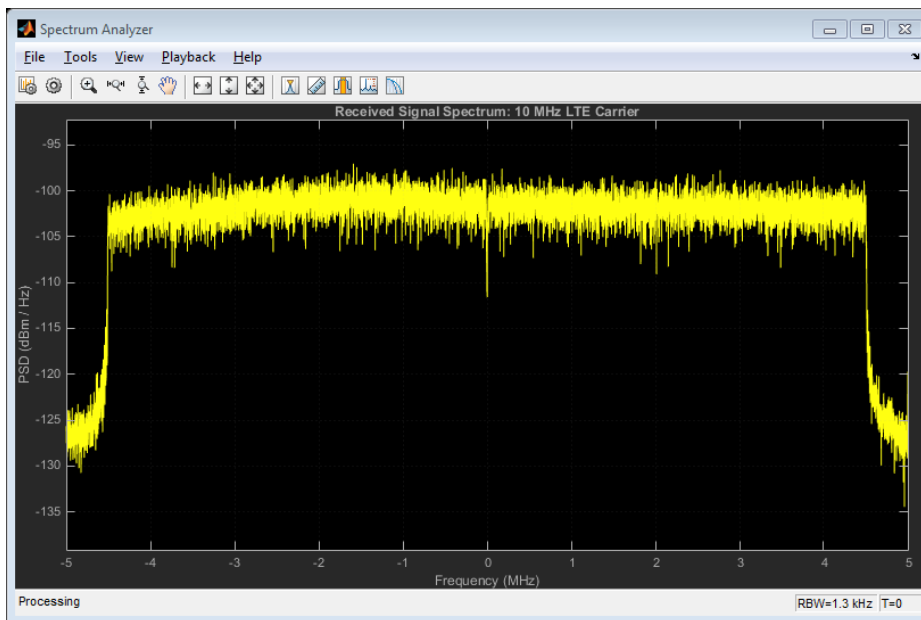


Figure 3. Frequency spectrum of captured baseband LTE waveform using the DSP System Toolbox spectrum analyzer.

```

hsa = dsp.SpectrumAnalyzer('SampleRate',capsr, ...
    'SpectrumType','Power density','PowerUnits','dBm', ...
    'RBWSource','Property','RBW',1.3e3,...
    'FrequencySpan','Span and center frequency','Span',bw, ...
    'CenterFrequency',0,'Window','Rectangular','SpectralAverages',10, ...
    'YLabel','PSD','ShowLegend',false, ...
    'Title','Received Signal Spectrum: 10 MHz LTE Carrier');

step(hsa,rxwaveform);

```

Preparing the Captured LTE Signal for Analysis

To analyze the received waveform, we must know a number of system parameters. LTE System Toolbox provides functions to generate the standard system parameters for E-TMs and downlink and uplink RMCs.

```

% System parameters for Test Model 1.1, 10 MHz bandwidth
cfg = lteTestModel('1.1','10MHz');

```

System parameters are alternatively obtained through blind decoding using LTE System Toolbox receiver functions. To learn more, see the example Cell Search, MIB, and SIB1 Recovery [1].

To recover the resource grid, we resample the received waveform to the sample rate required for OFDM demodulation and then synchronize it to the first frame boundary. Finally, the received waveform is demodulated to recover the resource grid, as shown in the following code:

```

% Obtain sampling rate and resample for OFDM demodulation
info = lteOFDMInfo(cfg);
cfg.SamplingRate = info.SamplingRate;
rxwaveform = resample(rxwaveform,cfg.SamplingRate,capsr);

% Synchronize to the first frame head
offset = lteDLFrameOffset(cfg,rxwaveform);
rxwaveform = rxwaveform(1+offset:end,:);

% OFDM demodulate to recover resource grid
rxgrid = lteOFDMDemodulate(cfg,rxwaveform);

```

Capturing Signal Analysis

We now analyze the recovered waveform `rxwaveform` and resource grid `rxgrid`. LTE System Toolbox provides functions and examples for signal analysis, including adjacent channel leakage power ratio (ACLR) and error vector magnitude (EVM).

LTE System Toolbox helper functions `hACLRMeasurementEUTRA.m` and `hACLRMeasurementUTRA.m` measure the E-UTRA and UTRA ACLR for the received waveform. To learn more about ACLR measurement, see the example [LTE Downlink Adjacent Channel Leakage Power Ratio \(ACLR\) Measurement](#) [2].

```
% Calculate ACLR measurement parameters
rmc.UTRACHipRate = 3.84; % UTRA chip rate in MCPS
[acldr, nRC, R_C, BWUTRA] = hACLRParameters(cfg);

% Apply required oversampling
resampled = resample(rxwaveform,acldr.OSR,1);

% Measure E-UTRA ACLR
acldr = hACLRMeasurementEUTRA(acldr,resampled);
acldr = hACLRMeasurementUTRA(acldr,resampled,nRC,R_C,BWUTRA);
```

MATLAB can create custom plots for data visualization, as shown in the graphs depicting ACLR measurement results (Figure 4).

The helper function `hPDSCH EVM.m` measures the PDSCH EVM. For more information about measuring EVM, see [PDSCH Error Vector Magnitude \(EVM\) Measurement](#) [3] and [LTE Uplink EVM and In-Band Emissions Measurements](#) [4].

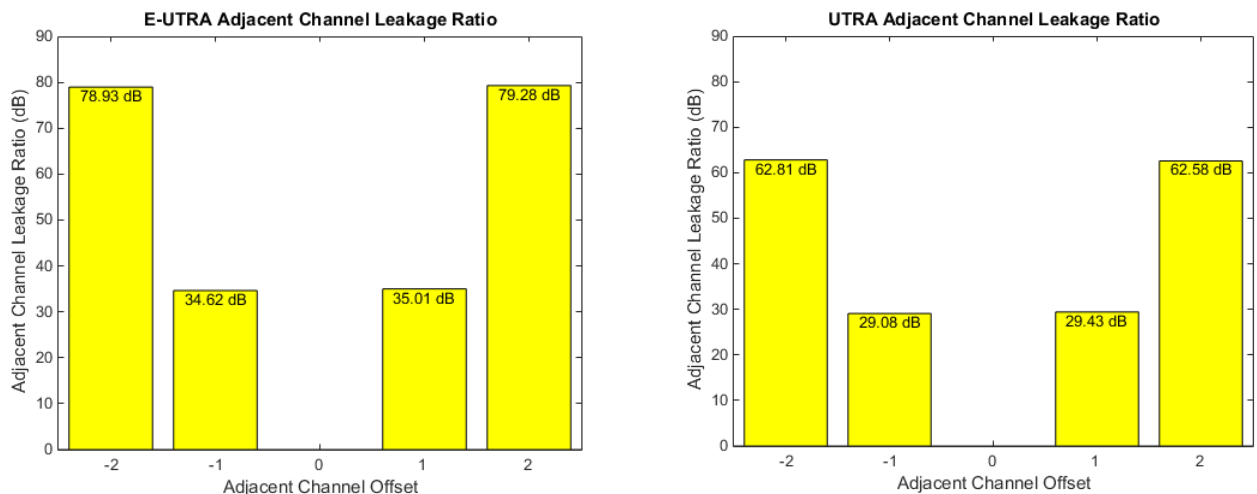


Figure 4. Example visualization of UTRA and E-UTRA ACLR measurement results.

```
% Configure the channel estimator to average over frequency and time
```

```
cec.PilotAverage = 'UserDefined';
```

```
cec.FreqWindow = 9;
```

```
cec.TimeWindow = 9;
```

```
cec.InterpType = 'cubic';
```

```
cec.InterpWinSize = 3;
```

```
cec.InterpWindow = 'Causal';
```

```
% Perform EVM measurement
```

```
evmMeas = hPDSCEVM(cfg,cec,rxwaveform);
```

The returned structure contains the measured peak EVM (5.0%), RMS EVM (1.2%), and an array, EV, containing the error vector for each PDSCH symbol.

```
evmmeas =  
    Peak: 0.0509  
    RMS: 0.0127  
    EV: [10464x1 double]
```

Summary

This example illustrated how to use Instrument Control Toolbox when working with live LTE signals. We created a baseband waveform using LTE System Toolbox and generated an over-the-air signal using an RF signal generator. We captured this signal and then analyzed it using MATLAB and Instrument Control Toolbox. This process streamlines the design and verification of LTE systems by expediting hardware test and measurement when working with live LTE signals.

References

[1] *Cell Search, MIB, and SIB1 Recovery*,

mathworks.com/help/lte/examples/cell-search-mib-and-sib1-recovery.html

[2] *LTE Downlink Adjacent Channel Leakage Power Ratio (ACLR) Measurement*,

mathworks.com/help/lte/examples/lte-downlink-adjacent-channel-leakage-power-ratio-aclr-measurement.html

[3] *PDSCH Error Vector Magnitude (EVM) Measurement*,

mathworks.com/help/lte/examples/pdsch-error-vector-magnitude-evm-measurement.html

[4] *LTE Uplink EVM and In-Band Emissions Measurements*,

mathworks.com/help/lte/examples/lte-uplink-evm-and-in-band-emissions-measurements.html

Products Used

MATLAB

DSP System Toolbox

Instrument Control Toolbox

LTE System Toolbox

Learn More

Introducing LTE System Toolbox 44:57 (Webinar)

mathworks.com/videos/introducing-lte-system-toolbox-91920.html

Developing Measurement and Analysis Systems Using MATLAB 50:53 (Webinar)

mathworks.com/videos/developing-measurement-and-analysis-systems-using-matlab-81938.html

Waveform Generation and Analysis using LTE System Toolbox with Test and Measurement Equipment (Example)

mathworks.com/help/releases/R2014a/lte/examples/waveform-generation-and-analysis-using-lte-system-toolbox-with-test-and-measurement-equipment.html

PDSCH Error Vector Magnitude (EVM) Measurement (Example)

mathworks.com/help/releases/R2014a/lte/examples/pdsch-error-vector-magnitude-evm-measurement.html

LTE Uplink EVM and In-Band Emissions Measurements (Example)

mathworks.com/help/releases/R2014a/lte/examples/lte-uplink-evm-and-in-band-emissions-measurements.html