Generating and Analyzing LTE Signals

Presented by: Frederic Bis

Agilent Technologies
Topics

• LTE Frame Structure Overview
  – Downlink
  – Uplink
• LTE Transmitter Tests – Signal Analysis
• LTE Component and Receiver Test – Signal Generation
• Demo
• Summary
• Q&A
Downlink frame structure type 1

$N_{\text{sym}}^{\text{DL}}$ OFDM symbols (= 7 OFDM symbols @ Normal CP)

1 slot = 15360 Ts = 0.5 ms

1 sub-frame = 2 slots = 1 ms

1 frame = 10 sub-frames = 10 ms

P-SCH - Primary Synchronization Channel
S-SCH - Secondary Synchronization Channel
PBCH - Physical Broadcast Channel
PDCCH - Physical Downlink Control Channel
PDSCH - Physical Downlink Shared Channel
Reference Signal – (Pilot)
Downlink – Let’s check it by VSA

- P-SCH - Primary Synchronization Channel
- S-SCH - Secondary Synchronization Channel
- PBCH - Physical Broadcast Channel
- PDCCH - Physical Downlink Control Channel
- PDSCH – Physical Downlink Shared Channel
- Reference Signal – (Pilot)

Slot#0 Symbol#0
RS + PDCCH
Downlink – Let’s check it by VSA

- P-SCH - Primary Synchronization Channel
- S-SCH - Secondary Synchronization Channel
- PBCH - Physical Broadcast Channel
- PDCCH - Physical Downlink Control Channel
- PDSCH – Physical Downlink Shared Channel
- Reference Signal – (Pilot)

Slot#0 Symbol#6

P-SCH + PDSCH
Downlink – Let’s check it by VSA

- P-SCH - Primary Synchronization Channel
- S-SCH - Secondary Synchronization Channel
- PBCH - Physical Broadcast Channel
- PDCCH - Physical Downlink Control Channel
- PDSCH – Physical Downlink Shared Channel
- Reference Signal – (Pilot)

Slot#1 Symbol#0
RS + PBCH + PDSCH

Agilent B9600 Vector Signal Analyzer

[Image of VSA interface showing signal analysis results]
**Uplink frame structure type 1**

**PUSCH mapping**

\( N_{symb}^{DL} \) OFDM symbols (= 7 OFDM symbols @ Normal CP)

- CP 0 CP 1 CP 2 CP 3 CP 4 CP 5 CP 6

1 slot = 15360 Ts = 0.5 ms

\( Ts = 1/(15000 \times 2048) = 32.6 \text{ ns} \)

1 sub-frame
= 2 slots
= 1 ms

1 frame
= 10 sub-frames
= 10 ms

The Cyclic Prefix is created by prepending each symbol with a copy of the end of the symbol.

PUSCH - Physical Uplink shared Channel

Reference Signal – (Demodulation)
Uplink – Let’s check it by VSA

**PUSCH - Primary Uplink Shared Channel**
**Reference Signal – (Demodulation)**

Slot #0 Symbol #0

**PUSCH**
Uplink – Let’s check it by VSA

- PUSCH - Primary Uplink Shared Channel
- Reference Signal – (Demodulation)

Slot #0 Symbol #3
PUSCH-DMRS

Agilent Technologies
Topics

• LTE Frame Structure Overview
  – Downlink
  – Uplink
• LTE Transmitter Tests – Signal Analysis
• LTE Component and Receiver Test – Signal Generation
• Demo
• Summary
• Q&A
LTE Signal Analysis - 89601A Vector Signal Analysis Software

Features/Capabilities Summary

- LTE downlink (OFDMA) and uplink (SC-FDMA) analysis in a single option
- Industry leading performance: EVM of < -50 dB (hardware dependent)
- FDD mode, Type 1 generic frame structure
- All LTE bandwidths: 1.4 MHz to 20 MHz
- All LTE modulation formats: BPSK, QPSK, 16 QAM and 64 QAM
- All LTE modulation sequences: CAZAC, OSxPRS
- Supports all Agilent signal analyzers: PSA, MXA, EXA, 89600 as well as Agilent logic analyzers and scopes
- Connectivity with Agilent’s Advance Design System (ADS) LTE wireless library
Consistent Measurement SW = Correlation of results across the block diagram

**DUT**

- **Digital (SSI)**
- **BB (I-Q)**
- **IF/RF**

---

**Logic Analyzer**

**Oscilloscope**

**Signal Analyzer**

**ADS connectivity**

Direct connection to ADS LTE signal simulation output using ADS 89600 instrument sink.
N9080A LTE Measurement Application
For Agilent’s X-Series Signal Analyzers

Features/Capabilities Summary

✓ In-depth LTE modulation analysis capability* based on the same feature set as the 89600 VSA software’s option BHD LTE modulation analysis

✓ Embedded solution with Hard-key/Soft-key MUI and SCPI RUI—no need for external PC

✓ LTE downlink (OFDMA) and uplink (SC-FDMA) analysis in a single option

✓ LTE FDD frame structure signal according to March 2008 release of 3GPP LTE standard docs (v.8.2.0)

✓ All LTE bandwidths: 1.4 MHz to 20 MHz

✓ All LTE modulation formats and sequences: BPSK, QPSK, 16 QAM and 64 QAM, Zadoff-Chu, OSxPRS

✓ All LTE physical layer channels and signals: Data, control, sync

✓ Color coding by channel type to highlights signal errors

✓ Supports Agilent’s MXA and EXA** Signal Analyzers

* Initial release is modulation quality measurements, one button RF power measurements to follow in 2009. Until then customer must use Power Suite and manually setup power measurements.

** EXA can only be used for LTE BW ≤ 10 MHz
Transmitter Characteristics – eNB

- 6.2 Base Station Output Power
- 6.3 Output Power Dynamics
- 6.4 Transmit ON/OFF Power
- 6.5 Transmit Signal Quality
  - 6.5.1 Frequency Error
  - 6.5.2 Error Vector Magnitude
  - 6.5.3 Time alignment between transmitter branches
- 6.6 Unwanted Emissions
  - 6.6.1 Occupied bandwidth
  - 6.6.2 Adjacent Channel Leakage Power Ratio (ACLR)
  - 6.6.3 Operating band unwanted emissions (same as SEM)
  - 6.6.4 Transmitter spurious emission
- 6.7 Transmit Intermodulation

These transmitter tests are work in progress and the definitions and requirements covered in this presentation are working assumptions per TR36.804 v 1.0.0 & TS 36.104 V8.1.0
Transmitter Characteristics – UE

- 6.2 Transmit Power
- 6.3 Output Power Dynamics
- 6.4 Control and Monitoring Functions
- **6.5 Transmit Signal Quality**
  - 6.5.1 Frequency error
  - 6.5.2 Transmit modulation
- **6.6 Output RF Spectrum Emissions**
  - 6.6.1 Occupied bandwidth
  - 6.6.2 Out of band emission
    - 6.6.2.1 Spectrum emission mask (SEM)
    - 6.6.2.3 Adjacent channel leakage power ratio (ACLR)
  - 6.6.3 Spurious emissions
- 6.7 Transmit Intermodulation

These transmitter tests are work in progress and the definitions and requirements covered in this presentation are working assumptions per TR36.803 v 1.0.0 & TS 36.101 v8.1.0
Transmit Power – UE

- MOP (Maximum Output Power)
  - Method: broadband power measurement
    (No change)
- MPR (Maximum Power Reduction)
  - Definition: Power reduction capability to meet ACLR requirements
  - It depends on modulation format and number of RB (Resource Block)
  - MPR and A-MPR (Additional MPR)

Agilent 89601A VSA provides power measurement for each active channel after demodulation
Output RF Spectrum Emissions

Unwanted emissions consist of:

1. **Occupied Bandwidth**: Emission within the occupied bandwidth

2. **Out-of-Band (OOB) Emissions**
   - Adjacent Channel Leakage Power Ratio (ACLR)
   - Spectrum Emission Mask (SEM)

3. **Spurious Emissions**: Far out emissions
Occupied Bandwidth Requirement

- **Occupied bandwidth**
  Occupied bandwidth is a measure of the bandwidth containing 99% of the total integrated mean power of the transmitted spectrum on the assigned channel.

**Minimum Requirement:** The occupied bandwidth shall be less than the channel bandwidth specified in the table below.

<table>
<thead>
<tr>
<th>Channel bandwidth [MHz]</th>
<th>1.4</th>
<th>3.0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Transmission bandwidth configuration for FDD</td>
<td>6 RB (1.08 MHz)</td>
<td>15 RB (2.7 MHz)</td>
<td>25 RB (4.5 MHz)</td>
<td>50 RB (9 MHz)</td>
<td>75 RB (13.5 MHz)</td>
<td>100 RB (18 MHz)</td>
</tr>
</tbody>
</table>
ACLAR Requirements – eNB case

- Adjacent Channel Leakage power Ratio (ACLR) is the ratio of the filtered mean power centred on the assigned channel frequency to the filtered mean power centred on an adjacent channel frequency.

- ACLR defined for two cases:
  - E-UTRA (LTE) ACLR 1 and ACLR 2 with rectangular measurement filter
  - UTRA (W-CDMA) ACLR 1 and ACLR 2 with 3.84 MHz RRC measurement filter with roll-off factor $\alpha = 0.22$. 

ACLAR limits defined for adjacent LTE carriers

ACLAR limits defined for adjacent UTRA carriers
## ACLR Limits – eNB case

<table>
<thead>
<tr>
<th>E-UTRA Channel BW (MHz)</th>
<th>ACLR limit for 1st and 2nd Adjacent channel relative to assigned channel frequency [dB]</th>
<th>UTRA(^1) 5.0 MHz</th>
<th>E-UTRA(^2) 1.4 MHz</th>
<th>E-UTRA(^2) 3.0 MHz</th>
<th>E-UTRA(^2) 5.0 MHz</th>
<th>E-UTRA(^2) 10 MHz</th>
<th>E-UTRA(^2) 15 MHz</th>
<th>E-UTRA(^2) 20 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4</td>
<td>ACLR 1 [45]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>ACLR 2 [45]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3.0</td>
<td>ACLR 1 [45]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>ACLR 2 [45]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>ACLR 1 [45]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>ACLR 2 [45]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>ACLR 1 [45]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>[45]</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>ACLR 2 [45]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>[45]</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>ACLR 1 [45]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>[45]</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>ACLR 2 [45]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>[45]</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>ACLR 1 [45]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>[45]</td>
</tr>
<tr>
<td></td>
<td>ACLR 2 [45]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>[45]</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Measured with a 3.84 MHz bandwidth RRC filter with roll-off factor \(\alpha = 0.22\) centered on the adjacent channel.
2. Measured with a rectangular filter with a bandwidth equal to the transmission bandwidth configuration \(N_{RB} \cdot 180\) kHz centered on the 1st or 2nd adjacent channel.

TR 36.804 v1.0.0 Table 6.6.2.3-1: Working assumption for BS ACLR for adjacent E-UTRA carriers (paired spectrum)
ACLR Requirements – UE case

ACLR defined for two cases:

- E-UTRA (LTE) ACLR1 with rectangular measurement filter
- UTRA (W-CDMA) ACLR1 and ACLR 2 with 3.84 MHz RRC measurement filter with roll-off factor \( \alpha = 0.22 \).

The data presented in this slide is still 3GPP working assumptions.
### ACLR Limits – UE case

#### In the case of LTE adjacent carrier:

<table>
<thead>
<tr>
<th></th>
<th>Channel bandwidth / E-UTRA&lt;sub&gt;ACLR1&lt;/sub&gt; / measurement bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.4 MHz</td>
</tr>
<tr>
<td>E-UTRA&lt;sub&gt;ACLR1&lt;/sub&gt;</td>
<td>30 dB</td>
</tr>
<tr>
<td>E-UTRA channel Measurement bandwidth</td>
<td>4.5 MHz</td>
</tr>
</tbody>
</table>

TS 36.101 v8.1.0 Table 6.6.2.3.1-1: General requirements for E-UTRA<sub>ACLR</sub>

#### In the case of W-CDMA adjacent carriers:

<table>
<thead>
<tr>
<th></th>
<th>Channel bandwidth / UTRA&lt;sub&gt;ACLR1/2&lt;/sub&gt; / measurement bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.4 MHz</td>
</tr>
<tr>
<td>UTRA&lt;sub&gt;ACLR1&lt;/sub&gt;</td>
<td>33 dB</td>
</tr>
<tr>
<td>UTRA&lt;sub&gt;ACLR2&lt;/sub&gt;</td>
<td>-</td>
</tr>
<tr>
<td>E-UTRA channel Measurement bandwidth</td>
<td>-</td>
</tr>
<tr>
<td>UTRA channel Measurement bandwidth</td>
<td>-</td>
</tr>
</tbody>
</table>

TS 36.101 v8.1.0 Table 6.6.2.3.2-1: Additional requirements
Spectrum Emission Mask (SEM)

Spectrum emissions mask is also known as “Operating Band Unwanted emissions”

These unwanted emissions are resulting from the modulation process and non-linearity in the transmitter but excluding spurious emissions.

eNB example:
Base station SEM limits are defined from 10 MHz below the lowest frequency of the BS transmitter operating band up to 10 MHz above the highest frequency of the BS transmitter operating band.

TR 36.804 v1.0.0 figure 6.6.2.2-1 Defined frequency range for Operating band unwanted emissions with an example RF carrier and related mask shape (actual limits are TBD).
Spectrum Emission Mask – UE Example

Regulatory Masks + Proposed 20MHz LTE Mask

TR 36.803 v1.0.0 Figure 6.6.2.1-1: Regulatory mask and proposed E-UTRA masks
Spurious Emission Requirements

Spurious emissions are emissions caused by unwanted transmitter effects such as harmonics emission & intermodulation products but exclude out of band emissions.

Example of spurious emissions limit for a UE

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Maximum Level</th>
<th>Measurement Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 kHz ≤ f &lt; 150 kHz</td>
<td>-36 dBm</td>
<td>1 kHz</td>
</tr>
<tr>
<td>150 kHz ≤ f &lt; 30 MHz</td>
<td>-36 dBm</td>
<td>10 kHz</td>
</tr>
<tr>
<td>30 MHz ≤ f &lt; 1000 MHz</td>
<td>-36 dBm</td>
<td>100 kHz</td>
</tr>
<tr>
<td>1 GHz ≤ f &lt; 12.75 GHz</td>
<td>-30 dBm</td>
<td>1 MHz</td>
</tr>
</tbody>
</table>

TS 36.101 v8.1.0 table 6.6.3.1-2: Spurious emissions limits
Transmitter Tester for RF Power Measurements

- Agilent’s PSA, MXA and EXA signal analyzers have flexible power suite measurements that can be set to make Channel Power, ACP, SEM and Spurious emission tests.
Frequency Error Test

If the frequency error is larger than a few sub-carriers, the receiver demod may not operate, and could cause network interference

- A quick test is use the Occupied BW measurement (Agilent 89601A VSA SW shown)
- An accurate measurement can then be made using the demodulation process

• Minimum Requirement:
  – UE: ±0.1 ppm
  – Wide Area BS: ±0.05 ppm
  – Medium Range and Local Area BS: TBD
Error Vector Magnitude Measurement eNB – Downlink (OFDM)

The basic unit of EVM measurement is defined over one subframe (1ms) in the time domain and 12 subcarriers (180kHz) in the frequency domain.

Measurement Block: EVM is measured after the FFT and a zero-forcing (ZF) equalizer in the receiver.

Current working assumptions for downlink EVM limits are:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK</td>
<td>%</td>
<td>[17.5]</td>
</tr>
<tr>
<td>16QAM</td>
<td>%</td>
<td>[12.5]</td>
</tr>
<tr>
<td>64QAM</td>
<td>%</td>
<td>[7 to 8]</td>
</tr>
</tbody>
</table>

Agilent Signal Analyzer EVM Performance – Both Uplink and Downlink

<table>
<thead>
<tr>
<th>Signal BW</th>
<th>89650S (typ)</th>
<th>MXA (typ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 MHz</td>
<td>0.28 %</td>
<td>0.5 %</td>
</tr>
<tr>
<td>10 MHz</td>
<td>0.32 %</td>
<td>0.5 %</td>
</tr>
<tr>
<td>20 MHz</td>
<td>0.35 %</td>
<td>0.56 %</td>
</tr>
</tbody>
</table>
For the downlink, the EVM equalizer has been constrained. Rather than use all the RS data to correct the received signal, a moving average is performed in the frequency domain across the channel which limits the rate of change of correction.

For uplink, it has not yet been fully defined. The current proposal is to use a similar approach to WiMAX, which is to use an unconstrained equalizer.
Error Vector Magnitude Measurement
UE – Uplink (SC-FDMA)

\[ EVM = \sqrt{\frac{\sum_{v \in T_m} |z'(v) - i(v)|^2}{|T_m| \cdot P_0}} \]

for allocated Resource Block

- \( z'(v) \) is modified signal under test
- \( i(v) \) is the ideal signal reconstructed by the measurement equipment
Error Vector Magnitude Requirements
UE – Uplink

- EVM requirements are still to be finalized
- Currently there are three requirements under the transmit modulation category for a UE:
  1. **EVM** for allocated resource blocks
  2. **In-Band Emission** for non-allocated resource blocks
  3. **I/Q Component** (also known as carrier leakage power or I/Q origin offset) for non-allocated resource blocks

Let’s look at each one of these transmit modulation requirements…
Error Vector Magnitude Requirements

UE – Uplink

EVM – For allocated resource blocks

• EVM is a measure of the difference between the reference waveform and the measured waveform

Minimum requirement
For signals above -40 dBm, the RMS EVM for the different modulations must not exceed the value in the table below

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK</td>
<td>%</td>
<td>17.5</td>
</tr>
<tr>
<td>16QAM</td>
<td>%</td>
<td>12.5</td>
</tr>
<tr>
<td>64QAM</td>
<td>%</td>
<td>[tbd]</td>
</tr>
</tbody>
</table>

• It is not expected that 64QAM will be allocated at the edge of the signal

TS 36.101 v8.1.0 Table 6.5.2.1.1-1: Minimum requirements for Error Vector Magnitude
Error Vector Magnitude Requirements

UE – Uplink Cont..

In-band emission – For non-allocated resource blocks
The in-band emission is measured as the relative UE output power of any non-allocated RB(s) and the total UE output power of all the allocated RB(s)

Minimum requirements
The relative in-band emission must not exceed the values in the table below

<table>
<thead>
<tr>
<th>In band emission</th>
<th>Relative emissions (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[ \max[-25, (20 \cdot \log_{10} EVM) - 3 - 10 \cdot (\Delta_{RB} - 1) / N_{RB}] ]</td>
</tr>
</tbody>
</table>
Error Vector Magnitude Requirements
UE – Uplink cont..

I/Q Component – For non-allocated resource blocks
I/Q Component reveals the magnitude of the carrier feedthrough present in the signal

Minimum requirements
The relative carrier leakage power (I/Q origin offset power) must not exceed the values in table below:

<table>
<thead>
<tr>
<th>LO Leakage</th>
<th>Parameters</th>
<th>Relative Limit (dBc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power &gt;0 dBm</td>
<td></td>
<td>-25</td>
</tr>
<tr>
<td>-30 dBm ≤ Output power ≤0 dBm</td>
<td></td>
<td>-20</td>
</tr>
<tr>
<td>[-40] dBm ≤ Output power &lt; -30 dBm</td>
<td></td>
<td>[-10]</td>
</tr>
</tbody>
</table>

TS 36.101 v8.1.0 Table 6.5.2.2.1-1: Minimum requirements for Relative Carrier Leakage Power
Important notes on EVM
No transmit/receive filter will be defined

• In UMTS a transmit/receive filter was defined
  – Root raised cosine $\alpha = 0.22$
• This filter was also used to make EVM measurements
  – Deviations from the ideal filter increased the measured EVM
• In LTE with OFDMA/SC-FDMA no filter is defined
• The lack of a filter creates opportunities and problems:
  – Signal generation can be optimized to meet in-channel and out of channel requirements
  – Signal reception and measurement have no standard reference
• It is expected that real receivers will use the downlink reference signals (pilots) to correct for frequency and phase
  – But no standard for how to do this will be specified
OFDMA & SC-FDMA Demodulation Measurements

Color code relates EVM reading to a specific channel. This is an example for Uplink (SC-FDMA) but same measurements are available for Downlink (OFDMA) as well.
EVM Measurement – OFDMA & SC-FDMA

- Various EVM metrics are available on 89601A LTE application:
  - Composite RMS EVM
  - Peak EVM
  - Data EVM
  - Reference Signal (pilot) EVM
  - EVM for individual active channels
  - EVM for non-allocated resource blocks
Modulation Analysis
16QAM data plus CAZAC Reference Signal

The 16QAM data channel

The reference signal (pilot)

The Non-Allocated subcarriers are shown at the centre (Note: this can be turned off)
I-Q impairments such as IQ gain imbalance and quadrature skew create an image for each OFDM subcarrier, which falls in-channel and adds to the “mirror” subcarrier as a distortion component. Thus, the image of subcarrier -150 affects subcarrier 150, etc.

108 allocated subcarriers
= 9 RB = 1.6 MHz

Approx -30 dBc
in-band spurious emissions
at the image subcarrier
frequencies created using a
0.5 dB IQ gain imbalance

LO leakage around -
39 dBc caused by IQ impairments
EVM For Allocated & Non-Allocated Resource Blocks

The instantaneous EVM of the allocated subcarriers is shown in red and the average over the measurement interval is in white.

EVM for the LO feed through and non-allocated subcarriers is measureable but these impairments are specified separately from EVM as shown on previous slides.
EVM Traces to Reveal Filter Effects

The RB’s and subcarriers at the edges have high EVM because of the fast roll-off of the filter used.
Channel Response Traces

Amplitude flatness ± 0.05 dB
Phase flatness ± 0.5 degrees
Topics

• LTE Frame Structure Overview
  – Downlink
  – Uplink
• LTE Transmitter Tests – Signal Analysis
• LTE Component and Receiver Test – Signal Generation
• Demo
• Summary
• Q&A
N7624B Signal Studio for 3GPP LTE

A user-friendly, parameterized and reconfigurable 3GPP LTE signal creation software for use with Agilent E4438C ESG or N5182A MXG signal generators.

- Supports 3GPP TS36.211 and TS36.212 (Release 8 2007-09)
- Provides partially- and fully-coded uplink and downlink signals for component and receiver testing
- Includes signals with MIMO encoding and static fading
Signal Generation: Two Major Challenges

1: Creating partially-coded spectrally-correct signals for component test
   – simulate real-world signals to adequately stress amplifiers, I/Q modulators, filters and other components (e.g. CCDF, PAPR)
   – ensure component measurement results are minimally affected by the signal generator performance (e.g. EVM, ACPR)
   – provide flexibility to test performance with a wide variety of signals

2: Creating fully-coded signals for receiver test
   – generate fully-coded signals that enable block error rate (BLER) and bit error rate (BER) testing
   – provide flexibility to test receiver performance with a wide variety of signals
   – provide ability to add impairments
   – provide encoding and fading for MIMO signals
Test Signal Flexibility with Signal Studio

- Easy-to-use pre-defined setups and ability to define custom configurations
- Settable LTE downlink and uplink waveform parameters
  - Bandwidth (up to 20 MHz)
  - Cyclic prefix (Normal or Extended)
  - Modulation type (QPSK, 16QAM, or 64QAM)
  - Payload data (PN sequence or user-defined)
  - Downlink synchronization signals
  - Downlink reference signal with frequency shifting
  - Uplink demodulation reference signal
  - Uplink demodulation reference signal cyclic shift
  - Multiple carriers (up to 16)
- Allocate resources at the resource block, physical channel, or transport channel level
- Generate fully coded signals on downlink and uplink shared channels with Advanced capability
  - Transport/Physical layer coding
  - Transport/Physical layer mapping
  - MIMO pre-coding with static fading
- Display resource element allocation, CCDF curves, and waveform plots
- Add W-CDMA signals to evaluate interference between W-CDMA and 3GPP LTE signals
Testing Power Amplifiers

• The non-linear characteristics of amplifiers affect in- and out-of-channel performance of the eNB or UE transmitter
• EVM is a key in-channel metric of amplifier performance
• ACLR is key out-of-channel metric
• Examples of signals used to test amplifiers:
  – varying bandwidth up to 20 MHz
  – multi-carrier, e.g. four 5 MHz, for eNB amplifier: all LTE, or mixed LTE & W-CDMA/HSPA
  – varying signal configuration to simulate worse case scenario for DUT: bursted or non-bursted, heavily or lightly loaded resource configurations
- Varying signal content results in different PAPR (peak-to-average power ratio) as shown by CCDF curve.
- Example: Uplink signal with only control channel transmission vs with full data on shared channel.
- PUCCH only results in higher PAPR, so more stress on amplifier.
- Solving test need: Signal generation flexibility to test under real-world worse case conditions.
Amplifier Performance - ACLR

LTE QPSK-5MHz 4 carriers
- eNB spec -45 dBc
- amplifier expectation -55 dBc
- desired sig gen -65 dBc
- actual sig gen -68 dBc

Mixed LTE QPSK-5MHz / W-CDMA test model 1-64DPCH
- eNB spec -45 dBc
- amplifier expectation -55 dBc
- desired sig gen -65 dBc
- actual sig gen -68 dBc adjacent to LTE
- -70 dBc adjacent to W-CDMA

LTE 64QAM-20MHz 1 carrier
- eNB spec -45 dBc
- amplifier expectation -55 dBc
- desired sig gen -65 dBc
- actual sig gen -71 dBc
Types of Receiver Test – Uplink & Downlink

Receiver characteristics:
- Reference sensitivity level
- Dynamic range
- Adjacent Channel Selectivity (ACS)
- Blocking characteristics
- Intermodulation characteristics
- In-channel selectivity
- Spurious emissions

Note: These receiver characteristics are work in progress for the LTE standard. Definitions and test requirements are still incomplete and evolving!

Solving test needs:
- Flexibility to easily create varying signals that simulate real-world conditions
- Signal generation capability that evolves as the standard evolves to ensure most accurate test results
2x1, 4x1 Tx Diversity with static multipath fading

N7624B: Signal Studio

2x1 Tx Diversity

<table>
<thead>
<tr>
<th>Quick Setup Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>M x 1</td>
<td>1 Antenna (Sim HW)</td>
</tr>
<tr>
<td>M x 2</td>
<td>2 Antennas (Sim HW)</td>
</tr>
<tr>
<td>M x 4</td>
<td>4 Antennas (Sim HW)</td>
</tr>
</tbody>
</table>

Total number of Antennas: 2 Antennas

4. Fading
   - Channel State: On
   - Channel Type: Static
   - Number of BS Antennas: 2
   - Number of MS Antennas: 1
   - Channel Parameters: Static Fading Profile Setting
     - Multi-Paths Setting (Static): 1 Paths, 1 Paths

Enable each Transmission Path

Channel H00
   - Enable: On
   - Delay(us): 0
   - Power(dB): 0.00
   - Phase(deg): 0.00

Channel H10
   - Enable: On
   - Delay(us): 0
   - Power(dB): 0.00
   - Phase(deg): 0.00
2x2, 4x4 Spatial Multiplexing with CDD and static multipath fading

### 2x2 SDM

<table>
<thead>
<tr>
<th>Quick Setup Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>M x 1</td>
<td>1 Antenna (Sim HW)</td>
</tr>
<tr>
<td>M x 2</td>
<td>2 Antennas (Sim HW)</td>
</tr>
<tr>
<td>M x 4</td>
<td>4 Antennas (Sim HW)</td>
</tr>
</tbody>
</table>

Enable each Transmission Path

### Proper matrix is selected

#### 3. MIMO

<table>
<thead>
<tr>
<th>Diversity Method</th>
<th>Spatial Multiplexing</th>
<th>Codebook index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small-delay CDD</td>
<td>0</td>
</tr>
</tbody>
</table>

#### Cyclic Delay Diversity

- Zero-delay CDD
- Small-delay CDD
- Large-delay CDD

### 4. Fading

<table>
<thead>
<tr>
<th>Channel State</th>
<th>On</th>
</tr>
</thead>
</table>

| Channel Type  | Static |

| Number of BS Antennas | 2 |
| Number of MS Antennas | 2 |

<table>
<thead>
<tr>
<th>Channel Parameters</th>
<th>MultiPaths Settings (Static)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Paths, 1 Paths, 1 Paths, 1 Paths</td>
</tr>
</tbody>
</table>

Enabled channels are:

- Channel H00
- Channel H01
- Channel H10
- Channel H11
Coded signal for BLER measurement

BLER measurement is possible at every TTI (subframe)
N7624B provides multiple DL-SCH up to 8
For UE BLER measurement
eNB capacity verification with multiple UEs

N7624B provides multiple UE up to 16 with cyclic shift for eNB capacity verification (overloading test)
Topics

• LTE Frame Structure Overview
  – Downlink
  – Uplink
• LTE Transmitter Tests – Signal Analysis
• LTE Component and Receiver Test – Signal Generation
• Demo
• Summary
• Q&A
Measurement & Troubleshooting Trilogy
Three Steps to successful Signal Analysis

Step 1: Frequency, Frequency & Time
Get basics right, find major problems

Component design - R&D
Base station and receiver design - R&D

Step 2: Basic Digital Demod
Signal quality numbers, constellation, basic error vector meas.

Component design - R&D
Base station and receiver design - R&D

Step 3: Advanced & Specific Demod
Find specific problems & causes

Base station and receiver design - R&D
Learn by Making Measurements

- 89601A VSA Software, Free Demo License, N7624B Signal Studio, Free Simulation Mode
  - Recorded signals provided: perform any kind of vector analysis or demodulation
  - Simulated hardware
  - Tutorials
  - Troubleshooting help
  - Example displays
- 14-day Free Trial Licenses
  - Connect to hardware
  - Generate, download & play back signals
- Tech Overviews, Demo Guides
Topics

• LTE Frame Structure Overview
  – Downlink
  – Uplink
• LTE Transmitter Tests – Signal Analysis
• LTE Component and Receiver Test – Signal Generation
• Demo
• Wrap-Up
• Q&A
Agilent 3GPP LTE Portfolio

**Software Solutions**
- E8895 ADS LTE Library
- N7624B LTE Signal Studio
- 89601A LTE VSA Software

**Analyzers, Sources, Scopes, Logic Analyzers**

**E6620A Wireless Communications Platform**

**Agilent/Anite SAT LTE – Protocol Development Toolset**

**MXA/MXG R&D**

**Digital VSA**

**Network Analyzers, Power supplies, and More!**

**Coming Soon!**

**NEW!**

**Coming Soon!**

**NEW!**

**NEW!**

**Product development**

**Conformance & IOT**

**Deployment**
Topics

• LTE Frame Structure Overview
  – Frame Structure for Downlink
  – Frame Structure for Uplink
• LTE Transmitter Tests – Signal Analysis
• LTE Component and Receiver Test – Signal Generation
• Demo
• Wrap-up
• Q&A
Questions?

Thank you for your attention!
You take LTE forward Agilent clears the way

www.agilent.com/find/lte