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Permanent Link to GNSS Test Standards for Cellular Location
2021/03/15
Downtown Seattle, a typical test-case environment. Multi-Constellations Working in a Dense Urban Future GNSS receivers in cell phones will soon support four or more satellite constellations and derive additional location measurements from other sources: cellular location, MEMS sensors, Wi-Fi, and others. The authors propose test standards covering these sources, meeting industry requirements for repeatable testing while considering the user experience. By Peter Anderson, Esther Anyaegbu, and Richard Catmur Cellular location test standards include well-defined and widely used standards for GPS-based systems in both the 3rd Generation Partnership Program cellular technologies of GSM/WCDMA/LTE, typically referenced as the 3GPP standards, and for CDMA technologies in the 3GPP2 standards. These standards provide a reference benchmark for location performance in the laboratory, when the unit under test is directly connected to the test system via a coax connection. In addition, standards are being rolled out, such as the CTIA — The Wireless Association total isotropic sensitivity (TIS) requirement, for over-the-air (OTA) testing and developed further with LTE A-GPS OTA using SUPL 2.0. These tests are typically performed in an anechoic chamber and allow the performance of the antenna to be included. Recently developed standards such as the 3GPP Technical Specification (TS) 37.571-1 cover multi-constellation systems, typically GPS and GLONASS for a two-constellation system, or GPS, GLONASS and Galileo for a three-constellation system, with options for additionally supporting QZSS and space-based augmentation system (SBAS) satellites. During 2014, the standards will encompass additional constellations such as the BeiDou satellite system. Figure 1A. GNSS systems available in the 2015-2020 timescale. Figure 1B. GNSS systems available in the 2015-2020 timescale. Significant change is also happening with the additional technologies such as cellular location, Wi-Fi, and micro-electromechanical systems (MEMS) sensors providing location information. Hybrid solutions using all/any available location information from these multiple technologies present significant

challenges to both the test environment and the related test standards. The acceptance levels required for the platform integrators and their customers are becoming much more stringent, as the use cases of the location become more diverse. These present further challenges to the performance requirements for test standards for cellular location. Measuring Performance The rapid growth in the GNSS applications market has driven users to demand improvements in the performance and reliability of GNSS receivers. The test standards currently employed by cellular phone and network manufacturers to evaluate the performance of GNSS receivers are even more stringent than the regulatory mandates for positioning of emergency callers and other location-based services. Emergency-call positioning is an example of a service that must provide a position fix in both outdoor and indoor environments. A user’s experience with a GNSS receiver begins when he switches on the device. The quality of his experience defines the basic performance criteria used to assess the performance of a GNSS receiver. How long did it take to get a position fix? How accurate is the position fix? When the fix is lost, how long did it take the device to reacquire satellites and re-compute the fix? These expectations define the performance of the GNSS receiver. Manufacturers use these performance metrics to compare the performance of different GNSS receivers. The receiver’s time-to-first-fix (TTFF) depends on the initial conditions; that is, the type of acquisition aiding data (almanac data, ephemerides, knowledge of time and frequency, and so on) available to the receiver when it is switched on. Users now expect location-based applications to work regardless of where they are and whether they are in a fixed location or on the move. They expect the same level of performance when they are indoors at home or at work, as outdoors in a rural or urban environment. This has led to an increased demand for accurate and reliable outdoor and indoor positioning. Reacquisition time — how quickly a receiver recovers when the user goes through a pedestrian underpass or under a tunnel or a bridge, for instance — is not tested in any of the existing test standards discussed here. The useable sensitivity of any GNSS receiver is key to its performance. It defines the availability of a GNSS positioning fix. The acquisition sensitivity defines the minimum received power level at which the receiver can acquire satellites and compute a position fix, while the tracking sensitivity of a receiver defines the minimum received power level at which a GNSS receiver is still able to track and maintain a position fix. Different applications use different criteria to characterize the performance of a GNSS receiver. In an E911 scenario, for instance, position accuracy and response time are critical, whereas for navigation while driving, accuracy and tracking sensitivity are important. The test criteria employed by different manufacturers are intended to verify the suitability of a particular device for the required application. The initial test conditions are defined by the manufacturers to ensure that the different devices are tested in the same way. These conditions describe how the test sessions are started, and what acquisition aiding data are available at the start of the test session. The main divisions among performance tests are: Laboratory-based tests, either conducted versus OTA RF testing, or simulated versus record-and-playback signal testing. Real-world testing (field testing). This can be difficult because the test conditions are never the same. Fortunately, it is possible to record these scenarios using an RF data recorder. This allows the same real-world scenario (with the same test conditions) to be tested repeatedly in the lab. Static scenario testing versus moving scenario testing.

Comparison tests — relative testing (comparing one receiver against another): for reported signal-to-noise ratio (SNR), reported accuracy, and repeatability tests. Current GNSS Test Standards Varying performance requirements test the TTFF, accuracy, multipath tolerance, acquisition, and tracking sensitivity of the GNSS receiver. The first three following are industry-defined test standards: 3GPP2 CDMA Performance Standards. The 3GPP2 CDMA test standards (C.S0036-A) are similar to the 3GPP test standards. The 3GPP2 is for CDMA cellular systems, which are synchronized to GPS time. 3GPP GNSS Performance Standards. The latest 3GPP TS 37.571-1 test standard describes the tests for the minimum performance requirements for GNSS receivers that support multi-constellations. It is slightly more stringent than the original 3GPP TS 34.171 test standard. In the 3GPP TS 37.571-1 coarse-time sensitivity test case, signals for only six satellites are generated, whereas in the TS 34.171 coarse-time sensitivity scenario, signals for eight satellites are generated. Table 1 shows the power levels and satellite allocation for a multi-constellation 3GPP TS 37.571-1 coarse-time sensitivity test case. In this scenario, the pilot signal will always be GPS, if GPS is supported. The signal level of the pilot signal for GPS and GLONASS have been set as –142 dBm, while the non-pilot signal level for GPS and GLONASS have been set as –147 dBm. Table 1. 3GPP TS 37.571-1 Satellite allocation. For the 3GPP TS 37.571-1 fine-time assistance test case, six satellites are generated. For the dual-constellation fine-time test, the split is 3+3, and for a triple-constellation test case, the split is 2+2+2, as shown in Table 2. Table 2. 3GPP TS 37.571-1 fine-time satellite allocation. OTA Requirements. Testing standards have been rolled out for OTA testing, where the testing is typically performed in an anechoic chamber, allowing antenna performance to be included, with tests for the receive sensitivity referenced to an isotropic antenna and over partial summations such as the upper hemisphere. They measure the TIS of the final receiver, and operator requirements typically require OTA acquisition sensitivity of –140 dBm and tracking sensitivity of –145 dBm or lower. Other modified test standards used by manufacturers to assess the performance of the GNSS receiver include: Nominal Accuracy Margin Test. This test is based on the 3GPP nominal accuracy test case. All signals are reduced in steps of 1 dB till the test fails to achieve a fix in 20 seconds. Dynamic Range Margin Test. This test is based on the 3GPP dynamic range test case. All signals are reduced in steps of 1 dB till the test fails to achieve a fix in 20 seconds. Sensitivity Coarse-Time Margin Test. This test is based on the 3GPP sensitivity coarse-time test case. Both the pilot and non-pilot signals are reduced in steps of 1dB till the test fails to achieve a fix in 20 seconds. Pilot Sensitivity Coarse-Time Margin Test. This test is based on the 3GPP coarse-time sensitivity test case. The non-pilot signals are always kept at –152 dBm while the signal level of the pilot signal is reduced in steps of 1 dB till the test fails to achieve a fix in 20 seconds. Non-Pilot Sensitivity Coarse-Time Margin Test. This test is based on the 3GPP coarse-time sensitivity test case. In this test, the pilot signal is always kept at –142 dBm while the signal levels of the other seven non-pilot signals are reduced in steps of 1 dB till the test fails to achieve a fix in 20 seconds. These modified performance tests are used because they map directly to the end-user's experience in the real world, measuring the position accuracy, response time, and sensitivity of the GNSS receiver. Current Equipment. The equipment required for the current test standards are all GNSS multi-satellite simulator-based, either using a single constellation (for GPS), or a multi-constellation GNSS simulator as a component of a larger cellular test system. Limitation of Current Standards So far, tests for GNSS in cellular devices have been very much customer/manufacturer specific, starting with 3GPP-type tests, but adding to them. Each will have its own preferred type of tests, with different configurations and types of tests. They have included primarily GNSS simulator tests, either directly connected to the device under test or using radiated signals, together with some corner cases. With chips such as the ST-Ericsson CG1960 GNSS IC, this means that different tests need to be performed for each customer. Typically the tests are focused on cold or hot TTFF type tests, or sensitivity type tests. Live signal tests have typically been used for drive tests, with a receiver being driven around an appropriate test route, normally in an urban environment. More recently RF replays have become much more widely used, but do require truth data to give validity. RF replay tests are typically used for specific difficult routes for urban drive tests or pedestrian tests. The 3GPP types of test standards were developed to provide a simple set of repeatable tests. However, they are idealistic, and they do not relate closely to any real-world scenario, and the test connection is defined to be at the antenna port of the system. In reality, different manufacturers and network operator standards take these tests as a given, and define margins on the tests to allow for typical losses due to antennas and implementation on a platform. These margins might be as much as 8 or 10 dB. In addition, manufacturers and network operators define their own variants of the 3GPP tests to match typical real-world usage cases, such as deep indoor. Challenges Current location test specifications assume that the key input to the location calculation is always the GPS constellation. With the rise of additional constellations and alternative location sources, and the challenges of the urban environment, GPS will be one of many different inputs to the location position. The key for the future will be for standards focused on testing location performance, irrespective of which constellations are visible, and also being able to fully test the system performance. Tests will be suggested that allow the basic functionality of a system to be checked, but can be enhanced to stress-test the performance of a receiver. As future location systems will use all available inputs to produce a location, there will be challenges to the supporting test standards and test equipment to handle all of these in parallel. The initial challenge for location test standards has been the use of GNSS constellations in addition to GPS. Current leading GNSS receivers in cellular devices make use of GPS, GLONASS, SBAS, and QZSS, and network-aiding information for A-GLONASS is being rolled out in the cellular networks. The 3GPP TS 37.571-1 specification has been derived from the original GPS-only specification TS 34.171, with the addition of GLONASS and Galileo constellation options. These allow single-, dual-, or triple-constellation tests to be performed. If there is GPS in the system, then GPS is viewed as the primary constellation, and tests like the sensitivity coarse-time assistance test would have a satellite from the GPS constellation with the highest signal level. The test standards also accommodate the use of some satellites from SBAS such as WAAS and QZSS. These tests require that the performance shall be met without the use of any data coming from sensors that can aid the positioning. This is only the first stage in the rollout of new GNSS constellations, and in the near future, GNSS receivers in cellular phones will support four or more constellations, and possibly also on frequencies additional to the L1 band, covering some or all of: GPS, GLONASS, Galileo, BeiDou

Phase 2, BeiDou Phase 3, QZSS, SBAS, and IRNSS. Table 3. Suggested four-constellation mix (Pilot signal to rotate round constellations). The challenge for the minimum-performance specifications is to accommodate these different constellations as they become fully available. For the new constellations, this will initially be purely simulator-based, but could be extended to use of live data for certain test cases as the constellations are built up. A further challenge for the test specifications is that some of the systems are regionally based, so a performance specification based on a global approach is not applicable. Further, tests must be severe enough to stress the receiver. With multiple constellations, it can be simple to pass a test without using all available satellites or constellations. Other Location Sources (Hybrid Solution). Within the cellular platform, location can be provided by a number of different technologies, either separately or compositely, to provide a location to the accuracy required by the user. Technologies currently available include: Cellular network: cell ID and cell network triangulation LTE Positioning Protocol Fine time assistance (for aiding) Wi-Fi network name (service set identifier, or SSID) Wi-Fi ranging MEMS sensors Near-field communication Bluetooth Pseudolites, other beacons, coded LED lights, and so on. Real-World Environments. Measuring performance in a real environment is becoming much more important, as the user experience becomes much more key. The product must not only pass particular specifications, but must also meet customer expectations. In the age of the blog, negative customer feedback can damage a product’s reputation. But with the various GNSS constellations and other sources of location information, performance testing is growing significantly in complexity, and test standards needed to cover this complexity will also become more complex. The simple user criteria could be stated as “I want the system to provide a rapid, accurate position wherever I am.” But how accurate? The end-user of a location system does not use a GNSS simulator with clean signals, but a location device with live signals, often in difficult environments. This has been recognized by platform integrators, and live test routes for both urban drive and urban pedestrian routes are now required. The performance required of the receiver in these locations has also changed, from “just need to get a fix of limited accuracy” to getting accurate location information, both from a fix (even from a cold start in a built-up area), to continuous navigation (better than 30-meter accuracy 99 percent of the time) throughout a test run. Typical environments for these test cases include locales in many major cities, such as the environment in the OPENING PHOTO of Seattle and one shown here of Seoul, Korea. Seoul, Korea, a typical test-case environment. Coexistence and Interference. Recent controversies have raised the profile of GNSS interference from other wireless technologies. However, within the cellular platform, significant coexistence and potential interference issues are already present. These can occur due to adjacent channel interference, or from harmonics of cellular frequencies on the platform, for example, the second harmonic of the uplink channel for LTE Band 13 overlays the BeiDou-2 frequency of 1561MHz, and the second harmonics of both Bands 13 and 14 create out-of-band emissions in the GPS band (Figures 2 and 3). Figure 2. BeiDou and LTE bands 13/14. Figure 3. GPS and LTE bands 13/14. Test Proliferation. The increase in the number of GNSS constellations together with the use of other location sources to provide a hybrid solution could increase the number of tests to be performed exponentially. When this is then combined with the need to test over a range of simulated and real-world locations, together with customer specific requirements, a set of tests could easily take weeks to run. It is therefore important to ensure that the cellular location test standards are carefully constructed to not significantly proliferate the number and time for tests to be performed. Future Test Equipment A new generation of test equipment is emerging to meet the new challenges and requirements of multi-constellation GNSS and hybrid location systems. These include: GNSS Simulators. Simulators currently provide up to three GNSS constellations, together with augmentation systems. With the roll-out of BeiDou-2, four-constellation simulators will now be required. Currently all GNSS devices integrated in cellular platforms use the L1 band. This will also potentially change to multi-frequency use. The appropriate GNSS simulator will need to be included in the cellular test system. New Hybrid Test Systems. As the need for testing hybrid positioning systems in cellular devices emerges, hybrid location test systems (HLTS) are becoming available that can simulate and test hybrids of A-GNSS, Wi-Fi, MEMS sensors, and cellular positioning technologies, all in one system. Today, these test systems use separate simulators for the different individual technologies (like GNSS, Wi-Fi, and so on), but these are now being merged into multi-system simulators that combine a number of different technologies into one device (see Figure 4). RF Replay. The use of RF replay units for replicating live trials is already widespread. This will extend with further constellations and further frequency bands. The advantages of using RF recorded data include: Gives real-world data, which if the location is chosen carefully will stress the device under test; Allows use of recorded test data from several/many urban locations; Good for drive and pedestrian test applications; Will be integrated in the HLTS type of test system. The disadvantages of using RF recorded data include: Results not deterministic; Taken at one point in time, do not allow for future development of satellite constellations; Proprietary recording devices, difficult to define a standard; Need to include an inertial measurement unit (IMU) to get accurate truth data. The difficulties of using RF replays include: Successfully integrating all the signal environment (cellular, Wi-Fi, MEMS, and so on); Multiple runs required to give reliable data (for example, 13 runs at different times of day to give a range of satellite geometry and user speed, between rush hour and middle of night); Multiple locations required to stress the system; Test time can be up to a day of real-time testing to re-run tests on one location. Proposal for Hybrid Positioning Tests should include a mixture of simulator-based tests, RF-replay-based tests, and live tests. This would comprise the following suite: GNSS Performance Tests. The 3GPP type of tests (TS 37.571-1) are a good starting point for a minimum performance test, but they rely on the person running the test to define the number of constellations. To automate this, there could be a single test at the start of each test sequence to identify which constellations are supported (one to four), and then the formal test run for that mix of constellations. The constellations supported should be reported as part of the test report. An option should be provided to allow margin tests for specific tests to be run, and these should again be reported in a standard method in the test report, specifying how far the device under test exceeds the 3GPP test. The typical margins expected for a GPS-only test would be between 8 and 10 dB in the 2014 timeframe. For a multi-constellation test, it will depend on the specific constellations used, but could be between 5 and 8 dB margin. Ideally, a multipath scenario should be created that more closely matches the environment seen in a real urban environment. Hybrid Location Tests. The main purpose of the hybrid location test is to prove that the different components of a cellular platform providing location are all operating correctly. A basic test would provide a sequence where the different combinations providing location are tested for correct operation separately, and then together. This would not be envisaged as a complete stress test, but each technology should be running in a mode where a location solution is not simple. A simple example sequence of tests would be: GNSS performance test; Cell ID static test; Wi-Fi SSID static test Cell ID and Wi-Fi SSID static test Cell ID and GNSS static test (GNSS –142 dBm) Wi-Fi SSID and GNSS static test (GNSS –142 dBm) Cell ID, Wi-Fi SSID, and GNSS static test (GNSS –142 dBm) Cell ID, Wi-Fi SSID, GNSS, and sensors moving test. See how easily tests can proliferate! A more stringent test could then be performed to stress-test the performance if required, and if required a playback test could be performed (see RF Replay test below). The additional location sources can also aid in providing initial states and information for the position-determination system, in addition to the common assisted-GNSS information provided by the network. This will be particularly important in indoor and other environments where GNSS performance is compromised. Further developments such as the LTE Positioning Protocol Extensions (LPPe) from the Open Mobile Alliance will also allow the sending of additional information to the device to improve the accuracy of the position. This additional information could include accurate time, altitude information, and other parameters. Future assistance standards should enhance the use of this information, and test standards should verify the correct use of this information. RF Replay (or Playback) Tests. GNSS performance is statistical, and it is important to ensure that any tests have sufficient breadth and repetition to ensure statistical reliability. This applies to the more normal standard simulator tests, as well as to the uses of tests in the urban environment. For example, performance in the urban environment can vary significantly between two closely spaced runs, and can also be very dependent on the time of the day. A test done in the daytime may hit rush-hour traffic, whereas tests done at night will have relatively free flow, and hence faster average speeds. Additionally, the space-vehicle constellation geometry is constantly changing, which can enhance or degrade the GNSS performance. These factors need to be considered in generating any test routes. For RF replay tests, a number of specific locations for urban driving and pedestrian routes should be specified. These locations should be based on network-operator test requirements, and include a mixture of suburban and deep urban environments (such as Tehran Street, Seoul). For each location, ten different data sets should be used, captured at different times, including peak rush hour at a specified hour. The data set should also include separate high-performance IMU data to provide truth data. To provide test consistency, a golden-standard data set should be used. But with different suppliers this would be difficult. For pedestrian tests, a similar number of different routes should be defined, and data captured similarly. Ideally, all data useable for a hybrid solution should be captured, and available for replay. The test criteria analyzed for this could include: yield; horizontal position error, along-track error, across-track error, heading error, and speed error. Interference Tests with Different Cellular Bands. It is important to have a standard test to demonstrate that the device under test does not have performance degradation due to interference from particular cellular subsystems interfering with the GNSS. For this test, the device should be tested in an OTA environment to ensure that all interference coupling mechanisms are present. Two tests should be performed: first, a tracking test. In this the A-GPS performance is tested by measuring the GNSS carrier-to-noise ratio for each GNSS band, while all the wireless channels on the platform are exercised sequentially. The test result would indicate the maximum number of dBs degradation that occurs. Second, a cold-start test at –140 dBm should be performed separately while each wireless channel on the platform is exercised. Any extension in cold-start TTFF should be noted. Conclusions The challenges for cellular location test standards have increased significantly with the availability of new GNSS constellations, and the use of all available technologies within the cellular platform to provide the best appropriate location for the required use case. For test standards to be relevant, and also able to be run in an appropriate time, they must consider both the requirements to prove that the appropriate technology is operating correctly, and also bear a relationship to the final system performance required. This means, for example, that a multi-constellation GNSS receiver is really using all the constellations appropriately, and also that the end-user performance requirement is considered. Existing cellular test standards are minimum performance requirements, but future standards should encapsulate the minimum performance requirements while also allowing standard extension to provide a consistent performance description. Further to this, platform performance must be proved in all standing operating modes, which means, for example, that the cellular system be checked when operating in all supported bands. Test equipment to support future cellular test standards is in development, but the significant challenges will be in providing equipment to fully support urban drive and pedestrian performance requirements. In conclusion, the ability to appropriately test a hybrid location system, comprising multi-constellation GNSS and additional location technologies, presents almost as many challenges as generating the hybrid solution in the first place. Acknowledgments Many thanks to the GNSS team at ST-Ericsson, and at Spirent, and also to our customers for the challenges that they have presented as the required location performances have changed and increased. Manufacturers Figure 4 is taken from a Spirent Hybrid Location Test System (HLTS). Peter Anderson received master’s degrees in electrical sciences from Cambridge University and in microelectronics from Durham University. Until recently, he was a GPS systems manager and the GNSS Fellow at ST-Ericsson; he is now a consultant with PZA Systems Ltd. Esther Anyaegbu is a senior systems architect at ST-Ericsson. She earned her Ph.D. in data communications systems from the University of Leeds, where she focused on the processing of GNSS signals in the frequency domain. Richard Catmur is head of standards development at Spirent Communications. He holds an M.A. in engineering science from Oxford University. He has served as rapporteur, editor, or major contributor to all 3GPP and OMA standards on the testing of positioning in wireless devices.

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Energizer fm050012-us ac adapter 5v dc 1.2a used 1.7x4x9.7mm rou,toy transformer ud4818140040tc ac adapter 14vdc 400ma 5.6w used,sil ua-0603 ac adapter 6vac 300ma used 0.3x1.1x10mm round barrel,9v dc 100ma graco dv-9100s ac/dc power supply adapter / adaptor 9v dc 100ma graco dv-9100s ac/dc power supply adapter.original zebra 24v 2.5a gt820/gt800/gk420 6.5..