LTE, Positioning, and the Implications for GNSS Over-the-Air Testing

RONALD BORSATO
SPIRENT COMMUNICATIONS
MICHAEL D. FOEGELLE
ETS-LINDGREN

Typical antenna measurement and OTA test chamber with a multi-position measurement array, device positioner, communication antennas, and phantom head and hand.

Evolving wireless communications technology, the incorporation of GNSS positioning into mobile devices, and increasingly crowded radio frequency spectrum are driving the creation of new specifications and standards for user equipment. Testing procedures and practices are changing in parallel with these developments and receiving additional impetus by real-world experiences such as the recent LightSquared/GPS controversy. Two engineers with extensive backgrounds in standards-setting and testing describe how these circumstances are shaping the evaluation methods for positioning capabilities in mobile devices that incorporate "fourth-generation" or 4G communications technology — including a growing reliance on over-the-air testing.

Long Term Evolution (LTE) technology in mobile communications, often called 4G, is making its way into a host of consumer devices. It started with data-only modules for Internet connectivity but quickly made its mark on smartphones, automotive communication, and embedded modules that provide fast and reliable wireless data connectivity to the machine-to-machine (M2M) market.

Nearly all consumer devices migrating to LTE also have a strong need to provide positioning capabilities, with most consumer applications striving for 5–10-meter accuracy in all environments — something we call "accurate everywhere" location. GNSS systems remain the leading technology for positioning. When coupled to a cellular technology such as LTE, assisted GNSS (A-GNSS), where assistance data is provided by the network) can provide improved location performance by making position fixes faster and with improved yield when used at low GNSS signal strengths.

However, because GNSS signal levels indoors are generally too low to be usable, other technologies — are increasingly employed to ensure accurate everywhere positioning performance. These cellular network positioning techniques include LTE-specific technologies such as observed time difference of arrival (OTDOA) and uplink time difference of arrival (UTDOA), wireless LAN (Wi-Fi) positioning, and micro-electro-mechanical system (MEMS) sensor positioning (accelerometers, barometers, and so forth)

This article discusses location technology in LTE-equipped devices and the implications for GNSS receiver testing. In addition to detailing the new technologies and positioning protocols that have been adopted in conjunction with LTE, industry standardized methods for GNSS testing will be reviewed in detail, with a focus on radiated GNSS antenna performance tests.

Impetus for Receiver Testing

The wireless mobile device industry has long been a proponent of standardized minimum requirement testing of wireless technologies, and this philosophy has held true for all the positioning technologies and positioning-related protocols used in mobile devices. The GNSS community's renewed interest in receiver performance standards (heavily spurred by the U.S. Federal Communications Commission (FCC) in the wake of the LightSquared technical working group testing) makes it more important to understand the GNSS receiver performance standards already in existence.

LTE-specific standardized testing is being driven by two industry organizations. The 3rd Generation Partnership Project (3GPP), a leader in wireless standards-setting, has released the TS 37.571 test specification for use of A-GNSS, OTDOA, and enhanced cell ID (eCID) positioning technology in mobile devices. Moreover, the Effective Radiated Power (ERP) Ad-Hoc group of the CTIA Certification Program is adding LTE A-GNSS over-the-air (OTA) testing in the v3.2 release of the CTIA Test Plan for Wireless Device Over-The-Air Performance (hereafter referred to as the CTIA OTA Test Plan).

Both 3GPP and CTIA test specifications are explained in this article, but the CTIA's approach is dissected in greater detail. The ability of over-the-air testing to account for the radiated performance of GNSS receivers led to its extensive use by the LightSquared technical working

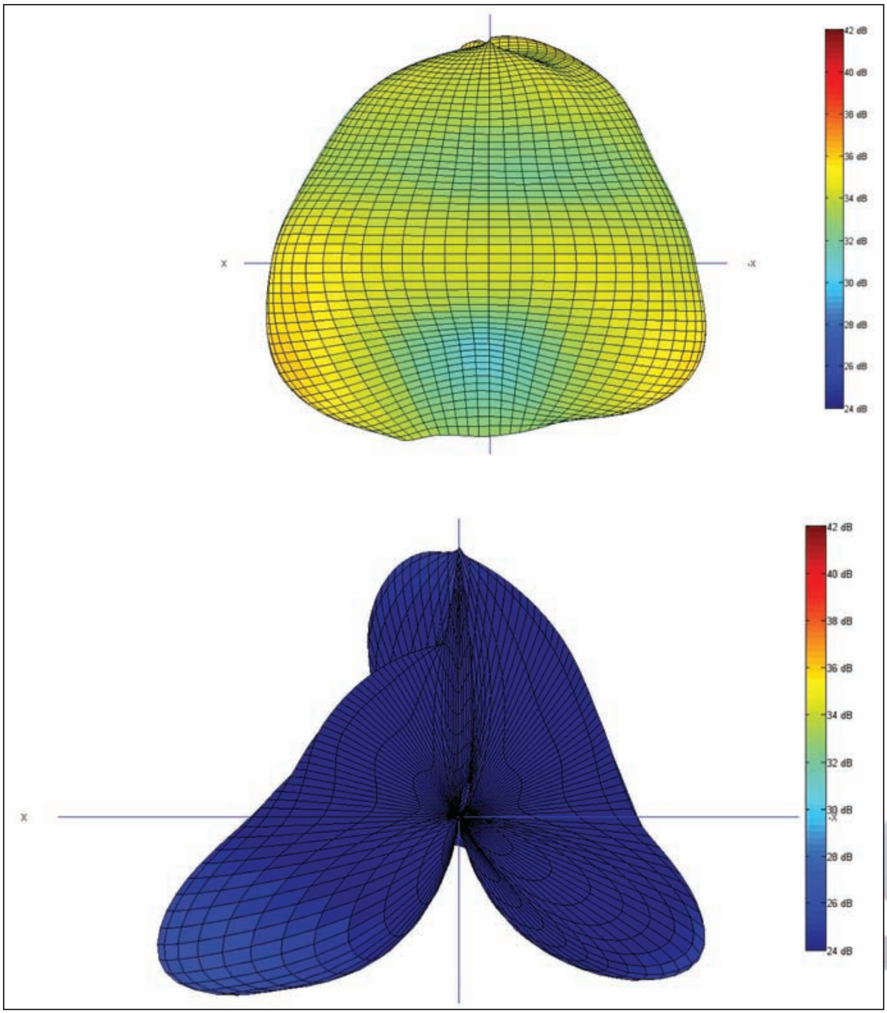


FIGURE 1 (top) Device without case. (bottom) Device with case.

group set up under FCC auspices, and an overall trend has emerged towards this method of testing GNSS performance, despite its greater complexity.

This article will introduce the wireless industry standards for A-GNSS testing, discuss why it is important, how it is tested, and new requirements that have come with the introduction of LTE cellular networks.

GNSS OTA Testing Drivers

For wireless mobile devices, the need for testing stems from the rapid rise in popularity of location-based services (LBS). Also, in the United States, the FCC's E911 (enhanced 911) mandate requires wireless communications companies to provide the location (with certain accuracy limits) of emergency callers from mobile phones.

With the rollout of LTE comes a new focus on enabling E911 and LBS performance on these networks, along with the need to provide a seamless transition between positioning services on LTE and 2G/3G networks. In the next few years, we expect positioning technologies to evolve to the point where multiple technologies will be used in combination to provide a significantly higher level of accuracy (5–10 meters) in all locations than is currently available. This will provide the positioning performance needed to support more rigorous Phase II E911 requirements and next-generation LBS on LTE networks.

As mentioned earlier, the promise of accurate "everywhere location" is real, but it will result in increased complexity and testing challenges for chipset and device manufacturers. Developers need test methodologies that will allow them to quantify and benchmark real-world positioning performance of devices. To achieve a complete picture of real-world device performance and its effect on end-user experience of LBS applications, testing must assess the GNSS antenna performance and other real-world device factors that can only be fully determined with an OTA test methodology.

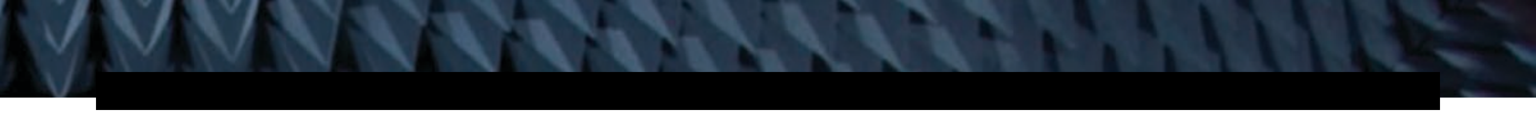
Unlike conducted testing that uses a physical RF cable to connect signals between test equipment and user equipment, bypassing the antenna, A-GNSS OTA testing takes place in a controlled radiated environment (for example, an anechoic chamber) and provides a thorough "snapshot" of the performance of the device under test in all directions (see GNSS OTA Test Methodology section below). A key aspect of this testing is that test signals are transmitted and received wirelessly, as they are in the real world. This ensures that all interactions between the radio and the rest of the wireless platform, including radiation pattern and platform interference, are taken into account when determining overall wireless performance.

A powerful example of the need for radiated GNSS testing can be found in a recent report, "A-GNSS Chipset and Smartphone Benchmark Study," from Signals Research Group, cited in the Additional Resources section near the end of this article. A key conclusion from this report was that, although the variation in performance of leading A-GNSS chipsets was quite small (when tested as per 3GPP industry standards for conducted minimum performance), the performance of commercial devices using these same chipsets (tested as per CTIA industry standards for radiated OTA performance) varied greatly.

Figure 1 reveals an unexpected result of the research where the fitting of a commercial protective case to a device very significantly degraded its A-GNSS receive sensitivity.

A Model for GNSS Receiver Standards?

Before jumping into the details of wireless A-GNSS radiated and conducted (cabled) test standards, we should note that the key performance indicators (KPIs) and GNSS performance test



methods defined by 3GPP and CTIA are applicable to many other industries that use GNSS receivers. Despite the focus on "assisted" GNSS, most of the tests could be applied to standalone autonomous GNSS uses.

As mentioned in the introduction, the standardized A-GNSS requirements for mobile devices proved very useful in 2011 when the FCC initiated a technical working group (TWG) to investigate the potential impacts of LightSquared's proposed terrestrial LTE deployment on seven types of widely deployed GNSS receivers.

One of the seven subgroups within the TWG focused on cellular mobile devices and used a test methodology very similar to the one discussed in this article. Two other subgroups, focusing on high-precision and general navigation devices, also used radiated testing to get a general assessment of how receivers were affected by LightSquared's LTE Band 24 signals, a subject that we will discuss more later. However, these groups did not use the exact same criteria when determining the level of performance degradation that was acceptable versus unacceptable.

The TWG testing (and subsequent test efforts) ultimately resulted in the FCC halting LightSquared's deployment, but test methodologies and pass/fail criteria used by each of the seven subgroups made it very clear that very little alignment exists among receiver performance standards in different industries that rely on GNSS technology. As a result, the FCC Office of Engineering and Technology, in conjunction with the Wireless Telecommunications Bureau and the Office of Strategic Planning, hosted a workshop on spectrum efficiency and receiver performance on March 12 and 13, 2012. The topic of GNSS receiver standards remains an important topic to this day.

Because the subject of this article is LTE GNSS OTA testing, we should point out that the only TWG sub-group to reach a conclusive and unanimous decision about whether LightSquared would cause "harmful interference" or not was the "cellular" subgroup. In large part, this was due to the fact that this subgroup based its test plan on well-established industry standards.

When the test results indicated that a representative cross-section of wireless mobile devices on the market were not severely affected by LightSquared signals, the group comprised of network operators, handset manufacturers, and A-GNSS chipset companies concluded that LightSquared would not significantly disrupt cellular or E911 performance in the United States.

A significant amount of the cellular sub-group testing was performed using radiated signals in anechoic chambers, and the results were proven to be repeatable when a second round of testing was performed and produced very similar results to the first.

GNSS OTA Test Methodology

A-GNSS Over-The-Air testing requires specialized equipment beyond that required for "conducted testing" in which the device under test is connected directly to the test equipment via a test port and an RF cable. The test method described in this section applies to mobile devices operating with LTE, UMTS, GSM, and/or CDMA air interfaces.

Required Equipment and Setup. The goal of OTA testing is to obtain a "snapshot" of the performance of the device under test (DUT) in all directions around it. The DUT is configured for typical use cases. For a mobile device, this includes use of a phantom head and hand to simulate the effects of a device held against the human head. For handheld applications, such as personal navigation using A-GNSS, a phantom hand is used to hold the device in the same way an actual user typically would. Thus, when evaluating a device's performance, the test can take into account the RF shadows and near-field effects caused by the proximity to these phantoms.

The radiated energy from or to the DUT is measured by placing a measurement antenna (MA) a fixed distance away from the device. Because the DUT can be randomly oriented with respect to the MA, a dual-polarized measurement antenna is used to measure two orthogonal polarizations, recording the total radiated energy irrespective of the relative orientation.

To cover all points on the surface of a sphere surrounding the device, test personnel need to be able to move the MA relative to the DUT in two orthogonal axes. This requires some form of positioning system to move the MA and/or the DUT in spherical coordinates around theta (θ) and phi (ϕ) axes to achieve full spherical coverage.

To avoid unwanted interference from external signal sources, and to prevent interference with other communication systems, the DUT and MA must be shielded from the outside world. This is done by placing them inside an RF-shielded room.

Although the shield reflects external energy away from the DUT, it also reflects energy radiated from the DUT back towards the MA, and vice versa. This can result in the energy being measured more than once. Such duplication occurs because the energy can not only be measured directly from the DUT but also after it reflects off the walls of the room. To prevent this from happening, the room must be lined with RF-absorbing material to reduce unwanted reflections. A fully anechoic chamber, therefore, has all of the walls, the floor, and the ceiling lined with RF absorber.

Outside the chamber, the measurement antenna must be connected to test instrumentation to measure the power radiated from the DUT, or to transmit signals at a known level to the DUT in order to determine its receive sensitivity. To determine the GNSS receiver sensitivity of the DUT, a GNSS satellite simulator is used to provide a known downlink signal. A network emulator capable of supporting LTE, WCDMA, GSM, and/or CDMA air interfaces in all frequency bands of interest provides the cellular signal.

Depending on which test instrument must be connected to the MA, maintaining a communication link to the DUT through the MA is often not practical. Thus, tests typically employ a separate communication antenna to provide a dedicated communication path between the network emulator and DUT. This can pro-

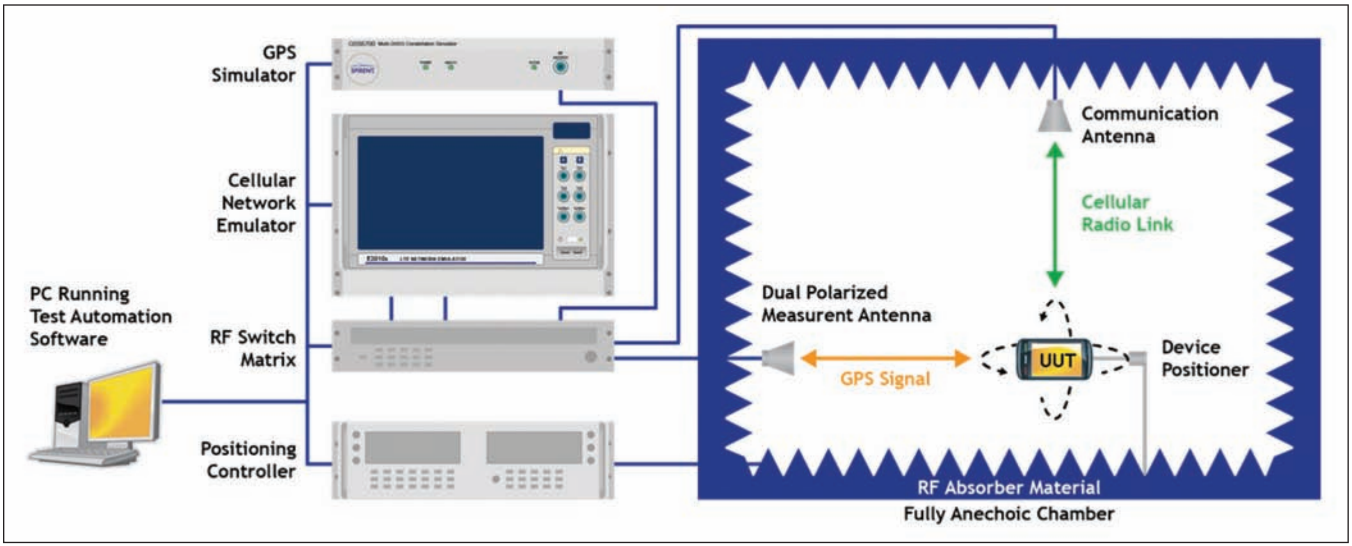


FIGURE 2 Typical design of an anechoic chamber A-GNSS OTA test system

vide a low-loss uplink path when the MA is used for downlink-only tests. It can also provide bi-directional communication signaling when the MA is connected to a signal analyzer for power measurement.

Finally, a PC running test automation software controls the positioning system and captures the desired measurements from all orientations around the DUT. Figure 2 illustrates a typical test system capable of performing OTA testing for a variety of technologies in which the DUT is rotated in two axes. .

Test Procedure and Interpretation of Results. Because GNSS user equipment incorporates a receive-only radio, the main interest is in evaluating receiver sensitivity from various directions around the device. The resulting *effective isotropic sensitivity* (EIS) pattern then determines the average radiated receiver sensitivity across the entire sphere around the device, a metric referred to as *total isotropic sensitivity* (TIS). The EIS pattern may also be measured across a portion of the sphere, when taking into account certain simulated environmental factors such as the distribution of GNSS satellites as they would appear in the sky.

In addition to determining the baseline radiated sensitivity of the GNSS receiver, the test procedure also evaluates the effect of cellular communication on the GNSS receiver in a mobile device to ensure that GNSS performance is not degraded due to interference from the mobile phone radio itself.

Version 3.1 of the *CTIA Test Plan for Mobile Station Over-The-Air Performance* standardized OTA performance testing for A-GPS in devices using UMTS, GSM, and CDMA, with LTE added in v3.2. This test plan formalizes the industry-standard method of measuring antenna performance in the controlled radiated environment of an anechoic chamber. The test procedure consists of measuring the GPS antenna pattern, TIS and other partial summation quantities, and the intermediate channel degradation (ICD) due to the mobile phone radio.

LTE Implications for GNSS OTA Testing

In version 3.2 of the test plan, the CTIA has adopted a similar methodology to that used for other technologies for testing A-GPS OTA performance on devices supporting LTE; so, the underlying test procedure to derive the associated GPS performance values discussed earlier does not change. However, there are underlying changes for LTE that need to be considered for OTA testing of LTE devices.

The exchange of positioning information between user equipment and the LTE network is enabled by the LTE Positioning Protocol (LPP). LPP is similar to previously established protocols such as the Radio Resource Control (RRC), Radio Resource LCS (LoCation Service) Protocol (RRLP), and IS-801 already deployed in 2G and 3G networks. LPP is used at both the network architecture level or *control plane* and the user-to-user level or *user plane* (as enabled by the *secure user plane location* protocol, SUPL v2.0). The relationship between LPP and SUPL 2.0 is discussed in further detail in a later section.

Evolved Serving Mobile Location Center (E-SMLC). The key entity that handles positioning in the core network of a wireless communications system is the *evolved serving mobile location center* (E-SMLC). The E-SMLC is responsible for providing accurate assistance data and the calculation of position. SUPL 2.0 can be deployed across 2G, 3G, and 4G networks to provide a common user plane protocol.

In initial LTE deployments, wireless service providers can use SUPL 2.0 with RRLP over LTE, which helps in enabling user plane positioning before implementing LPP. So, to summarize, positioning in LTE networks can be accomplished in one of three ways:

- Control Plane with LPP
- SUPL 2.0 with RRLP
- SUPL 2.0 with LPP

Full positioning support over LTE is enabled by LPP, which is designed to support the positioning methods covered previously. LPP call flows are procedure-based, where each procedure has a single objective (for example, delivery of assistance data). The main functions of LPP are:

- to provide the E-SMLC with the

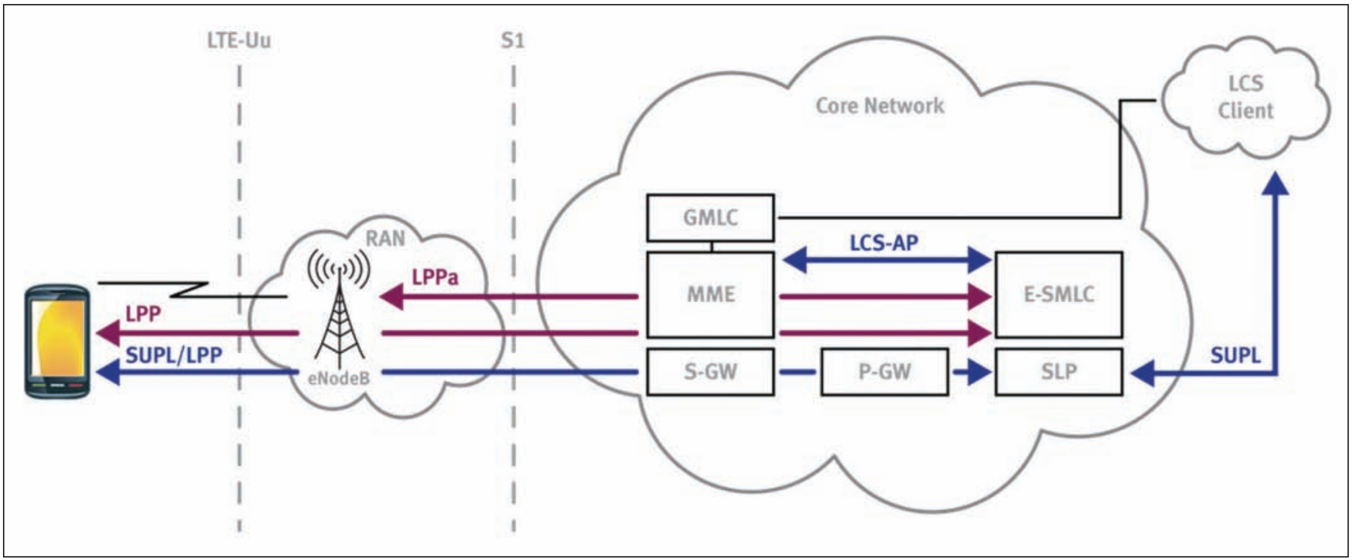


FIGURE 3 Network architecture for user plane and control plane LTE positioning

positioning capabilities of the user equipment (UE). (This means that the UE will tell the E-SMLC what location technologies it is capable of supporting. For example, a very low-end device might have no GPS chipset; so, it would report only ECID and OTDOA.)

- to transport assistance data from an E-SMLC to the UE
- to provide the E-SMLC with coordinate position information or UE measured signals
- to report errors during the positioning session.

LPP can also be used to support “hybrid” positioning such as OTDOA + A-GNSS. This topic is outside the scope of this article; for more information, interested parties can refer to the white paper *An Overview of LTE Positioning*, cited in Additional Resources.

Control Plane. With control plane implementations, which are most commonly used in emergency services, positioning messages are exchanged between the network and user equipment over the signaling connection. In LTE, control plane positioning is enabled by a mobility management entity (MME), the key control-node for the LTE-access network that routes LPP messages from the E-SMLC to the UE using NAS (non-access stratum) Downlink Transfer Messages. (See **Figure 3**.)

Control plane positioning is quick, reliable and secure because it is exchanged over Layer 3 messaging, which is the same messaging used to establish calls on the device. The processing and priority of this messaging on the UE side lead to more timely delivery of assistance data for the GNSS receiver. This allows a GNSS receiver to quickly acquire signals from space vehicles (SVs) as well as additional time to perform deeper searches for obscured SVs or low power–level SVs, depending on quality-of-service (QoS) settings.

User Plane. User plane positioning over LTE uses an Internet protocol (IP) data connection to transmit positioning information. SUPL 2.0 supports positioning over LTE as well as 2G and 3G networks and provides a common user plane platform for all air interfaces.

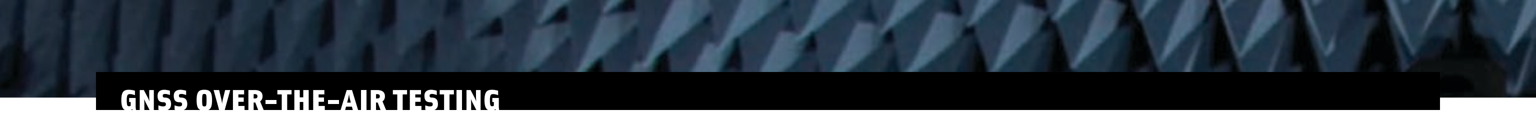
SUPL does not introduce a new method to package and transport assistance data; instead it uses existing control plane protocols (such as RRLP, IS-801, and LPP), as illustrated in Figure 3. SUPL uses the data link to transmit positioning information and is enabled by an entity called the SUPL Location Platform (SLP). The SLP handles SUPL messaging and is typically able to interface with the E-SMLC to obtain assistance data. SUPL messages are routed over the data link via the LTE PDN Gateway (P-GW) and the Serving Gateway (S-GW) entities.

SUPL 2.0 enables a complex feature set that is pertinent to mobile applications, including area-based triggering, periodic reporting, and batch reporting. It also supports emergency positioning over the data link using the major positioning technologies (including non-GNSS technologies such as Wi-Fi positioning).

LPP and SUPL 2.0. The primary positioning enabler in SUPL 2.0 is an underlying control plane protocol (such as RRLP or LPP). This implies that SUPL 2.0 can be used over any network, as long as the SLP and the E-SMLC are able to interface and agree upon a common positioning protocol. The initial LTE specifications in 3GPP Release 8 did not include location services (LCS) or LPP support. Nonetheless, the flexibility of SUPL 2.0 has been useful in initial LTE roll-outs as it has allowed operators to enable SUPL 2.0–based positioning over an existing control plane protocol such as RRLP.

With the addition of LCS and LPP support in 3GPP Release 9, both control plane and user plane solutions can be deployed over LTE. User plane deployments can leverage the existing SUPL 2.0 architecture while supporting the LPP protocol. However, SUPL 2.0 can still be used with LPP on a Release 8 device as long as the positioning protocol support is available. This is because SUPL 2.0 does not rely on any signal communications between a Radio Access Network (RAN) layer in a network and the user equipment.

For these reasons, the CTIA OTA Test Plan has adopted A-GPS OTA testing in the user plane based on SUPL 2.0



with either RRLP or LPP. Support for LPP control plane testing will be added at a later date.

User Plane versus Control Plane. Complete end-to-end performance tests that measure the location accuracy, response time, and yield are very important because they map directly to the end-user experience. The 3GPP conformance test specification TS 37.571-1 does specify some basic end-to-end tests for A-GNSS, as discussed later, but the specification only applies to control plane LPP implementations.

Because most deployments will include user plane implementations using LPP and/or RRLP, it is very important to test OTA performance using LTE User Plane (SUPL 2.0). However, potential performance differences need to be considered.

Typically, the control plane and user plane implementations are managed using different QoS mechanisms. The QoS settings for a control plane deployment that is focused on emergency services may be optimized for performance, as long as the response time to provide the location to the emergency responders can be fulfilled.

In contrast, QoS settings for a user plane implementation may vary depending on the LBS services offered. This tradeoff can have a profound effect on the level of performance when comparing user plane and control plane deployments.

As user plane implementations employ an IP data connection, the timeliness of the assistance data is not as well controlled as in the control plane case. The inherent delays in the TCP/IP stack on the UE side, the priority assigned to data within the multi-tasking environment, and the possible data demands from other applications can affect the speed with which assistance data is delivered to the GNSS receiver. This, in turn, will affect the overall ability of user equipment to find and track SVs and increase or reduce the amount of time it takes a receiver to search for the satellite signals.

The delivery of assistance data over the IP data connection can also be affected by link layer issues (transmission control protocol or TCP errors) that will only further delay the reception of the data. These issues can also have an adverse effect on the delivery of location information to the network or end application.

LTE A-GNSS Testing – 3GPP TS 37.571-1

Following the precedent set by standardization for 2G and 3G positioning, LTE positioning minimum performance test specifications have been published by 3GPP.

Test standards for LTE control plane positioning are covered under TS 37.571-1, which lays out the required minimum performance of A-GNSS, OTDOA, and ECID techniques. The minimum performance tests for A-GNSS are similar to 3GPP test specifications TS 34.171 and TS 34.172, which are intended to establish a minimum level of A-GNSS performance on UMTS networks.

However, the LTE positioning standard goes beyond just A-GNSS to include tests for ECID and OTDOA. The key focus of the test specification is to characterize the minimum performance of the UE using each major positioning technique. For A-GNSS, analysis is based on a final position calculation under the following test scenarios:

- nominal accuracy
- sensitivity (*coarse time* and *fine time*)
- dynamic range
- multipath
- moving scenario

Enabling LTE A-GNSS OTA Testing. Support of the A-GNSS OTA test procedures only needs a subset of the conducted performance tests. For the pattern measurement, the UE's SV carrier-to-noise (C/N_0) measurements are used. Averaging sufficient C/N_0 measurements at each position and polarization of the test sphere surrounding the DUT enables derivation of the antenna pattern.

Because the tests rely on the DUT to make these measurements without *a priori* knowledge of their accuracy and linearity, we can subsequently use a known signal source to correct the measurements made by the UE, ensuring that the pattern data is an accurate representation. These OTA procedures make use of a *GNSS nominal accuracy test*, which provides multiple C/N_0 measurements at a high satellite signal power level that is constant for all SVs and provides a maximum dynamic range for the pattern measurement.

Once the radiation pattern is determined, a GNSS sensitivity search can be performed at the maximum point on the sphere in the range of $\theta = 0$ to 90 degrees. The resulting pattern data can be used to determine total isotropic sensitivity or any other partial summation quantity such as the upper hemisphere isotropic sensitivity that evaluates device response to only the portion of the signal that would be seen in a direct line of sight from the satellite constellation when in an open area.

For the OTA procedure, the GNSS Sensitivity (Coarse Time) test from 3GPP TS 37.571-1 can be modified to determine the actual sensitivity level of the DUT, as opposed to testing only at the conducted test requirement. This provides traceability in the OTA procedure to a conducted test involving a direct physical connection between a simulator and the DUT.

Interference Testing

Conducted testing performed per 3GPP TS 37.571-1 can identify some issues with transmitter desensitization, where the receiver sensitivity is degraded by some external interference, but only when the coupling mechanism that allows the interference to reach the receiver is contained within the circuit board.

Most device desensitization effects can only be detected in OTA testing. This is due to the fact that any interference signal radiated by the device (either purposely or not, e.g., from the display, CPU clock, etc.) can be subsequently received by a device's antenna and presented to the receiver as an interferer. This coupling mechanism is not present during conducted testing because the antenna path is disabled.

LTE technology offers a range of wider RF channel bandwidths (5, 10, 15, and 20 megahertz) that exceed those used in previous 3G technologies. These wider RF channel bandwidths introduce additional out-of-band, spectrum-emission challenges.

The bandwidth allocation made available to any particular UE does not have to occupy the entire bandwidth of a single LTE RF channel. Thus, the interference of the LTE signals on the GNSS receiver is a complicated function of the LTE channel and resource block allocation settings specified by the network.

LTE also introduces many operating bands with different duplexer spacing. Some of these bands can only support maximum output power with partial RF allocations. When the mobile transmits using the entire channel bandwidth, the technology must lower the total channel power to avoid potential non-linearities in the modulated signal. All of these factors need to be taken into account when considering OTA tests that use LTE as mode of transmission.

Some wireless operating bands, such as Band 13 (uplink, 777–787 MHz; downlink, 746–756 MHz) and Band 24 (uplink, 1625.5–1660.5 MHz; downlink, 1525–1559 MHz) in which LightSquared proposed its wireless broadband service, have specific issues related to GNSS. The second harmonic of the upper end of the transmitter allocation in Band 13 falls immediately next to GNSS. Therefore, any out-of-band emissions immediately above the transmitter allocation from Band 13 UE will subsequently fall in the GNSS band, depending on the UE harmonic performance.

All of these factors were taken into account when developing the test conditions for LTE in the CTIA OTA Test Plan v3.2. For Band 13, one would want to evaluate the antenna pattern using an RF allocation near the low end of the transmitter band at a reduced power. This would minimize any self-desensitization issues in GNSS, because the C/N_0 measurements can be affected by this noise.

However, for the GNSS sensitivity search, where the satellite signal power level is lowered until the device fails in five out of 100 fix attempts, the device's LTE transmitter would use a partial channel bandwidth allocation that allowed for maximum RF output power. Further, this allocation would be located in the upper end of the RF channel bandwidth such that the effect on GNSS performance would be maximized, thus evaluating the device under a worst-case scenario to help ensure that its performance can be guaranteed.

In Band 24, the interference issues are related to the proximity of the downlink and uplink LTE signals to GNSS. At the request of the company, the LightSquared frequency plan was introduced in the 3GPP LTE Release 10 specifications, and the band can accommodate both 5- and 10-megahertz RF channel bandwidths.

The FCC TWG effort considered various test conditions to account for the receiver blocking and intermodulation effects that could harmful to GNSS based on this band plan. An explanation of receiver blocking and intermodulation effects can be found in the article, "GPS Interference Testing: Lab, Live, and LightSquared," cited in the Additional Resources section of this article.

Conclusion

With LTE deployments under way in many markets around the world, and many more planned for the near future, it clearly will not be long before the majority of connected mobile devices and M2M modules rely on this technology. The fact that GNSS receivers will frequently be paired with LTE technology makes testing the two in conjunction with one another a necessity.

Considering all of the LTE frequency bands being deployed and all the possible interference scenarios, over-the-air testing is emerging as the best way to ensure that GNSS and LTE performance meets user expectations and industry mandates such as the FCC's E911 Phase II requirements. Manufacturers, regulators, and operators, will probably place more emphasis on standardized OTA testing in the future.

In the case of LTE-equipped mobile devices, we can already see additional requirements such as A-GLONASS and LPP control plane that are likely to be added to the CTIA specification in the next year. In the future, the testing standardized by CTIA and 3GPP may also serve as a reference for other industries that rely on GNSS.

Additional Resources

[1] 3rd Generation Partnership Project (3GPP), "Universal Terrestrial Radio Access (UTRA) and Evolved UTRA (E-UTRA) and Evolved Packet Core (EPC); User Equipment (UE) conformance specification for UE positioning; Part 1: Conformance test specification (Release 10)," September 2012, accessed November 2, 2012 at <http://www.3gpp.org/ftp/Specs/archive/37_series/37.571-1/>

[2] Boulton, P., and R. Borsato, B. Butler, and K. Judge, "GPS Interference Testing: Lab, Live, and LightSquared," *Inside GNSS,* July/August 2011

[3] Signals Research Group LLC, "A-GNSS Chipset and Smartphone Benchmark Study," *Signals Ahead,* September 13, 2012, Vol. 8 No. 10 .The full report is available at <www.signalsresearch.com>, and a short overview can be found at <http://bit.ly/signalsresearch-gnss>.

[4] Spirent Communications, *An Overview of LTE Positioning,* 2012, available on-line at <http://www.spirent.com/White-Papers/Mobile/LTE_Positioning_Overview_WhitePaper>

Authors

Ronald Borsato is principal architect at Spirent Communications with 17 years of wireless industry experience. He is vice-chair of the CTIA's ERP Ad-Hoc Subgroup and also served as a technical advisor to the cellular sub-team of the LightSquared TWG. He actively participates in 3GPP on LTE and OTA matters. Borsato served as chair of the CTIA GPS Subgroup during the development of the test requirements. He received his master of science degree in electrical engineering from the University of Texas at Arlington.

Michael D. Foegelle is the director of technology development at ETS-Lindgren in Cedar Park, Texas, and has more than 20 years of test and measurement experience in RF and wireless. He received his Ph.D. in physics from the University of Texas at Austin. Foegelle has been actively involved in standards development on the American National Standards Institute (ANSI) Accredited Standards Committee C63 on electromagnetic compatibility, CTIA Certification Program Working Group, Wi-Fi Alliance, WiMAX Forum, IEEE 802.11, and 3GPP. He has served as chair or vice-chair of various working groups in those organizations and currently co-chairs the joint CTIA/Wi-Fi Alliance Converged Wireless Group.