Overview

The 3GPP Long Term Evolution (LTE) standard moves beyond current 3G wireless communications capabilities to provide increased peak data rates, improved spectral efficiency, and reduced user plane and control plane latency. To realize these performance improvements, the standard relies on highly flexible and dynamic radio technologies, where the control messages are essential to understanding the RF signal. There are three key ingredients to the LTE downlink (DL): Orthogonal Frequency Division Multiple Access (OFDMA), Multiple-Input Multiple-Output (MIMO) and Hybrid Automatic Repeat Request (HARQ). The OFDMA signal format allows rapid adaptation of the signal format to the user’s data bandwidth requirements and channel conditions. MIMO is a smart antenna technology that can deliver increased spectral efficiency. Use of HARQ allows the optimization of overall system performance when many users are present and interference is a limiting factor in overall capacity.

While OFDMA, MIMO and HARQ are critical to enabling the LTE standard, attention to detail is needed to ensure their effective operation. The number and complexity of possible signal formats, coupled with the need to ensure interoperability between devices from different vendors, introduces a multitude of design and test challenges. One of these is to verify the data content and RF structure of the DL signal. Doing so is critical to ensuring LTE devices have been implemented according to the 3GPP Release 8 standard, and to help ensure all base stations and mobile devices work together in real networks.

Problem

Messages in the LTE DL signals provide all the information needed for the base station and mobiles to work together. Engineers require tools to examine their contents. This measurement information is necessary to independently verify baseband signals, find out what is in a third-party base station signal feeding into a User Equipment (UE) receiver, diagnose a low-level interoperability problem, or to just better understand the signal’s structure and its impact on system operation. DL signal information is also valuable in helping the engineer find out why throughput results are not as high as expected.

The construction of the LTE DL signal is the most complex used thus far in the implementation of a cellular system, making its analysis particularly challenging. The content of the transmitted signal is the result of a mixture of messages across several layers in the protocol stack, from the DL Control Information (DCI) to the Master Information Block (MIB) and System Information Blocks (SIBs). The messages are built up to create a highly dynamic signal that changes on every subframe. Verifying the resulting DL signal has been constructed according to the 3GPP Release 8 standard is often accomplished using multiple disparate measurement instruments and can be an error-prone process.
Solution

Today’s engineers are required to deal with problems that cross conventional diagnostic and test boundaries. They need a tool that combines the ability to analyze the radio signal and the messages that determine the RF format. The tool has to be specifically designed to handle the LTE standard’s complexity and can quickly adapt to its changing requirements. Realizing this goal requires flexible signal analysis software that can be used in a software-only environment and with different hardware, such as a general-purpose signal analyzer, a logic analyzer or oscilloscope, to quickly find and isolate any potential problems. Such a tool allows the engineer to examine both physical signals and the decoded information describing them, as well as the link between protocol messages and the actual RF signals they control.

With existing signal analysis software and a signal analyzer, a radio engineer can perform a range of standard-based parametric measurements such as EVM, ACPR and in-band or out-of-band spectrum emission mask. A highly flexible graphical user interface allows the engineer to measure and analyze LTE DL signals from a number of different perspectives in the time, frequency and modulation domains. A remote user interface based on .NET programmability suits the repetitive testing often associated with verification.

In operation, once the DL signal has been constructed, the signal analysis software is first used to create a spectrogram view of the DL RF. This versatile diagnostic tool allows the engineer to examine the signal’s spectrum and time structure, providing a fast, pattern-oriented basic check. Once satisfied with this view, the software’s automatic decoding of the logical, transport and physical channels within the signal (e.g., BCH, CFI, PHICH, PDCCH and PDSCH), enables verification of both configurations and resource allocations.

Using the signal analysis software, the engineer can:

- Examine the DL item by item to identify and check for suspect DCI signals.
- Isolate cyclic redundancy check (CRC) failures and check the configuration when they occur. This is especially critical when there is more than one transmitter in the LTE system, since control messages and user data can be transmitted differently in the same frame.

The 89600B Vector Signal Analysis (VSA) software from Agilent Technologies is a prime example of a solution that is capable of performing these tasks (Figure 1). It provides superior general-purpose and standards-based signal evaluation, and troubleshooting tools that R&D engineers can use to dig into signals and gather the data they need to successfully troubleshoot physical layer signal problems. Moreover, its high-resolution spectrum analysis enables the fast basic check of DL signal structure that today’s engineers demand.

FIGURE 1. Agilent’s 89600B VSA provides many correlated views of an LTE downlink signal, including the detailed message decoding shown in the lower trace. It provides high-resolution spectrum analysis, advanced general-purpose modulation analysis (AM/FM/PM and 2FSK to 1024QAM), extensive standards-based analysis (e.g., LTE (MIMO), WiMAX™ (MIMO), WLAN (MIMO), 3GPP (HSPA+), RFID, and UWB), and a large suite of time-domain analysis tools for burst analysis.
The 89600B VSA supports over 70 demodulation formats and enables advanced signal modulation analysis and troubleshooting of more than 30 standard modulation types, with flexible modulation analysis capabilities for proprietary, non-standardized formats as well. It is compatible with over 30 Agilent signal analyzers, scopes and logic analyzers. Running the software in Agilent’s MXA signal analyzer, coupled with the MXA’s ability to deliver the industry’s widest application and format coverage, allows the engineer to easily measure and troubleshoot signals at both RF and baseband frequencies in a single instrument.

For MIMO verification, an additional MXA analyzer or Agilent’s 90000 X-Series oscilloscope is used (Figure 2). The oscilloscope enables additional characterization of complex, phase-coherent LTE MIMO and beamforming signals with detailed and simultaneous spectrum, modulation and time waveform analysis. This provides the engineer with deeper analysis insight and more accurate signal information that can be used to quickly diagnose and isolate hardware performance issues.

### Checking the DL Signal Spectrum and Time Structure

Spectrograms show how the use of spectrum changes over time and is, therefore, a useful tool for verifying the DL signal’s construction. As shown in the center right traces in Figure 1, using the 89600B VSA, engineers can quickly and accurately create a spectrogram view of the DL RF that enables them to see each signal component down to the individual RS subcarriers. A logical view of the DL signal can also be generated by the 89600B VSA (Figure 3). These are the resource block allocations (RB) detected either by power or from the DCI.

For a number of signal types, it is possible to deduce the signal format from the allocation of power throughout the DL frame. This view can also be helpful when checking the configuration messages. For more complex signals, the decoded allocation information is used for verification. Switching between the 89600B VSA’s power based and decoded detection mode is a powerful mechanism when debugging new or unknown signals.
Examining the Content of the DL Signal

The decoding capability of 89600B VSA is used to extract a wealth of information from the DL signal that can be explored item by item (Figure 4). Much of the information is used to make sure the UE is transmitting and receiving data where it is supposed to. The format of the data must also be correct. Information for a number of control loops is included, from power and MIMO control to uplink and DL HARQ processes.

Using the decoding features, the 89600B VSA can isolate specific decoded DL signals, an especially useful capability when looking at the formatting of the physical layer. Engineers can also move up the stack and examine the messages used to identify traffic of different sorts, which like the Radio Network Temporary Identifiers (RNTI) may be applicable to a specific UE.

The UE has to monitor the DL signal for more than one RNTI at one time. Therefore, during analysis, it’s essential to automatically decode any RNTI that is present, something that can be done with the 89600B VSA. Tracking an RTNI allows CRC failures to be readily isolated for decoding and displaying their content.

By examining the DCI information decoded with the 89600B VSA, the engineer is able to check control operations such as HARQ, to get to the bottom of typical problems, including:

• locating and debugging a PBCH CRC failure;
• identifying an incorrect DCI configuration;
• spotting a CRC failure with MIMO signal;
• resolving the cause of a higher order MCS CRC failure; and
• understanding why a UE under test can’t find the eNB—because of a SIB decoding issue.

Summary of Results

In contrast to the benefits offered by LTE, the complexity of the technology creates significant measurement challenges. Verifying the data in the LTE DL signal is one such challenge. The 89600B VSA signal analysis software allows engineers to dig deep into their signals and extract the information they need to identify and isolate physical layer signal problems. Compatibility to over 30 Agilent X-Series signal and logic analyzers and X-Series scopes ensures engineers have added flexibility to quickly and accurately measure and analyze LTE DL signals from different perspectives and using much more advanced techniques. Together, these instruments provide the fast and accurate solution today’s R&D engineers need to create optimal LTE DL signals.

For UE Transmission

<table>
<thead>
<tr>
<th>How to label its transmissions (RNTI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>When the UE can transmit and where (on which resource blocks)</td>
</tr>
<tr>
<td>Which modulation, transport block size and redundancy version, RV, to use</td>
</tr>
<tr>
<td>Adjustments to align timing with eNB</td>
</tr>
<tr>
<td>Whether to hop the PUSCH or not</td>
</tr>
<tr>
<td>Transmit power level to use</td>
</tr>
<tr>
<td>Transmit new block or re-transmit NACK’d blocks</td>
</tr>
</tbody>
</table>

For UE Reception

<table>
<thead>
<tr>
<th>Which signals to listen for (RNTI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>When and where the UE should listen for DL data. DL data may not be contiguous in frequency</td>
</tr>
<tr>
<td>Which modulation, transport block size and redundancy version were used to send this data Is this downlink spatially multiplexed</td>
</tr>
<tr>
<td>Is this downlink spatially multiplexed</td>
</tr>
<tr>
<td>For a spatially multiplexed DL, what pre-coding has been applied</td>
</tr>
<tr>
<td>Which HARQ does this data belong to</td>
</tr>
<tr>
<td>Is this new data or re-transmitted data?</td>
</tr>
</tbody>
</table>

FIGURE 4. The 89600B VSA extracts the information in this table during analysis of the LTE DL signal.

The Power of X

The Agilent MXA signal analyzer and Infiniium 90000 X-Series high-performance oscilloscopes are key products in Agilent’s comprehensive Power of X suite of test products. These products grant engineers the power to gain greater design insight, speed manufacturing processes, solve tough measurement problems, and get to market ahead of the competition.

Offering the best combination of speed and scalability, and created and supported by renowned worldwide measurement experts, Agilent’s X products are helping engineers bring innovative, higher-performing products to emerging markets around the globe.

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Related Applications

• Testing LTE FDD and TDD Performance using the PXB
• The 89600B VSA can also be used for modulation analysis of the LTE uplink signal and TDD and MIMO downlink signals

Related Agilent Products

• X-Series signal analyzers
• X-Series logic analyzers
• X-Series oscilloscopes
• E6621A (MIMO) real-time eNB emulator
• SystemVue system design software
• Signal Studio LTE waveform creation

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