ATTACHMENT 4

TEST PLAN

PRECISION AND TIMING RECEIVER
LIGHTSQUARED L-BAND LTE TEST PLAN

REVISION HISTORY

REV	Date	Editor	DESCRIPTION
N	5/16/11		Final revision of the TWG Test Plan
1.0-1.2	11/10/11	M. Tseytlin	Changes to convert the TWG document for next phase HP and Timing mitigation testing
1.3	11/12/11	M. Tseytlin	Incorporated comments from S. Dutta
1.4	11/14/11	M.Tseytlin	Added reference receiver description
1.5	11/25/11	M.Tseytlin	Added further test clarifications

TABLE OF CONTENTS

1 PURPOSE **4**
2 BASIC ASSUMPTIONS **4**
3 TEST SCENARIOS **4**
3.1 HIGH PRECISION RECEIVERS – ANECHOIC CHAMBER TESTING 4
4 ANECHOIC CHAMBER TESTING **5**
4.1 TEST SETUP REQUIREMENTS 5
4.2 LIGHTSQUARED LTE SIGNALS 7
4.3 SETUP AND CALIBRATION OF LIGHTSQUARED LTE SIGNALS 7
4.4 SETUP AND CALIBRATION OF GNSS SIGNALS 7
4.5 SETUP AND CALIBRATION OF THE TIMING EQUIPMENT 8
4.6 DATA RECORDING KPI'S 8
4.7 SPIRENT GPS SIMULATOR CONFIGURATION 9
4.8 INTERFERENCE TESTS 9
4.8.1 Test Configurations *10*
4.8.2 Tracking Test Procedure *12*
4.8.3 Sensitivity Tracking Test Procedure *12*
4.8.4 Acquisition Test Procedure *13*
4.8.5 Reacquisition Test Procedure *13*

List of Figures

FIGURE 1 EXEMPLARY TEST SETUP 6

1 PURPOSE

This document outlines the test setup and test procedures to assess the performance of improved (enhanced compatibility) High Precision Location and Timing GNSS receivers in the presence of LightSquared ATC signals emitted by both base stations and devices (handsets). The emitted signals correspond to the deployment of a 10 MHz bandwidth, Long Term Evolution (LTE) Signal at 1526-1536 MHz for the downlink and 1627.5-1656.7 MHz. for the uplink.

2 BASIC ASSUMPTIONS

The following assumptions control certain aspects of this Test Plan.

1) The Devices Under Test (DUT's) for all testing will be High Precision Location and Timing receiver systems[1] with improved external antenna's.
2) Testing will be controlled and executed at Alcatel Lucent anechoic chamber and the tests managed by Alcatel Lucent personnel
3) High Precision Location and Timing receiver systems will be initially tested in Javad's anechoic chamber in Moscow and in Greenwood facility in Chicago and the test results will be available to Alcatel Lucent to establish performance reference baselines (expected performances).
4) High Precision Location and Timing Devices will be initially tested with legacy unimproved external antennas and then with modified external antennas. The tests will include receiver system combinations that include the Javad improved antenna with non-Javad, unmodified receivers. These tests are intended to validate LightSquared's retrofit plan.
5) Testing over temperature is not required, and can be at ambient temperature.

3 TEST SCENARIOS

3.1 High Precision Receivers – Anechoic Chamber Testing

High Precision Location and Timing receivers have multiple modes, depending on the particular receiver, which must be tested. These include:

- Network vs. Autonomous (stand alone)
  - The only mode tested under this test plan is Autonomous (stand alone).

- RTK

  For RTK testing, there are four sub-cases to consider:

  1. The Rover and Base both experience interference.
  2. The Rover experiences interference and the Base does not.
  3. The Base experiences interference and the Rover does not.

[1] The term "receiver system" is used to indicate the composite of both the antenna and the receiver.

4. The Rover and Base both do not experience interference (this is for comparison to the interference cases).

Only mode (1) will be tested as it comprises the worst case.

- Augmentation (OmniSTAR, StarFire)

  OmniSTAR and StarFire simulators are not generally available and can be only supplied by the service providing companies – Trimble and Deere. It is not expected that the MSS signal simulators will be available for this testing. It is sufficient to capture a frequency response of the external antennas in the 1555MHz-1559MHz range, where future MSS augmentation signals will be allocated to show that the augmentation signals can be supported

  If the simulators will be made available, the MSS signal will be incorporated in the test plan for the MSS augmented receivers.

4 ANECHOIC CHAMBER TESTING

4.1 Test Setup Requirements

To permit testing that meets the requirements of Section 2, the test setup must have the following characteristics:

1) Calibration of the transmitters and anechoic chamber must be done to ensure the transmitted signals are well characterized and understood. There must be sufficient high quality instrumentation to ensure that the measurements taken are valid.
2) It must be possible to generate GPS L1 and L2 satellite signals with varying number of satellites and signal powers. The only GPS signals to be generated are L1 C/A, L1P, and L2P. LightSquared supplies Spirent 8000 GPS simulator capabale to generate above GPS signals.
3) 'Live Sky' scenario will be tested by retransmitting live GPS signals from the GPS antenna installed outside of the anechoic chamber, inside the chamber to validate performance in realistic multi-path environment
4) If StarFire and OmniSTAR augmentation signals simulators will be available, the tests will be executed with the augmentation signals for the MSS enabled receivers. Otherwise the tests will capture a CW frequency response at the input of the High Precision and Timing Recevier. WAAS will not be used.
5) There must be sufficient isolation and attenuation to ensure that signals from inside the chamber do not feed back or affect the measuring instruments or receivers outside the chamber.
6) The frequency stability of the GNSS Signal Generator must be of higher quality than the oscillators in the Timing DUTs.
7) Each high precision manufacturer may have one reference receiver outside the chamber which will receive the GPS simulator signal to characterize the differences in performance between units subject to LightSquared signals and those not subject to it. This will also enable the RTK test cases to be performed.

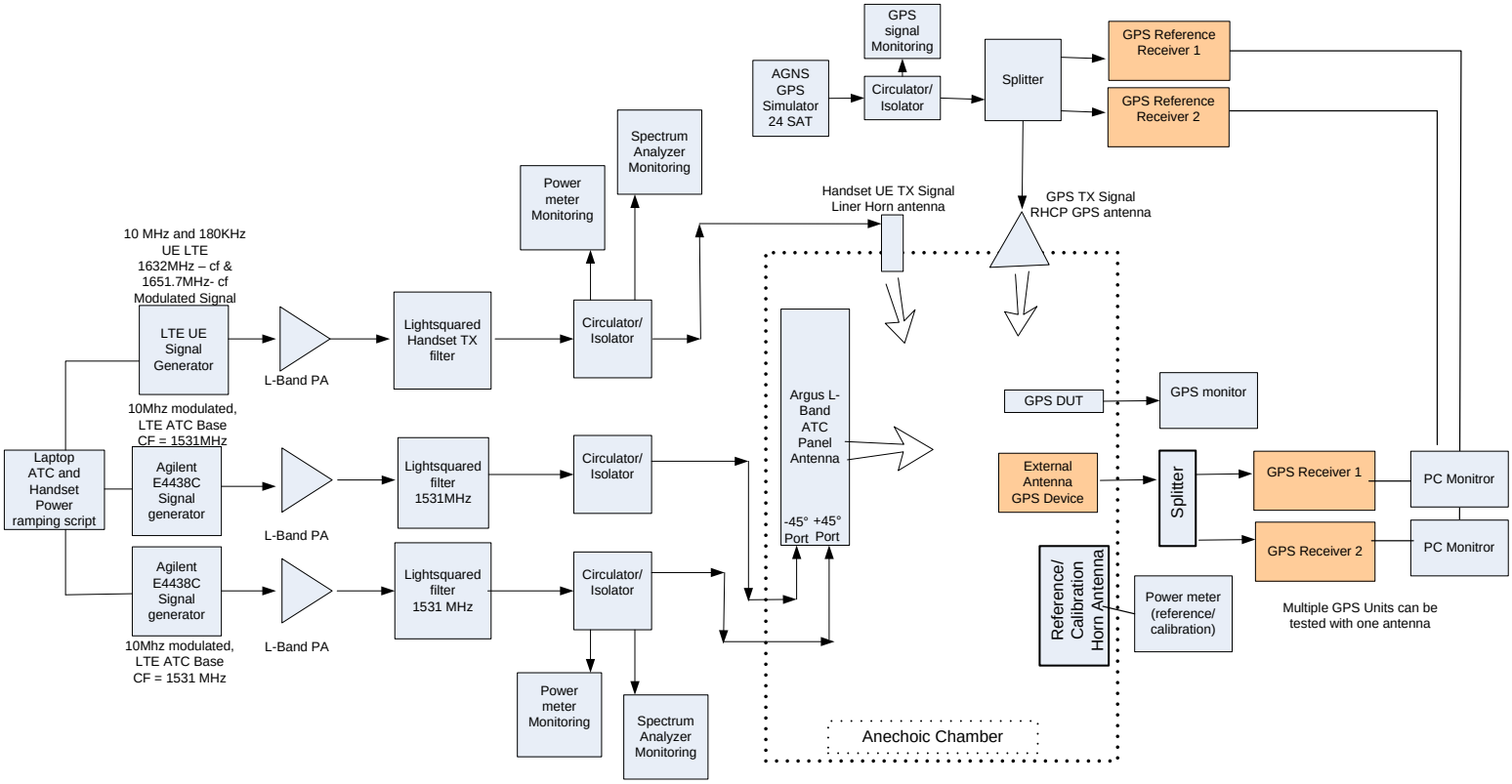

Figure 1 Exemplary Test Setup

4.2 LightSquared LTE Signals

Only the lower 10 MHz ATC channel (1526-1536 MHz) will be tested for downlink signals. For the uplink signals, two 10 MHz blocks with center frequencies of 1651.7 MHz and 1632.5 MHz will be tested. The tests will include uplink transmissions on each of the carriers individually as well as on both carriers simultaneously.

4.3 Setup and Calibration of LightSquared LTE Signals

- Since the actual base station antenna cannot be used, measured and calibrated field strength will be generated using a +45/-45 degree linearly polarized antennas with a known gain. This antenna will be directed with the peak gain pointed at the region where the DUTs will be tested.
- The LTE signal will be pointed directly at the boresight of the DUT antenna.
- The distance in meters between the face of the horn antenna and the DUTs will be measured and recorded.
- The set up procedure is a follows.
    - Mount both the LTE horns and the GPS simulator transmit antenna in their respective locations with no DUT equipments in place.
    - Turn the LTE transmitter on with the attenuator at a known setting and measure the field strength at the locations where the DUTs will be placed.
    - Vary the attenuator through at least three settings across a range encompassing the expected LightSquared power power on the ground (-30 dBm) and record the field strength to calibrate the attenuator(s), or calibrate the attenuator(s) using a network analyzer.

The LTE signal will be pointed directly at the boresight of the DUT. It is noted that a typical use case will correspond to a lower elevation. This will need to be considered in the interpretation of the results vis a vis practical use cases.

4.4 Setup and Calibration of GNSS Signals

- The GNSS signal generator shall be locked to a high quality external frequency source.
- The simulator used to generate the GNSS signals will have internal noise that permits the C/N_0 ratios to be set independent of the actual output power. This can be maintained even when using external amplifiers, provided the additional amplifier's noise power is well below the simulator output power.
- The GPS radiating antenna must be right hand circularly polarized and be pointed at the boresight (usually top or zenith) of the DUTs.
- The antenna gain characteristics of a typical DUT antenna should be entered into the simulator, or an approximation, to correct for elevation variations of the constellation.
- Set the peak C/N_0 to 47 dB-Hz.
- This level and setting must be recorded and used throughout the testing as the reference level.

- All tests involving GPS signals emitted by the simulator shall be performed with an initial HDOP of 1.1 – 1.6.[2] This value shall be recorded. For tests where the GPS signal is received live, the date and time of the test initiation shall be recorded.

4.5 Setup and Calibration of the Timing Equipment

- Some Timing DUTs will have an associated Time Interval Counter (TIC).
- The primary 1PPS control signal shall be provided by the GNSS Signal Generator.
- If required by the TIC, a stable frequency source can be provided by the GNSS frequency reference.
- Measure and record the steady-state time interval before the LTE signals are applied.
- Use the clean steady-state measurement above as the "truth" value during the subsequent LTE emissions tests.
- All tests involving GPS signals emitted by the simulator shall be performed with an initial HDOP of 1.1 – 1.6.[2] This value shall be recorded. For tests where the GPS signal is received live, the date and time of the test initiation shall be recorded.

4.6 Data Recording KPI's

The following GPS and augmentation internal performance parameters will be recorded at a minimum rate of 1 second for each receiver undergoing test, inside or outside the chamber:

- Position Accuracy
- C/N0
- Number of tracked satellites
- Carrier Phase
- Doppler
- Pseudorange
- Optional Parameters (DUT specific)
  - Carrier tracking variance
  - Pseudorange tracking variance
  - Lock Times
  - Lock Breaks
  - Signal Quality
  - L band augmentation communications (if MSS simulators available)
    - Packet Error Rate

[2] This is based on 3GPP recommendation for cellular GPS testing [3GPP TS 34.171 V1.0.0 (2004-12)]

- E_b/N_0

To the extent possible, the following GPS and augmentation external performance parameters will be recorded at a minimum rate of 1 second for each receiver undergoing test, inside or outside the chamber:

- Position and velocity accuracy (GPS stand alone, augmentation, and RTK)
- Pseudorange accuracy
- Carrier phase accuracy
- Range Rate (Doppler) accuracy
- Mean Time between Cycle Slips
- Mean Time between Lock breaks
- Reacquisition time statistics (Hot Start)
- Acquisition time statistics (Warm and Cold Starts)
- RTK ambiguity resolution statistics
- 1PPS error as measured by the TIC (for timing receivers)
- Receiver Status including Holdover Mode flag (for timing receivers)

4.7 Spirent GPS Simulator configuration

1) The GPS scenarios in the Spirent simulator will use 24 satellites. The power from the satellites will be set to the minimums specified in ICD-GPS-200C. There will be 4 satellites in each of the 6 GPS planes, with spacing between satellites reasonably uniform.

   ICD-GPS-200C gives minimum power at 5 degrees elevation of -160 dBW for L1 C/A, -163 dBW for L1P, and -166 dBW for L2P. It shows power increases of up to 2 dB as elevation increases. The curves shown in Figure 6-1 in ICD-GPS-200C should be used for the satellites in this test plan.

2) The receive antenna model used in the Spirent simulator will be that from a standard Dorne and Margolin choke ring, but modified to increase low elevation gain. The gain drop from zenith to horizontal should be 10 dB.

3) The assumed location of the receivers for the Spirent scenarios will be:
   - Latitude: 30° 15'
   - Longitude 76° 25'

4.8 Interference Tests

Four types of tests will be conducted:

- Tracking
- Reacquisition
- Tracking Sensitivity

- Acquisition

These are defined in the sections below. The power ranges for the base station tests and the handset test are the same:

- Base station: -85 (MIN) dBm to -15 (MAX) dBm
- Handset: -85 (MIN) dBm to -15 (MAX) dBm

The terms MIN and MAX are used in the test description to refer to these power levels. These power levels assume input into a 0 dBi antenna at the center of the grid.

4.8.1 Test Configurations

Table 1 Summary of Test Events

TEST Configuration	LTE Signal Configuration	Received LTE Signal Profile	GPS Configuration
1.	OFF	16 hours test to obtain accurate position accuracy	AGNS 24 SVs Spec Constant Power
2.	LTE 10 MHz; Fc =1531 MHz; +45/-45 Polarization	-30 dBm for 30 minutes	AGNS 24 SVs Spec Constant Power
3.	LTE 10 MHz; Fc =1531 MHz; +45/-45 Polarization	-24 dBm for 30 minutes	AGNS 24 SVs Spec Constant Power
4.	LTE 10 MHz; Fc =1531 MHz; +45/-45 Polarization	-35dBm to -10dBm (1dB/2min); -10dBm to -35dBm (1dB/2min);	AGNS 24 SVs Spec Constant Power
5.	LTE OFF; Dual Handset 10 MHz BW; Fc=1631.5 & 1651.7MHz	HANDSET: -35dBm to -10dBm (1dB/30sec); -10dBm to -35dBm (1dB/30sec);	AGNS 24 SVs Spec Constant Power
6.	LTE 10MHz BW, Fc=1531MHz; +45/-45 Dual Handset 10 MHz BW; Fc=1631.5 & 1651.7MHz	LTE: -30 dBm Constant; HANDSET: -35dBm to -10dBm (1dB/30sec); -10dBm to -35dBm (1dB/30secs)	AGNS 24 SVs Spec Constant Power

TEST Configuration	LTE Signal Configuration	Received LTE Signal Profile	GPS Configuration
7.	OFF	OFF	Simulated Sky Test
8.	LTE 10 MHz; Fc =1531 MHz; +45/-45 Polarization	-85dBm to -10dBm (1dB/30sec); -10dBm to -85dBm (1dB/30sec);	Simulated Sky Test
9.	LTE OFF; Dual Handset 10 MHz BW; Fc=1631.5 & 1651.7MHz	HANDSET: -85dBm to -10dBm (1dB/30sec); -10dBm to -85dBm (1dB/30sec);	Simulated Sky Test
10.	LTE 10MHz BW, Fc=1531MHz; +45/-45 Dual Handset 10 MHz BW; Fc=1631.5 & 1651.7MHz	LTE: -30 dBm Constant; HANDSET: -85dBm to -10dBm (1dB/30sec); -10dBm to -85dBm (1dB/30secs)	Simulated Sky Test
11.	OFF		Live Sky Test
12.	LTE 10 MHz; Fc =1531 MHz; +45/-45 Polarization	-85dBm to -10dBm (1dB/30sec); -10dBm to -85dBm (1dB/30sec);	Live Sky Test
13.	LTE OFF; Dual Handset 10 MHz BW; Fc=1631.5 & 1651.7MHz	HANDSET: -85dBm to -10dBm (1dB/30sec); -10dBm to -85dBm (1dB/30sec);	Live Sky Test
14.	LTE 10MHz BW, Fc=1531MHz; +45/-45 Dual Handset 10 MHz BW; Fc=1631.5 & 1651.7MHz	LTE: -30 dBm Constant; HANDSET: -85dBm to -10dBm (1dB/30sec); -10dBm to -85dBm (1dB/30secs)	Live Sky Test

4.8.2 Tracking Test Procedure

For each GPS device, the tracking tests will be first executed with un-modified external antenna to establish the reference case and then with the modified antenna capable of rejecting LightSquared interference.

This test case will start after all receivers are tracking all GPS satellites for at least 1 minute.

For each of the test configurations LTE base station configurations specified in section 4.8.1 (with exception of test cases 0,4 and 8) , the following procedure should be performed with the GPS simulator set up as described in section 4.4.

1) Record the performance parameters for each DUT as defined in section XXX, including C/N_0.
2) Set each LTE simulator employed for the selected configuration to an output power of MIN dBm (at the receivers).
   a) Record the performance parameters for each DUT.
   b) Increase the power of the LTE simulators output by 1 dB.
   c) Repeat steps 2a) and 2b) until the output power of the LTE simulators has reached MAX dBm.
3) Dwell at MAX dBm for two minutes.
4) Set each LTE simulator employed for the selected configuration to an output power of MAX dBm.
   a) Record the performance parameters.
   b) Decrease the power of the LTE simulator output by 1 dB.
   c) Repeat steps 4a) and 4b) until the LTE simulator power is set to MIN dBm.

4.8.3 Sensitivity Tracking Test Procedure

This test case will start after receiver is tracking all GPS satellites for at least 1 minute.

For two configurations 1 and 6 from section 4.8.1 the following procedure should be performed with the GPS simulator set up for AGNS 24 SVs Spec Constant Power

1) With LTE simulator power off collect 15 minutes of tracking performance parameters.
2) For each LTE power level from MIN dBm to MAX dBm in 5 dB steps:
   a) Set the power level of the simulators to the specified power.
   b) Continuously record performance data during 2).
   c) Reduce GPS simulator power at a rate of 1 dB/min for 15 minutes.

d) Set the GPS simulator back to nominal signal level.

e) Turn the LTE simulator power off.

f) Wait 2 minutes to allow all DUTs to stabilize.

4.8.4 Acquisition Test Procedure

This test case will be done from a "warm" start condition. The intent is that a normal acquisition processes be conducted between restarts, one that results from having ephemeris and position, but not precise GPS time (bit sync unknown).

For two configurations 1 and 6 from section 4.8.1 the following procedure should be performed with the GPS simulator set up for AGNS 24 SVs Spec Constant Power

1) Power on device and record performance data for 5 minutes.
2) For each LTE power level from MIN dBm to MAX dBm in 10 dB steps:
   a) Record performance data for 15 minutes.
   b) During each 15 minute test, force restart of the receiver at least every 3 minutes. A minimum of 4 restarts should be initiated at each power level.

4.8.5 Reacquisition Test Procedure

This test case will start after receiver is tracking all GPS satellites for at least 1 minute.

For two configurations 1 and 6 from section 4.8.1 the following procedure should be performed with the GPS simulator set up for AGNS 24 SVs Spec Constant Power

1) With LTE power off, collect 15 minutes of tracking performance parameters.
2) For each of the configurations:
   a) Set the LTE simulators to a power output of power of MIN dBm (at the receivers).
   b) Record tracking parameters for 30 seconds.
   c) Reduce the GPS signal power to zero for 10 seconds by disconnecting GPS simulator power to the radiating antenna through the use of a RF switch.
   d) Resume GPS signal level to nominal value indicated in section 4.4.

e) Repeat 2b) through 2d) for 25 iterations.

f) Increase LTE power by 5 dB.

g) Repeat steps 2a) through 2f) until the LTE output power is set to MAX dBm.