Appendix A.1

MOPS Based Procedure for Minimum Recommended Testing of LightSquared RFI to GPS Aviation Receivers

C MOPS-BASED GNSS RECEIVER BROAD BAND RFI TEST PROCEDURES

The objective of the following tests is to evaluate the overload and desensitization impact of the LightSquared transmissions on the GNSS receiver. This impact is verified by evaluating GPS receiver performance metrics (critical to a certified aviation receiver) in the presence of LightSquared 3GPP Interferers.

C.1 MOPS-based GPS Receiver Overload RFI Effect Test Procedures

The intent of the following test procedures is to evaluate the impact of LightSquared's LTE (3GPP) signal transmissions on the GPS receiver's performance. The following test procedures focus on the application of Continuous Wave (CW) and broadband interferers at specific frequency ranges and varying power levels.

The simulation conditions used for the measurement accuracy tests in DO-229D [1] (Section 2.5.8) are used as a baseline for the purposes of evaluating the GNSS receiver's performance in the presence of these transmissions. Based on available information, it is observed that LightSquared's LTE (3GPP) transmission bandwidths will be 10 MHz wide (2 channels across 1526 – 1536 MHz and 1545.5 – 1555.2 MHz) during their final phase 2 deployment. The LTE downlink closest to the GPS band will be centered at 1550.5 MHz (1550.5 +/- 5 MHz). However, during the initial phase zero deployment, the LTE downlink is centered on 1552.7 and is 5 MHz wide (1550.2 to 1555.2 MHz).

For the purposes of the preliminary evaluation the total transmit power in the downlink band is assumed to be concentrated at a single frequency point (for e.g. at 1552.7 MHz). At the outset, the LightSquared signal is not expected to correlate with the GNSS signal. To validate this, the test will initially be performed with CW interference (CWI). The next step would be to utilize a signal generator to replicate the LightSquared transmissions and compare the receiver impact of these transmissions at varying power levels to that of the CWI. This will aid towards obtaining a correction factor between CWI and the LTE modulations. It will also help provide a reference point for the range accuracy SBAS message loss rate tests. The initial power levels of the LightSquared transmissions (for the baseline test conditions explained below) would be set at the same level as the GPS Receiver's CW Interference mask DO-229D Appdx. C).

The reported Carrier to Noise ratio (CNR) from the GPS Receiver is used as a yardstick of receiver performance. In addition, the pseudorange measurement accuracy (which reflects a critical receiver performance metric) and SBAS Message failure rates (for applicable units) will be evaluated at specific 3GPP Interferer signal levels. However, for a given receiver architecture, the range measurement accuracy is typically tied to the CNR.

C.1.1 Carrier-to-Noise Ratio (CNR) Degradation Baseline Test

The following depicts the test conditions used for comparison of relative impact of the CW interference versus the 3GPP LTE interferers.

C.1.1.1 CNR Degradation Baseline Test Satellite Simulator and Interference Conditions

The simulator and interference conditions shall conform to the following requirements:

1. For all test scenarios, the broadband GNSS test noise and $N_{sky,antenna}$ (-172.5 dBm/Hz) shall be simulated. A broadband external interference noise ($I_{Ext,Test}$) has a spectral density equal to -173.5 dBm/Hz at the antenna port.

2. The CW power and frequencies are listed in Table C-1. These CW frequencies are the mid band frequencies of the 5 and 10 MHz LTE 3GPP BTS bands that would be rolled out across Phases 0, 1A and 2.

3. The GNSS test noise depends on the number, power, and type of satellites simulated during the test. The power spectral density of the total GNSS Noise (I_{GNSS}) is -171.9 dBm/Hz (RTCA DO-235B [2], Appdx.F.2.3). This GNSS Noise was derived for GPS tracking but is used in the test for both GPS and SBAS tracking to allow simultaneous testing of GPS and SBAS thereby reducing test time. However it is acceptable to run the SBAS testing separately using a total GNSS Noise (I_{GNSS}) of -172.8 dBm/Hz for collection of the SBAS message loss rate data. The effective noise power spectral density (I_{Test}) of the satellites present in the simulator scenario may be removed from the total GNSS Noise; to do so, the satellite equivalent power spectral density specified in Table C-2 (I_{GH}, I_{GL}, I_{SH}, and I_{SL}) is removed for each satellite present. The number of maximum power GPS satellites is N_{GH}, the number of minimum power GPS satellites is NGL, the number of maximum power SBAS satellites is N_{SH}, and the number of minimum power SBAS satellites is N_{SL}. The GNSS test noise is determined by removing I_{Test} from I_{GNSS} as follows:

$$I_{GNSS,Test} = 10log10[10^{-171.9//10} - 10^{I_{Test}/10}]; \text{ where:}$$

$$I_{Test} = 10log10[(N_{GL})10^{I_{GL}/10} + (N_{GH})10^{I_{GH}/10} + (N_{SL})10^{I_{SL}/10} + (N_{SH})10^{I_{SH}/10}]$$

Note: The indicated power levels (both signal and noise) are for the steady-state portion of the tests; power levels are set to the required values once steady state navigation has been achieved. Refer to Appendix M of DO-229D for an explanation of how I_{Test} is derived and examples of the computation of $I_{GNSS,Test}$ and how it may be applied. This appendix also provides guidance on how the test can be setup.

4. Simulated GPS and SBAS RF shall be at the minimum power level for the equipment. One GPS satellite shall be set to the maximum power level (including maximum transmit power and maximum combined satellite and aircraft antenna gain). At least two SBAS satellites shall be used.

5. When the setup uses an external amplifier to simulate the impact of the GNSS Antenna preamplifier (DO-301 [2] equivalent antenna), it is recommended that a net 30dB gain (to simulate maximum antenna pre-amp gain and minimum cabling loss) is implemented in order to evaluate the worst case impact of the 3GPP Interferers.

Table C-1: STEADY STATE ACCURACY TEST CWI VALUES*

Frequency (MHz)	Power (dBm)	I/S (dB)
1528.8	**-22.2**	**111.8**
1531	**-28.1**	**105.9**
1550.2	**-79.6**	**54.4**
1552.7	**-86.4**	**47.6**

* The CWI power is specified at the antenna port. The actual level used during testing is reduced by the minimum frequency selectivity of the active antenna adjusted for any filtering in the test set-up itself. When demonstrating compatibility with a minimum standard antenna, the frequency selectivity is specified in RTCA/DO-301. When using a specific antenna, its minimum frequency selectivity can be used when determined in accordance with RTCA/DO-301. A block diagram of an example test setup is shown Figure C-1.

Note: Care should be taken when applying non-L1 CW frequencies so that the L1 CW and broadband specifications are not exceeded.

Table C-2: SATELLITE EQUIVALENT POWER SPECTRAL DENSITY

Satellite Type	Maximum Power Satellite	Minimum Power Satellite
GPS	I_{GH} = -183.5 dBm/Hz	I_{GL} = -196.5 dBm/Hz
SBAS	I_{SH} = -179.8 dBm/Hz	I_{SL} = -198.3 dBm/Hz

Note: These values of equivalent power spectral density were computed using the same assumptions as were used to determine the total GNSS Noise in Appendix C of DO-229D.

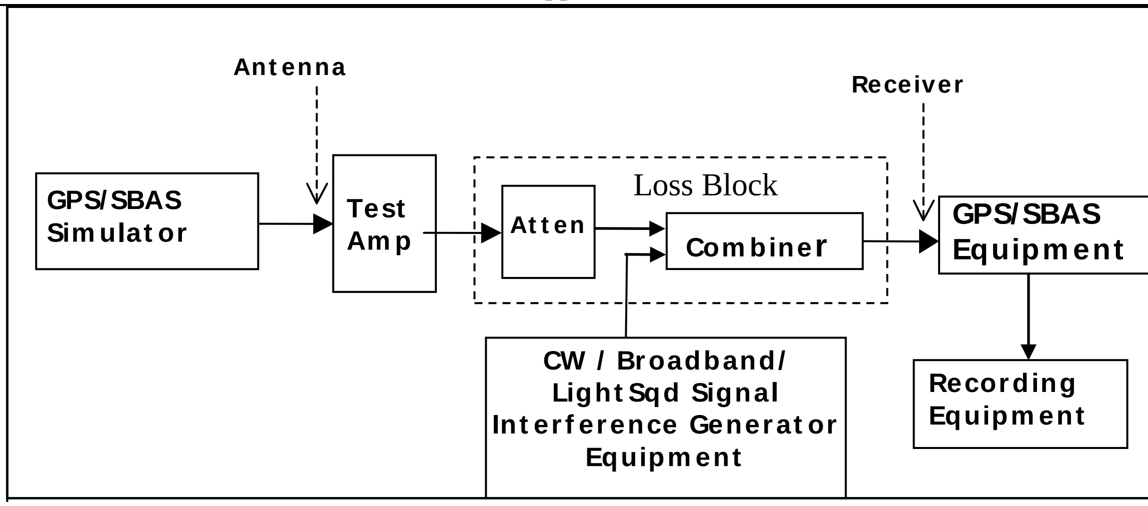


Figure C-1: **EXAMPLE TEST SET-UP**

C.1.1.2 CNR Degradation Baseline Test Procedure

1) The test unit is connected to the RF signal and interference source.
2) The simulator scenario shall be engaged and the satellites RF shall be turned on.
3) The equipment under test shall be powered and initialized. It is assumed that the receiver has obtained a valid almanac for the simulator scenario to be tested prior to conducting these tests.
4) When the unit is navigating, the interference to be applied shall be applied to the equipment under test, and the power of the signal and interference shall be adjusted to the required level (at the appropriate freq. as seen in Table C-1).
5) At this base power level ensure that the unit meets the MOPS requirements per DO-229D. Record the CNR's of individual satellites (SBAS and GPS).
6) Increase the level of the CWI by 2 dB (this step size may be varied) and hold this level for 60 seconds.
7) Record the CNR's of the individual GPS SV's and the CWI level.
    1. If the CNR's on the SV's have not degraded go back to step (6).
    2. If the CNR is reduced by > 1dB, record the result for that RFI level and go back to the previous CWI level, ensure the unit attains the original CNR level and increase the CWI in smaller steps (in order to capture the CWI level that cause a 1dB degradation).
    3. Proceed to the next step.
8) Repeat steps 5-7 at the other CWI frequencies listed in Table C-1.
9) Replace the CWI interference source with a signal generator that would replicate a 5 MHz bandwidth LTE (3GPP) signal transmission and repeat the test procedure (from step 1) for the 1528.8 and 1552.7 MHz frequencies.
10) Replace the CWI interference source with a signal generator that would replicate a 10 MHz bandwidth LTE (3GPP) signal transmission and repeat the test

procedure (The starting point may be a I/S value somewhat less than in step 9, and using only center frequencies 1531.0 and 1550.2 MHz).

Note 1: A comparison of the unit's CNR degradation across both types on interference sources is helpful to verify the assumptions in interference analyses. The value from steps 9 and 10 are also used in subsequent higher level receiver performance tests in Section 3 and following sections. *Any receiver margin above the interference mask is considered as design margin.*

Note 2: As an option, the comparison test of Section 2 above may be performed for higher CNR degradation values.

C.1.2 Measurement Accuracy Test

The purpose of this Accuracy Test is to evaluate the equipment's accuracy performance under specific interference levels that have been ascertained from the CNR degradation test procedure (see C.1.1.2). It is not intended to verify the accuracy of the atmospheric corrections; these corrections need not be included in the test. In order to meet the DO-229D MOPS requirements, the equipment must meet the accuracy requirements of Section 2.1.2.1, 2.1.3.1, and 2.1.4.1.3 of DO-229D.

Note: This evaluation method is based on the assumption that a least-squares position algorithm (per Section 2.1.4.1.4 of DO-229D) is implemented. If a different form of positioning is used, this evaluation method may not be appropriate.

C.1.2.1 Measurement Accuracy Test Satellite Simulator and Interference Conditions

The measurement accuracy test shall be performed under the following test conditions:

A. The baseline test condition (at the MOPS interferer levels) used in C.1.1.2 with a modification to $I_{Ext,Test.}$ Use $I_{Ext,Test}$ of -170.5 dBm/Hz vs. -173.5 dBm/Hz.

B. The equivalent LTE (3GPP) broadband RFI signal level at which the receiver's estimated CNR is lower by 1dB from the baseline used in Section C.1.1.2. (option: higher level CNR degradation values may be used as desired)

The total duration of each test case test shall be based upon sampling intervals required to obtain samples that are statistically independent. Independent samples collected during the initial acquisition and before steady-state operation are used for the validation of σnoise overbounding. The samples collected prior to steady-state operation should not be used for the steady-state RMS accuracy evaluation and the steady-state evaluation of $\left(\sigma_{noise}^2[\,]+\sigma_{divg}^2[\,]\right)^{1/2}$.

Note: It would be advantageous to extend the duration of this test to support evaluation of SBAS Message Loss Rate (for applicable receivers).

This test is performed for following cases (with the listed order of priority)

a. 5 MHz 3GPP Interferer BW at 1552.7 MHz

b. 5 MHz 3GPP Interferer BW at 1528.8 MHz

c. 5 MHz 3GPP Interferer BW's at both 1552.7 and 1528.8 MHz

d. 10 MHz 3GPP Interferer BW at 1531 MHz

e. 10 MHz 3GPP Interferer BW at 1550.2 MHz

f. 10 MHz Interferer BW's at both 1531 and 1550.2 MHz

It is recommended that the Doppler/delta range metrics on the tracked satellites (if available) be evaluated alongside the pseudorange accuracy procedure. This includes evaluation of the accuracy degradation of the Doppler/delta range measurement from the receiver, the Doppler/Delta range validity flag and available loss of code/carrier lock indicators. The measurement type (Doppler/delta range) and validity flag information is available on Label 060 (bits 21 and 22) on the ARINC standard 429 GNSS data bus. The measurement is found on Label 063/064 on this bus.

C.1.2.2 Measurement Accuracy Test Procedure

1) Perform steps 1 through 5 of C.1.1.2. Sampling should begin for each satellite immediately after it is included in the navigation solution for the σnoise overbounding evaluation described in paragraph 4) below.
2) When steady-state accuracy is reached, data are recorded as follows:
3) Initially, 50 independent samples of pseudorange data are recorded at the required sampling interval (see note below).

Note: The sampling interval will be two times the integration interval used for carrier phase smoothing of pseudoranges. For example, if the integration interval used for carrier smoothing of the pseudoranges is 100 second, the sampling interval will be 200 seconds. If ten pseudoranges are collected per sampling interval (nine independent measurements), the duration of the initial data collection period will be 20 minutes.

4) The normalized RMS range error statistic, RMS_PR, is computed according to the following formula, using all collected samples (including those prior to steady-state operation):

$$RMS\_PR(M) \equiv \sqrt{\frac{\sum_{j=1}^{M}\left\{\sum_{i=1}^{N_j}\frac{Z_{ij}^2}{\sigma_{norm,ij}^2 N_j}\right\}}{M}}$$

where:

$$Z_{ij} \equiv PR_{ij} - R_{ij} - (c\Delta t)_j$$

$$(c\Delta t)_j \equiv \frac{1}{N_j}\sum_{i=1}^{N_j}\left(PR_{ij} - R_{ij}\right)$$

$$\sigma_{norm,ij}^2 = \frac{\left[\left(N_j - 1\right)^2\sigma_{noise,ij}^2 + \sum_{\substack{k=1\\k\neq i}}^{N_j}\sigma_{noise,kj}^2\right]}{N_j^2}$$

where:

PR_{ij} = smoothed pseudo-range, channel i, time j

R_{ij} = true range, satellite i, time j (includes extrapolation)

N_j = number of satellites at time j

M = number of sampling intervals

$\sigma_{noise,ij}$ = satellite i, time j (refer to Appendix J.2.4 of the DO-229D MOPS)

Note 1: Interchannel biases on the simulator may impede the accuracy test specified herein. It may be necessary to determine this bias and inflate the test threshold based upon equipment calibration. If two receivers are used to remove this bias (via double-differencing), the test must account for potential interchannel biases in the receivers themselves and cannot simply remove all bias components.

Note 2: Since code-carrier divergence is not simulated in this test, the σ_{divg} term is not used in this normalization. Validation of σ_{divg} should be accomplished by analysis.

5) Verification of σnoise overbounding: The error statistic is compared to the 110% Pass Threshold of Table C-3 based on the Number of Independent Samples (NIS), where NIS is given by:

$$NIS(M) = \sum_{j=1}^{M} (N_j - 1)$$

If RMS_PR is below the pass threshold (Table C-3), the result is a pass. If the RMS_PR is not below the pass threshold, additional data may be collected. In this case, the RMS_PR shall include the initial independent samples plus all additional data, and the formulas and pass criteria of this section (which apply for an arbitrary number of samples) shall be used.

Note: It is expected that the pass criteria will not be met with the initial data collection (only the initial acquisition and 50 steady-state operation independent samples due to the limited sample size. Development of the test criteria, and the associated pass probabilities are described in Appendix M of DO-229D.

6) Steady-state value of $\left(\sigma^2_{noise}[i] + \sigma^2_{divg}[i]\right)^{1/2}$: Using only those samples collected during steady-state, the average $\left(\sigma^2_{noise}[i] + \sigma^2_{divg}[i]\right)^{1/2}$ output values for each satellite are compared to the requirements of Appendix J.2.4 of DO-229D. The output values must be less than or equal to the required accuracy values for the designator of the equipment.

7) Verification of RMS accuracy: The steps defined in paragraph 3 and 4 are repeated using only those samples collected during steady-state operation and using the required RMS accuracy (sections 2.1.4.1.3.1 and 2.1.4.1.3.2) (minus any steady-state value of σ_{divg}) instead of the output $\sigma_{noise,i,j}$ in the computation of $\sigma_{norm,i,j}$. The pass criteria defined in paragraph 4 applies.

Table C-3: PASS THRESHOLD TABLE

NIS	110% Pass Threshold	125% Pass Threshold
25-50	N/A	1.084
50-75	0.954	1.137
75-100	0.981	1.159
100-150	0.998	1.172
150-200	1.017	1.187
200-300	1.028	1.196
300-400	1.042	1.206
400-500	1.050	1.212
500-750	1.055	1.216
750-1000	1.063	1.222
1000-1250	1.068	1.226
1250-1500	1.072	1.229
1500-2000	1.074	1.231
> 2000	1.078	1.233

Note: The 110% pass threshold yields a 10% probability of passing equipment with a true accuracy of 110% of the required accuracy. The 125% pass threshold yields an 80% probability of failing equipment with a true accuracy of 125% of the required accuracy.

C.1.3 SBAS Message Loss Tests

The purpose of this test is to evaluate the loss rate of SBAS messages at degraded CNR's as a result of the LightSquared 3GPP LTE transmissions. Typically, SBAS Message Loss Rate requirements in Section 2.1.1.3.2 of DO-229D will need to be met at the minimum operating conditions (DO-229D Section 2.1.1.10) in the presence of DO-229D Appendix C interference conditions. In this case, the Message Loss rate requirement (Message Loss Rate < 1 in 1000 messages) is evaluated under interference conditions that also include the 3GPP interferers. This test will help evaluate 3GPP power levels at which the receiver does not meet the SBAS message loss requirement. Data necessary for this test may be collected concurrently during the tests in C.1.2.2 (by extending the period of time for the test in C.1.2.2).

Note 1: SBAS message loss information is typically not provided on the standard ARINC data outputs from a GNSS receiver. Instrumentation data from the GPS receivers may need to be used to obtain this information from the GPS receiver.

Note 2: It is expected that the SBAS message loss rate threshold would be exceeded prior to exceeding the pseudorange accuracy threshold.

REFERENCES

[1] RTCA, *Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment*, Washington, D.C., RTCA DO-229D, Dec. 13, 2006.
[2] RTCA, *Assessment of Radio Frequency Interference Relevant to the GNSS L1 Frequency Band*, Washington, D.C., RTCA DO-235B, March 13, 2008.

[3] *Minimum Operational Performance Standards for Global Navigation Satellite System (GNSS) Airborne Active Antenna Equipment for the L1 Frequency Band*, Washington, D.C., RTCA DO-301, December 13, 2006.

APPENDIX A.2

ADDITIONAL AVIATION RECEIVER TEST RESULTS

This appendix presents test results for four aviation receivers that were not tested following the aviation test plan in Appendix A.1 because they are not compliant with RTCA DO-229, DO-253, or DO-316. Three of these aviation receivers are for ground applications, including WAAS reference stations, Local Area Augmentation System (LAAS) ground facilities (LGF), and a Zyfer timing receiver used by an FAA automation system. The remaining receiver is for airborne use, but certified to the older FAA TSO-C129 (see discussion in Section 3.1.2).

The 1 dB carrier to noise density (C/N_0) degradation and loss of tracking results for three ground-based receivers and one GPS-only aviation receiver (#32) are in Table A.2-1. These were obtained with the Phase 0 LightSquared configuration and GPS signals at the SPS minimum level of -128.5 dBm. Note the WAAS G-II 1-dB degradation result is at a point when the automatic gain control (AGC) became unstable and caused a greater than 1 dB drop in C/N_0 and the LAAS LGF receiver did not lose lock up to the maximum level tested, -16 dBm. Also the results for Receiver #32 are based on observing the front panel readout during the test, which did not indicate C/N_0 but its own measure of signal strength, and thus the 1-dB degradation point is approximate. Plots of the Phase 0 test results for the WAAS G-II, LAAS LGF receiver and Zyfer GSync are in Figure A.2-1, Figure A.2-2 and Figure A.2-3, respectively.

Table A.2-1. LightSquared Phase 0 Signal Power (dBm) for 1 dB C/N_0 Degradation and Loss of Satellite Tracking

Receiver	1-dB C/N_0 degradation	Loss of tracking
WAAS G-II	-38*	-21
LAAS LGF	-36	> -16**
Zyfer GSync	-30	-17
#32***	-25	-16

* G-II AGC gain shifted and C/N_0 degraded by more than 1 dB at this level

** LGF did not lose lock at Phase 0 levels tested

*** Receiver #32 results based on front panel readout during test

Figure A.2-1. WAAS G-II C/N_0 Response to LightSquared Phase 0 Signal

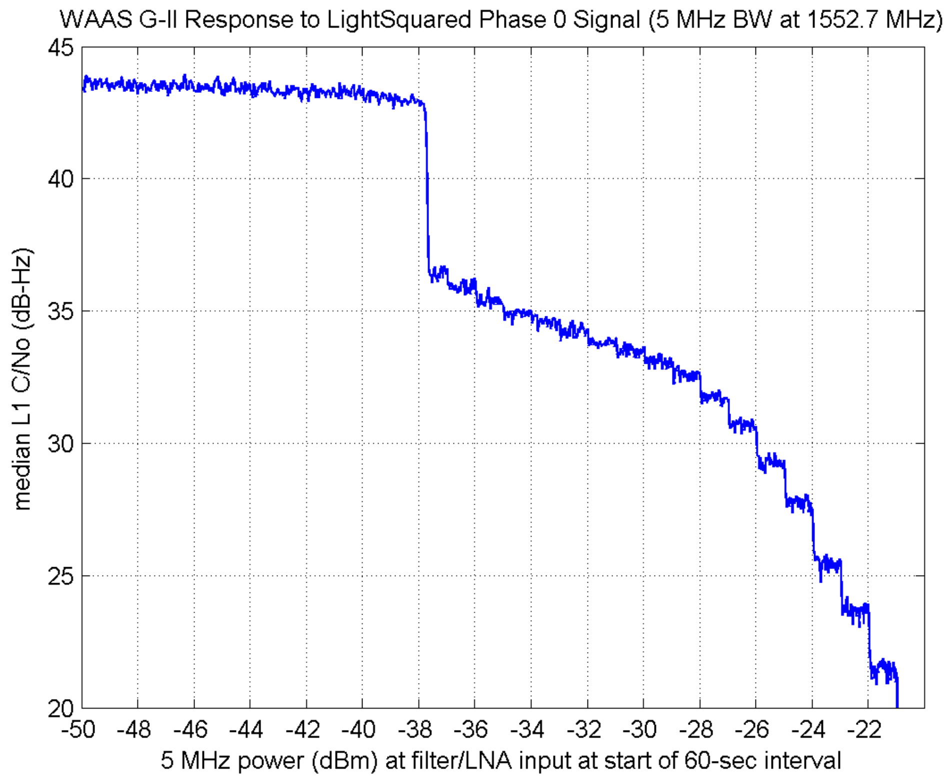


Figure A.2-2 LAAS LGF Receiver C/N$_0$ Response to LightSquared Phase 0 Signal

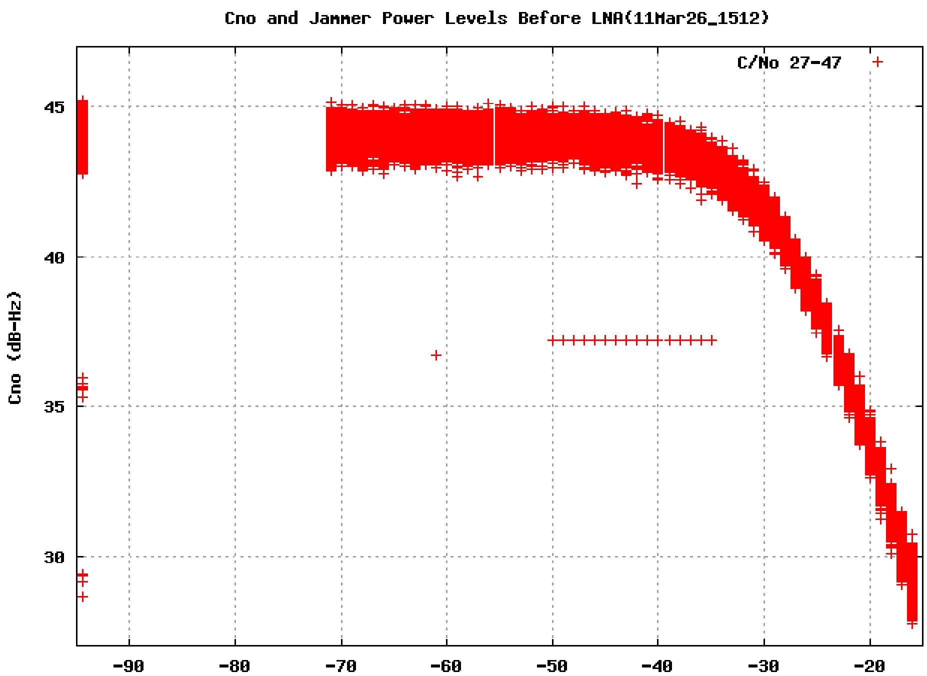
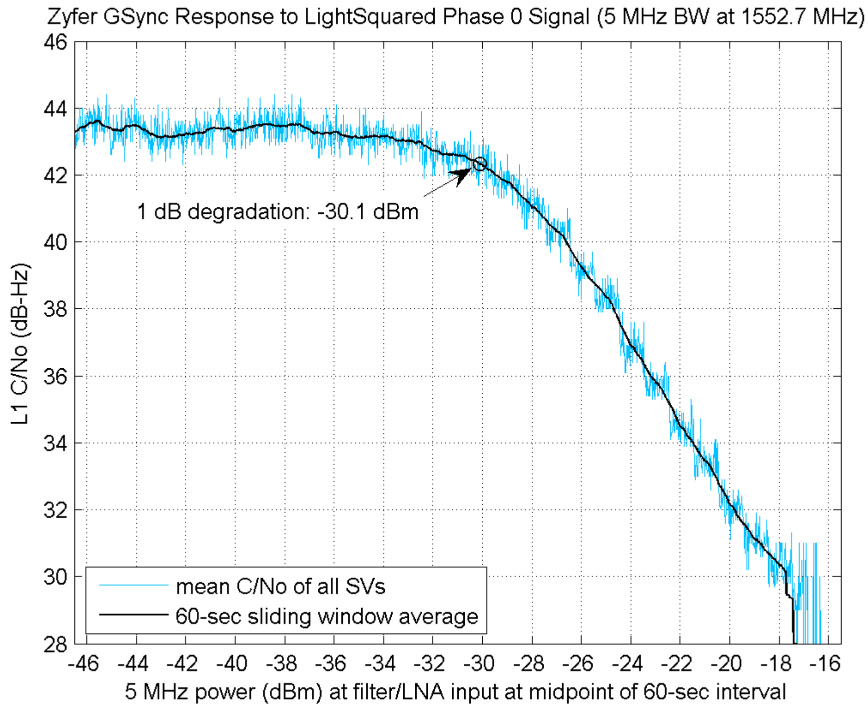


Figure A.2-3. Zyfer GSync C/N0 Response to LightSquared Phase 0 Signal


Zyfer GSync Response to LightSquared Phase 0 Signal (5 MHz BW at 1552.7 MHz)
1 dB degradation: -30.1 dBm
mean C/No of all SVs
60-sec sliding window average
L1 C/No (dB-Hz)
5 MHz power (dBm) at filter/LNA input at midpoint of 60-sec interval
46
44
42
40
38
36
34
32
30
28
-46
-44
-42
-40
-38
-36
-34
-32
-30
-28
-26
-24
-22
-20
-18
-16

Appendix A.3

High Performance GPS Filter

Delta Microwave

5/06/2011

Background

- LightSquared Planned 4G Network High Power Transmitter Signals
  - Approved Frequency Range: 1525 – 1559 MHz
  - Transmit Power : 1500 Watts CW
- May Interfere with GPS Signals
  - GPS Frequency Range : 1559 – 1610 MHz
  - GPS Frequency Allocations
    - L1 : 1575.42 MHz – C/A, P and M Codes
    - L2 : 1227.60 MHz – C/A, P and M Codes
    - L3 : 1381.05 MHz – NUDET & NDS Use
    - L4 : 1379.91 MHz – Study Use
    - L5 : 1176.45 MHz – Safety-of-Life (SoL) Data & Pilot Signals
  - Most Affected : L1 Signal
- May Interfere with WAAS (Wide Area Augmentation System)
  - Require 20 MHz Passband Bandwidth
- May Interfere with GNSS (Global Navigation Satellite System)
  - Require 40 MHz Passband Bandwidth

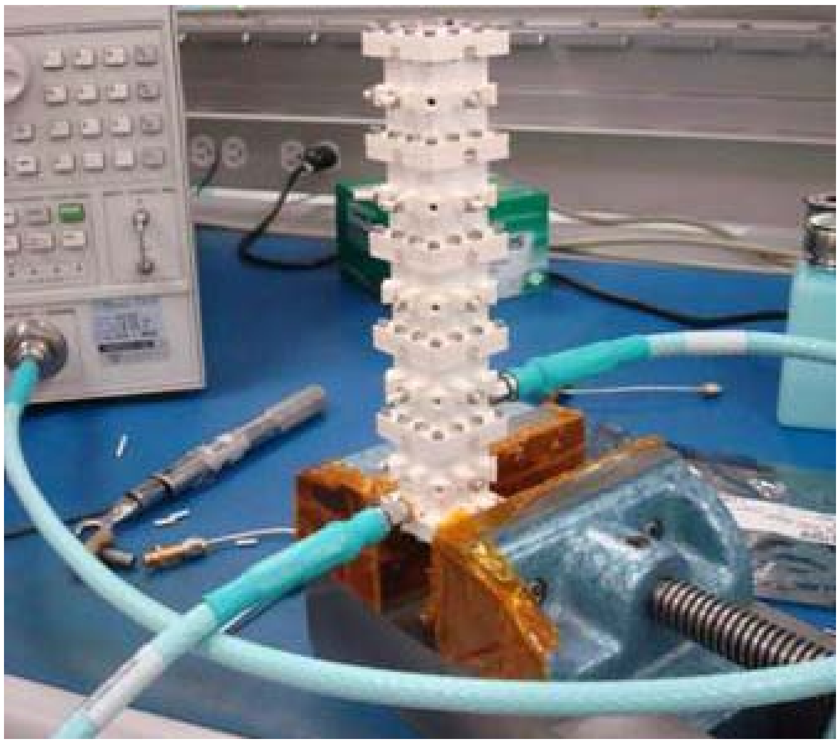
High Performance Filter Requirements

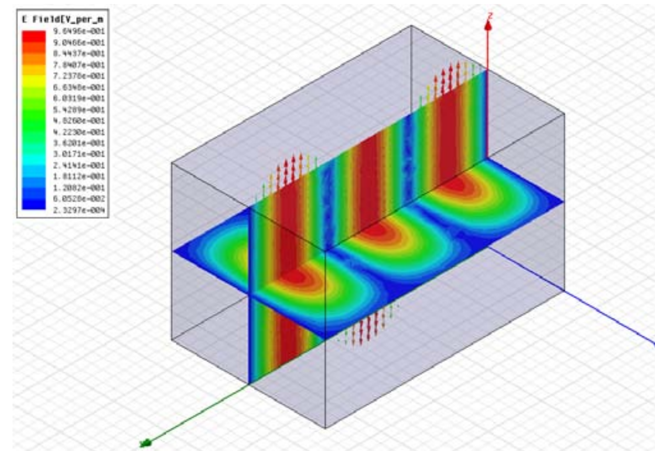
- Provide Sufficient Rejection in LightSquared Frequency (1526 – 1554.5 MHz)
  - Rejection over 1526 – 1554.5 MHz : > 50 dBc
- 20 MHz Bandwidth High Performance in GPS/WAAS Frequency
  - Passband Frequency : 1565.2 – 1585.7 MHz (1559 – 1591 MHz)
  - Insertion Loss : < 0.5 dB
  - Insertion Loss Variation : < 0.1 dB
  - Group Delay Variation : < 2 ns
  - Return Loss : > 20 dB
- 40 MHz Bandwidth High Performance in GPS/GNSS Frequency
  - Passband Frequency : 1565.2 – 1605 MHz (1559 – 1610 MHz)
  - All Other Parameter : Same as Above
- Size : Small as Possible
- Weight : Light as Possible
- Environment : Air Borne Compatible
  - Temperature Range : -40 to +85 deg C
  - Humidity : 0 – 95%

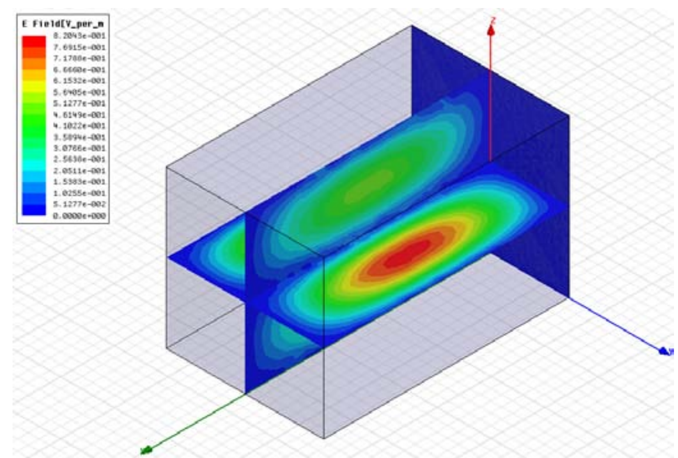
High Performance Channel Filter @ 20 GHz

(10,4,2,2) Dual Mode TE_{103}

Achieved Qu = 12.6 K

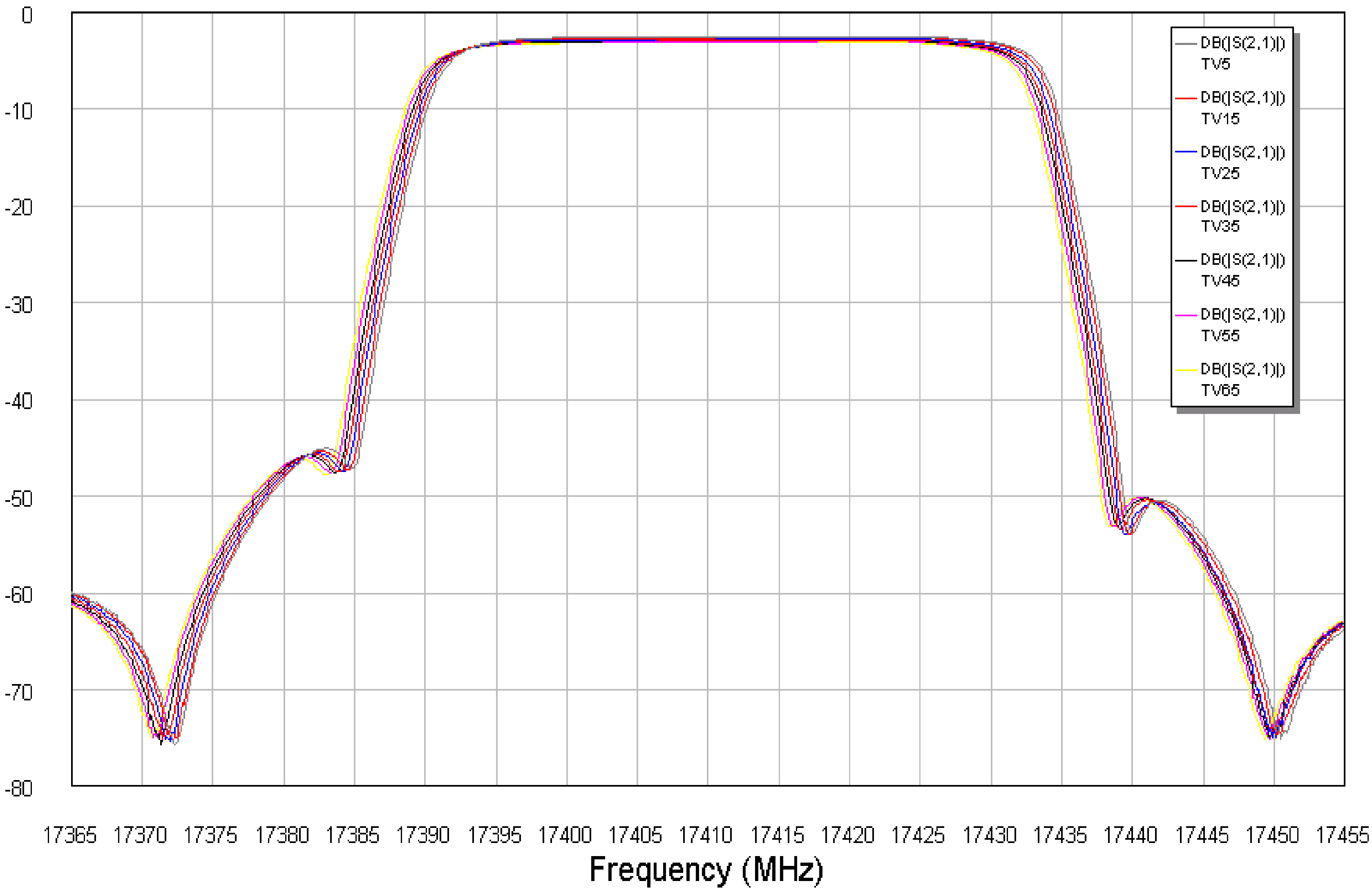






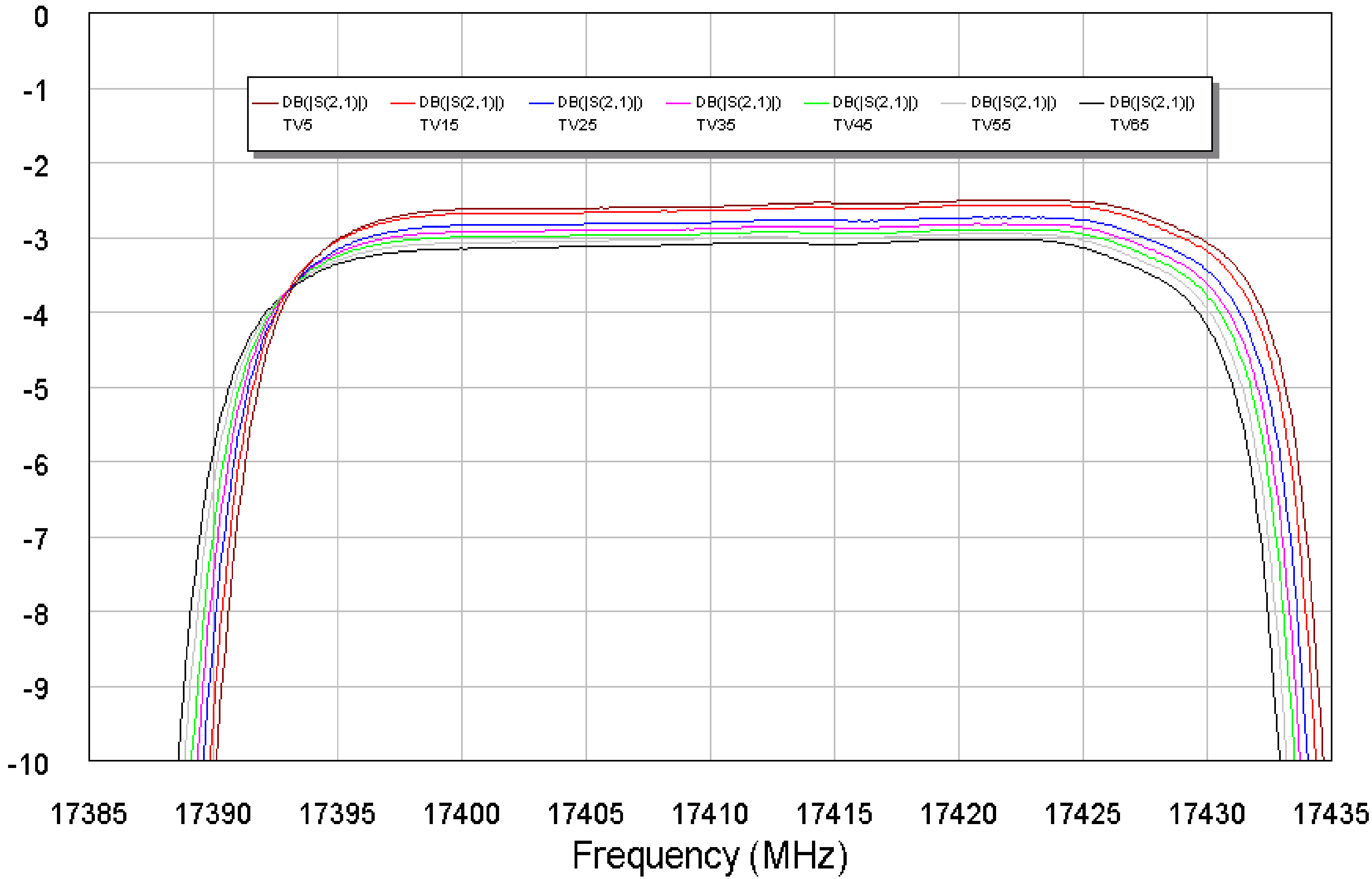
Thermal Vacuum Data– Wide Band Response

Over +5°C to +65°C in Test Fixture



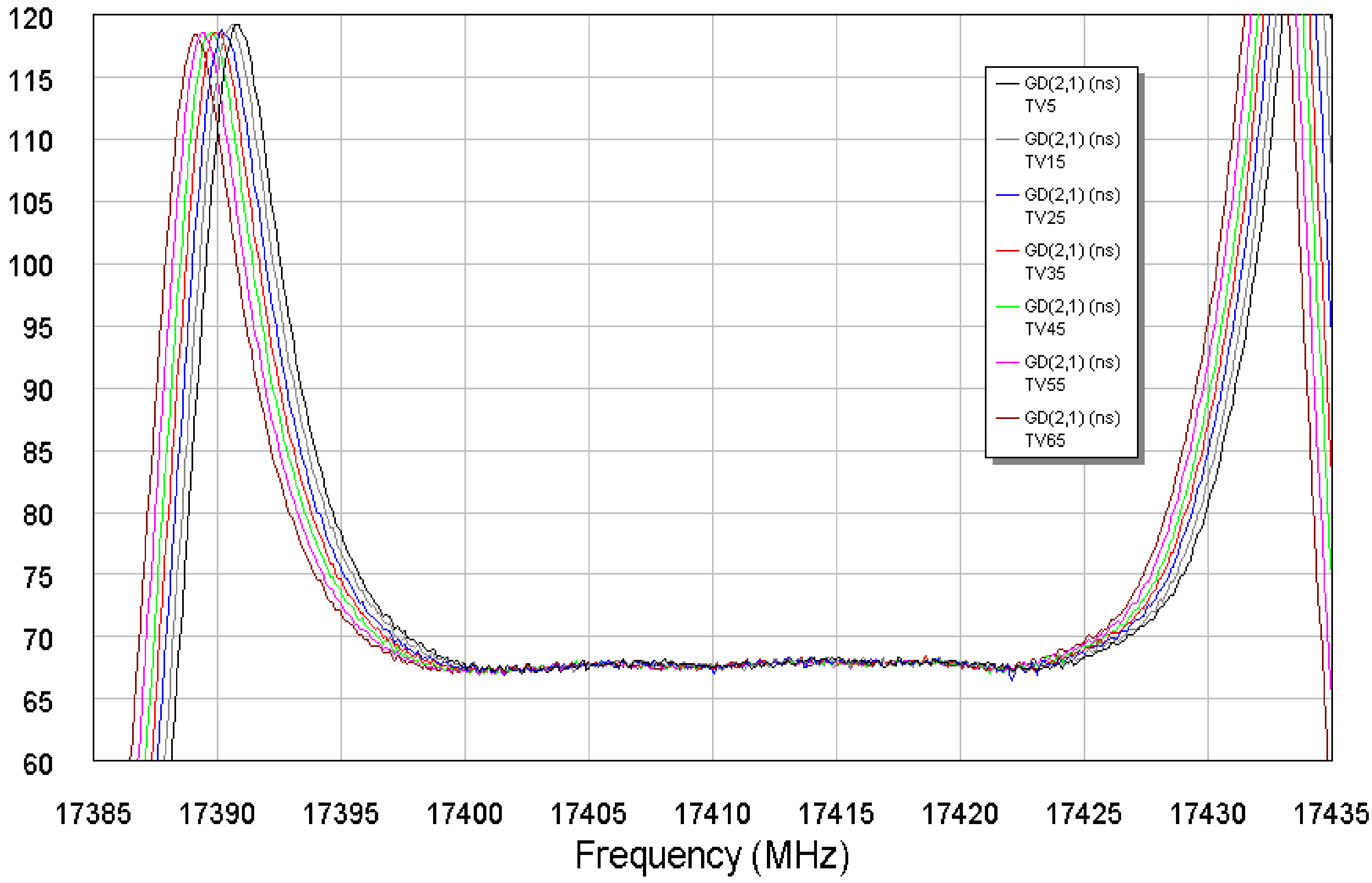
Thermal Vacuum Data– Narrow Band Response

Over +5°C to +65°C in Test Fixture



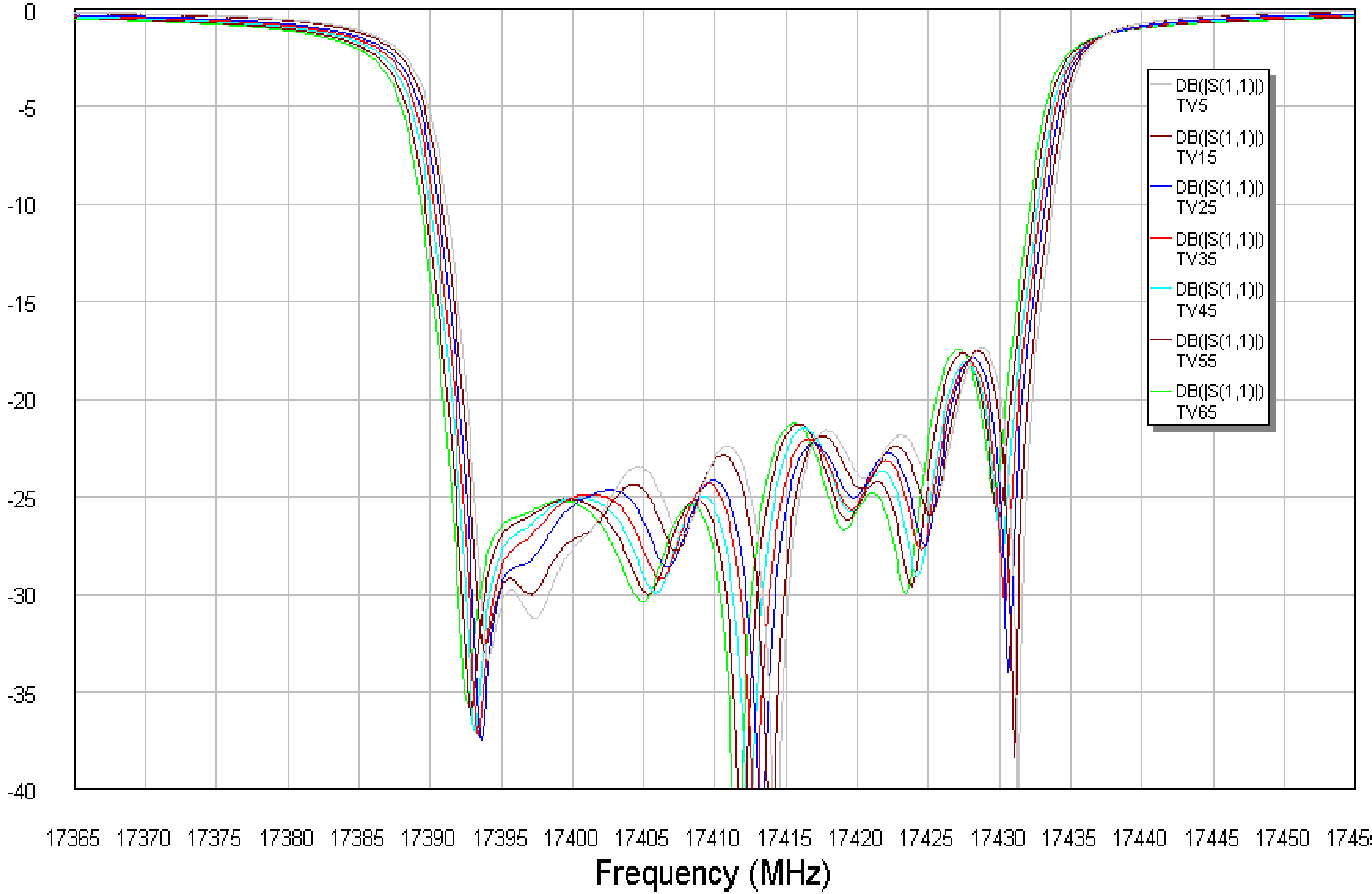
Thermal Vacuum Data– Group Delay Response

Over +5°C to +65°C in Test Fixture



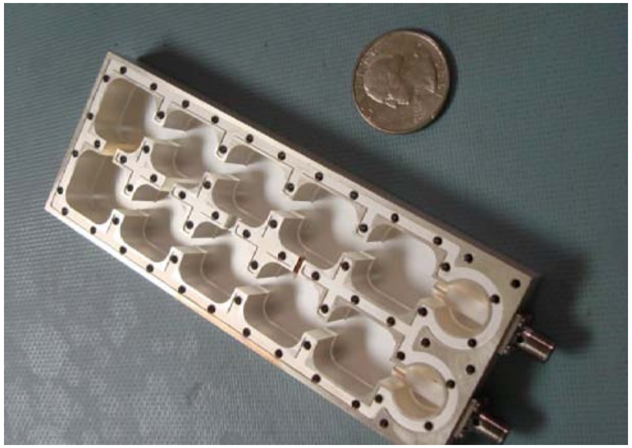
Thermal Vacuum Data – Return Loss Response

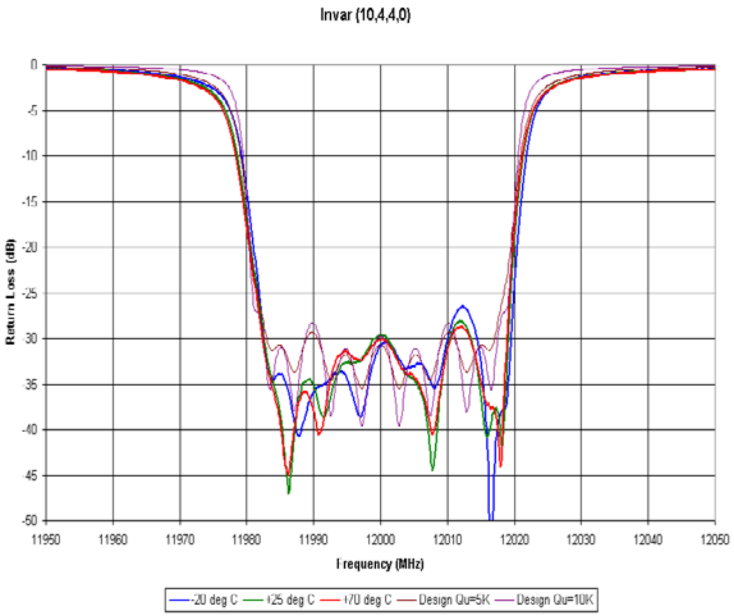
Over +5°C to +65°C in Test Fixture



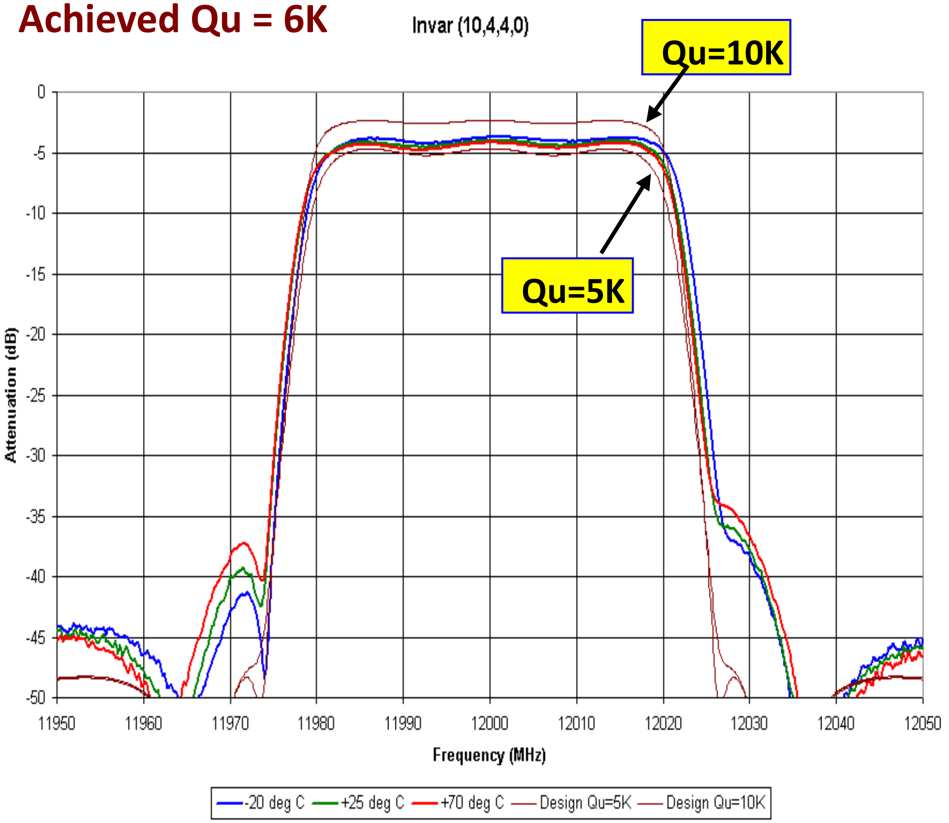
High Performance Channel Filter @ 12 GHz

(10,4,2,2) Dual Mode TE_{101}



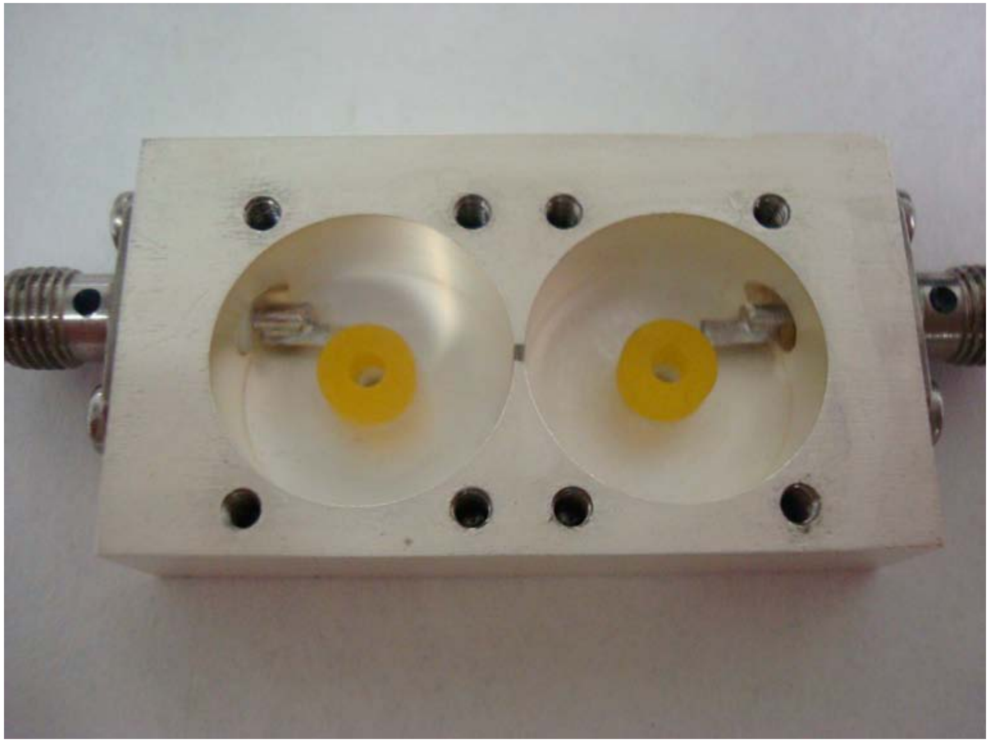


Achieved Qu = 6K



Dielectric Resonator Filter

Coupling Test Fixture Shown



Benefits

Temperature Stable
Ultra High-Qu
Qu > 20K Possible
Low Insertion Loss
Smaller Size

Draw Backs

Lead Time
Material Property
Harder to Tune
Tuning Reduces Qu

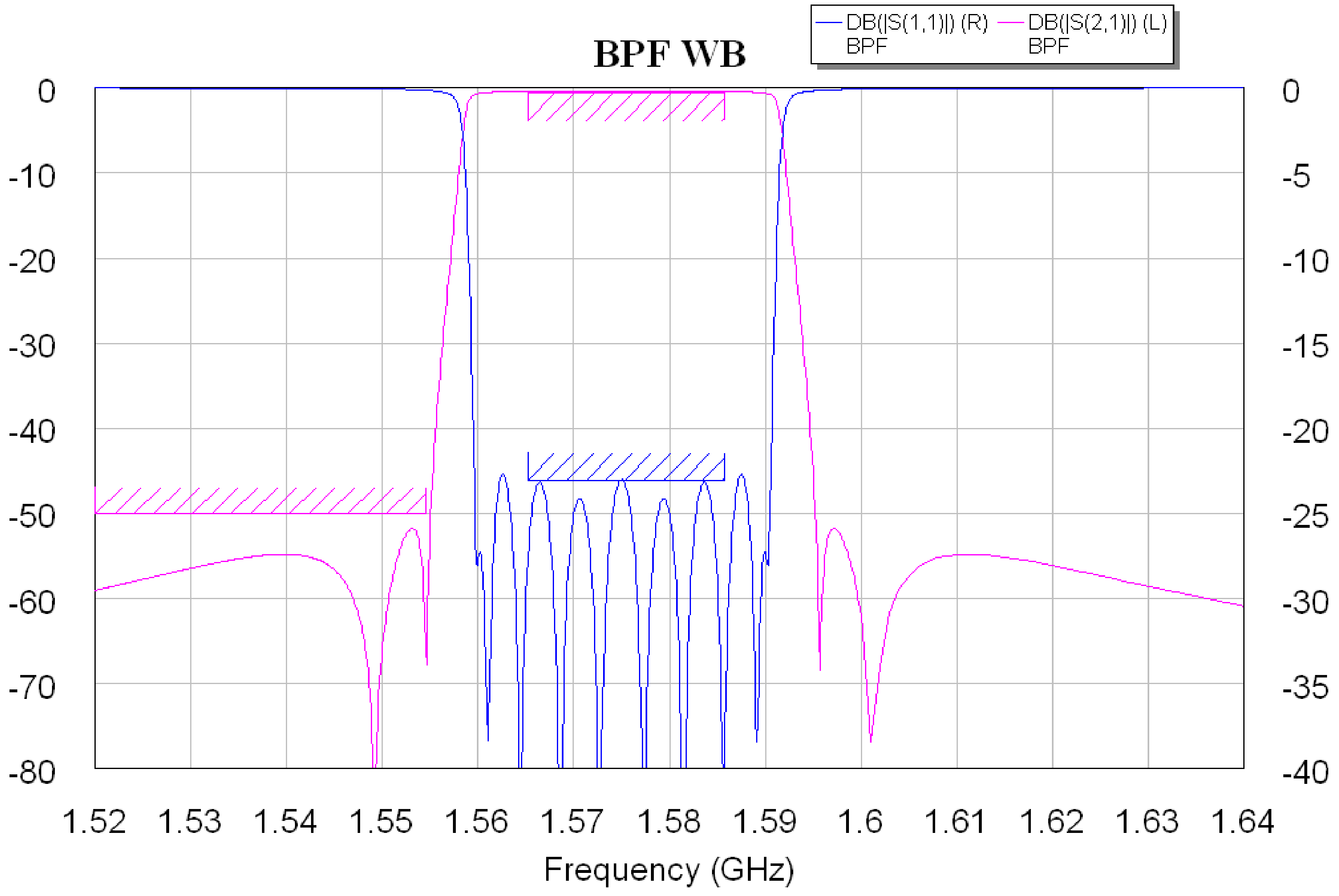
20 MHz High Performance Filter

- (10,4,2,2) Complex Band Pass Filter Topology
  - Amplitude & Group Delay Equalized Topology
  - Frequency Scaled Delta MW Channel Filter (10,4,2,2)
    - All Transfer Function Coupling Matrix Identical
    - Associated Cavity Dimensions for Frequency Scaling
  - Representative Performance Presented
- Short Term Solution
  - High-Q Cavity Resonators with Following Exception:
    - Insertion Loss : < 2.0 dB
    - Require Temperature Compensation Technology to be Implemented
      - Invar and/or Other Proprietary Material
- Long Term Solution
  - Ultra High-Q Dielectric Resonators :
    - Will Provide All Required Performance Parameters
    - Inherent Temperature Stable Material

Delta Microwave Proprietary

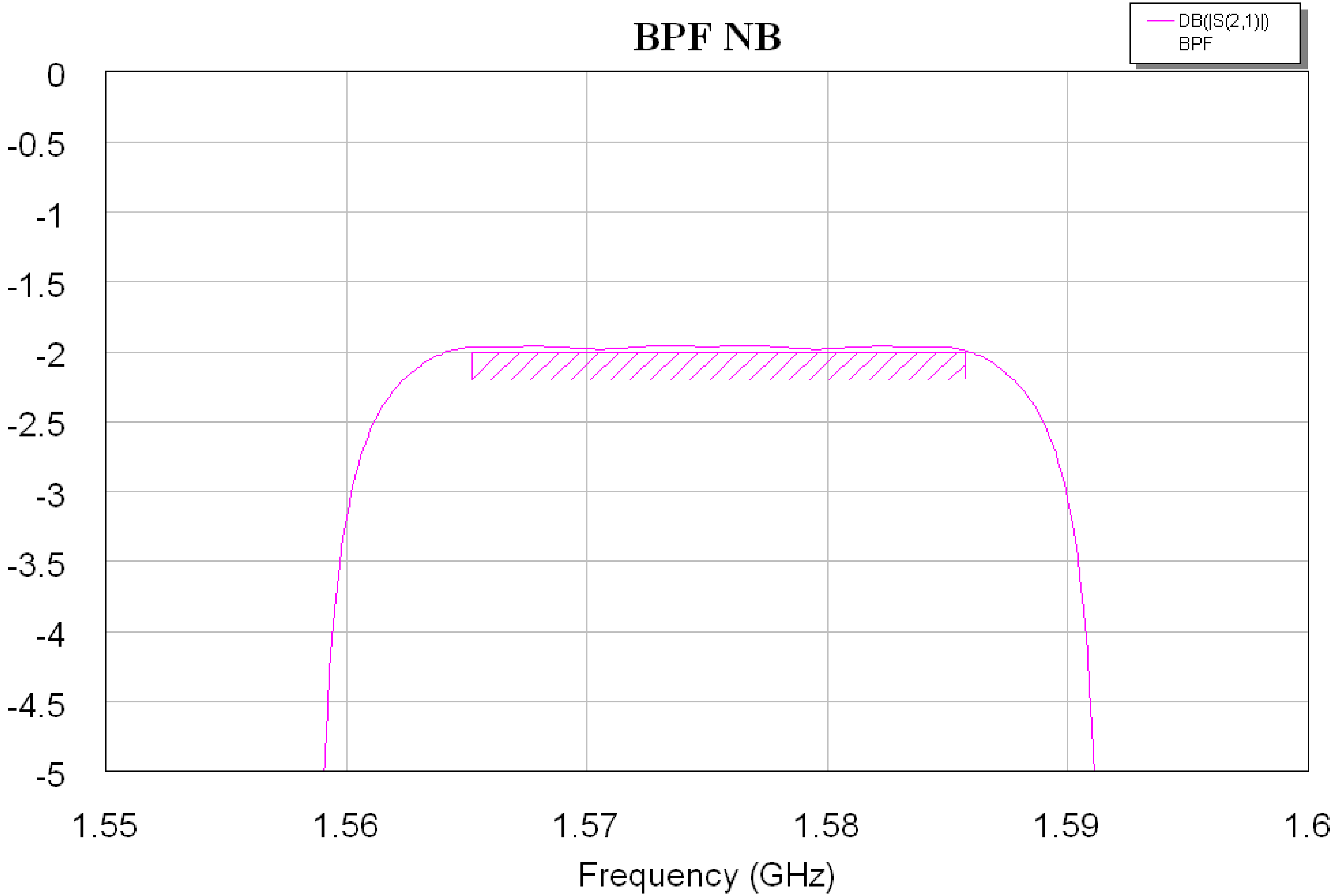
20 MHz High Performance BPF – WB Response

Both Ultra High-Q Dielectric Resonator & High-Q Cavity



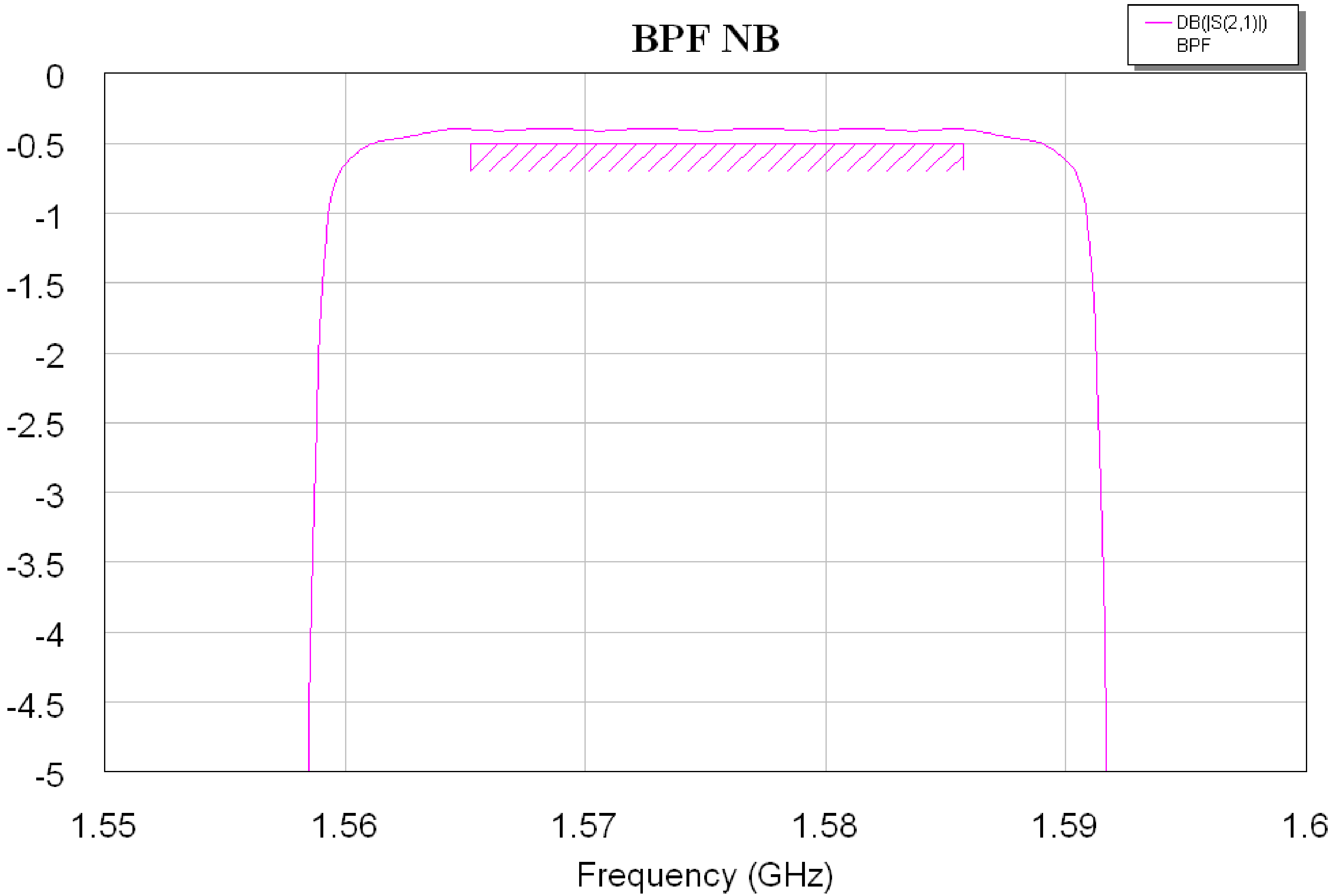
40 MHz High Performance BPF – NB Response

High-Q Cavity Only



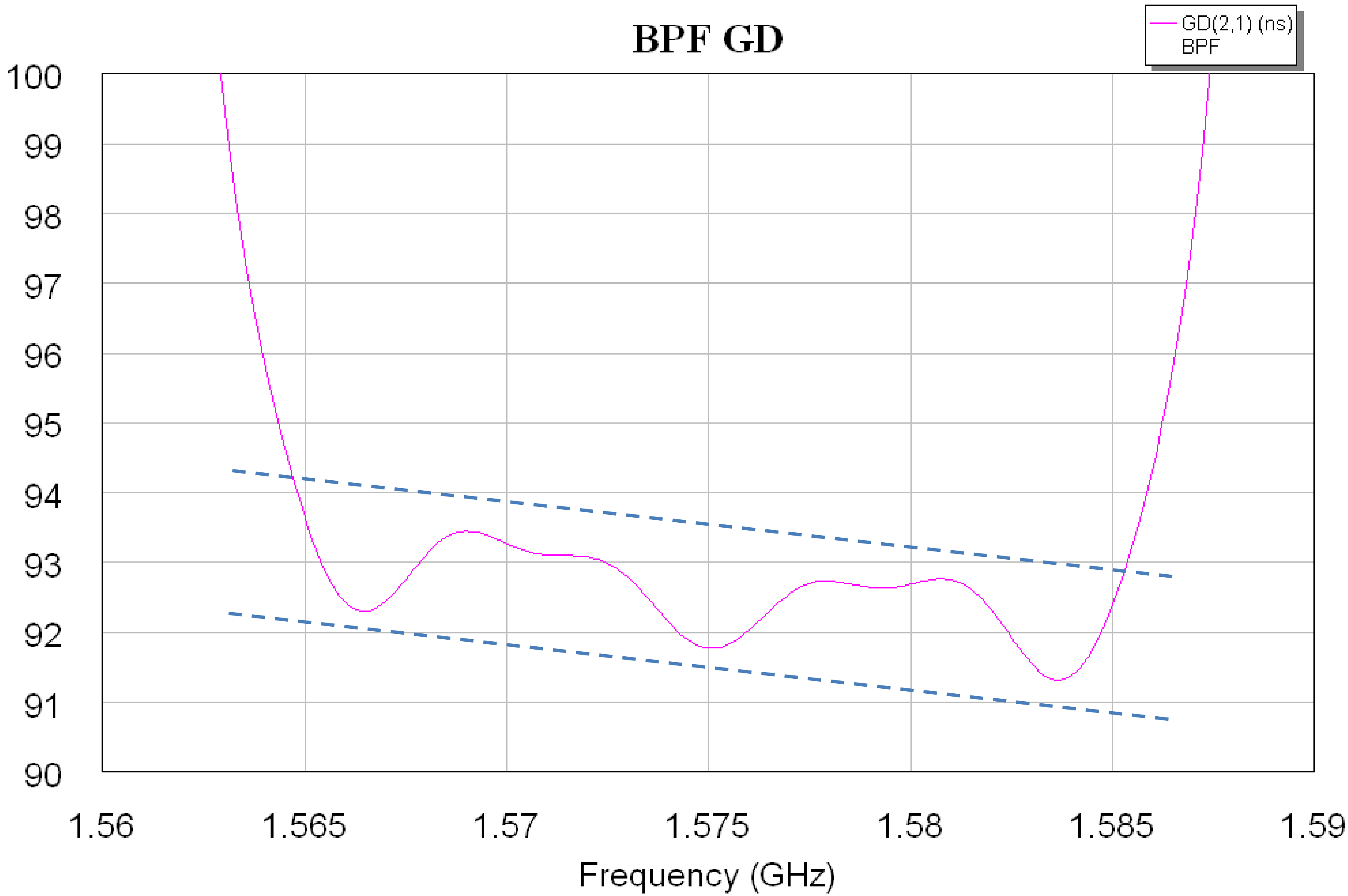
20 MHz High Performance BPF – NB Response

Ultra High-Q Dielectric Resonator Only

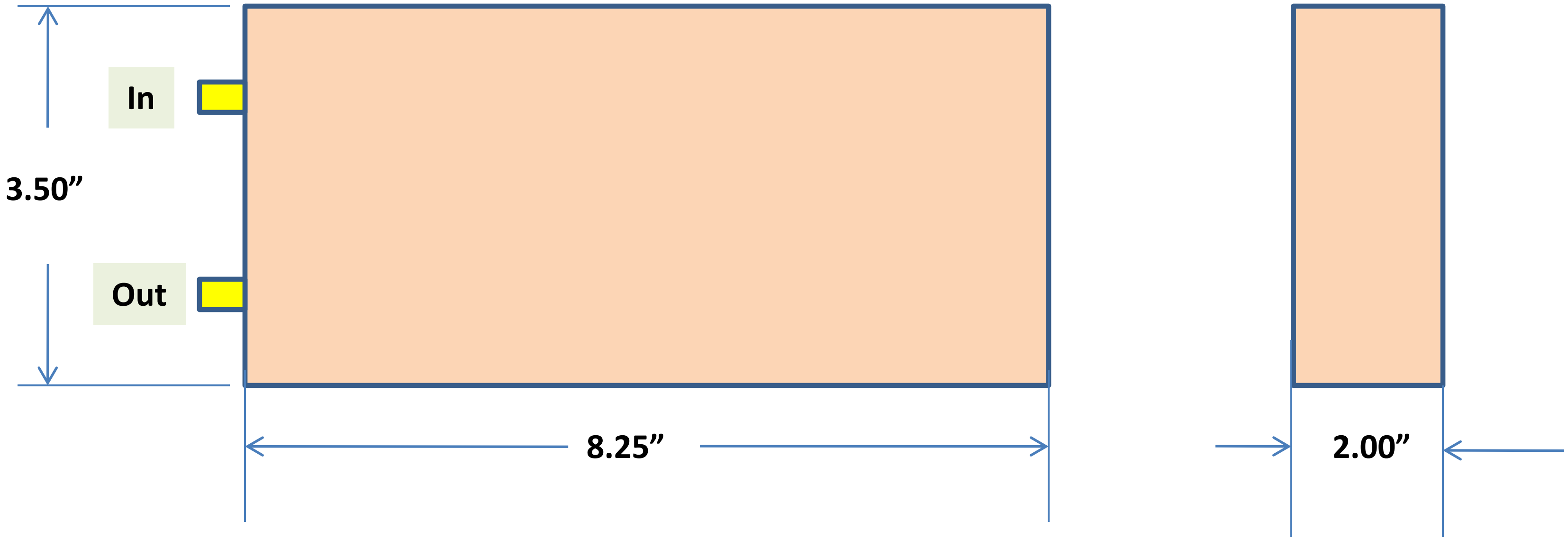


20 MHz High Performance BPF – GD Response

Both Ultra High-Q Dielectric Resonator & High-Q Cavity



Preliminary Configuration



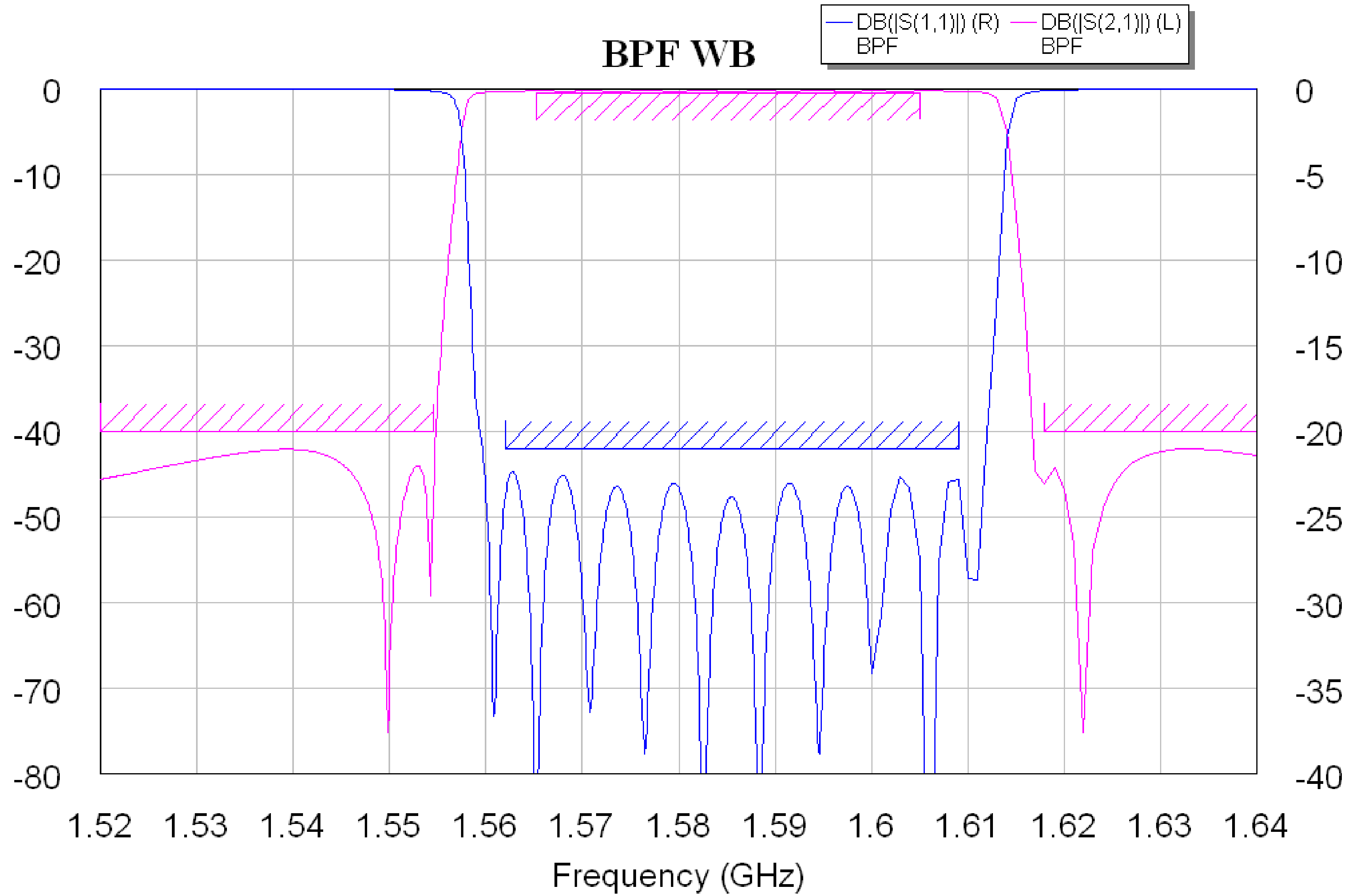
Dielectric Resonator Filter: The 2.00” will be Reduced to 1.25”

40 MHz BW High Performance Filter

- (12,4,2,2) Complex Band Pass Filter Topology
  - Similar to Delta MW Channel Filter (10,4,2,2)
  - Amplitude & Group Delay Equalized Topology
  - A Quick Preliminary Design Responses (Not Yet Optimized) Presented
- Long Term Solution
  - Ultra High-Q Dielectric Resonators :
    - Will be able to provide all required parameters
- Short Term Solution
  - High-Q Cavity Resonators with Following Exception:
    - Rejection : > 40 dB (May be able to improve)
    - Group Delay : < 3 ns (May be able to improve)
    - Insertion Loss : < 1.5 dB
    - Require Temperature Compensation Technology to be Implemented

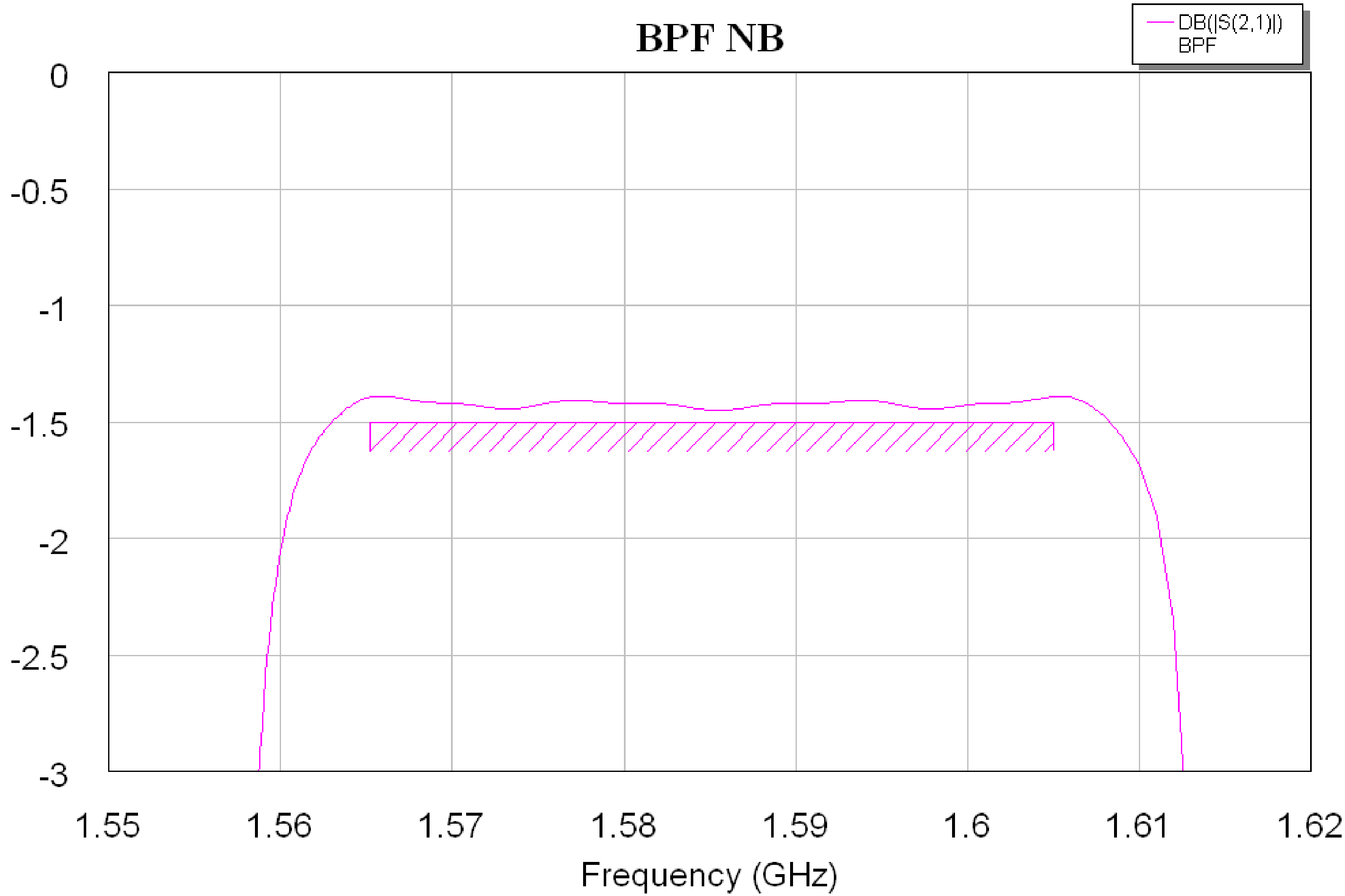
40 MHz High Performance BPF – WB Response

Both Ultra High-Q Dielectric Resonator & High-Q Cavity



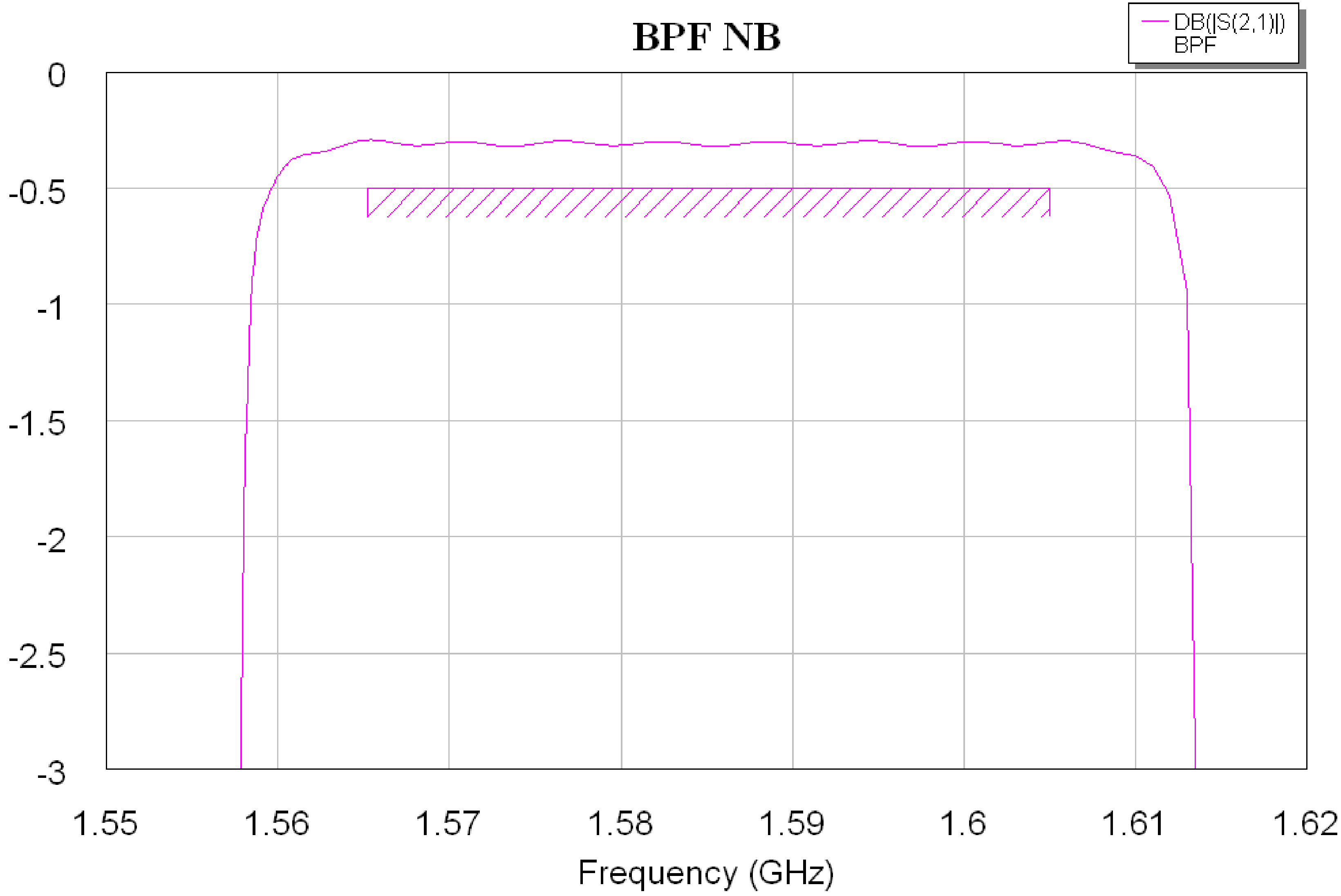
40 MHz High Performance BPF – NB Response

High-Q Cavity Only



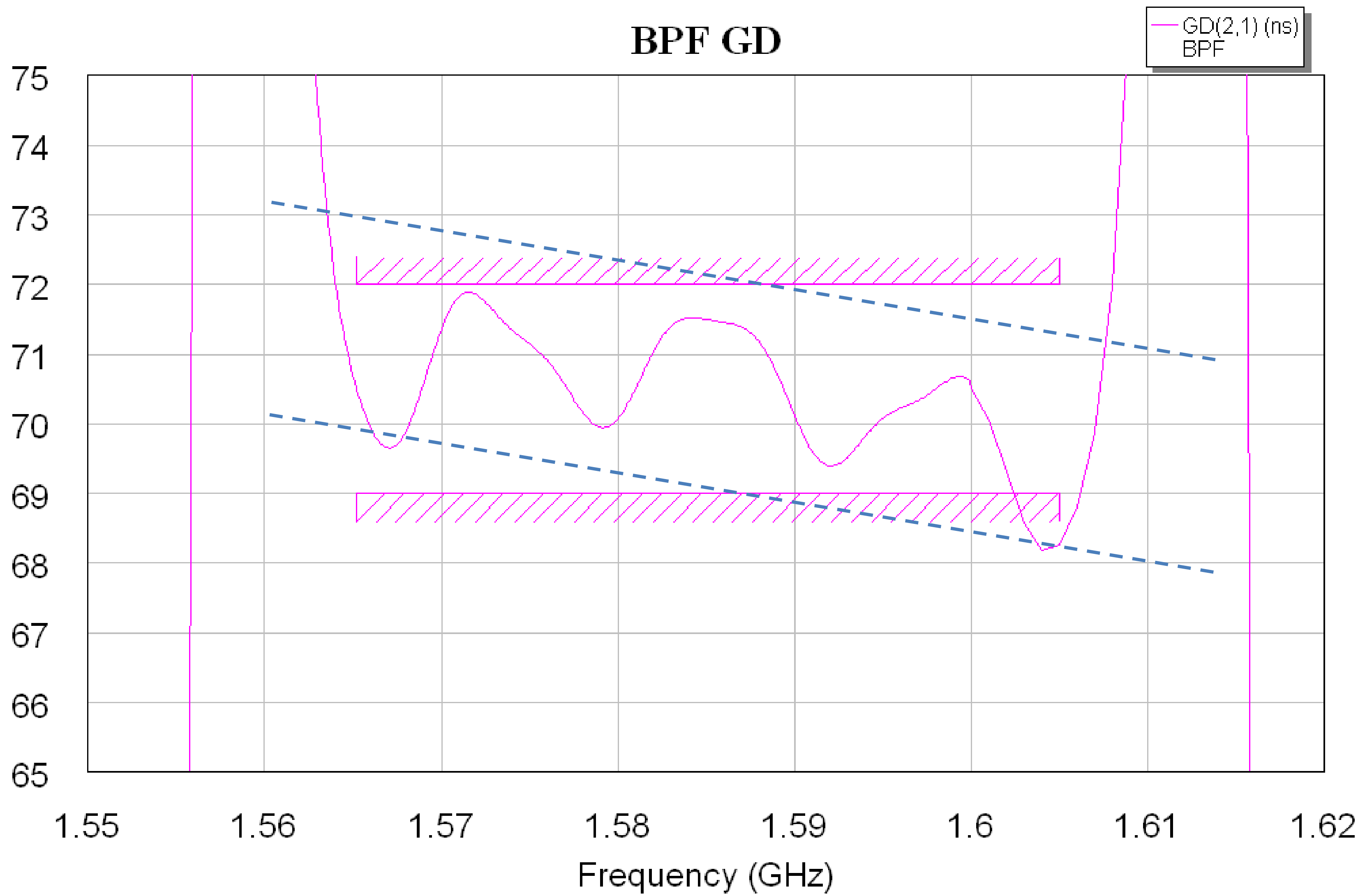
40 MHz High Performance BPF – NB Response

Ultra High-Q Dielectric Resonator Only

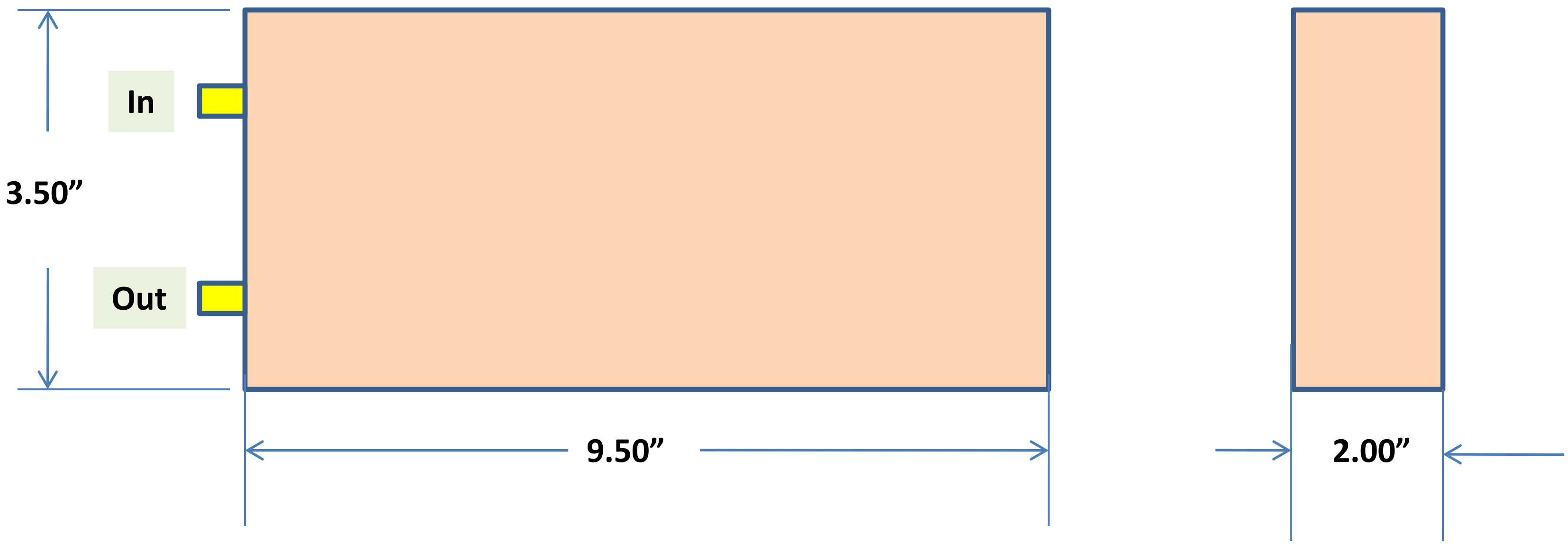


40 MHz High Performance BPF – GD Response

Both Ultra High-Q Dielectric Resonator & High-Q Cavity



Preliminary Configuration

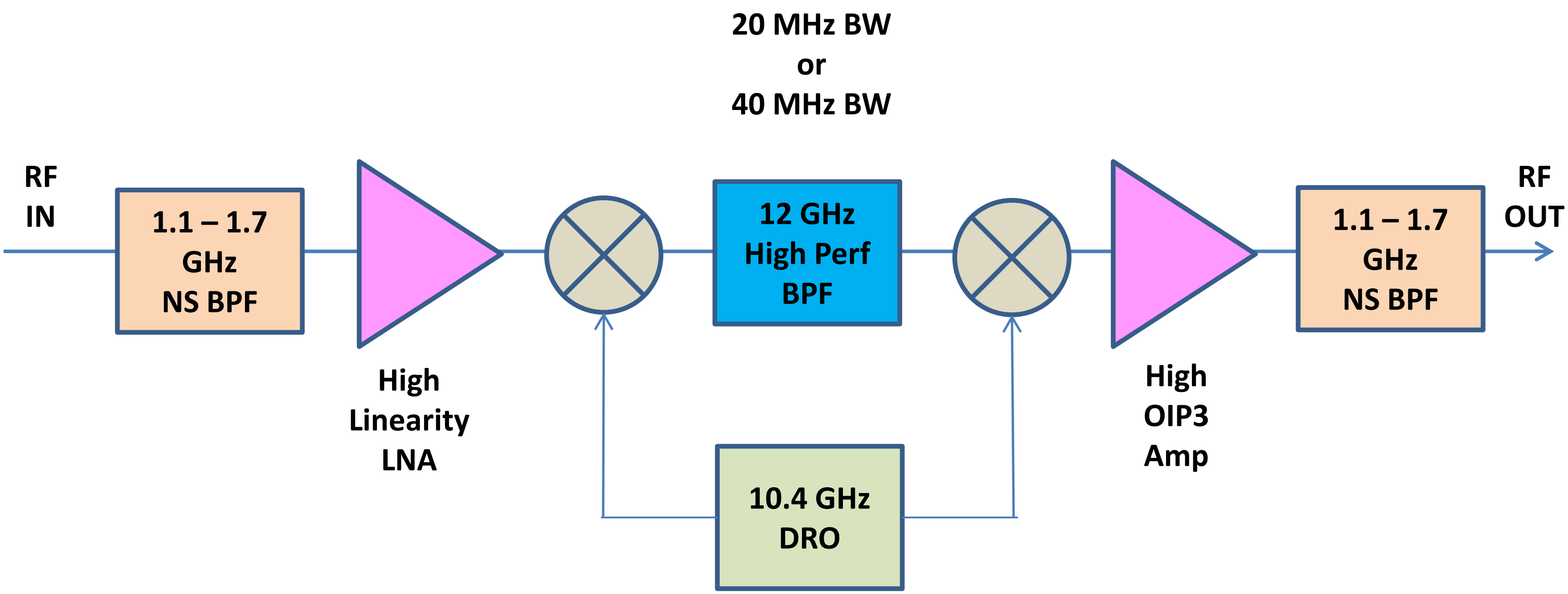


Dielectric Resonator Filter: The 2.00” will be Reduced to 1.25”

Size Reduction Option – Thinking Outside of Box

- Active Channel Filter (Dual Conversion Technology)
  - Lower Weight & Smaller Size
  - Maximum Utilization of COTS Devices
    - LNA, Mixers, MP Amp & Low Phase Noise DRO
  - Requires One High Performance Filter @ Ku-band
    - Either High-Q Cavity or Ultra High-Q Dielectric Resonator Type
  - Block Input/Output Filters to Reduce Out-of-band Noises
- Key Performances
  - Noise Figure : < 2.0 dB
  - Gain : 26 +/- 2 dB for Cavity, 29 +/- 2 dB for Dielectric
  - Passband BW : 20.0 MHz or 40.0 MHz
  - OIP3 : > + 34 dBm
  - Spur Free Dual Conversion
  - Rejection : > 50 dB

Proposed Architecture



Noise Figure & Gain

$$nFn = nF1 + \frac{nF2-1}{g1} + \frac{nF3-1}{g1*g2} + \frac{---}{---} + \frac{nFn-1}{g1*---gn-1}$$

	FE BPF	LNA (1st)	LNA (2nd)	Mixer	Attn	BPF	Attn	Mixer	LNA	BE BPF
Stage	1	2	3	4	5	6	7	8	9	10
NF (dB)	0.50	0.80	0.80	9.00	2.00	2.00	2.00	9.00	1.00	0.50
Gain (dB)	-0.50	18.00	18.00	-9.00	-2.00	-2.00	-2.00	-9.00	18.00	-0.50
AccumG	-0.50	17.50	35.50	26.50	24.50	22.50	20.50	11.50	29.50	29.00

$$nFi = 1.12 + \frac{0.20}{0.89} + \frac{0.20}{56.23} + \frac{6.94}{3548.13} + \frac{0.58}{446.68} + \frac{0.58}{281.84} + \frac{0.58}{177.83} + \frac{6.94}{112.20} + \frac{0.26}{14.13} + \frac{0.12}{891.25}$$

1.59	NF (dB)	Gain (dB)	29.00

Ultra High-Q Dielectric Resonator Filter

	FE BPF	LNA (1st)	LNA (2nd)	Mixer	Attn	BPF	Attn	Mixer	LNA	BE BPF
Stage	1	2	3	4	5	6	7	8	9	10
NF (dB)	0.50	0.80	0.80	9.00	2.00	5.00	2.00	9.00	1.00	0.50
Gain (dB)	-0.50	18.00	18.00	-9.00	-2.00	-5.00	-2.00	-9.00	18.00	-0.50
AccumG	-0.50	17.50	35.50	26.50	24.50	19.50	17.50	8.50	26.50	26.00

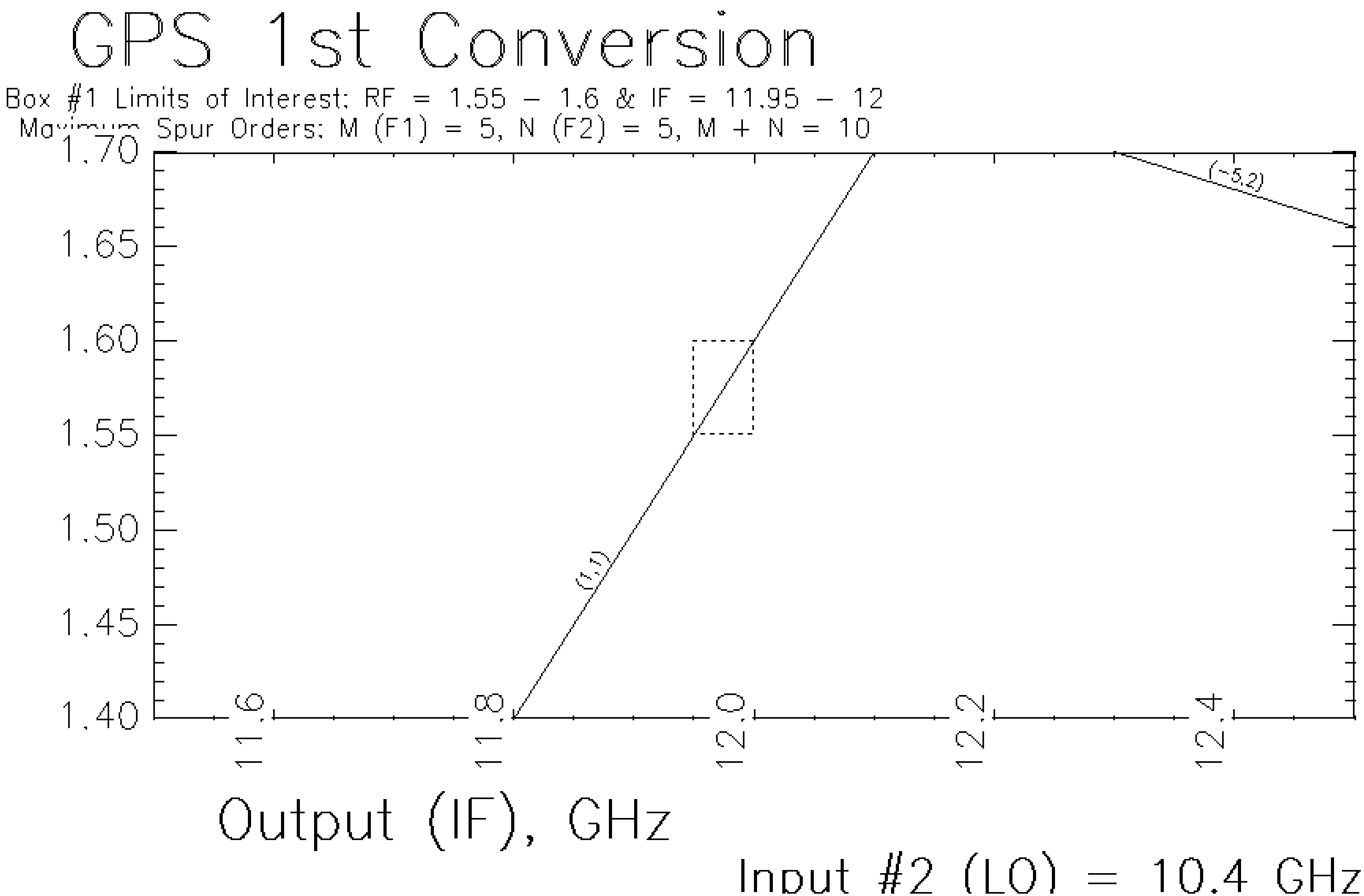
$$nFi = 1.12 + \frac{0.20}{0.89} + \frac{0.20}{56.23} + \frac{6.94}{3548.13} + \frac{0.58}{446.68} + \frac{2.16}{281.84} + \frac{0.58}{89.13} + \frac{6.94}{56.23} + \frac{0.26}{7.08} + \frac{0.12}{446.68}$$

1.85	NF (dB)	Gain (dB)	26.00

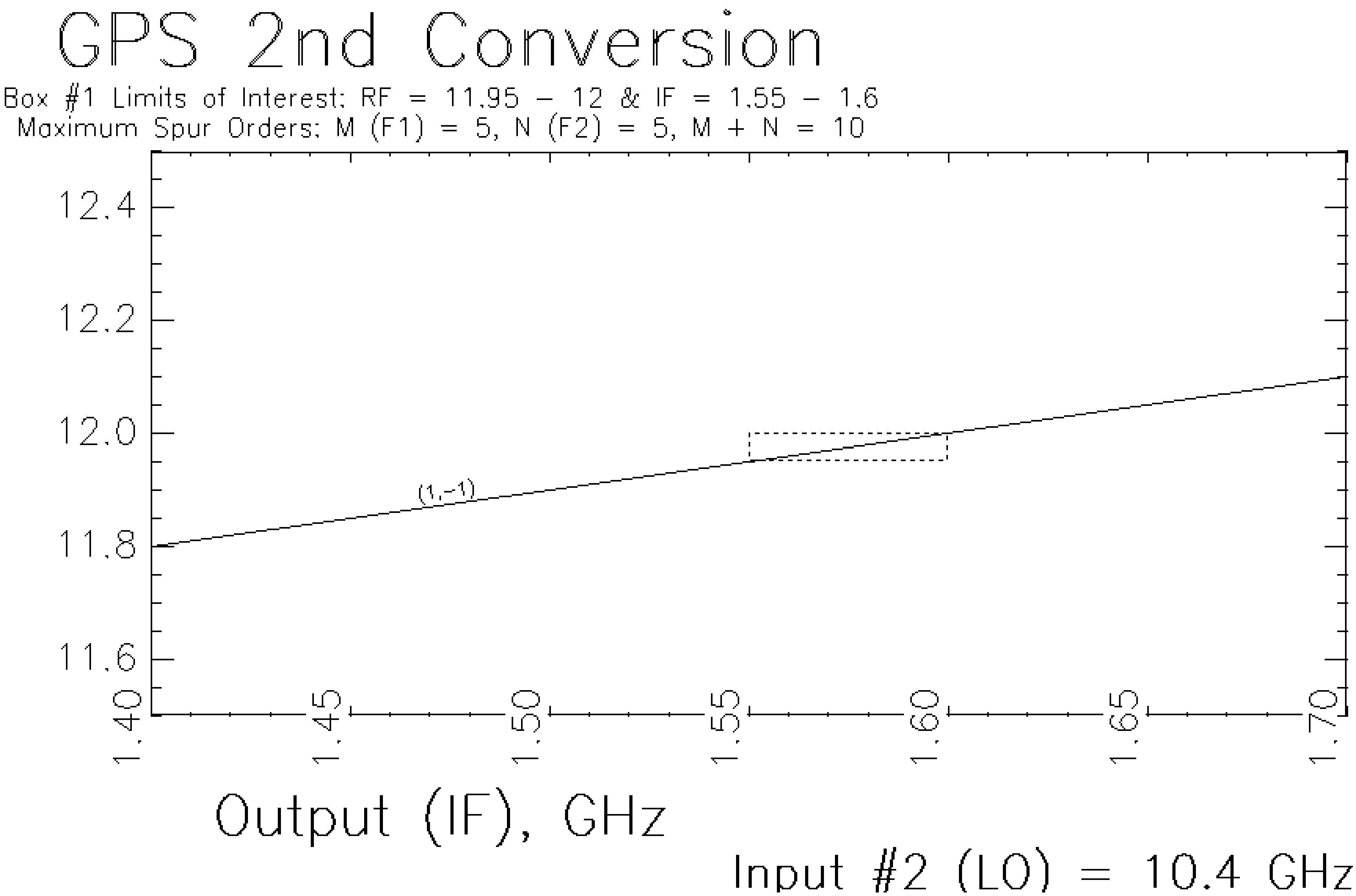
High-Q Cavity Filter

No significant Difference between Dielectric Resonator Filter vs Cavity Filter

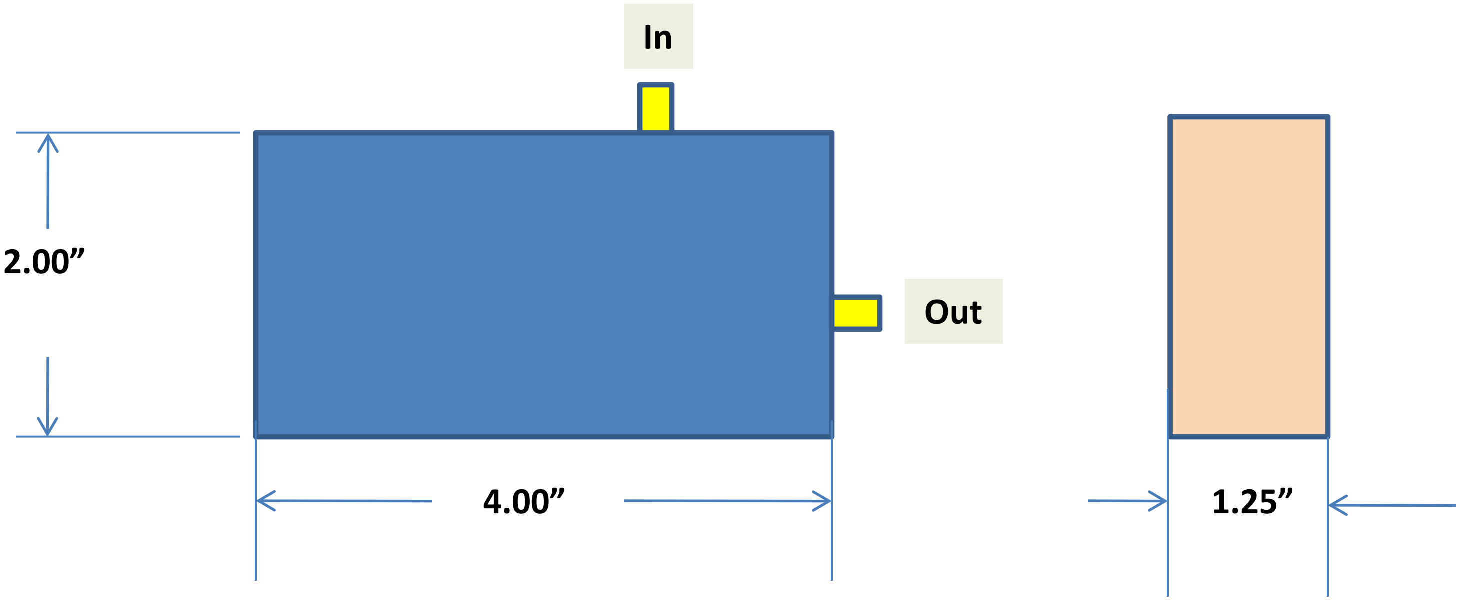
Spur Free Frequency Up Conversion



Spur Free Frequency Down Conversion



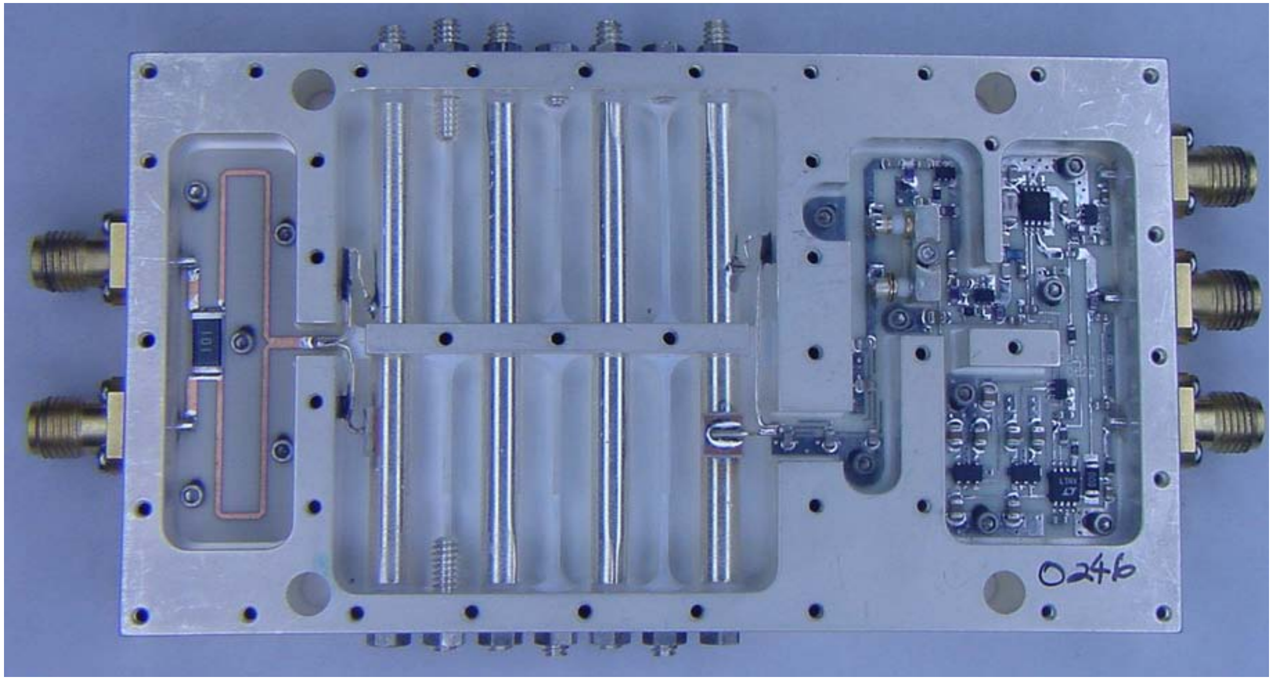
Preliminary Configuration



Preliminary Weight : < 1.0 lbs

GPS Related Filter Products

Offered by Delta MW



LNA/Filter/Limiter/Combiner/Switch

Over 300 Design Variations for:

Space, Launch Vehicles, Aircrafts, Helicopters, Ships & Ground Vehicles

Appendix A.4

Development Proposal

High Performance Active Sub-assembly for New GPS Antennas

Delta Microwave

Working with Reputable Antenna Manufacture

5/20/2011

Background

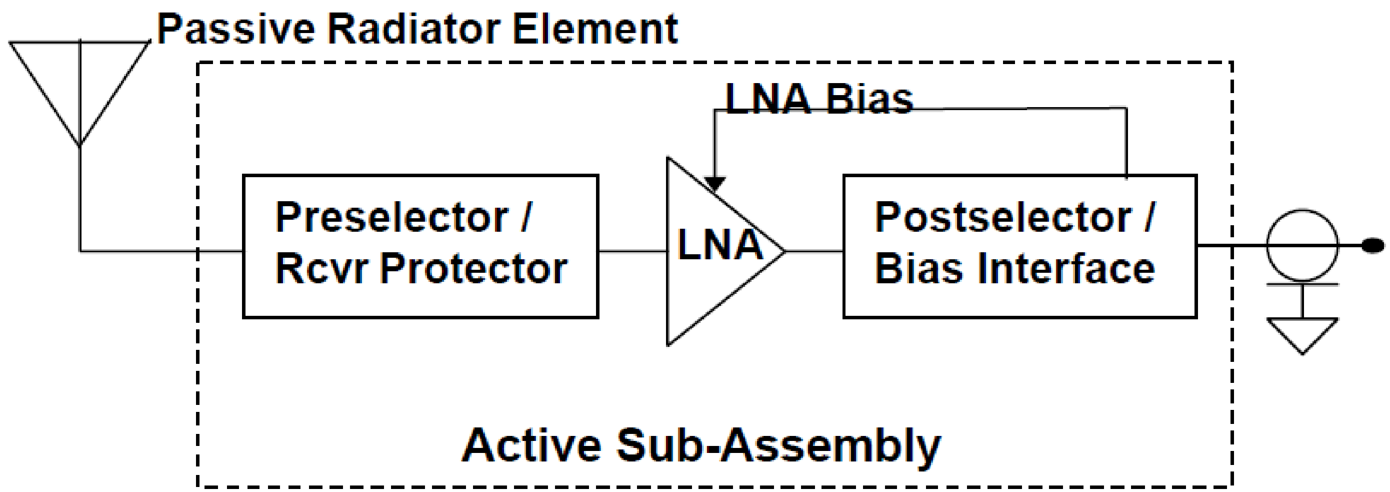
- LightSquared Planned 4G Network High Power Transmitter Signals
  - Approved Frequency Range: 1525 – 1559 MHz
  - Upper Transmit Frequency @ 1552.7 +/- 2.5 MHz & Power of 1500 WCW
- May Interfere with GPS Signals
  - GPS Frequency Range : 1559 – 1610 MHz
  - GPS Frequency Allocations
    - L1 : 1575.42 MHz – C/A, P and M Codes
    - L2 : 1227.60 MHz – C/A, P and M Codes
    - L3 : 1381.05 MHz – NUDET & NDS Use
    - L4 : 1379.91 MHz – Study Use
    - L5 : 1176.45 MHz – Safety-of-Life (SoL) Data & Pilot Signals
  - Most Affected : L1 Signal
- May Interfere with WAAS (Wide Area Augmentation System)
  - Require 20 MHz Passband Bandwidth
- May Interfere with GNSS (Global Navigation Satellite System)
  - Require 40 MHz Passband Bandwidth

GPS/GNSS Antenna Requirements (DO-301)

- GPS/GNSS Airborne Active Antenna Unit (Block Diagram – Next Page):
  - Antenna Radiating Element
  - Active Sub-assembly Consisting of Burnout Protection, Selective RF Filtering, Low Noise Amplifier (LNA) and DC Bias Interface Circuitry
- GPS L1 Operating Frequency Range
  - Passband Frequency : 1575.42 +/- 10.23 MHz (1564 – 1586 MHz)
  - Antenna Passive Element Gain : > -5.5 dBic over All Azimuth Angles
  - Antenna Gain Variation : < 1.0 dB
  - Group Delay Variation : < 25 ns
  - Return Loss : > 14 dB
  - Active Sub-assembly Gain : > 26.5 dB to Cover 13 dB of Cable Loss
  - 1dB Input Compression Point : -25 dBm
  - Burnout Protection : +20 dBm without damage
  - Rejection : 5 dB @ 1.555 MHz, -14 dB @ 1.545 MHz, -22 dB @ 1.535 MHz
  - DC Power Interface: 4.5 to 14.4VDC, 60mA

DO-301 GPS/GNSS Antenna

Functional Block Diagram



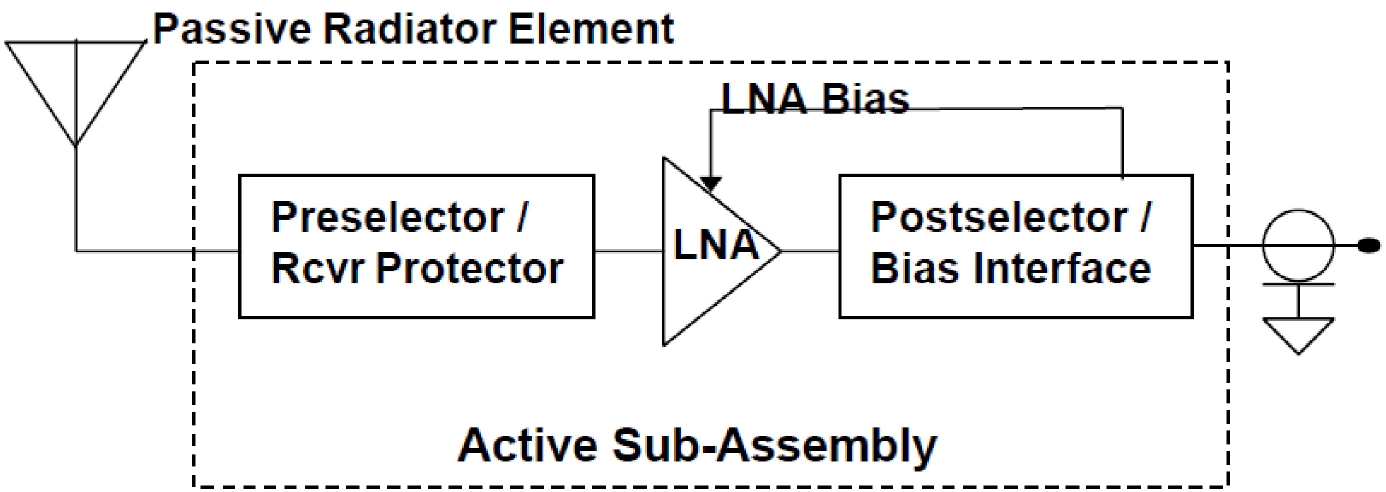
- Passband Frequency : 1575.42 +/- 10.23 MHz (1564 – 1586 MHz)
- Antenna Passive Element Gain : > -5.5 dBic over All Azimuth Angles
- Antenna Gain Variation : < 1.0 dB
- Group Delay Variation : < 25 ns
- Return Loss : > 14 dB

Active Sub-assembly

- Gain : > 26.5 dB
- Noise Figure : < 2 dB
- **1dB Input Compression Point : -25 dBm**
- Burnout Protection : +20 dBm
- **Rejection : 5 dB @ 1.555 MHz,**
  14 dB @ 1.545 MHz, 22 dB @ 1.535 MHz
- DC Power : 4.5 to 14.4VDC, 60mA

Proposed New GPS/GNSS Antenna Unit

with High Performance Active Sub-assembly



- Passband Frequency : 1575.42 +/- 10.23 MHz (1564 – 1586 MHz)
- Antenna Passive Element Gain : > -5.5 dBic over All Azimuth Angles
- Antenna Gain Variation : < 1.0 dB
- Group Delay Variation : < 25 ns
- Return Loss : > 14 dB

High Performance Active Sub-assembly

- Gain : > 26.5 dB
- Noise Figure : < 2 dB
- **1dB Input Compression Point : +0 dBm**
- Burnout Protection : +20 dBm
- **Rejection : 40 dB @ 1.555 MHz & Below**
- **DC Power : 4.5 to 14.4VDC, 250mA**

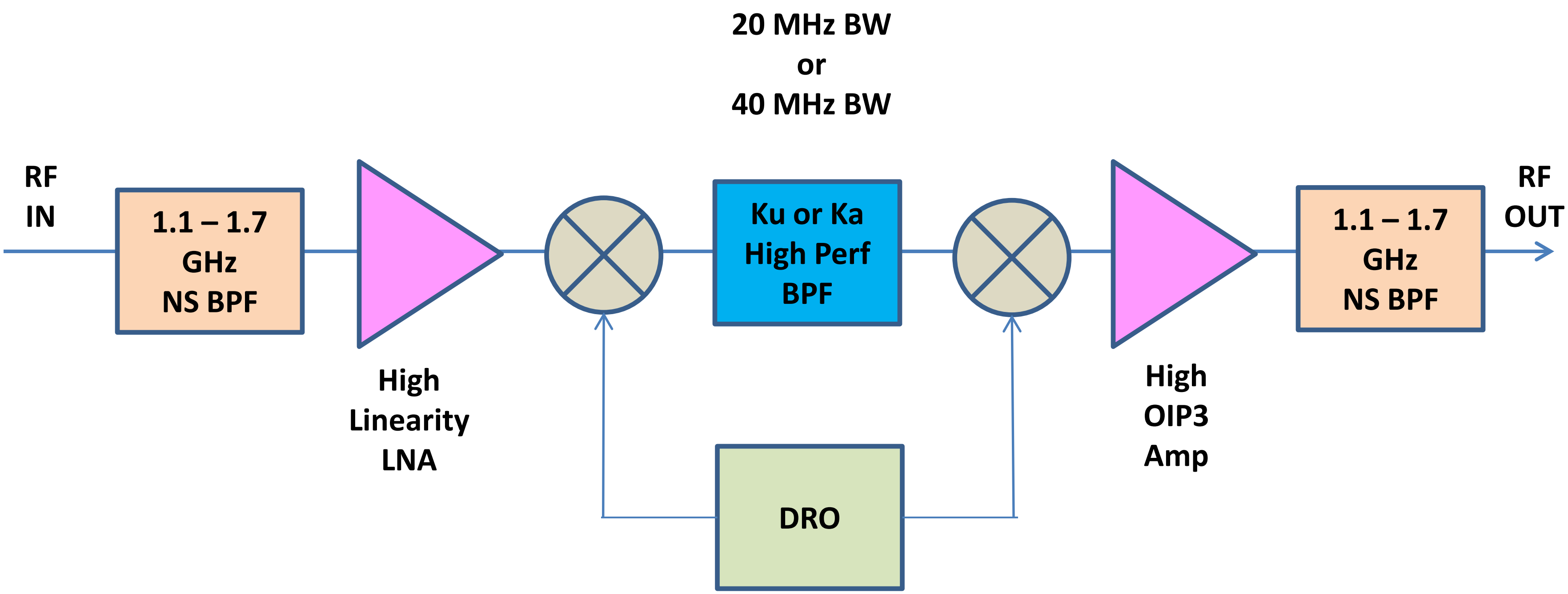
Key to Success : Delta MW High Performance Filter

Proposed Multi-Phased Development

- Phase 1 : Performance Demonstration (Concurrent Tasks 1 & 2)
  - Task 1 : Rapid Prototype Using Existing Technology & Hardware (9 Mo)
    - COTS Devices : High Linearity LNA, Output Amp, Mixers & DRO
    - Modify Existing High Performance Filter to Tailor LightSqaure Interference
    - Assemble & Test High Performance Active Sub-assembly by Itself
    - Integrate with Antenna Radiating Element & Perform Antenna Testing
  - Task 2 : Performance Enhancement Development (18 Mo)
    - Develop Higher Linearity LNA
    - Develop Dielectric Resonator High Performance Filter
    - Assemble & Test Active Sub-assembly by Itself
    - Integrate with Antenna Radiating Element & Perform Antenna Testing
- Phase 2 : Size & Cost Reduction (Concurrent Tasks 1 & 2)
  - Task 1 : Size Reduction Development (12 Mo)
    - Develop High Performance Filter Focus on Reducing Size & Weight
  - Task 2 : Cost Reduction Development (12 Mo)
    - Develop Manufacturing Methods & Tooling Required for Lower Cost Production

Proposed Architecture

High Performance Active Sub-assembly

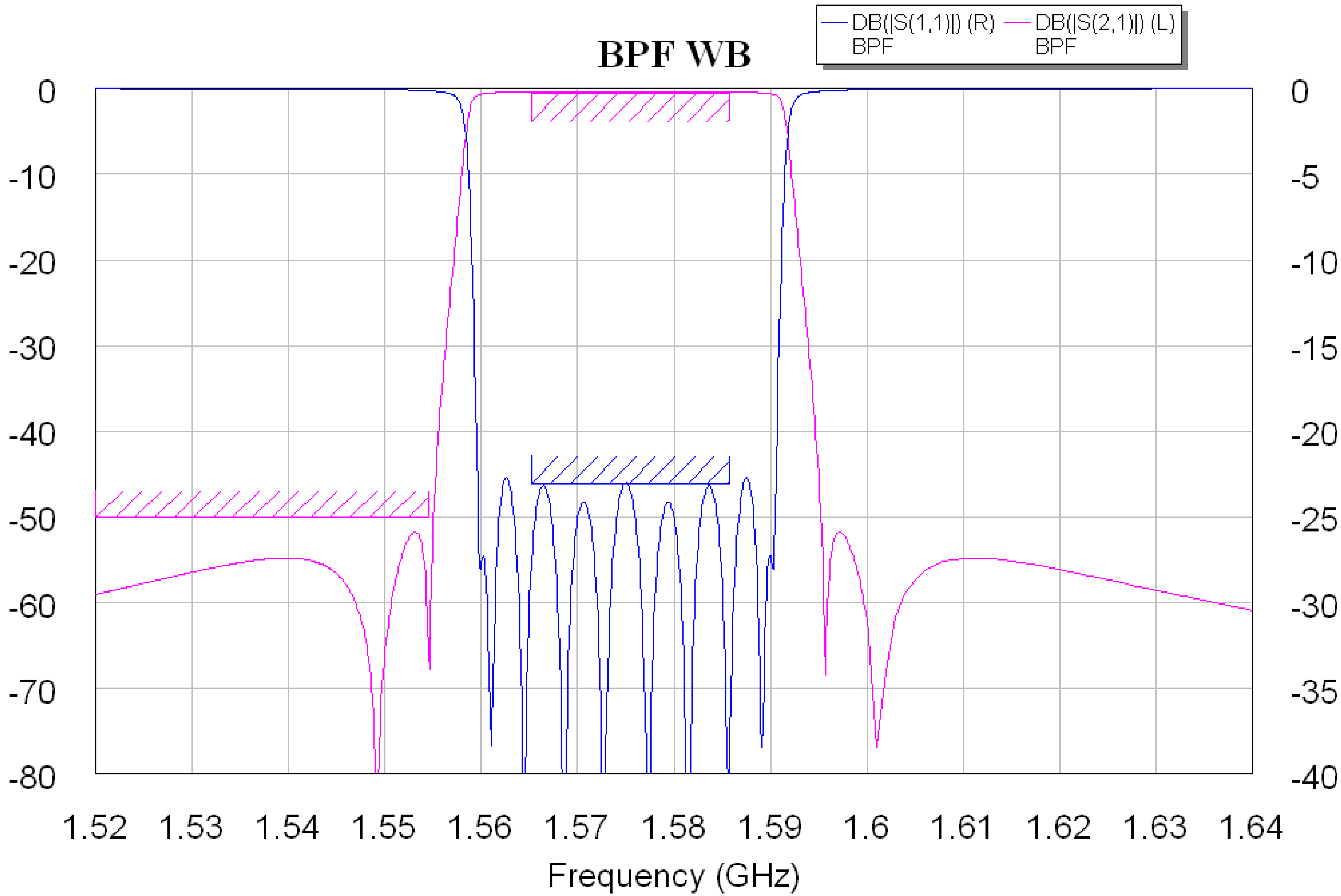


Preliminary Size for Phase 1 : 3.75” x 1.75” x 1.2”

Size Reduction Effort in Phase 2

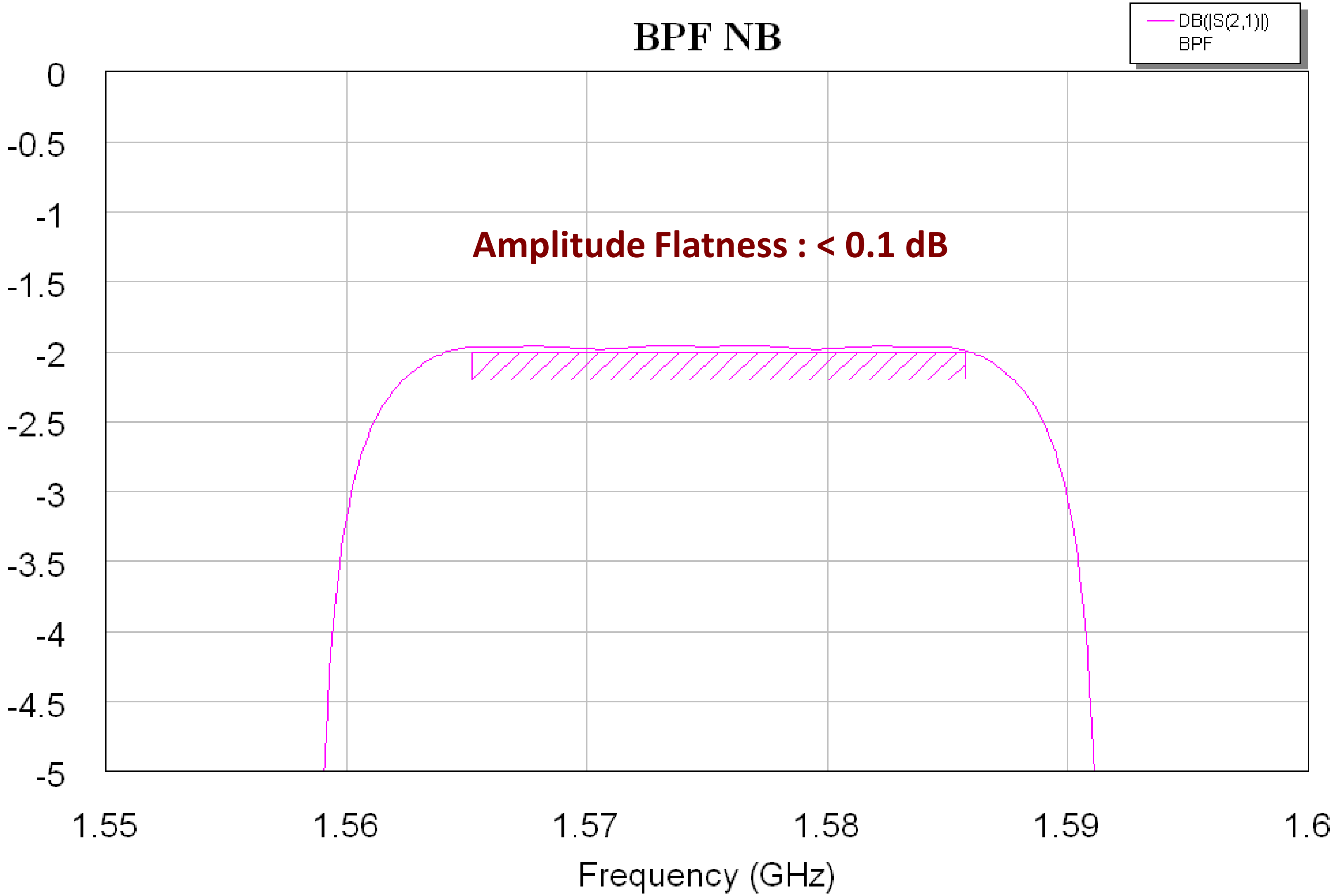
20 MHz High Performance BPF – WB Response

Mapped to GPS L1 – Rejecting LightSqaured Interference



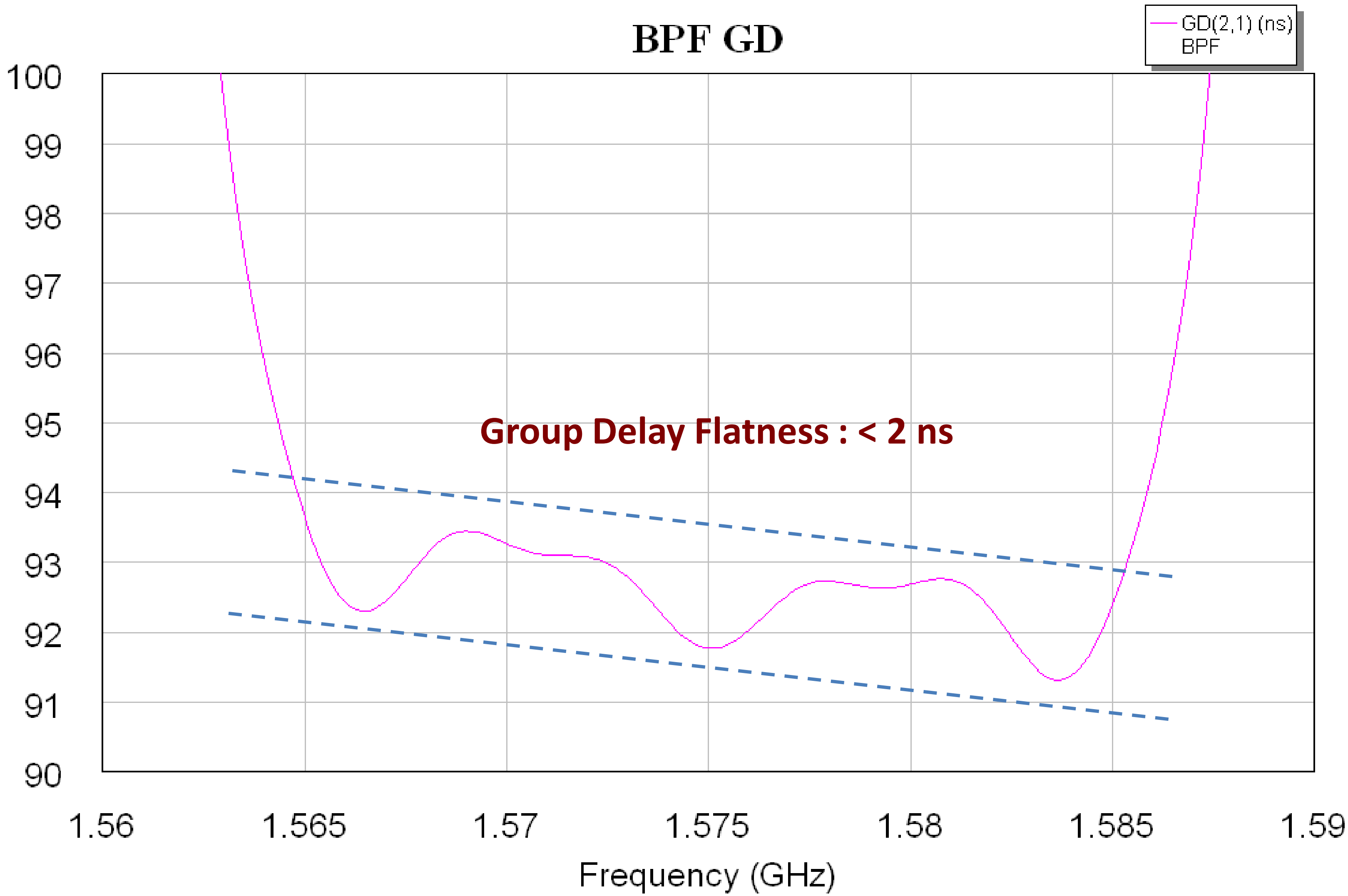
20 MHz High Performance BPF – NB Response

Mapped to GPS L1 Passband



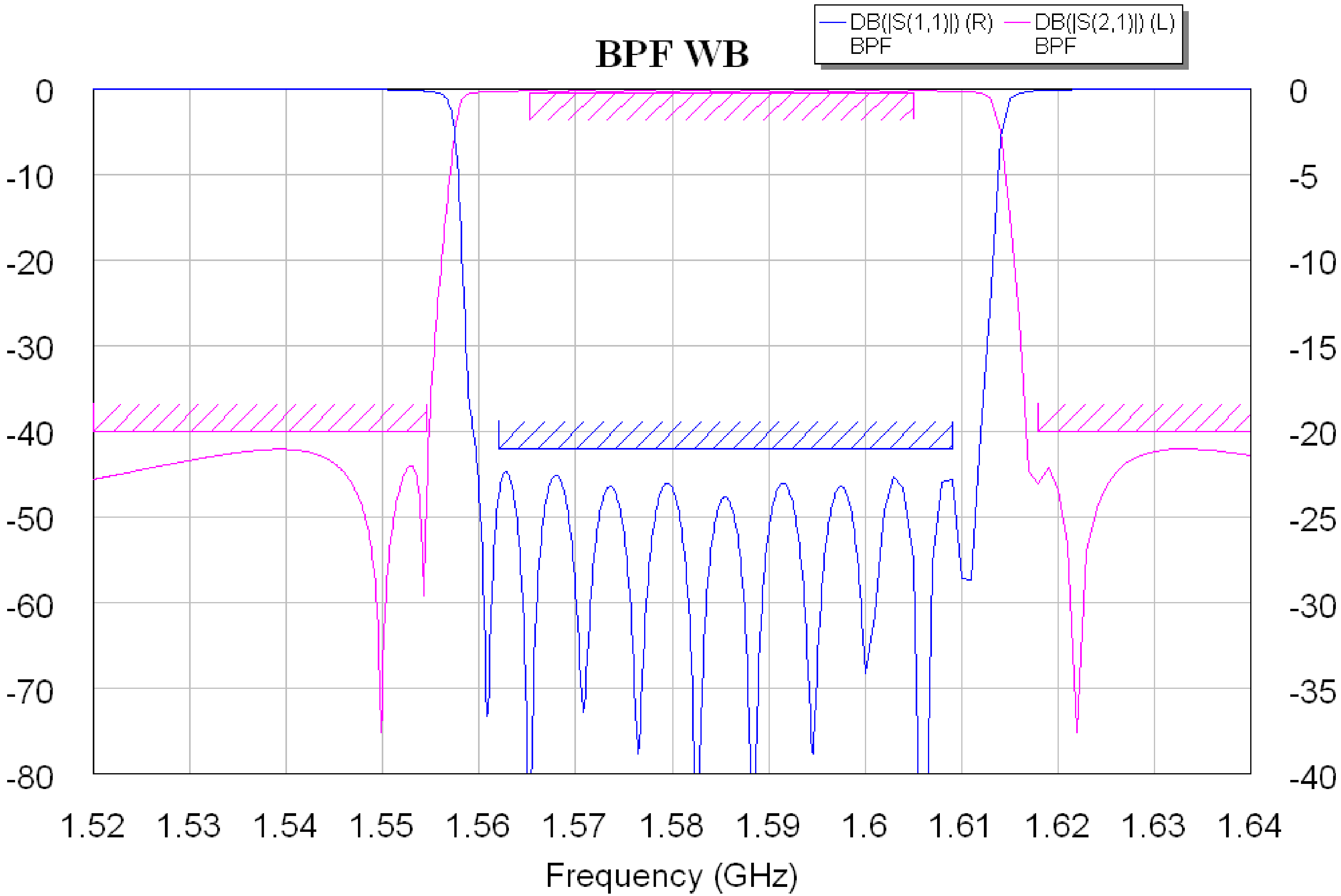
20 MHz High Performance BPF – GD Response

Mapped to GPS L1 Passband



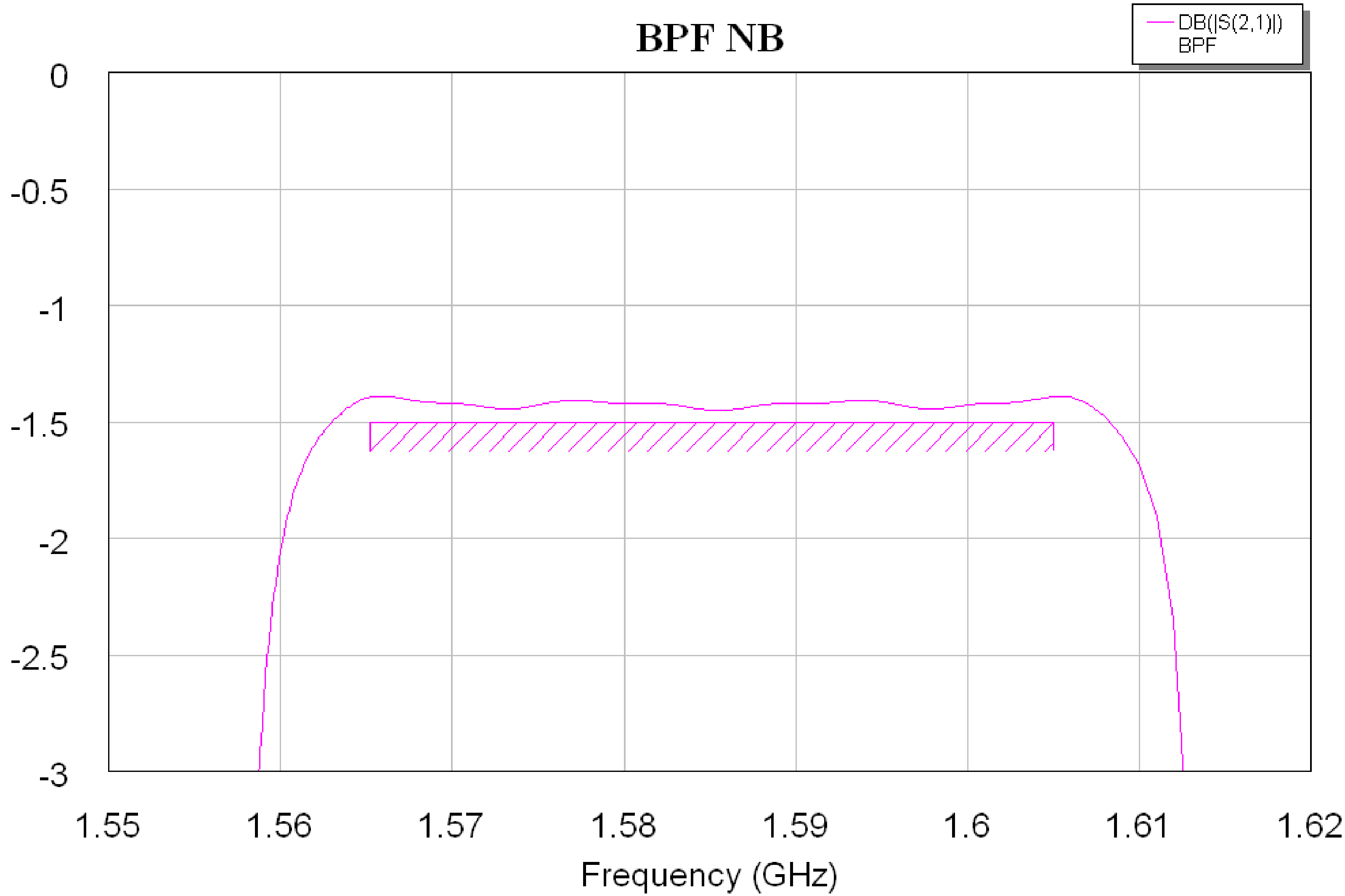
40 MHz High Performance BPF – WB Response

Mapped to GPS L1 – Rejecting LightSqaured Interference



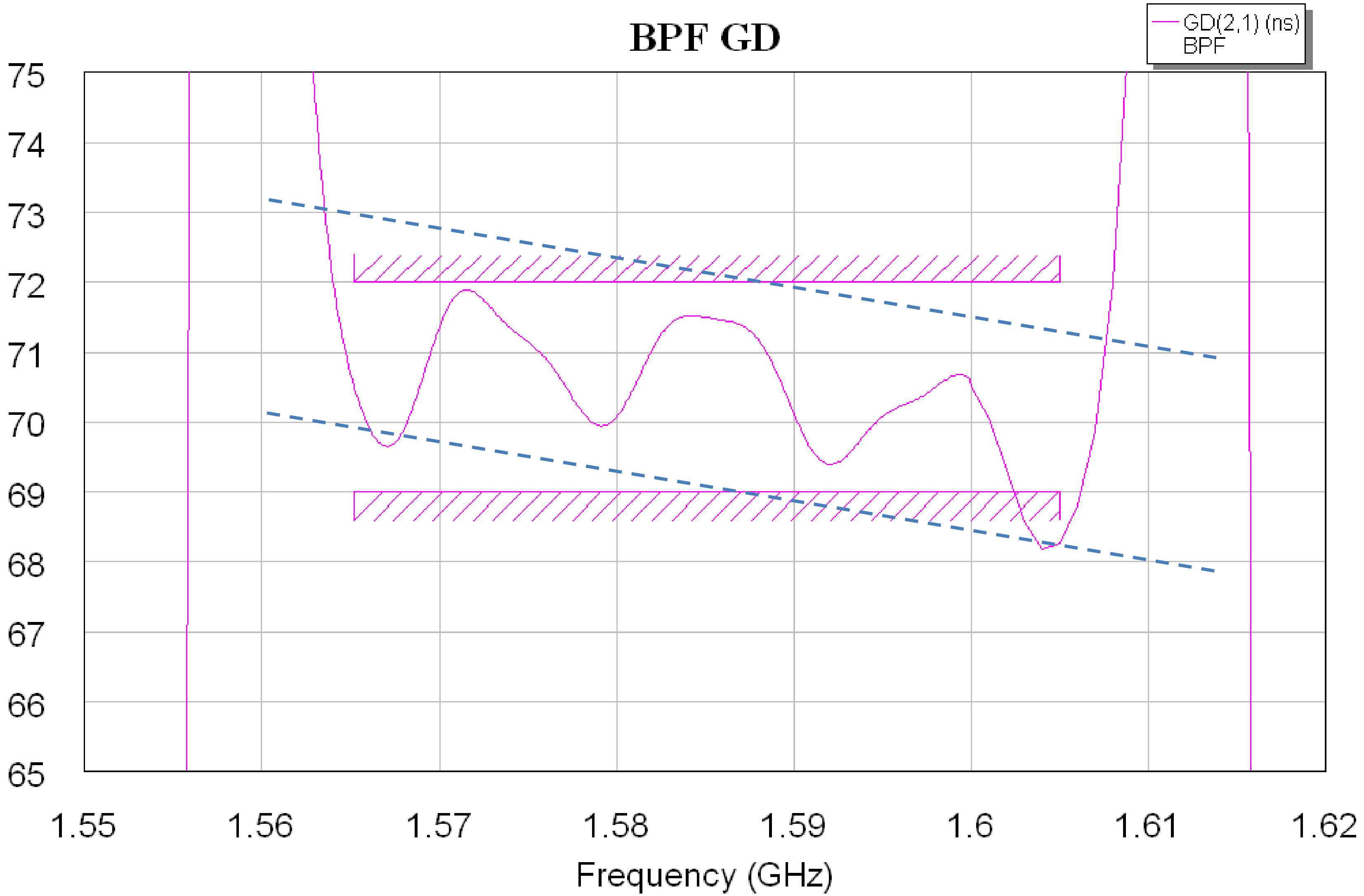
40 MHz High Performance BPF – NB Response

Mapped to GPS L1 Passband



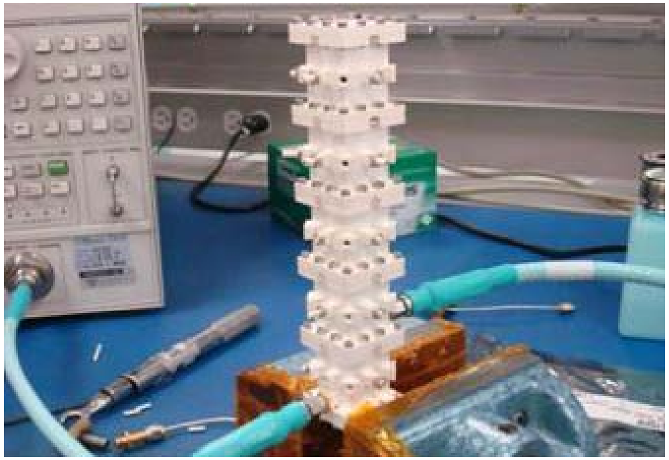
40 MHz High Performance BPF – GD Response

Mapped to GPS L1 Passband

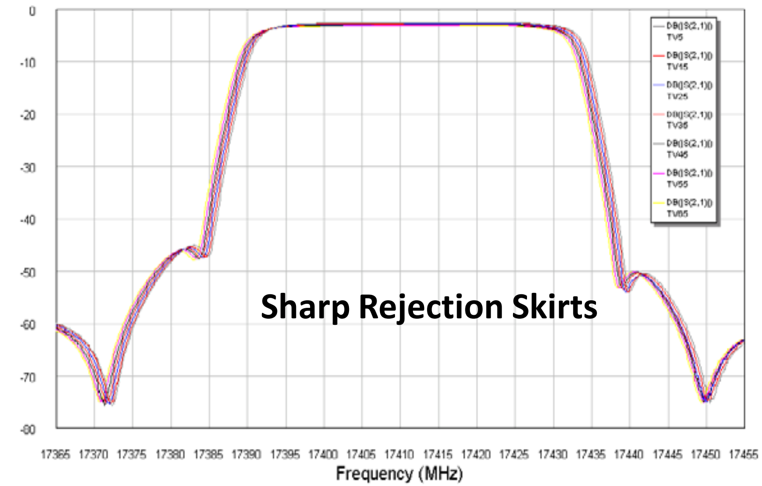


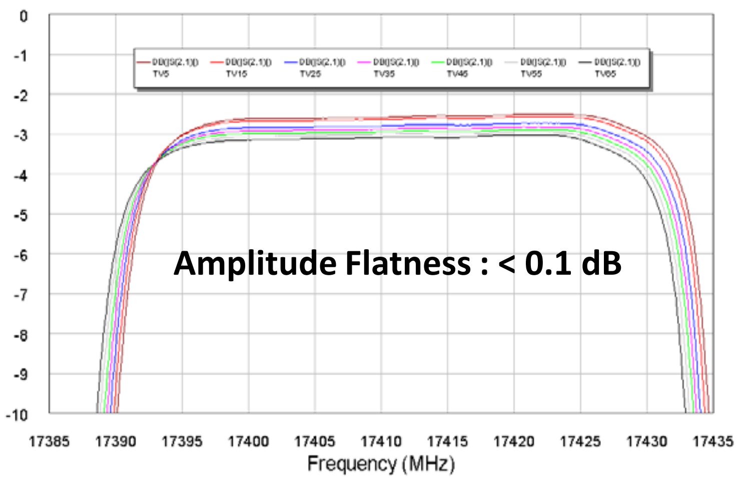
High Performance Channel Filter @ 17.5 GHz

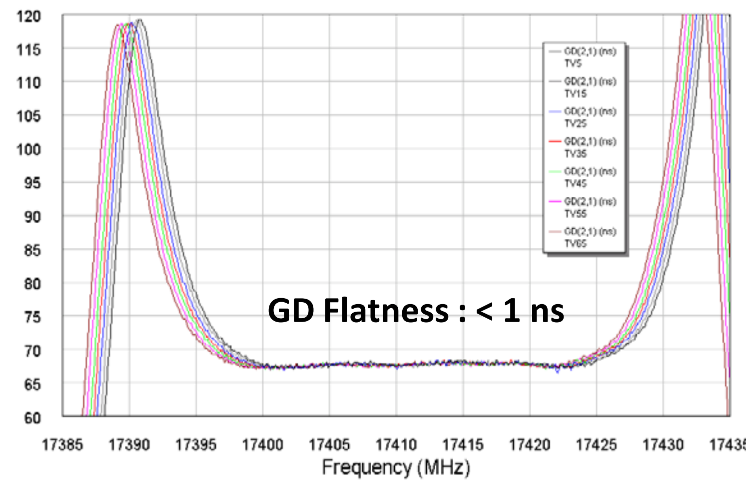
(10,4,2,2) Dual Mode TE_{103}



Achieved Qu = 12.6 K

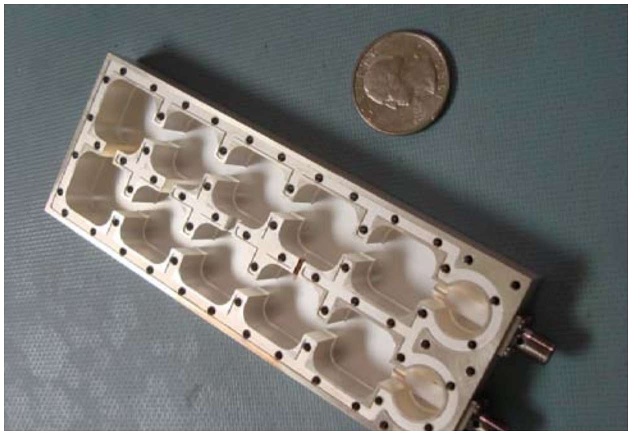


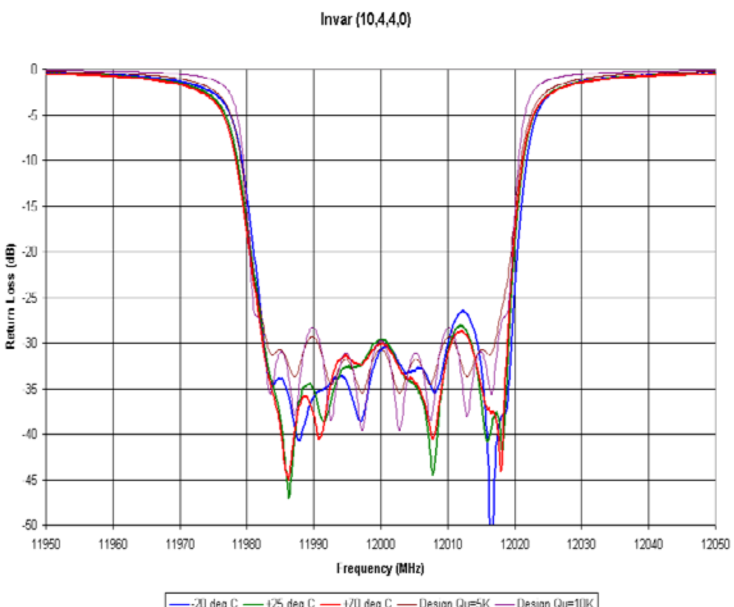




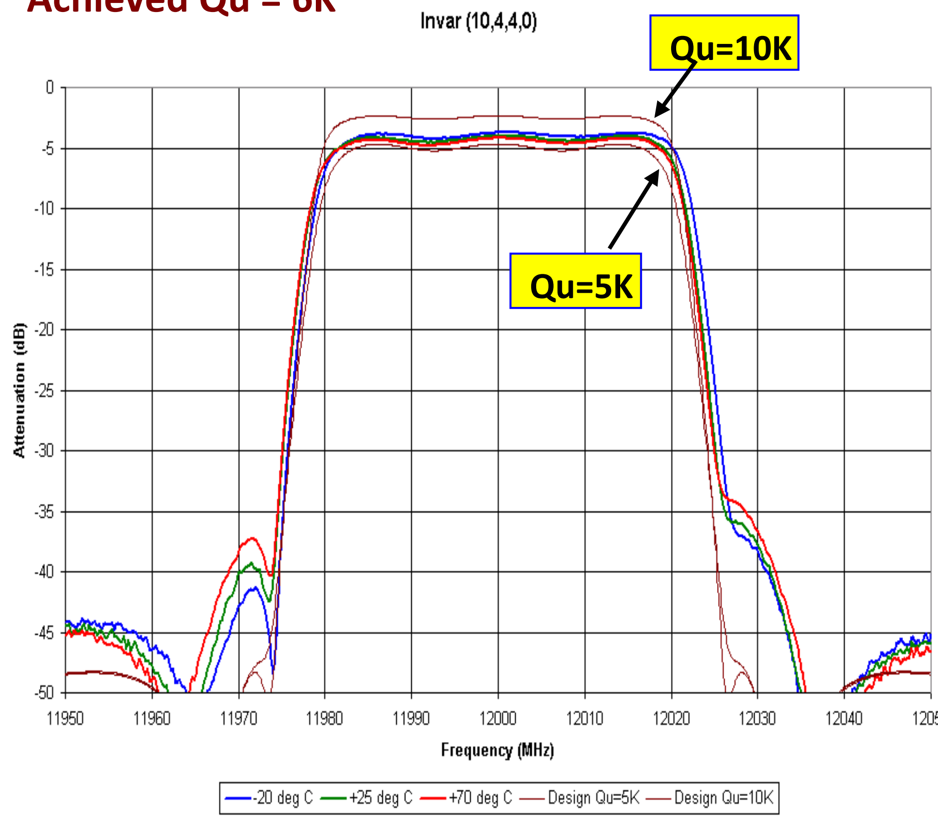
High Performance Channel Filter @ 12 GHz

(10,4,2,2) Single Mode TE_{101}





Achieved Qu = 6K

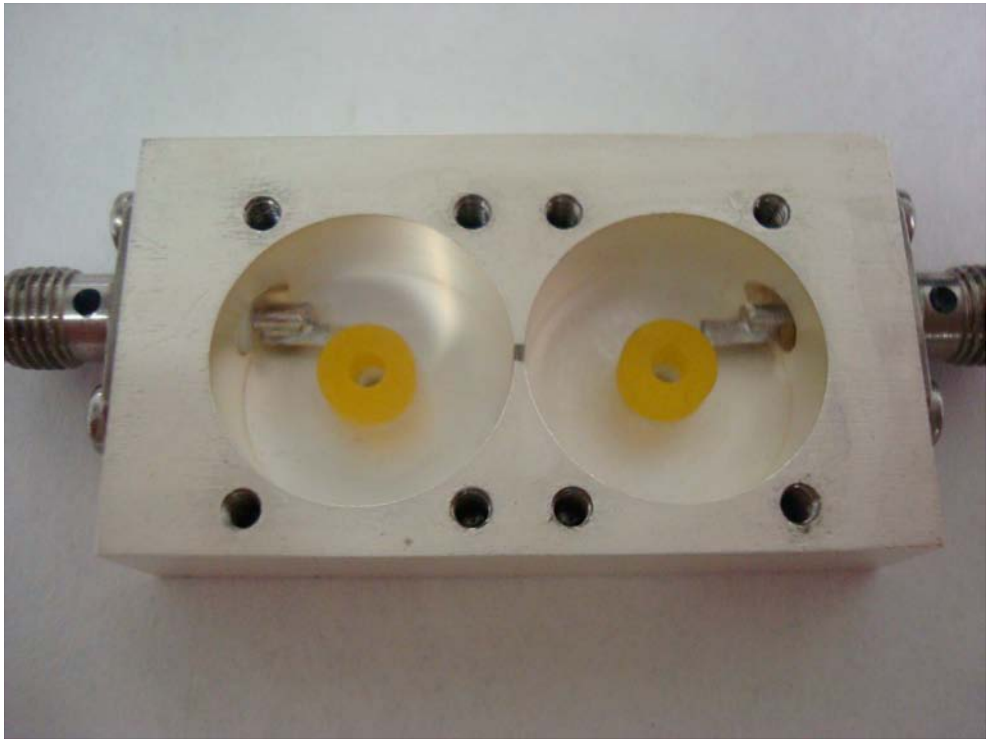


Dielectric Resonator High Performance Filter

Major Part of Phase 1, Task 2 Development Effort

Continued Development in Phase 2, Tasks 1 & 2

Coupling Fixture



Benefits

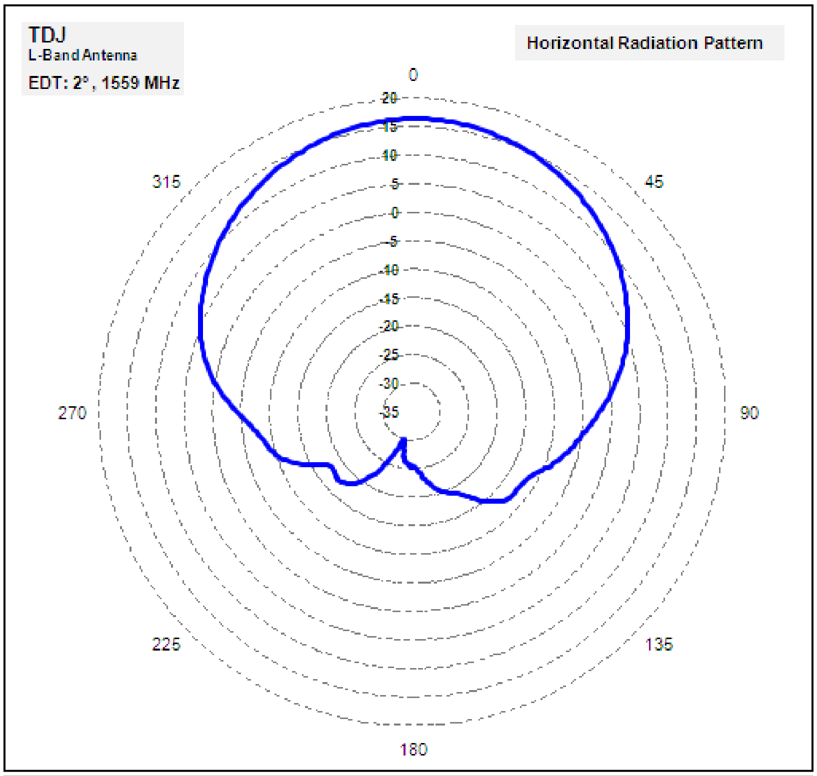
Temperature Stable
Ultra High-Qu
Qu > 10K Possible
at Ku or Ka band
Low Insertion Loss
Smaller Size

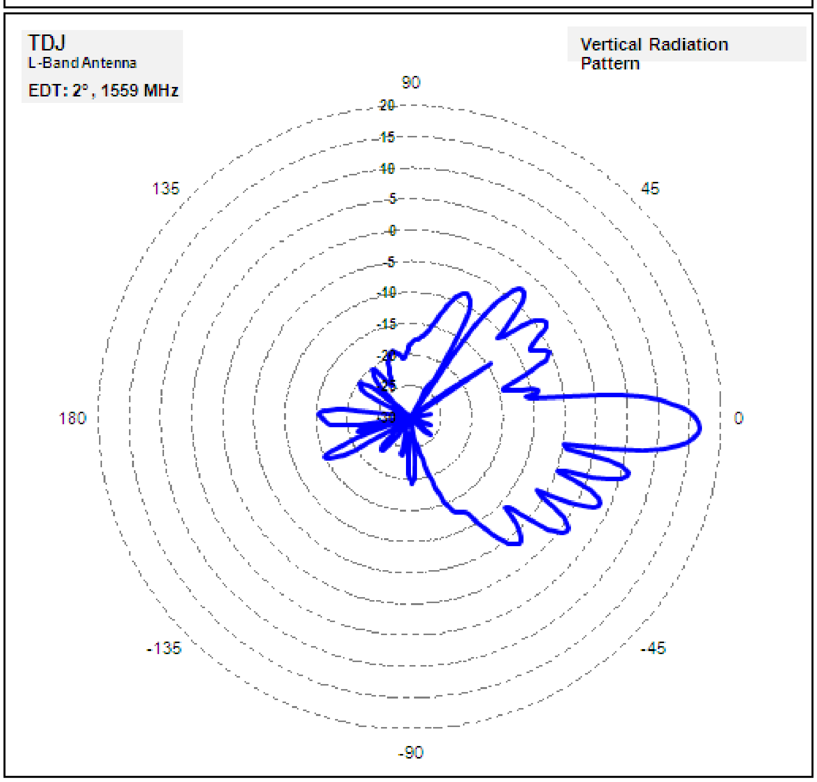
Draw Backs

Lead Time
Material Property
Harder to Tune
Tuning Reduces Qu

Appendix A.5

Antenna Patterns for LightSquared Base Stations





Appendix C.1

Cellular GPS Test Plan

Laboratory Test Methodology

Evaluation of

3GPP Band 24 (MSS L-band) ATC impact to Cellphone GPS Receivers

Version 1.2

May 15, 2011

Contents

Table of Revisions (partial to v 0.8)

Revisions	Author	Comments
Version 1.0	Edit team	Converged subgroup amendments to v0.8 (S.Datta)
Version 1.1	S. Datta	Caught up revisions proposed by Qualcomm to v1.0
Version 1.2	R. Lee	Formatting

1. Introduction

This document describes the test methodology to be used by the Cellular Subgroup of the GPS Technical Working Group (TWG) for overload testing of cell phone-based GPS receivers in proximity to LightSquared's base stations and UE's using 3GPP Band 24[1] (henceforth referred to simply as Band 24).

The tests shall accommodate both conducted and radiated cases. Conducted testing is preferred where a suitably connectorized device is available. Radiated testing shall be performed when such a device is not available. For checking correlation of results obtained by the two methods, radiated testing will be performed for some (at least 3) devices which are also subjected to conducted testing.

The testing will be based on industry standards but a number of extensions will need to be made as (a) none of the current standards specify performance testing with adjacent band interference, (b) the standards do not stress the capabilities of modern receivers to their sensitivity limits, and (c) the standards do not correspond to all use cases of interest with respect to distribution of satellite power levels.

The following standards will be used as the bases of the tests described here. Both UE based and UE assisted AGPS devices will be tested.

- 3GPP 34.171: AGPS Minimum Performance for WCDMA/HSDPA devices (suitable for connectorized testing of 3GPP devices) [1]
- TIA-916: AGPS Minimum Performance for CDMA devices (suitable for connectorized testing of 3GPP2 devices) [2]
- CTIA v3.1: AGPS Radiated test plan for CDMA and WCDMA/HSDPA devices: suitable for radiated testing (in a chamber) of both 3GPP and 3GPP2 devices [3]

While most of the testing will emulate proximity to LightSquared base stations, some testing time will be dedicated to emulation of overload caused by proximate LightSquared UE's.

2. Lab Test Methodology

Devices will be exposed to Band 24 power from signals that are representative of LightSquared's planned ATC base stations and UE's. The planned levels and spectrum occupancies are shown in

[1] Per ITU designation, this is also referred to as the MSS L-band and is at: 1525 – 1559 MHz for downlink transmissions and 1626.5 – 1660.5 MHz for uplink transimmions.

Figure 1; high level block diagrams of the test set up are show in

Figure 2 and 3.

The exposure of GPS devices to high power ATC signals will be emulated through the use of conducted injection of adjacent band signals into the device under test (DUT), as well as radiated injection of the same in an anechoic chamber. Care will be taken to ensure that the out-of-band-emission (OOBE) power spectral density (PSD) of the emulated base station signals in the RNSS band (1559 – 1605 MHz), relative to the in-band power of the Band 24 signal, is consistent with LightSquared's base station emission mask, which specifies a 125 dB reduction[2] between the in-band and out-of-band PSD in the RNSS band. Special LS provided transmit filters will be used that will ensure that, in conjunction of the PSD roll off of the LTE signal, the emulated base station signals have a PSD at the L1 frequency that is at least 16 dB below the system noise floor of the GPS receiver at the antenna connector, for all blocker power levels at which a measurement is performed. Instead of true LTE signals, bandpass filtered Gaussian noise, with an in-band PSD characteristic similar to that of 5 MHz wide LTE, may be substituted.

For testing with Band 24 UE signals, LTE signal generators producing out-of-band emissions according to 3GPP TS 36.101, Band 24, and transmitting at the corresponding uplink frequencies must be used. The special transmit filters may not be necessary with low OOBE signal generators like the R&S SMU200A, depending on the blocker level used. This subject is still under study. Appropriate bandpass filters suitable for uplink interference testing have been ordered by LightSquared and will be used if required.

Appendix I provides an example of test equipment that may be used in the lab setups.

2.1.Test Summary

The performance of each device under test (DUT) will be tested in the presence of simulated Band 24 downlink and uplink signals and simulated GPS satellite signals from a signal generator. This GPS simulator has the ability to create a summation of received GPS signals from different satellites (space vehicles, or SV's).

2.2.Lab Test Variables

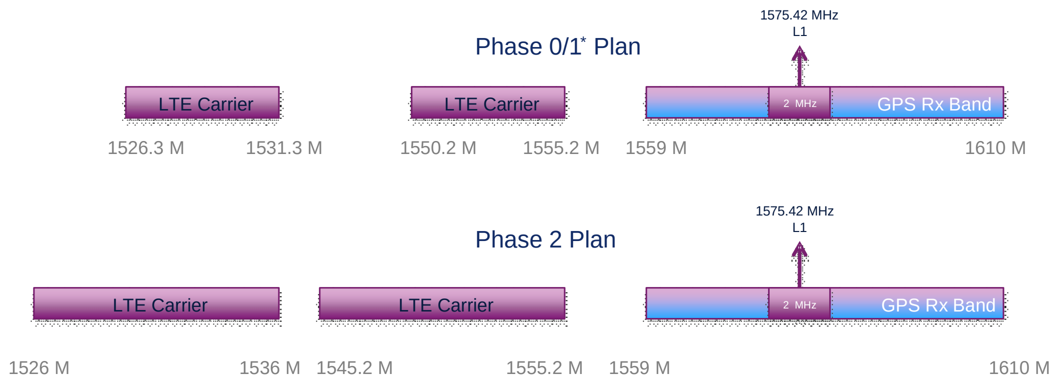
The GPS constellation on the GPS signal generator will be configured with 8 SVs. The GPS received signal power settings will be set as described in the individual test cases described below.

Tests will be performed for the spectrum occupancy corresponding to Phase 1 (two 5 MHz LTE carriers) as shown in

[2] The 125 dB rejection is based on transmitting 32 dBW in a 5 MHz carrier (resulting a PSD of 25 dBW/MHz) and achieving a PSD of -100 dBW/MHz in the RNSS band (1559 – 1605 MHz).

Figure 1. Phase 1 is selected as it is likely to comprise the worst case in terms of overload potential – it creates 3rd order IM products at the L1 frequency and has the highest power density closest to the RNSS band. Testing will also be performed with the 5 MHz LTE carriers individually – this may show whether 3rd order IM products are a major contributor to any observed performance degradation. At the discretion (basis TBD) of the TWG Cellular Subgroup, some devices may also be subjected to testing with Phase 2 signals.

Figure 1: LightSquared Downlink LTE Band 24 and GPS Band (EIRP per carrier: 32 dBW)



*Only upper 5-MHz LTE carrier is used in Phase-0. Both 5-MHz carriers are used in Phase-1

2.3.Lab Environment

The

Figure 2 and 3 below show the lab test setup for conducted and radiated mode testing, respectively. It is noteworthy that these figures only show the 2x10 MHz Phase 2 deployment (as an example).

Figure 2: Lab Setup for GPS Device Conducted Test (Overload from BTS signal).

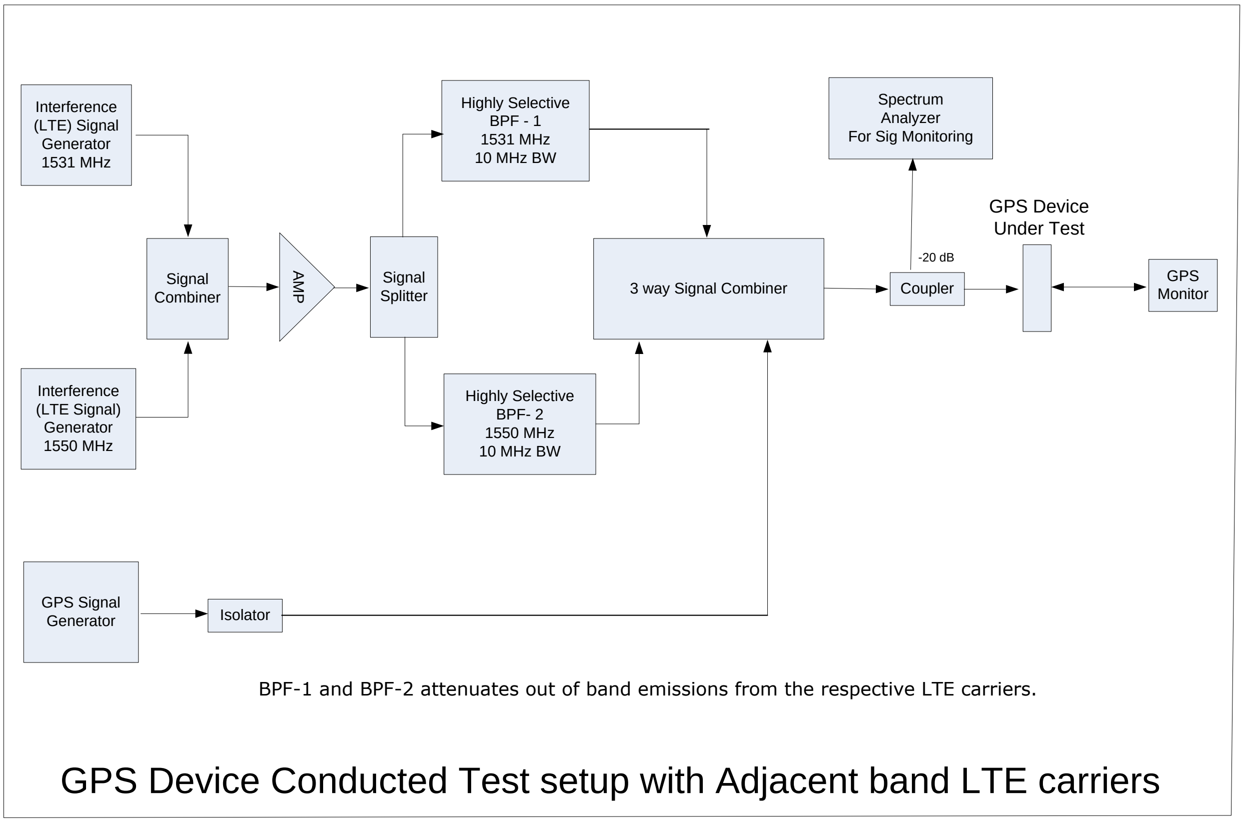
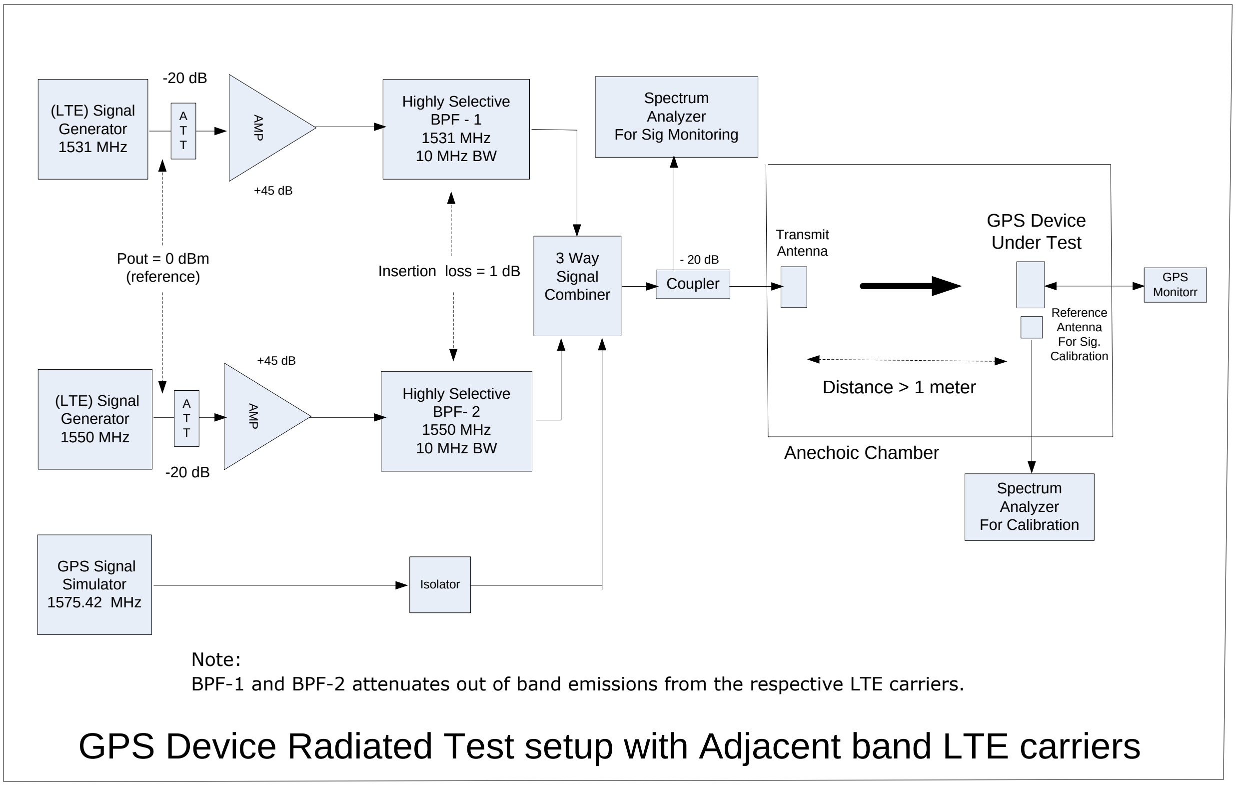


Figure 3: Lab Setup for GPS Device Radiated Test (Overload from BTS signal).



2.4. Test Execution

The tests described below will be performed. All tests are foundationally based on the standards specified in Section 1.

The following key performance indicators (KPI's), as defined in the relevant standards, will be logged:

a. 2D position error[3]

b. Response Time

C/N_0, as reported by the GPS, receiver will also be logged if it is available on the accessible interfaces of the receiver. Furthermore, the GPS SV power level will also need to be logged in order to perform the tests as per the standards.

In addition to determining the threshold values of Band 24 power levels where "failure", as defined in the standards, is encountered, all tests will be extended to higher levels of Band 24 power until any one of the following conditions is met:

- Lock cannot be maintained simultaneously on at least 3 satellites (i.e. the 4th satellite encounters consistent loss of lock, as observed continuously over a period of time to be finalized by the test team)

---

[3] It is recognized that, in the case of UE based position reporting (contrasted with UE assisted position reporting), special software (non-native to the UE) may be required to read position measurements logged by the UE.

- The device fails to provide a GPS-based position report
- The Band 24 Signal power at the DUT antenna connector exceeds -20 dBm.

The KPI's described above will be recorded as functions of Band 24 power levels from zero power until any one of the conditions described above is met. There is no pass/fail criterion in this test – simply logging of KPI's at different blocker power levels. In this document, this is referred to as *full range testing*.

When testing at blocker levels beyond the point where a defined pass/fail criterion has been met, the number of trials at each blocker level will be set at a fixed number (75) and the 67% and 95% values of the KPI will be recorded.[4]

It is recommended that, procedurally, the testing for pass/fail criteria be conducted from an assumed catastrophic blocker level (e.g. --20dBm) and then reduced to no blocker. This is to ensure that test system starts with the minimum number of trials and then increments up to the maximum. Notwithstanding the above, the testing team may propose alternate methods of optimizing the test execution.

It is noteworthy that all tests described below must be performed separately for Band 24 signals corresponding to base station and UE.

It shall be ensured that tests performed with and without Band 24 signals, for a given test environment, use exactly the same satellite constellations.

As multiple labs will be used, some devices will be used as common objects and subjected to the same tests at different labs to check calibration across test sites.

2.4.1. Connectorized Device 3GPP tests

The following tests, based on 3GPP 34.171 [1] will be performed. It is noteworthy that the test values in the following sections are subject to the test tolerances in Table F.2.1 of TS 34.171 [1].

2.4.1.1. AGPS Sensitivity test with Coarse Time Assistance *as per standard*

This test will exactly follow [1, Section 5.2.1], except for the addition of Band 24 signals. A permitted exception is that the number of trials used may change from [1] to speed test time, while giving up some confidence. The sensitivity without interference will be tested using the trial methodology of [1][5]

It is noteworthy that the SV levels for this test are set as follows [1, Section 5.2.1.2].

GPS signal for one satellite:	-142 dBm
GPS signals for remaining (7) satellites:	-147 dBm

To determine the relative impact of the jammer, the above test will be performed with the Band 24 blocker signal applied to the DUT at levels

[4] Alternative percentile values of the CDF and the number of trials may be proposed by the testing team and used if approved by the TWG Cellular Subgroup.

[5] Number of trials still under development in [1]

including zero and the maximum value where the success criterion as defined in [1, Table 5.2.1.4] is met (the result is a pass).

Additionally, full range testing will be performed as defined in Section 2.4, ignoring the pass/fail criteria.

2.4.1.2. AGPS Sensitivity test with Coarse Time Assistance at *minimum, uniform SV power levels*

This test will exactly follow [1, Section 5.2.1], except for the addition of Band 24 signals and the use of lower SV power levels. The test will determine, for a given DUT, the lowest set of SV power levels at which the test will pass as per [1, Table 5.2.1.4], while maintaining the same number of SV's and relative SV power levels as in [1, Section 5.2.1]. This makes the test essentially similar to the CTIA OTA Sensitivity test of [3, Section 6.12.2.1].

To determine the relative impact of the jammer, the above test will be performed with the Band 24 blocker signal applied to the DUT at levels including zero and the maximum value where the success criterion as defined in [1, Table 5.2.1.4] is met (the result is a pass), with the provision that, when a blocker signal of non-zero-power is applied, the minimum SV power levels determined above will be increased uniformly (for all SV's) by 1 dB.

2.4.1.3. AGPS Sensitivity Test with Coarse Time Assistance at *discrete, uniform SV power levels*

The test of ([1], Section 5.2.1) will be performed at the following discrete levels for the 7 lower powered SV's instead of the -147 dBm in the standard: -135, -149, -152 dBm. The 8^{th} SV is 5 dB above the other 7 SV's for each case. The testing is identical to that described in Section 2.4.1.1 in all other respects.

2.4.1.4. AGPS Nominal Accuracy test *as per standard*

This test will exactly follow [1, Section 5.3], except for the addition of Band 24 signals.

It is noteworthy that the SV levels for this test as set as follows [1, Section 5.3.5].

GPS signals for all (8) satellites: -130 dBm

To determine the relative impact of the jammer, the above test will be performed with the Band 24 blocker signal applied to the DUT at levels including zero and the maximum value where the success criterion as defined in [1, Table 5.3.4] is met (the result is a pass). Note the number of trials used presently follows [1] but is under sturdy.

Additionally, full range testing will be performed as defined in Section 2.4, ignoring the pass/fail criteria.

2.4.1.5. AGPS Performance Test with *different SV power levels*

This test will exactly follow [1, Section 5.3], except for the addition of Band 24 signals and the use of the following SV power levels: -125, -128, -131, -134, -137, -140, -143, -146 dBm.

To determine the relative impact of the jammer, the above test will be performed with the Band 24 blocker signal applied to the DUT at levels including zero and the maximum value where the success criterion as defined in [1, Table 5.4.2][6] is met (the result is a pass). Note the number of trials used presently follows [1] but is under sturdy.

Additionally, full range testing will be performed as defined in Section 2.4, ignoring the pass/fail criteria.

2.4.2. Connectorized Device 3GPP2 tests

The following tests, based on TIA-916 [2] will be performed on 3GPP2 compliant devices. All general requirements mentioned in Section 2.4 also apply here.

2.4.2.1. GPS Sensitivity Test *as per standard*

The test will exactly follow ([2], Section 2.1.1.3) except for the addition of Band 24 signals.

Per standard, the mobile device will return a **Provide Location Response** message if the mobile station is capable of location computation; or it shall return one or more **Provide Pseudorange Measurement** messages if it is not capable of location computation.

The measurement method will be as described in [2, Section 2.1.1.3.2]. In summary, the GPS SV signal levels will -147 dBm with C/No of 27 dB-Hz with 4 SVs visible.

The pass/fail criterion is as per the minimum standard set forth in [2, Table 2.1.1.3.3-1]. In summary the mobile device will provide the Pseudorange Measurements and Location Responses within the limit values defined in applicable table.

To determine the relative impact of the jammer, the above test will be performed with the Band 24 blocker signal applied to the DUT at levels including zero and the maximum value where the success criterion as defined in [2, Table 2.1.1.3.3-1] is met (the result is a pass).

Additionally, full range testing will be performed as defined in Section 2.4, ignoring the pass/fail criteria.

2.4.2.2. GPS Sensitivity Test at *minimum, uniform SV power levels*

The test will exactly follow [2, Section 2,1.1.3] except for the addition of Band 24 signals and the use of alternative satellite signal levels.

---

[6] The pass/fail criterion from the Dynamic Range test of [1] is used here owing to the similarity (although not exact identity) to the above test in [1]. It was decided to keep the constellation identical between the tests of Sections 2.4.1.5 and 2.4.2.5, which is based on the Dynamic Range test in [2]; hence a deviation was made for the present test relative to the standard.

Per standard, the mobile device will return a **Provide Location Response** message if the mobile station is capable of location computation; or it shall return one or more **Provide Pseudorange Measurement** messages if it is not capable of location computation.

The measurement method will be as described in [2, Section 2.1.1.3.2]. Instead of the SV levels used in the standard test case, this test will *determine* the minimum GPS SV signal level, with 4 SV's visible, where the pass/fail criterion defined in [2, Table 2.1.1.3.3-1] is passed.

To determine the relative impact of the jammer, the above test will be performed with the Band 24 blocker signal applied to the DUT at levels including zero and the maximum value where the success criterion as defined in [2, Table 2.1.1.3.3] is met (the result is a pass) with the provision that, when a blocker signal of non-zero-power is applied, the minimum SV power levels determined above will be increased uniformly (for all SV's) by 1 dB.

2.4.2.3. GPS Sensitivity Test at *discrete, uniform SV power levels*

The test of ([2], Section 2.1.1.3) will be performed at the following discrete SV levels: -135, -149, -152 dBm instead of the -147 dBm in the standard. The testing is identical to that described in Section 2.4.2.1 in all other respects. It is noted that the different SV power levels will be associated with different C/N_0 values, derived using a fixed N_0 of -174 dBm/Hz as is implied by ([2], Table 2.1.1.3.2-1).[7]

2.4.2.4. GPS Accuracy *as per standard*

The test will exactly follow [2, Section 2.1.1.1] except for the addition of Band 24 signals.

Per standard, the mobile device will return a **Provide Location Response** message if the mobile station is capable of location computation; or it shall return one or more **Provide Pseudorange Measurement** messages if it is not capable of location computation.

The measurement method will be as described in [2, Section 2.1.1.1.2]. In summary the GPS SV signal levels will be -130 dBm with C/No of 44 dB-Hz with 8 SV's visible.

The pass/fail criterion is defined per the minimum standard set forth in [2, Table 2.1.1.1.3-1]. In summary the mobile device will provide the Pseudorange Measurements and Location Responses within the limit values defined in the applicable table.

To determine the relative impact of the jammer, the above test will be performed with the Band 24 blocker signal applied to the DUT at levels including zero and the maximum value where the success criterion as defined in [2, Table 2.1.1.3.3-1] is met (the result is a pass).

[7] In [2, Table 2.1.1.1.3-1] an SV power level or -147 dBm is specified along with C/N_0 of 27 dB.Hz. From, this N_0 = -147-(-27) = -174 dBm/Hz.

Additionally, full range testing will be performed as defined in Section 2.4, ignoring the pass/fail criteria.

2.4.2.5. GPS Performance Test with *non-uniform SV power levels*

The test will be performed as exactly defined in Section 2.4.2.4 with the following exception: the following SV power levels will be used: -125, -128, -131, -134, -137, -140, -143, -146 dBm.

To determine the relative impact of the jammer, the above test will be performed with the Band 24 blocker signal applied to the DUT at levels including zero and the maximum value where the success criterion as defined in [2, Table 2.1.1.2.3-1][8] is met (the result is a pass).

Additionally, full range testing will be performed as defined in Section 2.4, ignoring the pass/fail criteria.

2.4.3. Radiated Tests

The objective is to run the tests described in Sections 2.4.1 and 2.4.2 (which are connectorized tests based on [1] and [2]) in a radiated environment by leveraging the CTIA OTA tests [3].

The blocker signal is added linearly to the SV signals and injected into the chamber from the direction of maximum gain. The latter is first determined as *relative gain* in 3D using standard methods described in [3] and the angle-of-arrival (AoA) corresponding to maximum gain is ascertained.

Knowledge of the SV and blocker power levels is necessary in the tests of Section 2.4.3.2. These are estimated using the method described in Appendix II.

Note that Appendix II describes using the C/N_0 reported by the GPS receiver to establish the GPS power representing -130dBm at C/no=44dB-Hz. All other levels both GPS and LTE band 24 are relative to the level provided to the Tx antenna to establish -130dBm.

2.4.3.1. Sensitivity Test (minimum, uniform SV power levels)

The *minimum SV level* sensitivity tests described in Sections 2.4.1.2 and 2.4.2.2 are essentially identical to the Sensitivity test defined in [3, Section 6.12.2.1] without the blocker. This test will be run both with and without the blocker to determine the relative impact of the blocker.

As in Sections 2.4.1.2 and 2.4.2.2, to determine the relative impact of the jammer, the above test will be performed with the Band 24 blocker signal applied to the DUT at levels including zero and the maximum value where the success criterion as defined in Sections 2.4.1.2 and 2.4.2.2 are met (the result is a pass), with the provision that, when a blocker signal of non-zero-power is applied, the minimum SV power levels determined above will be increased uniformly (for all SV's) by 1 dB.

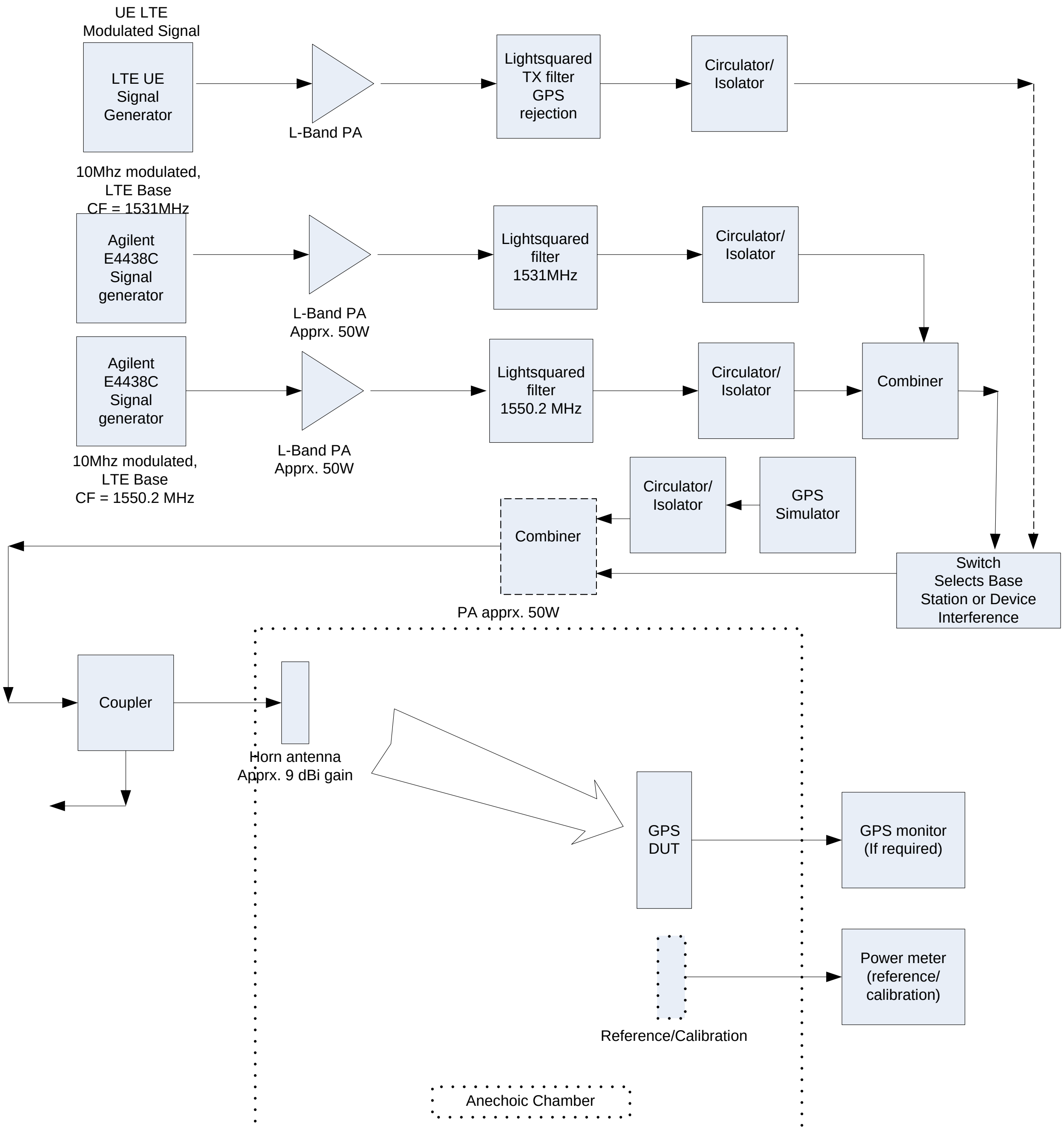
[8] The pass/fail criterion from the Dynamic Range test of [2] is used here owing to the similarity to the above test in [2].

2.4.3.2. Other tests based on [1] and [2]

Tests described in Sections 2.4.1.1, 2.4.1.3 - 2.4.1.5 and Sections 2.4.2.1, 2.4.2.3 - 2.4.2.5 fall in this category. All of these tests will be performed as *virtual connected mode tests* by injecting the composite signal (SV plus blocker) from the AoA corresponding to the maximum antenna gain of the DUT. The SV and blocker power levels will be estimated as described in Appendix II.

Appendix I

This section shows an example block diagram for a radiated test setup and is followed by a suggested equipment list.



Appendix

Example Equipment List

Band-24 Chain

Number required	Equipment	Manufacturer	Model
2	Vector Signal Generator (used to generate LTE signals for Base Station)	Agilent	E4438C w/ Options: 005 – Hard Drive 602 – Dig Bus Baseband 1E5 – High Stability Time Base 503 – 250 kHz to 3 GHz
1	LTE Signal Generator (used to generate LTE signals for UE)	Agilent	E4438C
2	Amplifier	Comtech	ARD8829 50 or ARD88285 50
2	Band Pass Filter	Lightsquared	1531MHz and 1550.2MHz
2	RF Isolator	MECA	CN 1.500
2	Power Combiner	MECA	H2N - 1.500V
1	Directional Coupler	Mini Circuits	ZGDC20-33HP
Multiple	Cable	Microwave Systems	LMR200
2	Transmission Antenna and Reference/Calibration antenna	AH Systems	SAS-751 Horn 9.5dBi gain
1	Power meter reference and calibration	Agilent	E4419B

GPS Chain

Number required	Equipment	Manufacturer	Model
1	GPS Simulator	Spirent	Spirent GSS6700, GSS6560, or GSS5060
1	Transmission Antenna	ETS-Lindgren	3201 Conical Antenna (RHCP)
Multiple	Cable	Microwave Systems	LMR200
N/A*	Power meter reference and calibration	Agilent	E4419B
N/A*	Reference/Calibration antenna	AH Systems	SAS-751 Horn 9.5dBi gain

* - The same equipment can be used for both the L-band chain and the GPS chain as they are for calibration.

Recommended configuration of LTE Signal from Base Station

If using the Agilent E4438C ESG vector signal generator, the latter needs to be loaded with the Agilent N7624B Signal Studio with the 3GPP LTE FDD option package.

Name	Setting	Comment
Center frequencies	For 2 x 5 MHz Downlink channels LTE Carriers centered @ 1552.7 MHz and @ 1528.8 MHz, BW:5 MHz For 2 x 10 MHz Downlink channels LTE Carriers centered @ 1531 MHz and @ 1550.2 MHz , BW:10 MHz	According to test
Release	3GPP R8	
Duplexing	FDD	
Modulation	OFDM/OFDMA	
Frame Duration	10 ms	
Sub frame Duration	1.0 ms	
Subcarrier Modulation	QPSK	For PCH , PDCCH, PDSCH
Subcarrier Size	15 KHz	
Channel Bandwidth	5/10 MHz	According to test
PRB Bandwidth	0.180 MHz	
Sampling Rate	7.68 MHz / 15.36 MHz	According to channel size 7.68 MHz for 5MHz channel and 15.36 MHz for 10 MHz channel
FFT Size	512/1024	According to channel size 512 for 5MHz channel and 1024 for 10 MHz channel
Dummy Data	PN9	

Recommended configuration of LTE Signal from UE

The Rohde and Schwarz CMU200A Vector Signal Generator, configured with worst case scenario for GPS interference - device operating at the lowermost single RB of lower LTE channel with full power

Name	Setting	Comment
Center frequencies	LTE Carriers centered @ 1632.5 MHz	According to test
Release	3GPP R8	
Duplexing	FDD	
Modulation	OFDM/OFDMA	
Allocation	1 Leftmost RB Frequency 1628-1628.180	
RB Bandwith	180 kHz	
UE power	23 dBm	
Subcarrier Modulation	QPSK	
Dummy Data	PN9	

A-GPS Systems Required for Test Plan Execution

Spirent A-GPS Test systems will be used to conduct the 3GPP2 TIA-916, 3GPP 34.171, and CTIA OTA testing. In addition, specific scripts will be provided by Spirent to automate the Interferer setup and power level sweeps in conjunction with A-GPS performance testing and metric analysis. The following Spirent solutions are required for this test plan:

2.4.1 Connectorized Device 3GPP tests:

- Spirent 8100-A500 UMTS Location Test System (ULTS)
- Test Pack: TM-LBS-3GPP-TS34.171

2.4.2 Connectorized Device 3GPP2 tests

- Spirent C2K-ATS Position Location Test System (PLTS)
- Test Pack: PLTS-MP-SET (PLTS C.S0036 SOFTWARE BUNDLE)

2.4.3 Radiated Tests (UMTS Devices)

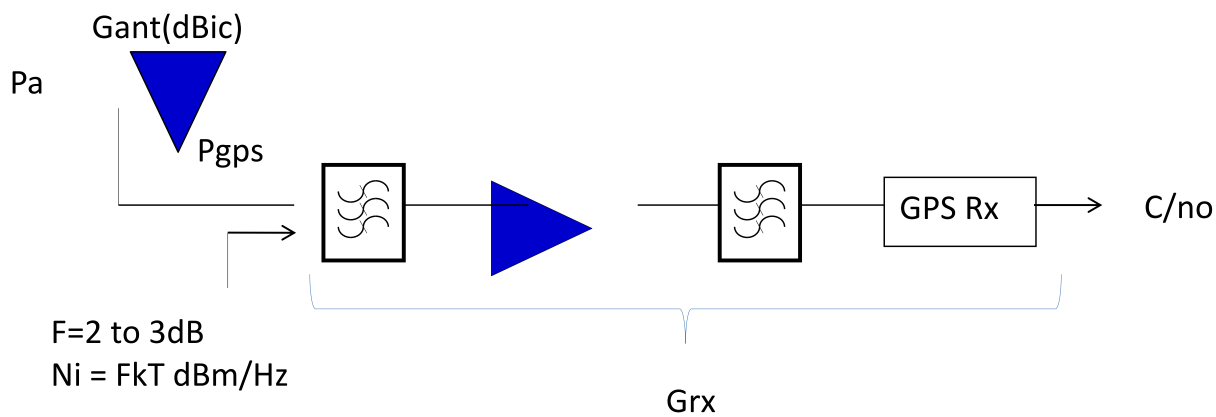
- Spirent 8100-A500 or 8100-A750 UMTS Location Test System (ULTS)
- Test Pack: TM-LBS-OTA

2.4.3 Radiated Tests (CDMA Devices)

- Spirent C2K-ATS Position Location Test System (PLTS)
- Test Pack: PLTS-OTA-01

Appendix II

In radiated (anechoic chamber) testing, the SV and blocker power levels at the antenna connector are estimate using the method described below.



From the Rx noise figure the noise spectral density at the output is

Allows the formation of the ratio with the signal at the output of the GPS Rx

Note the GPS antenna gain is irrelevant. The Rx gain cancels leaving

From which the Pgps can be calculated.

Surveying several Filter-LNA-Filter devices the F ranges from 2 to 3dB so if we use F=2.5dB we will have a reasonably accurate estimate of F.

The GPS chipset manufactures do not have a standard method of reporting the C/N_0, some include the noise figure and some do not. Since the noise figure is nominally 2.5dB we will adopt the position that assumes that the F is not included in the C/N_0 which will result in only a 2.5dB nominal error. This C/N_0 method (based on assuming that the C/N_0 is referenced to the DUT's antenna connector) is also in keeping with the C/N_0 tables reported in many of the standards as well.

In order to calibrate the power at the GPS transmit antenna in the anechoic chamber we will first establish the -130dBm level at the GPS Rx input by adjusting the GPS Tx level until the C/no =44dB-Hz. This represents the antenna noise of -174dBm/Hz and a signal level of -130dBm for a net C/no of 44dB-Hz. Lower GPS levels are established by reducing the power at the transmit antenna of the anechoic chamber relative to the GPS Tx power at this level. We will not use C/N_0 at lower levels to establish GPS signal levels since the C/N_0 variation will increase with decreasing signal and C/N_0. We will also establish the LTE band 24 power by referencing it to the GPS power level at the anechoic chamber Tx antenna.

References

[1] 3GPP TS 34.171

[2] TIA-916

[3] CTIA v3.1

Appendix C.2

Avago Presentation

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Pre-LNA Filter Capability for LightSquared Coexistence with GPS

Design study / Comparison:

A. **Wideband** GPS+GNNS filter with **Lowest Insertion Loss**
B. **Wideband** GPS+GNSS filter with **High-Rejection** including LightSquared requirements
C. **Narrowband** GPS+GNSS filter with **High-Rejection** including LightSquared requirements

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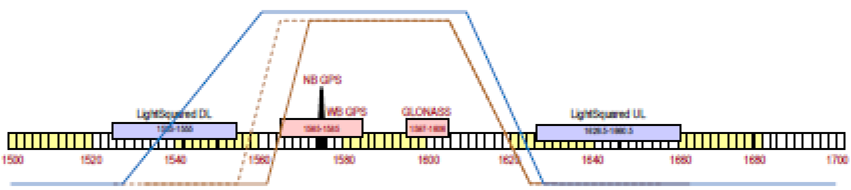
Required Performance for LightSquared Coexistence



Filter pass band:
Narrowband GPS + GLONASS: 1574-1606 MHz (tan)
Wideband GPS + GLONASS: 1565-1606 MHz (dashed tan)

Target IL 1.5 dB max at 1575 MHz for LightSquared filters
Target IL 1.0 dB max at 1575 for low loss filter (blue)

Filter reject bands:
LightSquared Downlink: 1525-1555 MHz
LightSquared Uplink: 1626.5 – 1660.5 MHz

Target 40 dB min attenuation in reject bands (tan, dashed tan)
Not applicable to low loss filter (blue)
Note that present filtering already supports this level of rejection in the uplink band

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Comments on Simulations

The plots shown on the following pages are linear simulations useful in predicting the capabilities of Avago Technologies' present Film Bulk Acoustic Resonator (FBAR) filter manufacturing process. FBAR is a Bulk Acoustic Wave filtering technology that utilizes high Q resonators to solve difficult filtering challenges. FBAR filters have been used by the mobile handset industry for over 10 years. In the course of this time more than 2 billion FBAR filters have been shipped. The process today supports many high volume applications, including a significant portion of the GPS pre-LNA filters used in mobile handsets.

Linear simulations of the kind included here typically give a good indication of the bandwidth and roll off (rejection) that can be achieved in physical filters. Insertion loss numbers are realistic, though sometimes slightly (tenths of a dB) optimistic. While these simulations do not allow negotiation of a final specification in full detail, they provide enough information to indicate process capability, and can be used to make tradeoffs when considering design options.

The plots represent the performance of typical filters at room temperature (25C). Variations in performance across manufacturing variation and over temperature also need to be accounted for when guaranteeing filter performance. This can be done by adding a frequency "guard band" to the nominal performance. For the technology used at a frequency of 1575 MHz and a temperature range of -30 to +85 C, the required frequency margin is ± 4 MHz.

In the following plots, this guard band is represented by red and blue rectangles with a dashed line placed at the nominal (room temperature of a typical device) performance. By reading the value of the typical plot appropriately shifted in frequency, expected performance over temperature and over manufacturing variation can be determined from the typical plots.

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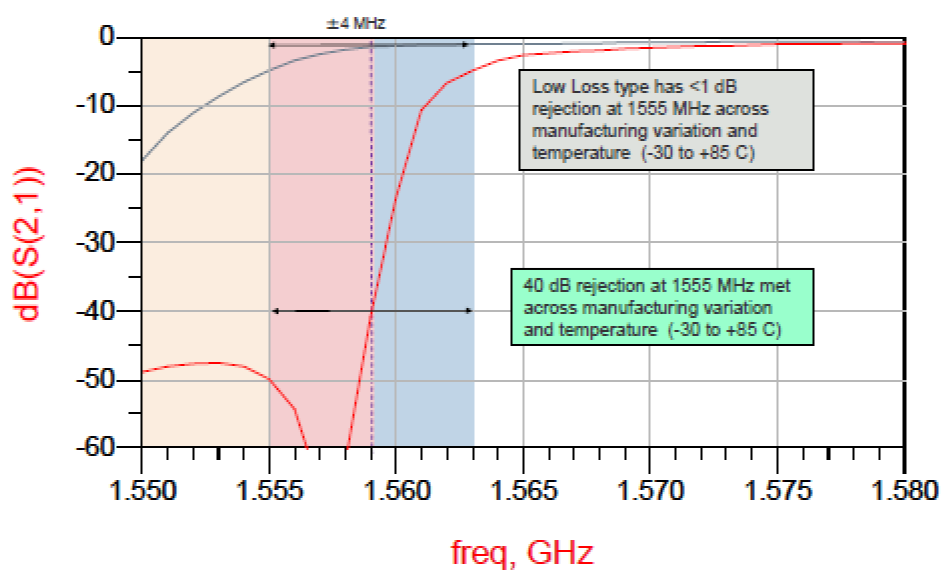
Narrowband High Rejection Type: Nominal Transition Band



Grey – Wideband „Low IL type"

Red – Narrowband „High Rejection type"

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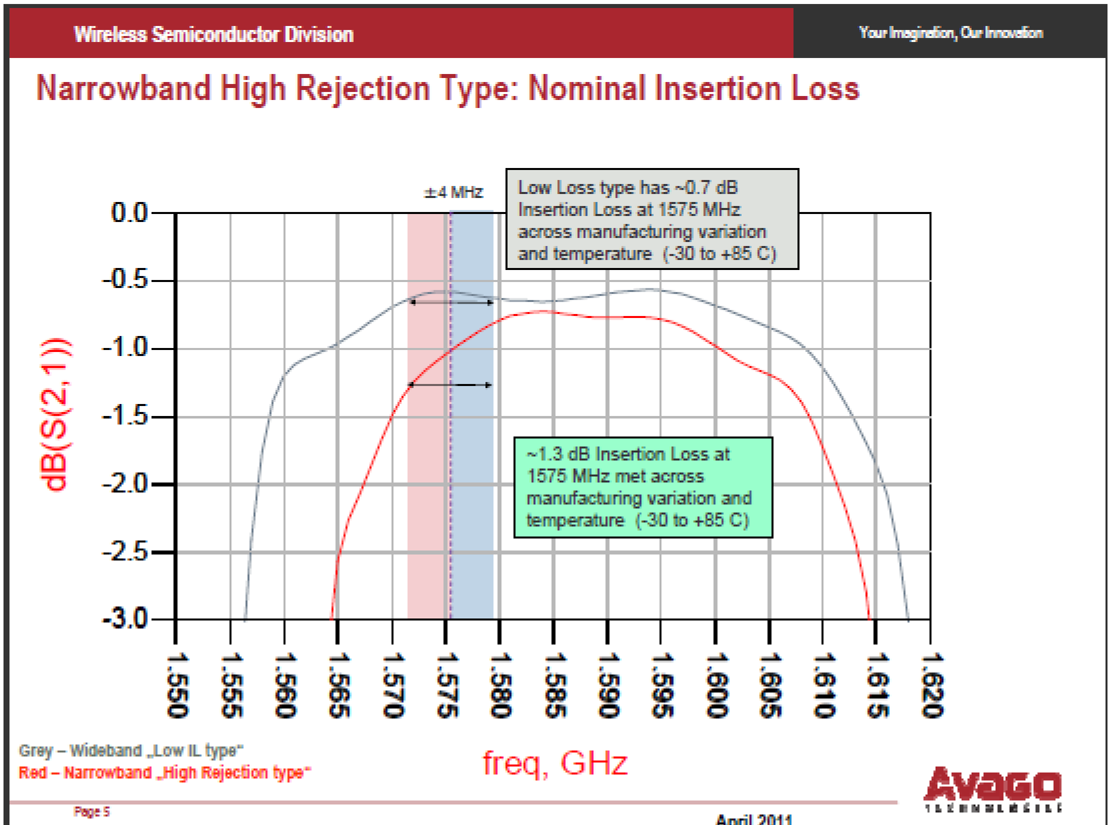
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Narrowband High Rejection Type: Nominal Insertion Loss
±4 MHz
Low Loss type has ~0.7 dB Insertion Loss at 1575 MHz across manufacturing variation and temperature (-30 to +85 C)
~1.3 dB Insertion Loss at 1575 MHz met across manufacturing variation and temperature (-30 to +85 C)
dB(S(2,1))
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
1.550
1.555
1.560
1.565
1.570
1.575
1.580
1.585
1.590
1.595
1.600
1.605
1.610
1.615
1.620
freq, GHz
Grey – Wideband „Low IL type"
Red – Narrowband „High Rejection type"
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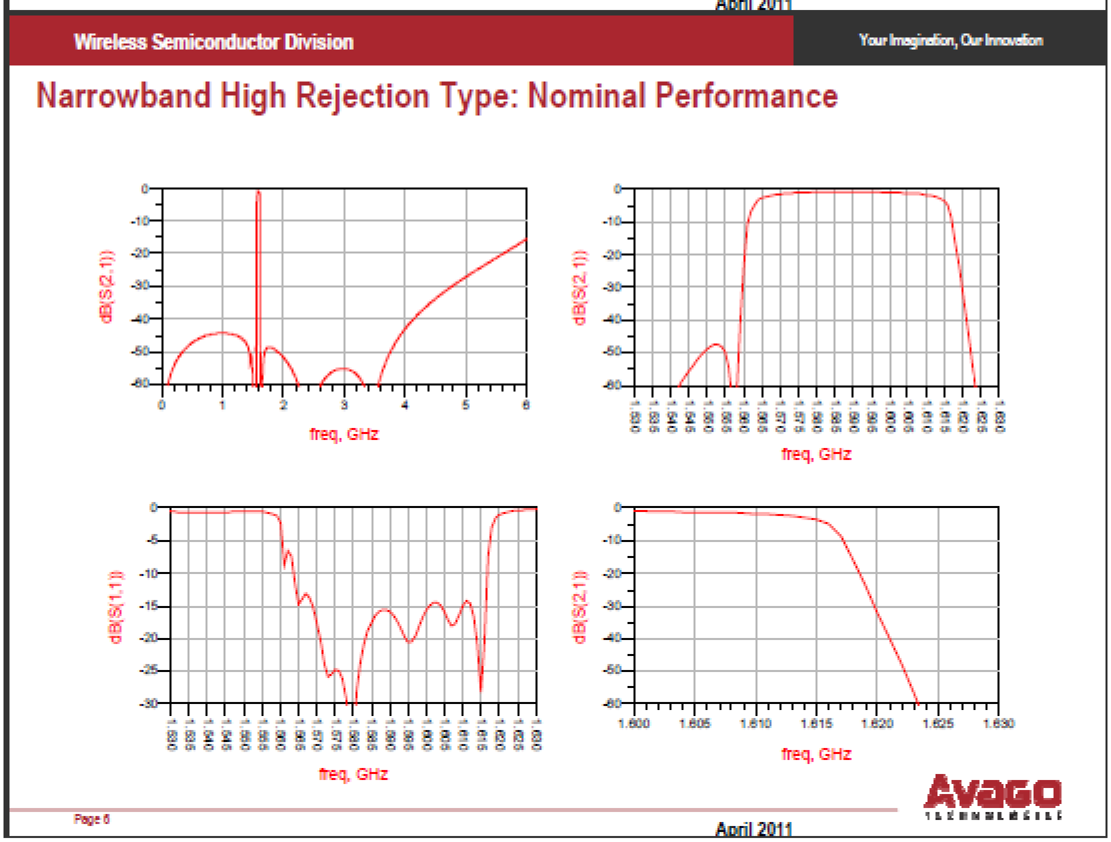
Wireless Semiconductor Division
Your Imagination, Our Innovation
Narrowband High Rejection Type: Nominal Performance
dB(S(2,1))
freq, GHz
dB(S(2,1))
freq, GHz
dB(S(1,1))
freq, GHz
dB(S(2,1))
1.600
1.605
1.610
1.615
1.620
1.625
1.630
freq, GHz
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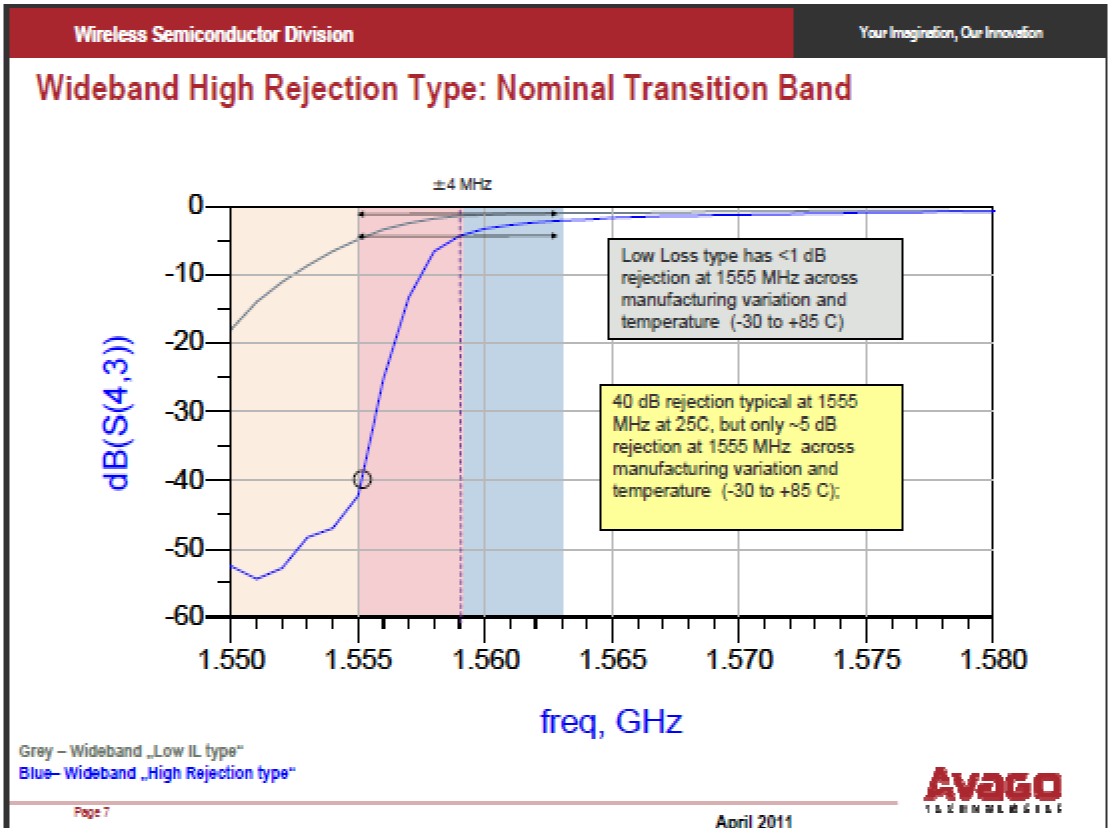
Wireless Semiconductor Division
Your Imagination, Our Innovation
Wideband High Rejection Type: Nominal Transition Band
±4 MHz
dB(S(4,3))
0
-10
-20
-30
-40
-50
-60
1.550
1.555
1.560
1.565
1.570
1.575
1.580
freq, GHz
Low Loss type has <1 dB rejection at 1555 MHz across manufacturing variation and temperature (-30 to +85 C)
40 dB rejection typical at 1555 MHz at 25C, but only ~5 dB rejection at 1555 MHz across manufacturing variation and temperature (-30 to +85 C);
Grey – Wideband „Low IL type"
Blue– Wideband „High Rejection type"
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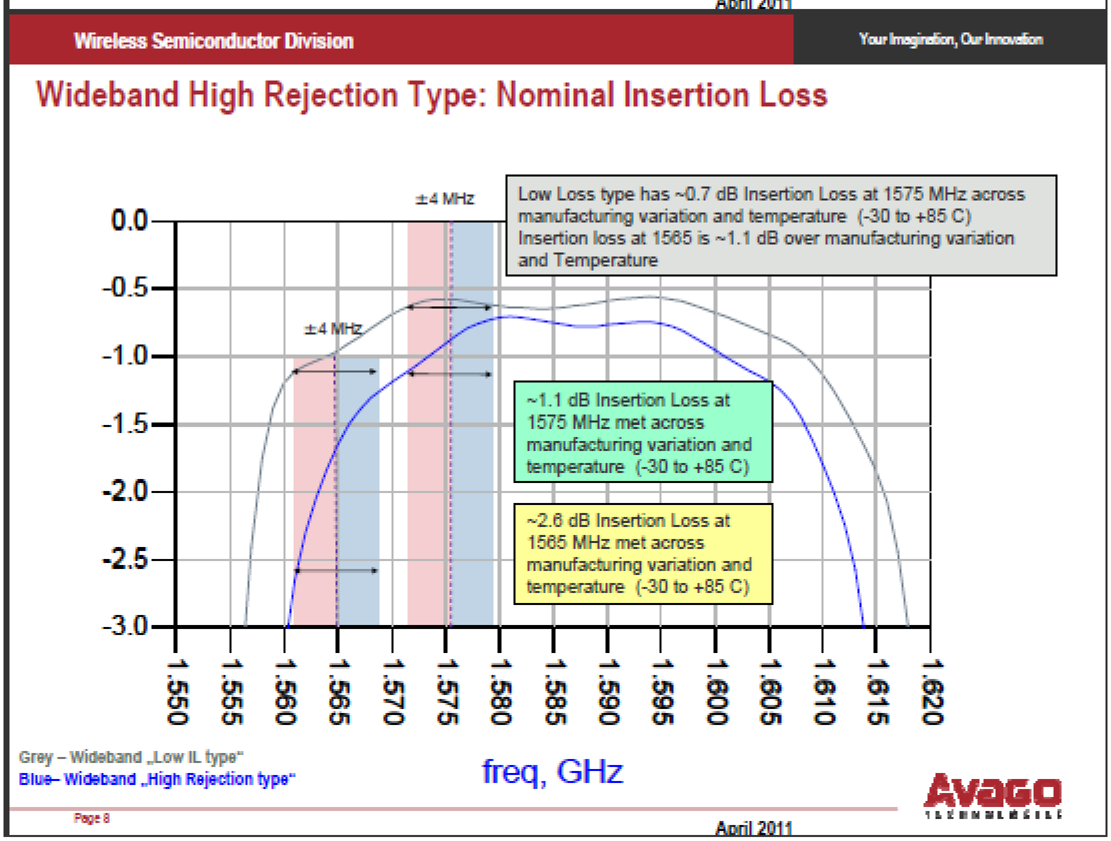
Wireless Semiconductor Division
Your Imagination, Our Innovation
Wideband High Rejection Type: Nominal Insertion Loss
±4 MHz
Low Loss type has ~0.7 dB Insertion Loss at 1575 MHz across manufacturing variation and temperature (-30 to +85 C) Insertion loss at 1565 is ~1.1 dB over manufacturing variation and Temperature
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
±4 MHz
~1.1 dB Insertion Loss at 1575 MHz met across manufacturing variation and temperature (-30 to +85 C)
~2.6 dB Insertion Loss at 1565 MHz met across manufacturing variation and temperature (-30 to +85 C)
1.550
1.555
1.560
1.565
1.570
1.575
1.580
1.585
1.590
1.595
1.600
1.605
1.610
1.615
1.620
freq, GHz
Grey – Wideband „Low IL type"
Blue– Wideband „High Rejection type"
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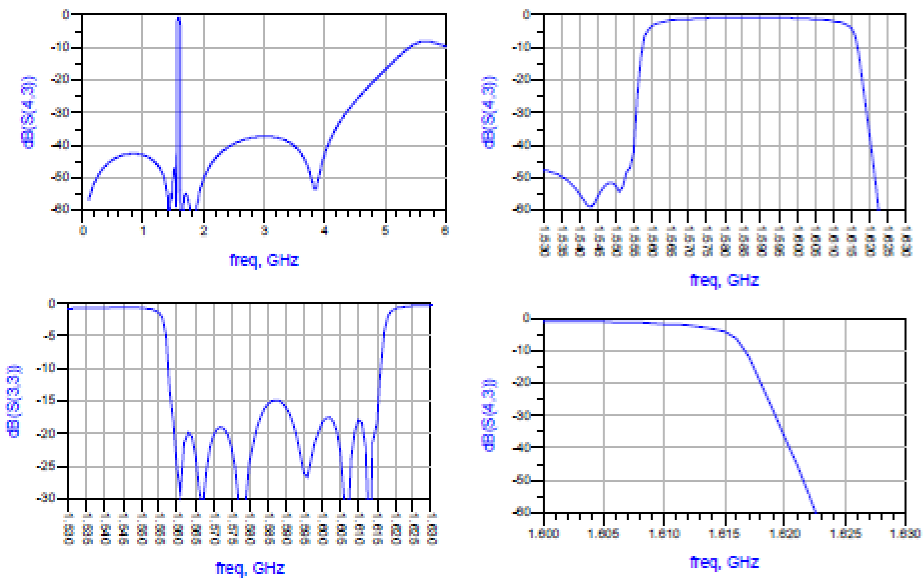
Wideband High Rejection Type: Nominal Performance



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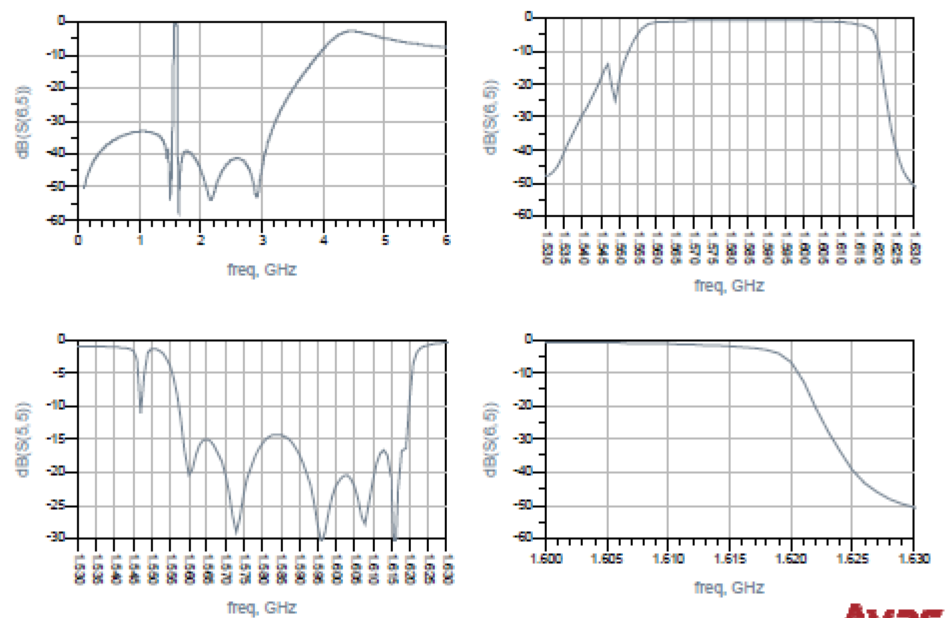
Wideband Low IL Type: Nominal Performance



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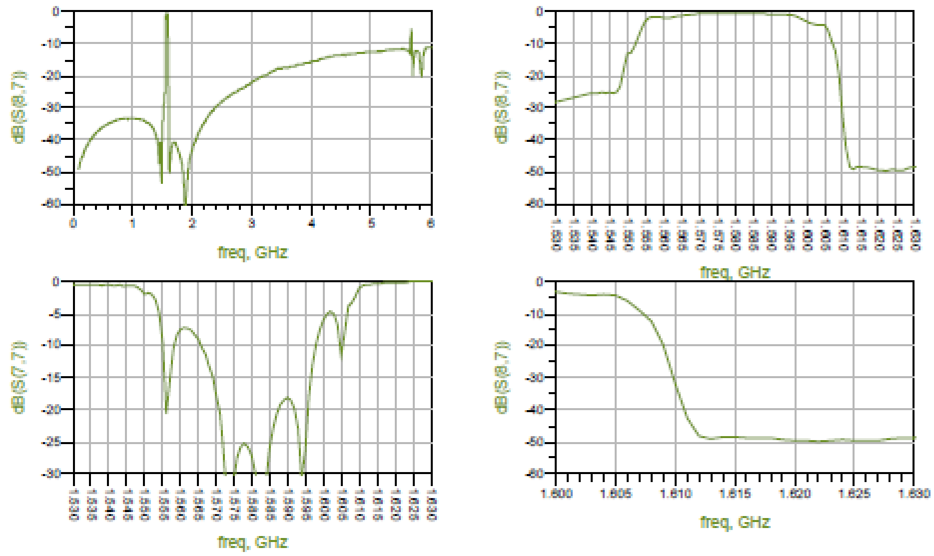
Reference Wide GPS Only Type: Nominal Performance



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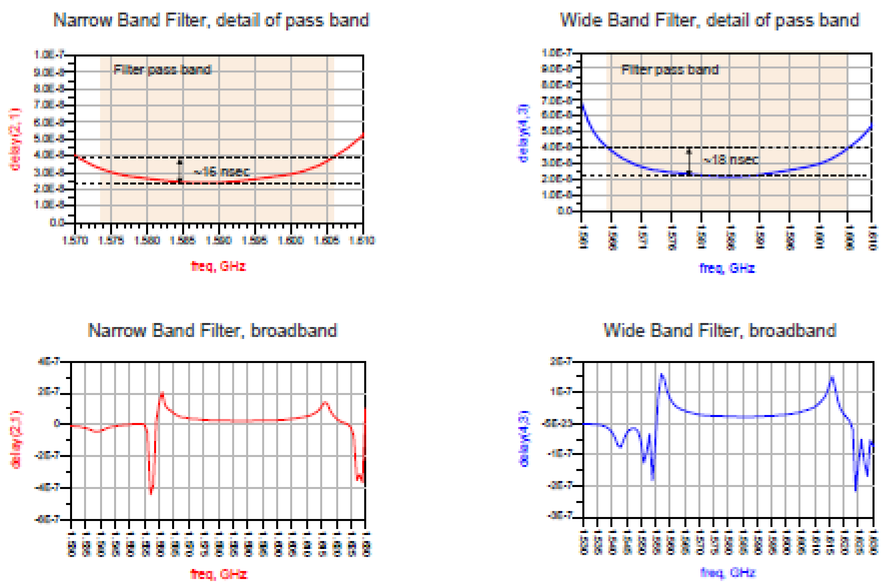
Group Delay Performance of Wideband and Narrowband Filters



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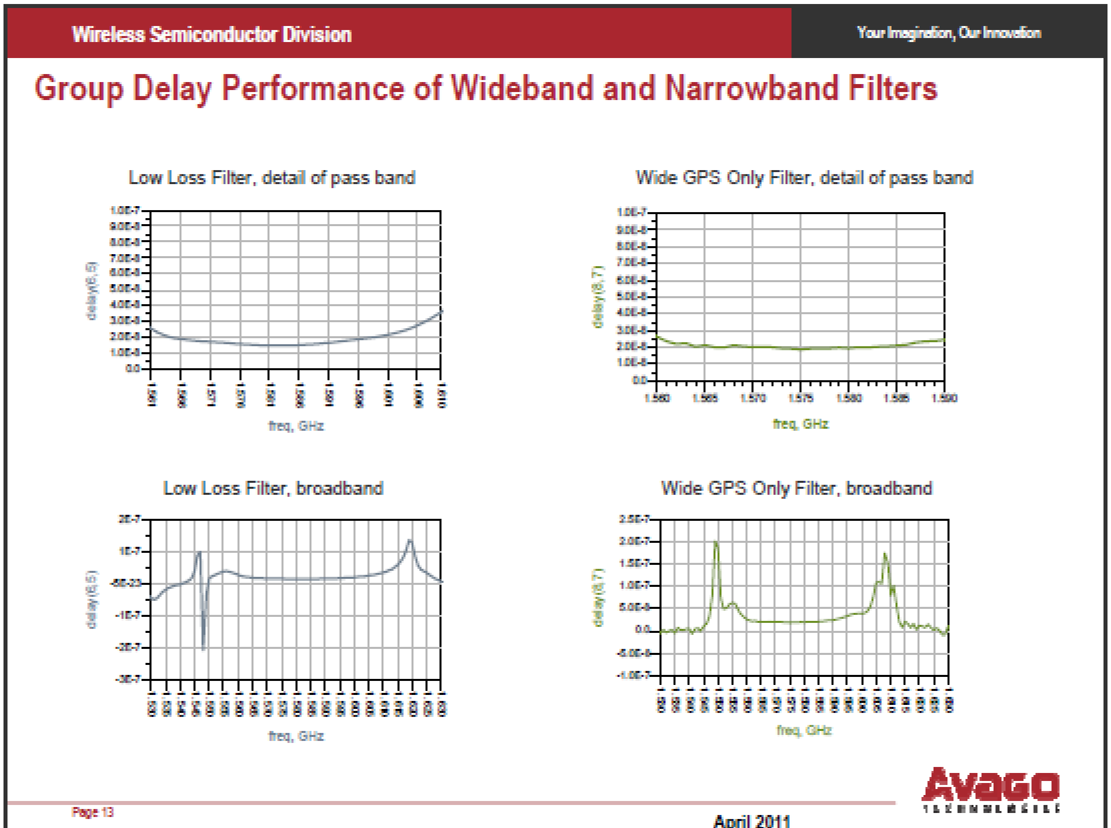
Wireless Semiconductor Division
Your Imagination, Our Innovation
Group Delay Performance of Wideband and Narrowband Filters
Low Loss Filter, detail of pass band
freq, GHz
Wide GPS Only Filter, detail of pass band
freq, GHz
Low Loss Filter, broadband
freq, GHz
Wide GPS Only Filter, broadband
freq, GHz
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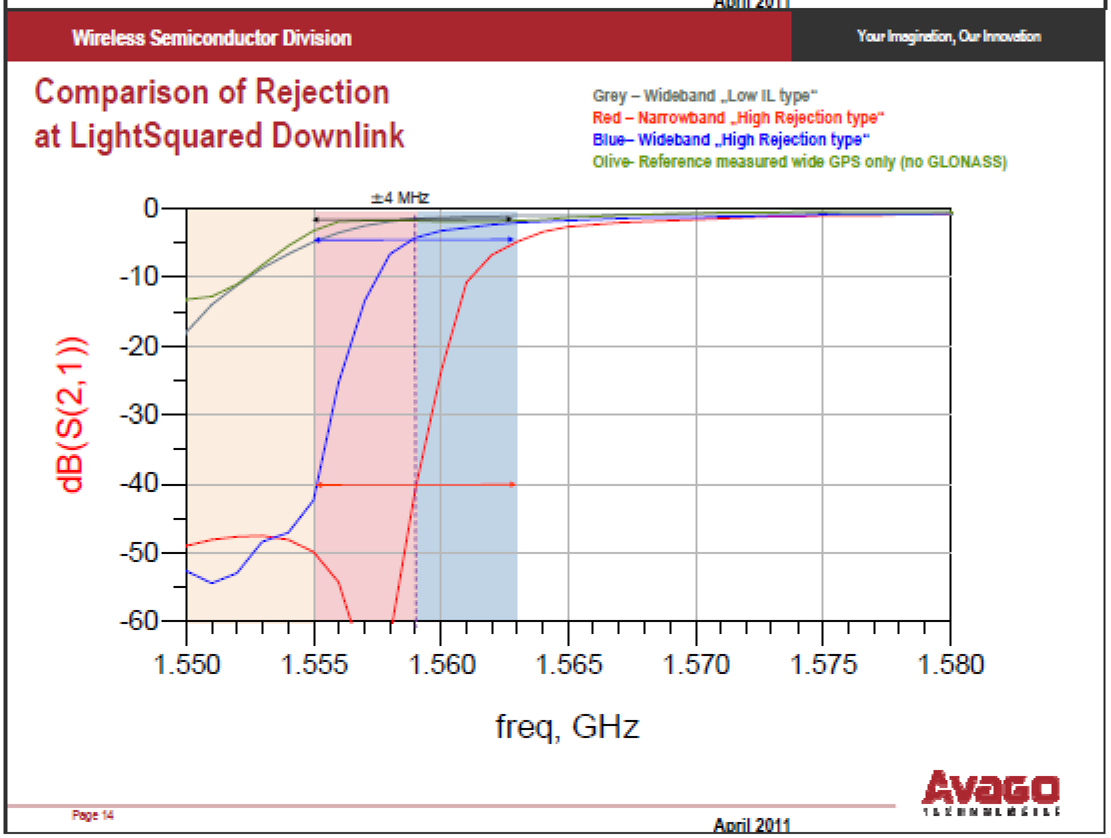
Wireless Semiconductor Division
Your Imagination, Our Innovation
Comparison of Rejection
at LightSquared Downlink
Grey – Wideband „Low IL type"
Red – Narrowband „High Rejection type"
Blue– Wideband „High Rejection type"
Olive- Reference measured wide GPS only (no GLONASS)
±4 MHz
dB(S(2,1))
0
-10
-20
-30
-40
-50
-60
1.550
1.555
1.560
1.565
1.570
1.575
1.580
freq, GHz
Page 14
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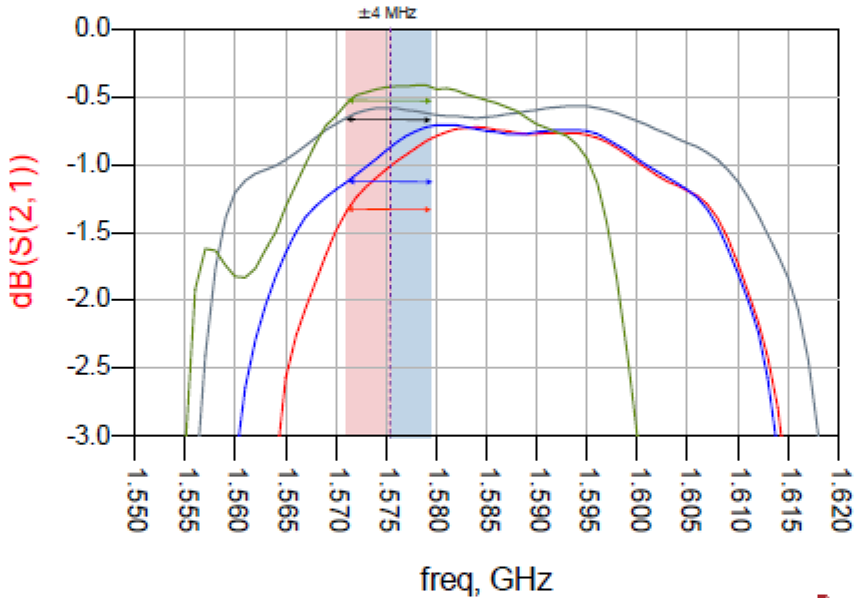
Comparison of Insertion Loss

Grey – Wideband „Low IL type"
Red – Narrowband „High Rejection type"
Blue– Wideband „High Rejection type"
Olive- Reference measured wide GPS only (no GLONASS)



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Conclusions from the Performance Plots

Present Avago FBAR manufacturing technology can support a filter with <1.5 dB insertion loss across narrow GPS + GLONASS (1574-1606 MHZ) that provides 40 dB of rejection in the LightSquared bands. This performance can be maintained across manufacturing variation and a temperature range of -30 to +85 C.

Present Avago FBAR manufacturing technology only marginally supports a filter with <1.5 dB insertion loss across wide GPS + GLONASS (1565-1606 MHZ) that provides more than 40 dB of rejection in the LightSquared bands. While acceptable performance can nominally be obtained at room temperature, at this time relaxations would be needed for guaranteed performance across manufacturing variation and temperature. It is the belief of Avago Technologies that improvements in technology that will become available in volume manufacturing over the next few years will allow the support of wide GPS + GLONASS filters as well.

It is appropriate to note that at this time this work is a feasibility study only. Avago Technologies does not presently manufacture filters that support LightSquared coexistence with GPS.

Avago Technologies

April 2011

Appendix C.3

Live Sky Test Plan

Las Vegas Live Sky Test Report

Evaluation of

3GPP Band 24 (MSS L-band) ATC impact to GPS Receivers in an outdoor environment

Draft Version 3.4.9

06/13/2012

Index

1. Introduction

This document describes the test methodology to be used by the GPS Technical Working Group (TWG) for overload testing of GPS receivers in proximity to LightSquared's base stations using 3GPP Band 24[9] (henceforth referred to simply as Band 24).

The present plan will allow GPS receivers to be tested in the field against a production LightSquared base station. The antenna will be mounted at a height that is representative of actual deployment for an EIRP of 32 dBW per ATC carrier. The GPS signals will be as received in the field at the time and location of the test.

Many variables can impact GPS performance. The influence of the LightSquared signal in different environments (Dense Urban, Urban, Suburban, and Rural) under real world conditions is to be characterized through mobile and stationary tests with some stationary tests conducted inside selected buildings.

The tests will be performed in morphologies that can be roughly classified as Dense Urban, Urban, Suburban, and Rural. Four cell sites, one in each morphology, have been selected in Las Vegas by LightSquared. Most likely, the tests will be conducted from May 16th till the 27th during the night or early morning hours. Performance in Dense Urban, Urban, Suburban, and Rural areas is to be evaluated during this time window.

2. Field Test Methodology

The test plan described here characterizes the performance of GPS receivers (the devices under test, or DUT's) in the presence of L-band base station downlink signals in an outdoor environment with live GPS satellite signals. Production base station transmitter subsystems (including production PA's, filters and other RF components) and antennas will be used. The base station installation will be representative of actual deployment, including a 2^0 electrical antenna downtilt. The antennas will comprise 45^0 cross-polarized elements fed by separate PA's emitting MIMO signals. As per LightSquared's initial deployment plan, the base station will emit L-band signals at the full 32dBW/carrier (29 dBW/carrier/MIMO branch). 100% loading will be emulated using dummy user data.

The planned base station power levels and spectrum occupancies are shown in Figure 3; details of the test sites are provided in Table 1 and a high level diagram of the test site locations is show in Figure 4.

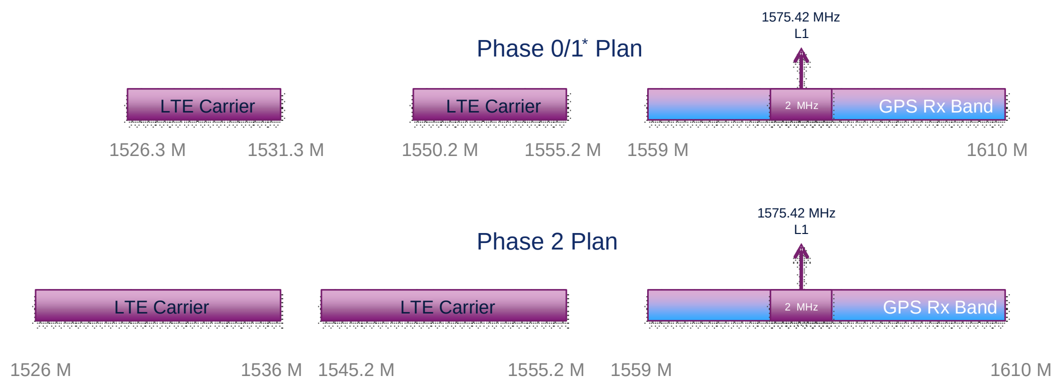
For the planned tests, owing to the limited time available, only the Phase-1 configuration will be tested.[10] This will comprise two 5 MHz carriers, each at 32 dBW, in each of 3 sectors. Some limited tests will also be performed with the two carriers individually.

---

[9] Per ITU designation, this is also referred to as the MSS L-band and is at: 1525 – 1559 MHz for downlink transmissions and 1626.5 – 1660.5 MHz for uplink transmissions.

[10] Phase-1 is considered to be the worst of all deployment phases for GPS receiver vulnerability as it has the (a) the highest inband power spectral density and (b) the highest power spectral density nearest to the RNSS band. The two individual 5 MHz channels will be tested separately as this test can show the vulnerability of a given device to 3rd order IM; this may be an indicator of the extent of preselector filtering across Band 24.

Figure 3: LightSquared Downlink LTE Band 24 and GPS Band (EIRP per carrier: 32 dBW)



*Only upper 5-MHz LTE carrier is used in Phase-0. Both 5-MHz carriers are used in Phase-1

Table 1: Test Site Details

LightSquared Site ID	Latitude	Longitude	Antenna Height AGL (ft)	Number of Sectors	Azimuths (degrees)	City
LVGS0053-C1	35.9697	-114.8681	60	2	30, 270	Rural
LVGS0068-C1	36.1245	-115.2244	55	3	0, 120 ,240	Suburban
LVGS0160-C1	36.127	-115.189	50	3	0, 120, 240	Urban
LVGS0217-C1	36.1065	-115.1705	235	2	0, 240	Dense Urban

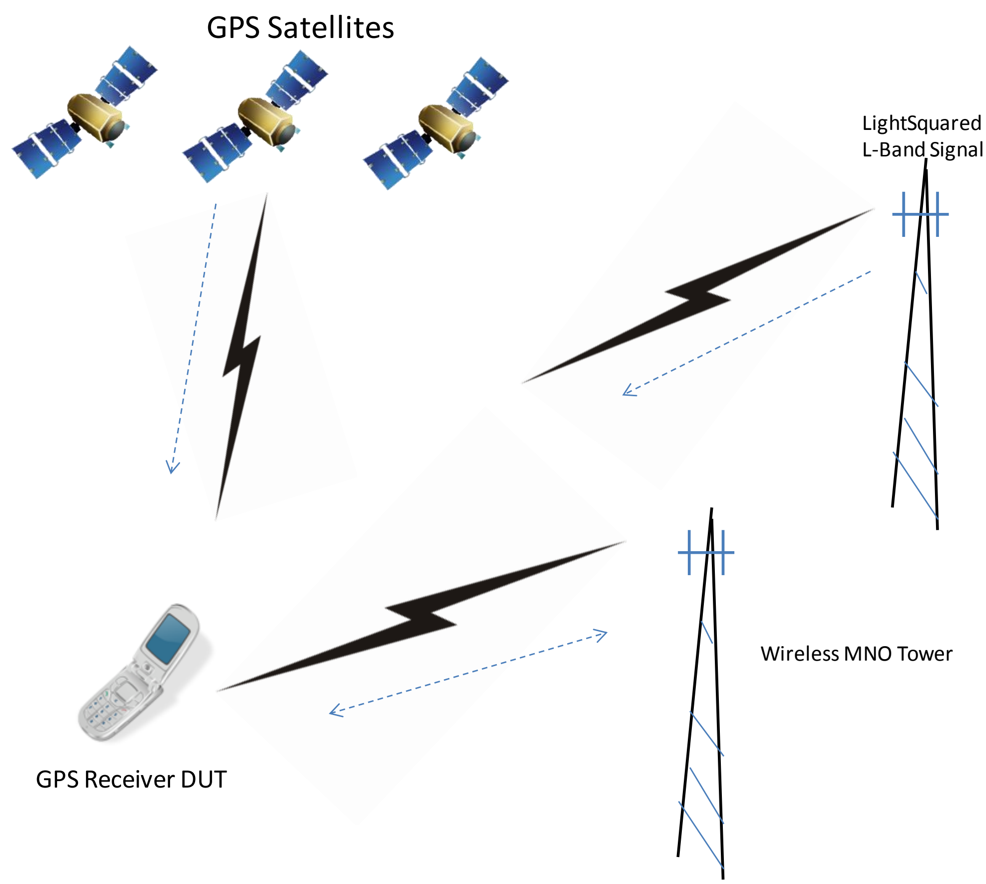
Figure 4: Test Site Location Map

2.1. Field Test Environment

The Figure 5 below shows the proposed field test setup to cover the field test cases and test conditions.

The L-band ATC channel configurations are varied at the base station equipment. The tests will be conducted in different morphologies, including at least dense urban, urban, suburban and rural as feasible within the schedule of this project.

Figure 5: LightSquared Field Setup



The Key Performance Indicators (KPI) recorded will be similar to those collected in the lab tests, to the extent supported by the available test software, i.e. C/N_0, 2D Position Error and TTFF (warm start). At the very least, the 2D Position reported by the device will be logged. Whether C/N_0 can be logged will depend on the software support available to TechnoComm for the particular device; e.g. such support is currently unavailable for the iPhone. Unlike the lab tests, there will be no pass/fail criteria.

No special attempt needs to be made to emulate cellular assistance – if the device uses cellular assistance, this will be automatically enabled as the measurements will be performed while the device is camped on to a cellular network. This means that it must be possible to register the devices on the local MNO's network. Some measurements will be performed indoors to determine the effect of LightSquared's ATC on indoor GPS operation, to the extent that such operation is feasible.

To determine the differential impact of the LightSquared signals on GPS receivers, an on-off method of applying the LightSquared signals, with a sufficiently short time separation between on and off modes, will be used[11]. The LightSquared signals will be applied for a known period of time (e.g. 15 minutes) at full power; then they will be turned off for the same period of time. This cycle will be repeated for each individual measurement. The actual on/off period to be used will be decided after some trials in the field but will not

[11] The on/off period has to be sufficiently short that the DOP factor, which is related to the satellite constellation geometry, does not change appreciably.

exceed 15 minutes. The LightSquared team will have their watches synchronized to local GPS time. At the test start, the LightSquared team will communicate prior to the manual start of the test signal automation scripts after which the scripts maintain the periodic signal cycling for 15 minutes on/off. The synchronization precision between the different cell sites for signal cycling will not be sub-second but should be within 5 seconds or less.

The following KPI data will be collected, both with and without the LightSquared signals:

1. C/N_0 for the tracked SVs
2. 2D Position Accuracy
3. Time to First Fix (TTFF): time required for device to acquire satellite lock

For each measurement, the KPI's collected will be averaged[12] over a TBD number of samples – the exact number will be determined after performing some initial trials. These trials will indicate the optimum number of samples necessary to balance test time and measurement confidence.

The Position Accuracy will be calculated with respect to a true position value which will be obtained from a DGPS system with dead reckoning assistance. It is noteworthy that, unlike the lab measurements, the LightSquared signal power emitted by the base station will not be varied (except for being turned on and off as described above). The variation of blocker power level at the DUT will be caused by varying the distance from the base station.

The tests will include both static and dynamic (in-vehicle) types. All testing will be automated and controlled from a central server by cellular wireless links.

2.1.1. Static Tests

For static tests, the LightSquared signal power level at the test location will be measured with a reference antenna (antenna of known gain towards the base station antenna). The base station power will be measured at 8 points, approximately 100 m apart, where the points are laid out in an approximately radial direction from the base station tower, corresponding to the peak of the azimuthal antenna pattern. The terrain and available access rights will determine the choice of actual sites, subject to the above guidelines. Sufficient averaging time (at least 10 s) will be allowed for the power measurements so as to average through slow fading. The power will be measured with a calibrated antenna on the roof of a van.

Based on these power measurements, two locations corresponding to the two highest power levels (hotspots) will be selected for KPI measurements for all devices. KPI data will be collected at two locations clustered around each hotspot with approximately 10 – 15 ft separation. This is to ensure that the results are not being affected by static multipath effects. Thus, in total, KPI data would be collected at 4 locations corresponding to the two hotspots. The latitude and longitude of each measurement location will be logged in an automated, true position recording system. The KPI data collection will span several hours for

[12] Standard percentiles of the CDF may be used for certain KPIs such as position error.

each device to allow some observation of the effects of GPS satellite constellation (DOP factor) changes.

Testing will also include static data collection in indoor locations. The objective is to document the A-GPS performance of the GPS integrated device when in a location such as a coffee shop, deli, or lobby that is receiving a 'typical service strength' signal from the LightSquared base stations.

2.1.2. Dynamic Tests

For dynamic tests, the device under test (DUT) will be mounted in a vehicle and used with its native antenna (not connected to an outdoor GPS antenna). The drive route will include distances up to 1 km from the base station antenna. The route will be logged and the same route will be driven during the transmitter on and off periods. The dead reckoning system will provide true positions, which will be logged simultaneously with the received LightSquared signal power inside the vehicle. The position error and other KPI will be measured by commands issued over cellular links from the central server.

There are some challenges with designing the dynamic tests as described below. As the *get-fix* call may be issued at arbitrary times during a 15-minute on/off epoch, it cannot be guaranteed that position fixes will be obtained at exactly the same location in the drive route with the LightSquared signals on and off. As the LightSquared signal power is a function of location, this would suggest that it would not be possible, from this test, to test the differential impact of a given LightSquared power level on the KPI's. However, it is felt that if sufficient trips are made up and down a given route, with sufficiently frequent calls, sufficient data points may be obtained to largely mitigate this problem.

The feasibility of this will be ascertained in a pretest period (before the LightSquared signals are turned on). During this period, a number of trials runs will be made on a 1 km route and repeated get-fix calls will be made. The results will be examined to determine the granularity of the locations covered. If the average inter-location distance is approximately 100 m, this will suffice for the present test objectives. The aim of the pretest will be to determine how many trips are needed to achieve this granularity.

3. Testing System Details

The RF parameters and all other relevant information will be documented to assure completeness and repeatability of the test results reported. As depicted in Figure 6, as many as two vehicles will be equipped with the following:

1. A Differential GPS receiver with Dead reckoning for gathering Ground Truth information including a GPS magnetic-mount antenna with cable and connector (placed on center of vehicle roof). The Dead reckoning unit is calibrated prior to the field tests and will be cross-checked periodically at know locations as it could be the only form of precise position determination in close proximity of the active LightSquared transmitters.
2. A LAD with integrated DGPS receiver as a backup to DGPS with Dead reckoning. Antenna will be placed inside the vehicle for more shielding from interference.
3. A Spectrum Analyzer and a LightSquared antenna for measurement of LightSquared signal strength received inside the vehicle. The selected instrumentation will be intended

to accurately handle received LightSquared signal levels in the -20 to -80 dBm range. The data gathered from the Spectrum Analyzer is to be time and location stamped using information from the DGPS/Dead Reckoning unit.

4. A number of Sprint, Verizon and ATT handsets to determine GPS key performance indicators, or KPI's, (Accuracy, GPS Signal Quality, and Latency if available). Upon initiation by the field personnel, an onboard application on each device will request a location from the device under test. The location subsystem of the device, after going through its location determination process, will send back the calculated position along with time and GPS Signal Quality estimates to the onboard application. The onboard application then stores the information and makes its next request to the location subsystem. This process will continue until a predefined number of samples are gathered. Upon reaching this limit, the application places a call to the central server and downloads all the gathered data. The application will then resume its location request and gathering until the tests are terminated by the field personnel.
5. Laptops with multiple serial ports to run data capture routines to gather data from ground truth devices and the spectrum analyzer.

The test setup will be utilized in the mobile testing as well as in-vehicle stationary tests. In Building stationary tests are conducted at locations for which the exact position is known. All points are surveyed during the first week of testing.

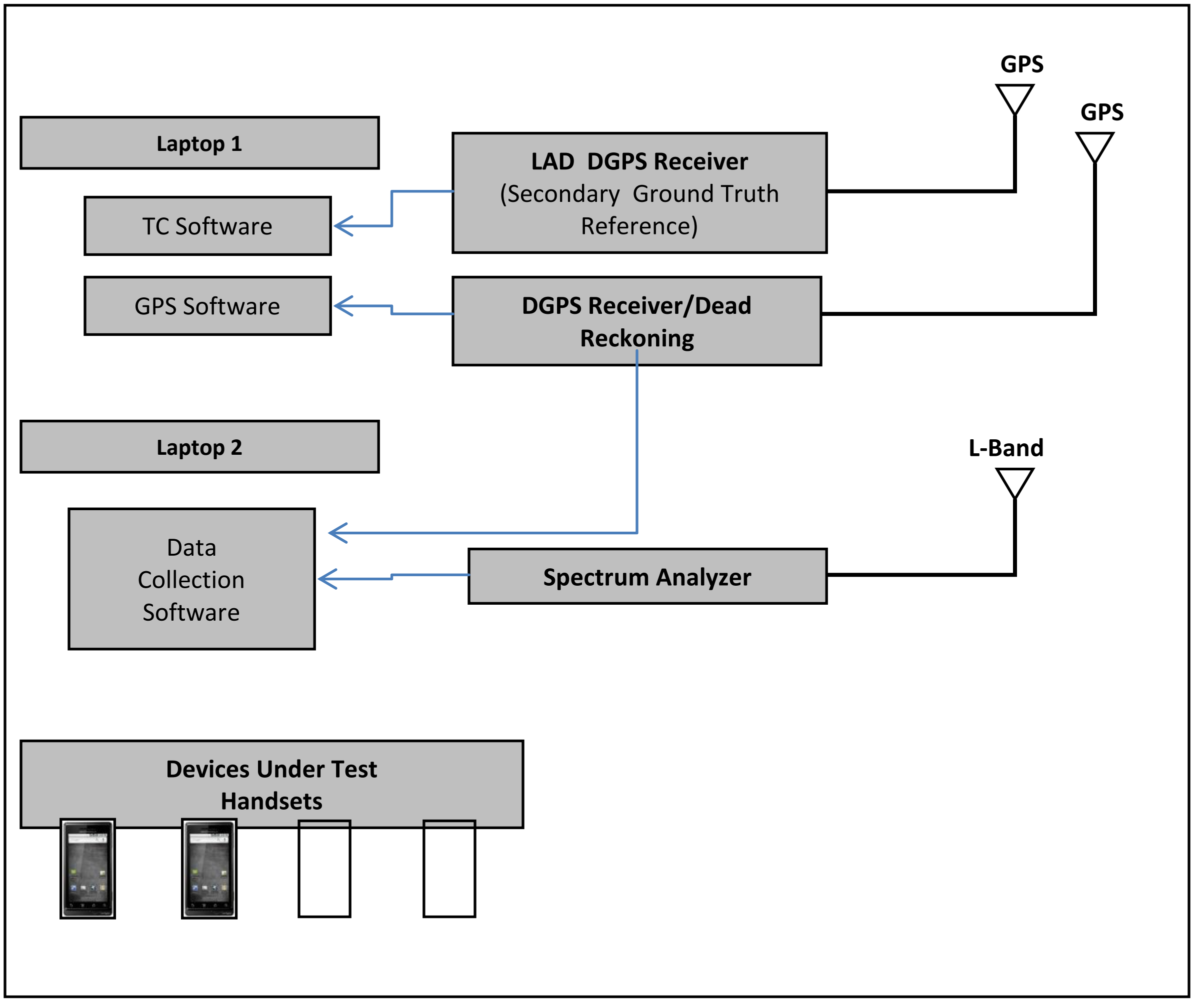
Various test speeds will be used as appropriate in the different test phases. This will be specified in the more detailed test procedures. The speeds will generally be quantized as:

1. Stationary
2. 20-40 mph

In addition, we will conduct limited indoor testing to augment the data collected in the field.

Appendix

Figure 6: Vehicle Test Setup



4. Revision History

Version	Author	Changes
1.0	Maqbool Aliani	Original Draft
1.1	Santanu Dutta	Some test plan alterations and general edits
1.2	Maqbool Aliani	Some general edits
1.3	Santanu Dutta	Additional edits
1.4	Maqbool Aliani	Additional edits.
1.5	Masoud (TechnoComm)	Additional edits.
1.6	Maqbool Aliani	Additional edits.
1.7	Ismael Garcia	Added cell site link budget details and LTE test signal characteristics in appendix. Also made some other formatting edits. Added a couple of sentences to section 2.1. Updated cell azimuth and sector info for site 53.
1.8	Ismael Garcia	Added additional appendix information section c and d for proposed radiation schedule and proposed signal cycling.
1.9	Maqbool Aliani	Added device list to Appendix e. Added text on indoor testing in Section 3.0
2.0	Maqbool Aliani	Switched spectrum plan between 5/17 and 5/18
2.1	Maqbool Aliani	Transmit link budget updated to reflect 62 dBm EIRP per sector. It has been confirmed that power out of the radio can be increased to compensate for the cable loss while maintaining OOBE spec of -100 dBW/MHz in the GPS band. **The Day 3 tests were run with 62 dBm EIRP per Sector**. Additionally, for Site 217 the LDF Coax Loss has been verified to be 3.8 dB
3.0	Neal Rollins	Test Result tables added
3.1	Maqbool Aliani	Miscellaneous edits
3.2	Neal Rollins	Dynamic Result tables added
3.3	Neal Rollins	In-Building Result tables added
3.4.x	Maqbool Aliani	Added additional test data results for the in-building and dynamic sections
3.4.7	Maqbool Aliani	Added additional test data results for the static section

5. Appendix

5.1. Cell Site Link Budget Details

Antenna TX Power Budget Site 68 (All Sectors)		
RRH Power	45.5	dBm
LDF4 1/2" Coax Loss	-3.3	dB
Antenna Gain dBi	16.8	dBi
EIRP	59	dBm
Total EIRP per sector with MIMO active	62*	dBm

Antenna TX Power Budget Site 160 (All Sectors)		
RRH Power	45.7	dBm
LDF4 1/2" Coax Loss	-3.5	dB
Antenna Gain dBi	16.8	dBi
EIRP	59	dBm
Total EIRP per sector with MIMO active	62*	dBm

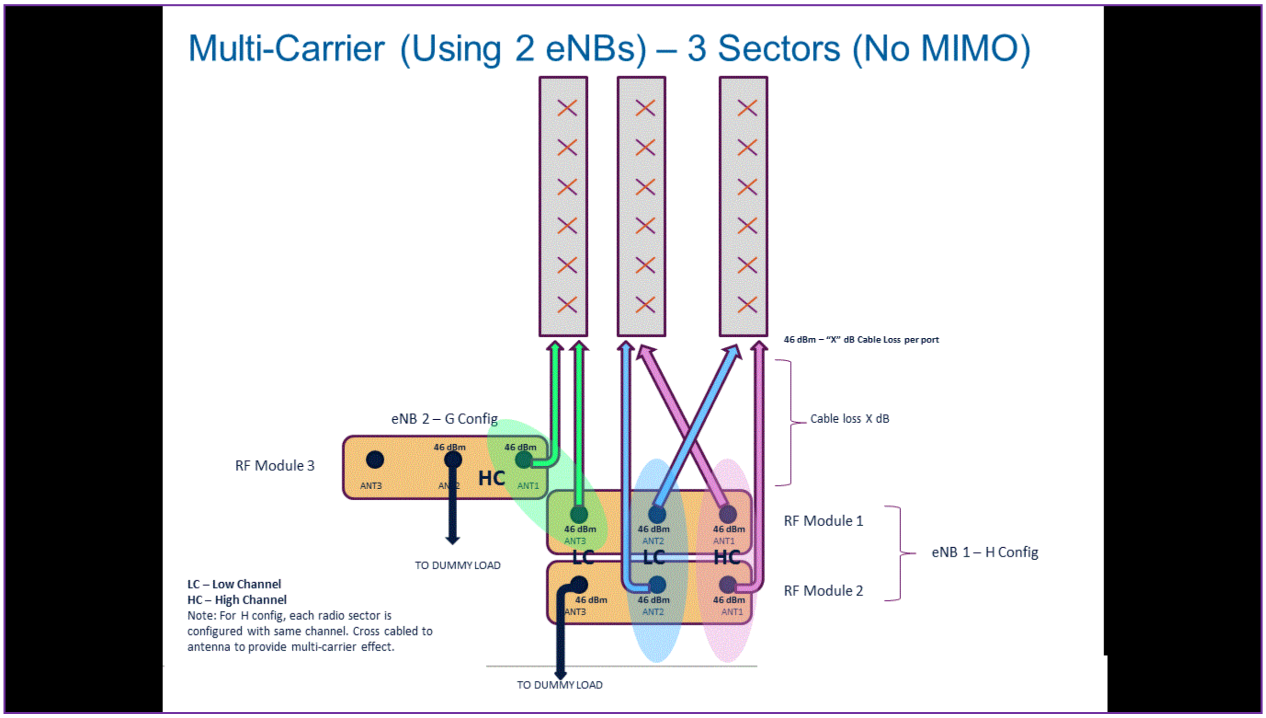
Antenna TX Power Budget Site 53 (All Sectors)		
RRH Power	45.7	dBm
LDF4 1/2" Coax Loss	-3.5	dB
Antenna Gain dBi	16.8	dBi
EIRP	59	dBm
Total EIRP per sector with MIMO active	62*	dBm

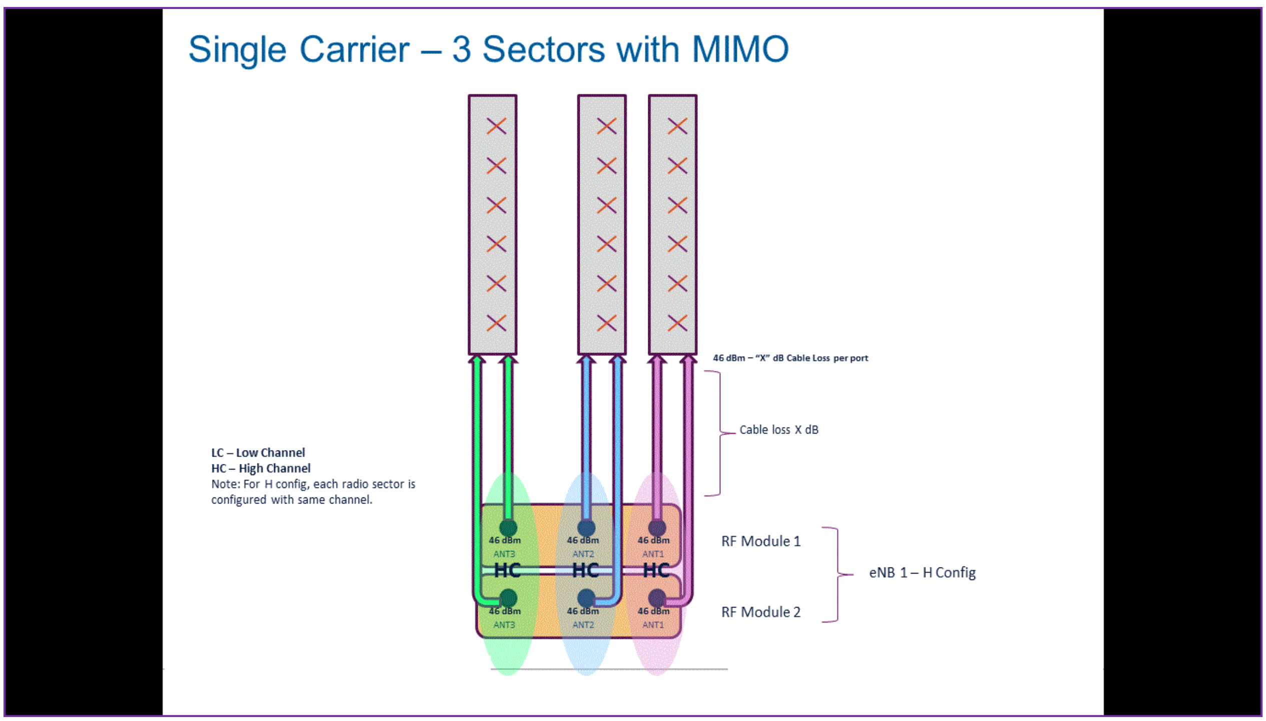
Antenna TX Power Budget Site 217 (All Sectors)		
RRH Power	46	dBm
LDF4 1/2" Coax Loss	-3.8	dB
Antenna Gain dBi	16.8	dBi
EIRP	59	dBm
Total EIRP per sector with MIMO active	62*	dBm

** Note 1: The eNodeB software does not support two carriers per sector until a future release. For two carrier tests, the eNodeB will require that each carrier be separately input to one of the two antenna ports and will result in the MIMO gain not being present. Thus total sector EIRPs will be down 3 dB from the table values for the two carrier tests.*

*** Note 2: For Site 217 the LDF Coax Loss has not been verified as of the revision of this document. A budgetary number of 3 dB was used and the nominal value for the actual measure value is not expected to be +/- 0.5 dB.*

5.2.Test Site RF Plumbing





5.3.Las Vegas Live Sky LTE Signal Characteristics

The LightSquared eNodeB LTE test signal is per an ETSI standard definition. The eNodeBs in the Las Vegas Live Sky testing will use the E-UTRA Test Model 1.1 (E-TM1.1) as defined for the applicable 5 MHz channels. The specific of the channel characteristics can be found in the ETSI 3GPP Technical Specification 36.141 version 10.1.0. Release 10 under section 6.1.1.1. The physical channel parameters for a 5 MHz channel apply as detailed in Table 6.1.1.1-1 of the test model.

Reference document:

http://www.etsi.org/deliver/etsi_ts/136100_136199/136141/10.01.00_60/ts_136141v100100p.pdf

5.4.Las Vegas Live Sky Proposed Channel and Radiation Schedule

The table provided in this section is the ***proposed*** channel and site radiation schedule. Please work with the LightSquared Test point of contact to received an updated plan prior to the start of testing.

		Frequency Bands to be tested		Sites to be tested			
Test Day	**Date**	**1526.3-1531.3 MHz LOWER BAND**	**1550.2-1555.2 MHz UPPER BAND**	**Site #68**	**Site #160**	**Site #217**	**Site #53**
1	5/16/2011		x	x		x	
2	5/17/2011	x		x		x	
3	5/18/2011	x	x	x		x	
4	5/19/2011		x		x		x
5	5/20/2011	x	x		x		x
6	5/21/2011	x		x		x	
7	5/22/2011		x	x	x	x	
8	5/23/2011	x		x	x	x	
9	5/24/2011	x	x		x		x
10	5/25/2011	x			x		x
11	5/26/2011	x	x	x	x	x	
12	5/27/2011	x	x	X*		X*	x

Note: On day 12, Sites 068 and 217 operated on the lower 5 MHz channel only.

5.5.Las Vegas Live Sky Proposed Signal Cycle Schedule

The table provided in this section is the ***proposed*** signal cycle schedule from the active eNodeBs for the daily testing. Please work with the LightSquared Test point of contact to received an updated / confirmed schedule prior to the start of testing.

Test Step	Time (Local PDT)	Site Operator
1	12:00:00 AM	Turn on site
2	12:15:00 AM	Turn off site
3	12:25:00 AM	
4	12:30:00 AM	Turn on site
5	12:45:00 AM	Turn off site
6	12:55:00 AM	
7	1:00:00 AM	Turn on site
8	1:15:00 AM	Turn off site
9	1:25:00 AM	
10	1:30:00 AM	Turn on site
11	1:45:00 AM	Turn off site
12	1:55:00 AM	
13	2:00:00 AM	Turn on site
14	2:15:00 AM	Turn off site
15	2:25:00 AM	
16	2:30:00 AM	Turn on site
17	2:45:00 AM	Turn off site
18	2:55:00 AM	
19	3:00:00 AM	Turn on site
20	3:15:00 AM	Turn off site
21	3:25:00 AM	
22	3:30:00 AM	Turn on site
23	3:45:00 AM	Turn off site
24	3:55:00 AM	
25	4:00:00 AM	Turn on site
26	4:15:00 AM	Turn off site
27	4:25:00 AM	
28	4:30:00 AM	Turn on site
29	4:45:00 AM	Turn off site
30	4:55:00 AM	
31	5:00:00 AM	Turn on site
32	5:15:00 AM	Turn off site
33	5:25:00 AM	
34	5:30:00 AM	Turn on site
35	5:45:00 AM	Turn off site
36	5:55:00 AM	Secure site
37	6:00:00 AM	

5.6. Las Vegas Live Sky Test Phones

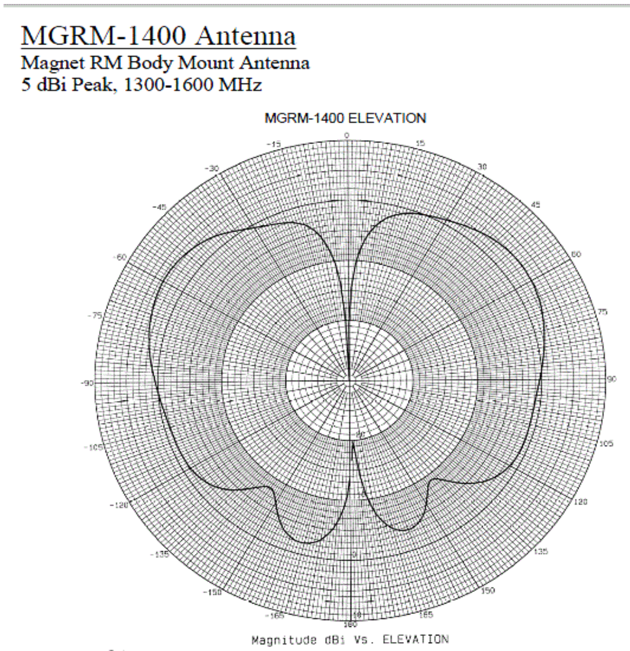
#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Device Anonymity Code	J13	U18	A19	N12	C29	R74	I19	S04	T68	I36	A33	N22	D23	O33	R22	E38	E10

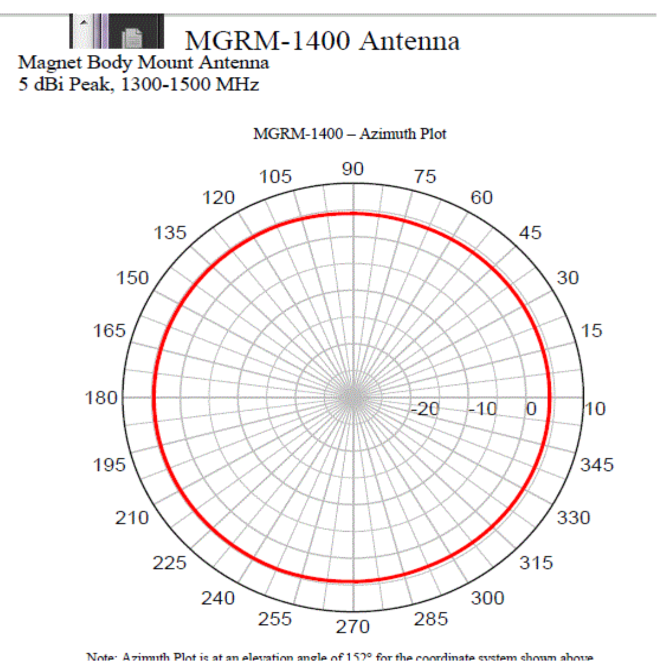
5.7. Test Vehicle L-band Receiver Configuration

- The following equipment and configuration was used to measure and collect the L-band blocker receive signal power:
  - Vertical monopole antenna magnetically mounted on a vehicle
  - Antenna gain: 5 dBi maximum, 3 dBi over angles of interest
  - Cable loss: 2 dB
  - Power measurement instrument: Spectrum Analyzer (Agilent Technologies N9912A) over a 5 MHz bandwidth using a 3 KHz equivalent resolution bandwidth. No additional averaging of sampled power. Data logging rate 2/s.
- The following corrections should be applied to the measured blocker receiver signal measurements as reported in the following test result section:
  - -3 dB (nominal antenna gain over elevation angle range of interest)
  - 2 dB cable loss
  - 3 dB (for single-polarized antenna)
  - Net correction: 2 dB

5.8. L-band Field Measurement Receive Antenna Specifications

The antenna used for the L-band blocker signal strength measurements has the gain described by the antenna pattern information shown in the figure below. The peak antenna gain in the elevation angle is 5 dBi but over all the angles of interest it is 3 dBi.

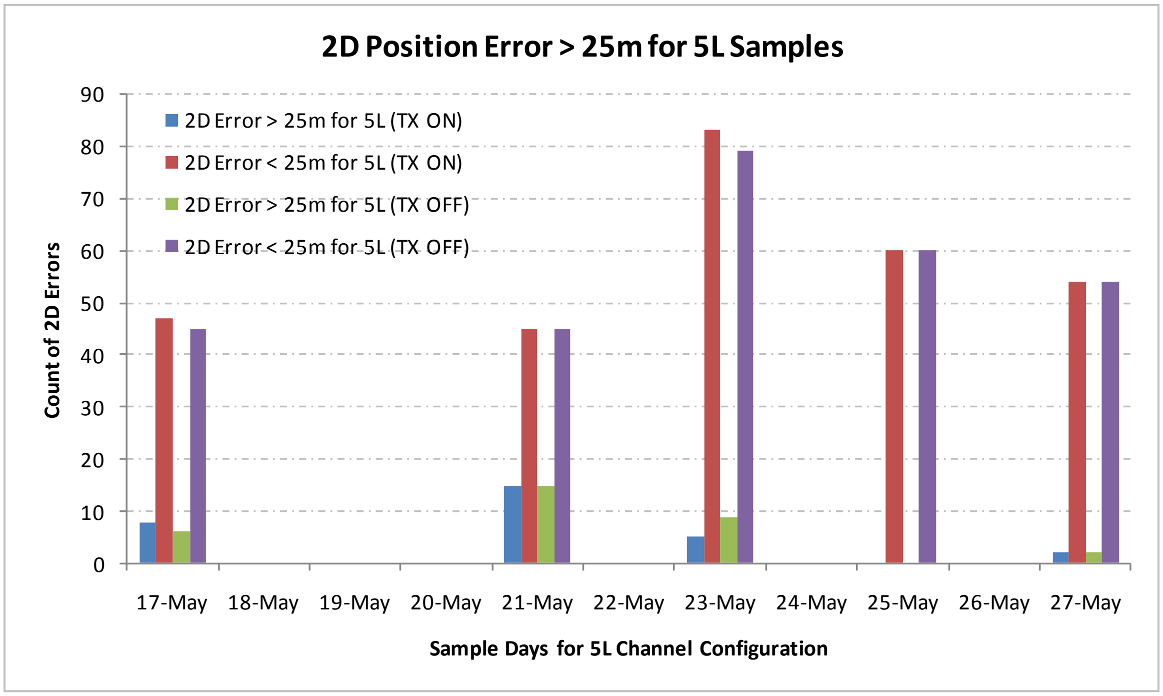


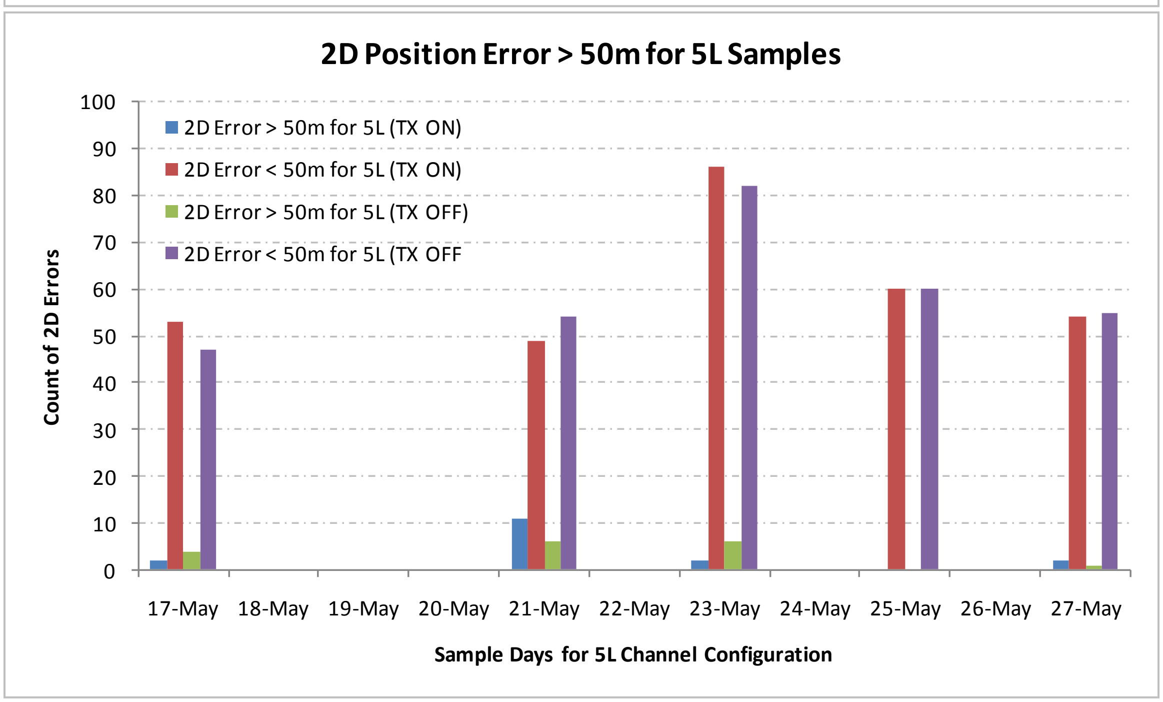


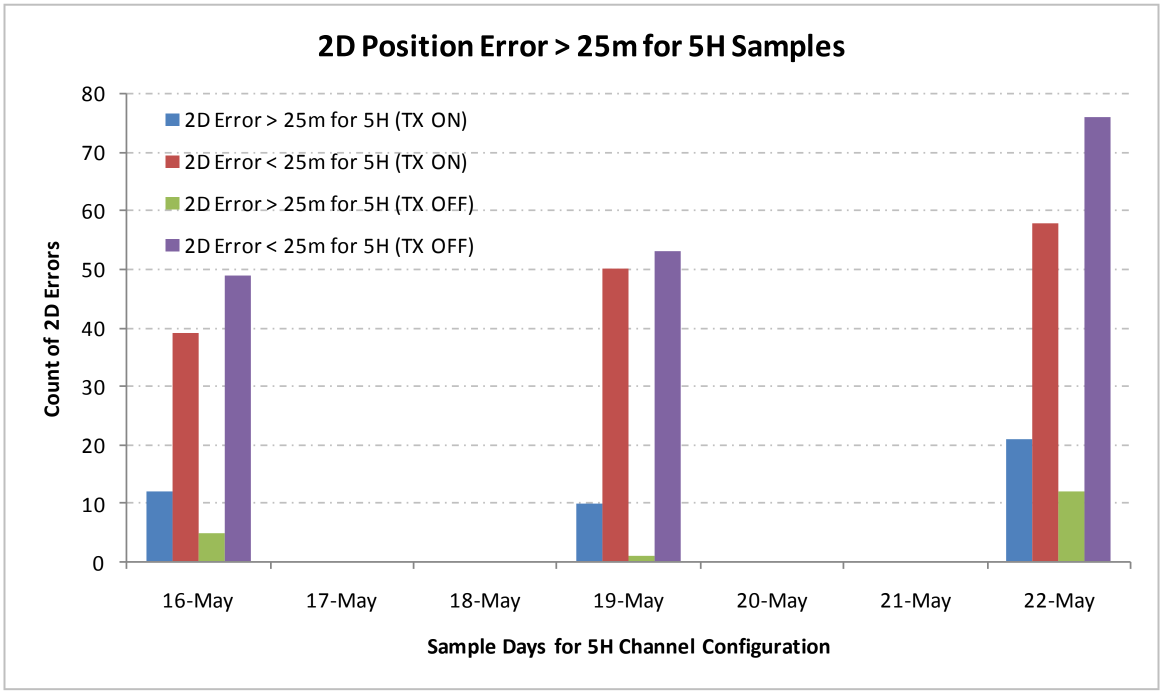
6. Summary Test Results

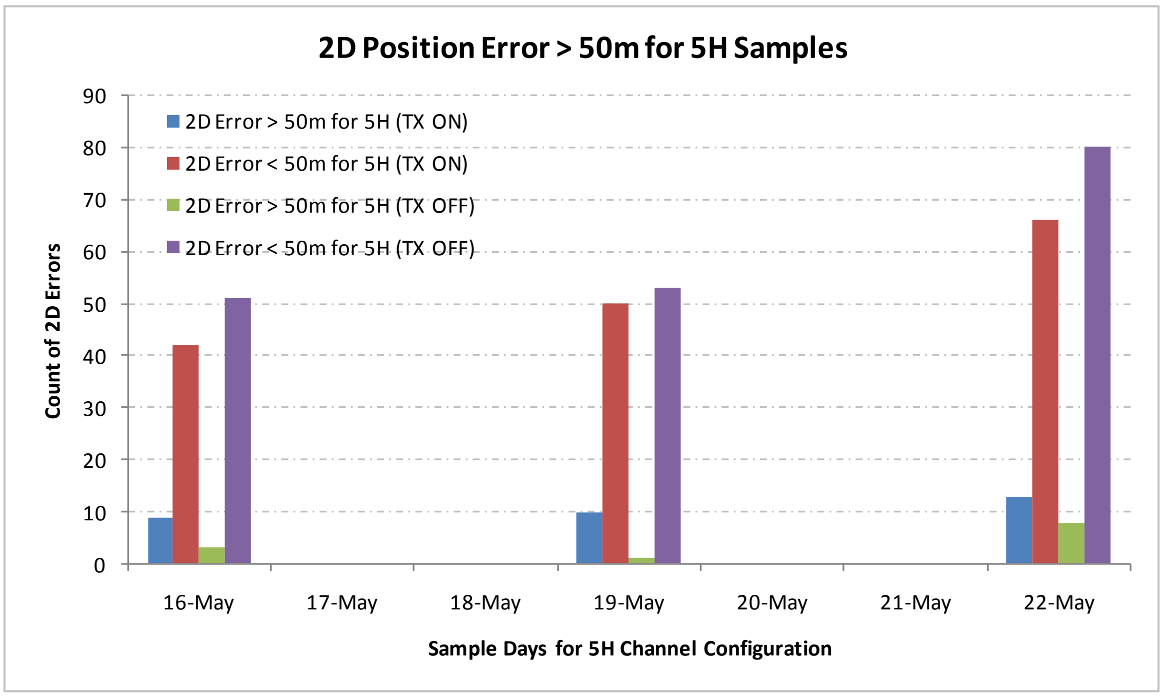
6.1. Static Tests

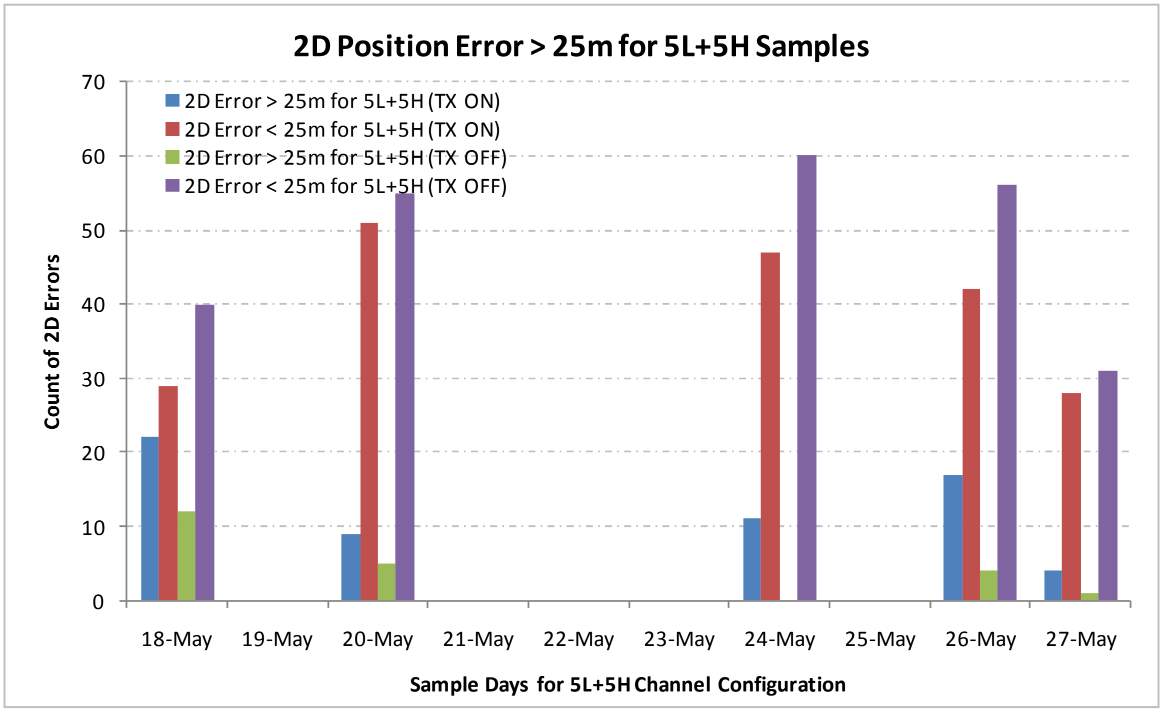
The following graphs provide an integrated summary of the performance at all sites over all devices for a given LightSquared channel configuration, named as follows: 5 MHz Low (5L), 5 MHz High (5H), 5 MHz Low + High (L+H).

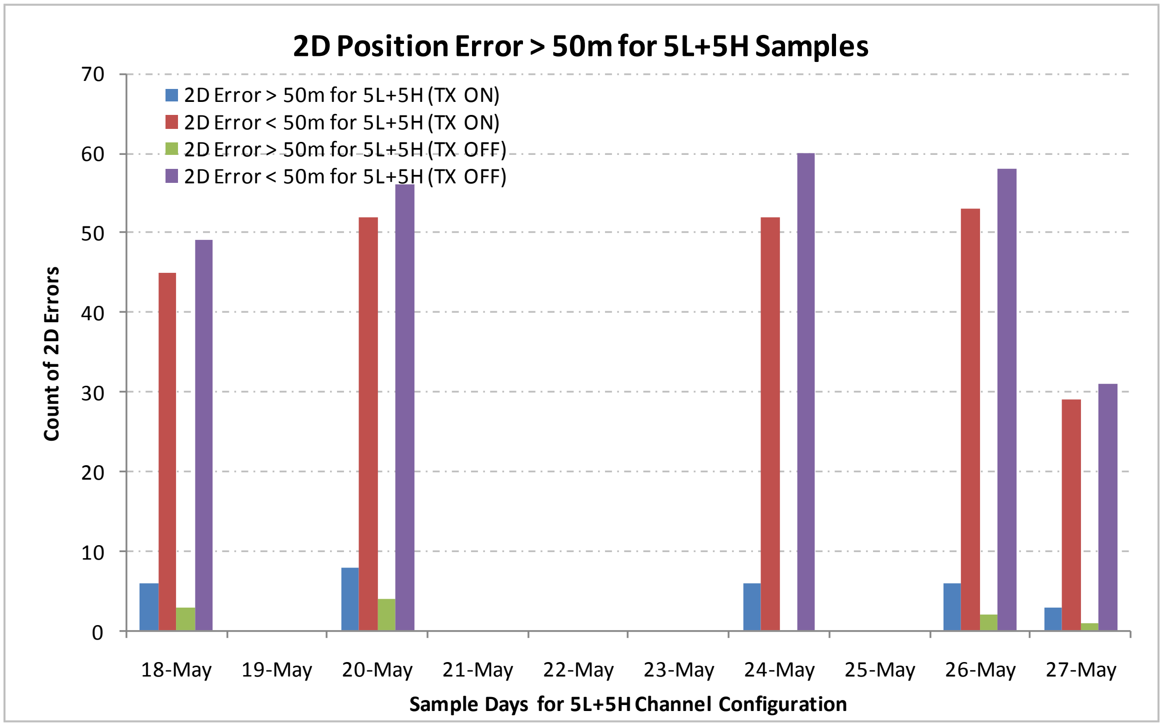





2D Position Error > 25m for 5H Samples
2D Error > 25m for 5H (TX ON)
2D Error < 25m for 5H (TX ON)
2D Error > 25m for 5H (TX OFF)
2D Error < 25m for 5H (TX OFF)
Count of 2D Errors
0
10
20
30
40
50
60
70
80
16-May
17-May
18-May
19-May
20-May
21-May
22-May
Sample Days for 5H Channel Configuration

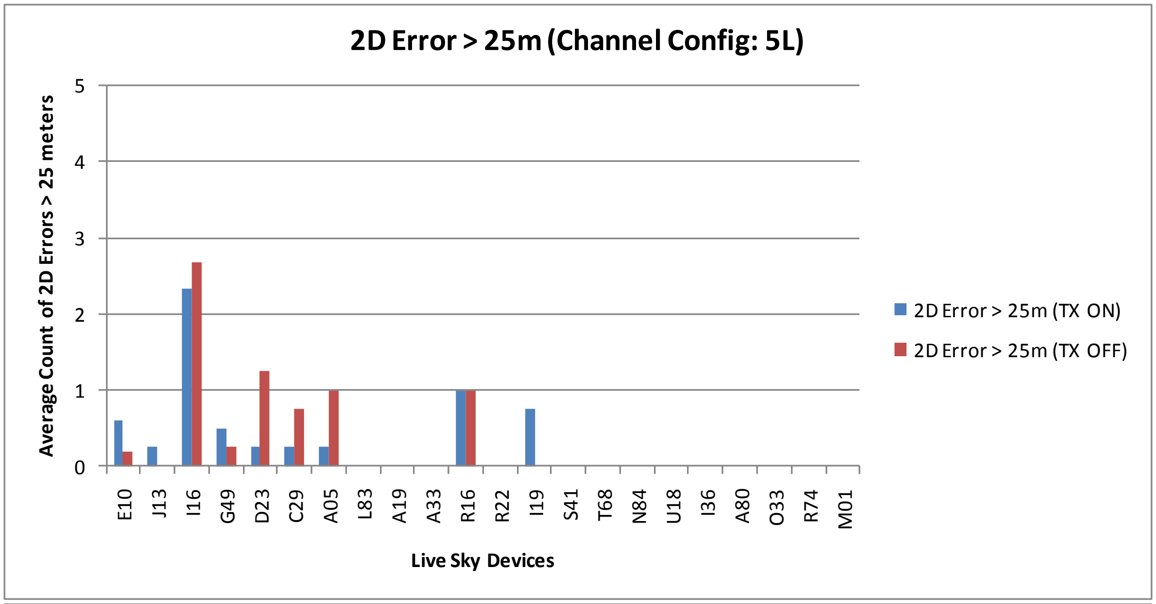

2D Position Error > 50m for 5H Samples
2D Error > 50m for 5H (TX ON)
2D Error < 50m for 5H (TX ON)
2D Error > 50m for 5H (TX OFF)
2D Error < 50m for 5H (TX OFF)
Count of 2D Errors
0
10
20
30
40
50
60
70
80
90
16-May
17-May
18-May
19-May
20-May
21-May
22-May
Sample Days for 5H Channel Configuration

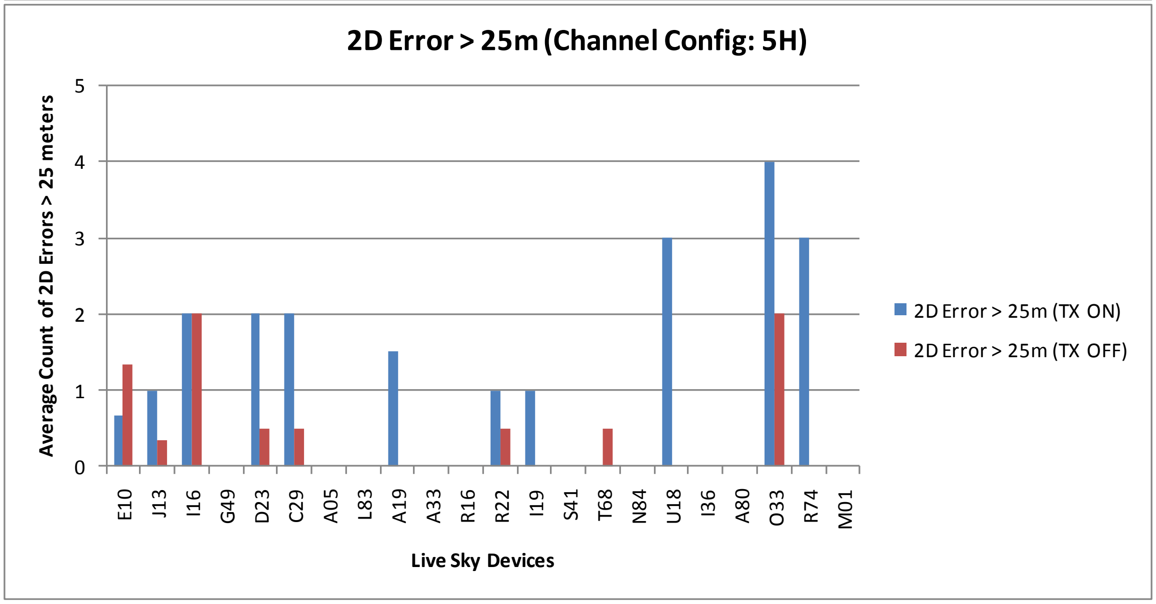

2D Position Error > 25m for 5L+5H Samples
2D Error > 25m for 5L+5H (TX ON)
2D Error < 25m for 5L+5H (TX ON)
2D Error > 25m for 5L+5H (TX OFF)
2D Error < 25m for 5L+5H (TX OFF)
Count of 2D Errors
0
10
20
30
40
50
60
70
18-May
19-May
20-May
21-May
22-May
23-May
24-May
25-May
26-May
27-May
Sample Days for 5L+5H Channel Configuration

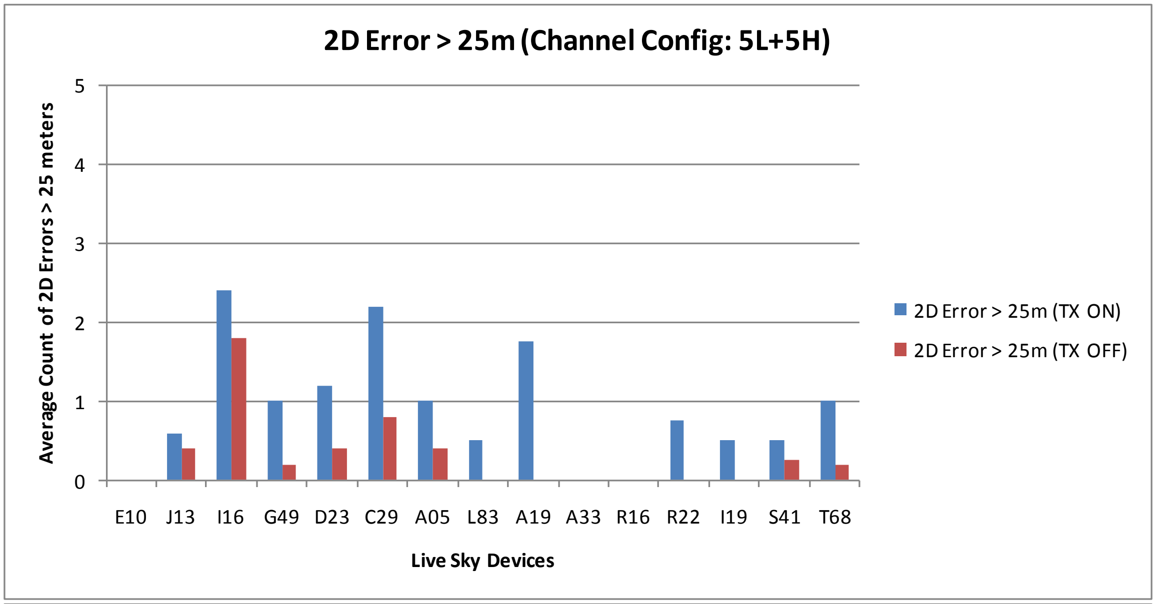

2D Position Error > 50m for 5L+5H Samples
2D Error > 50m for 5L+5H (TX ON)
2D Error < 50m for 5L+5H (TX ON)
2D Error > 50m for 5L+5H (TX OFF)
2D Error < 50m for 5L+5H (TX OFF)
Count of 2D Errors
0
10
20
30
40
50
60
70
18-May
19-May
20-May
21-May
22-May
23-May
24-May
25-May
26-May
27-May
Sample Days for 5L+5H Channel Configuration

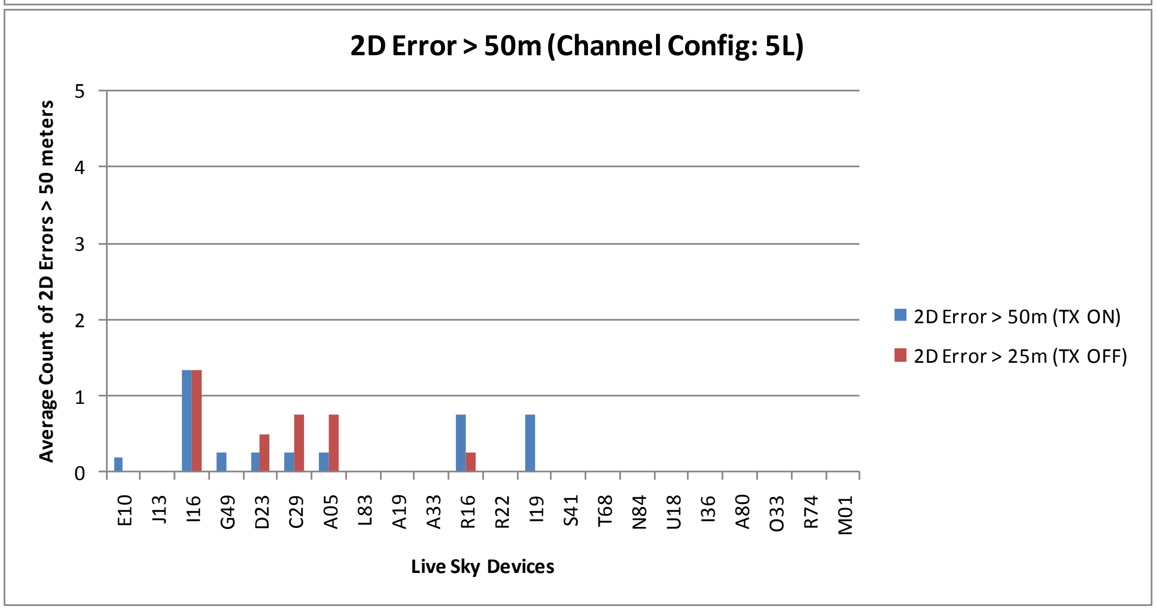
Appendix

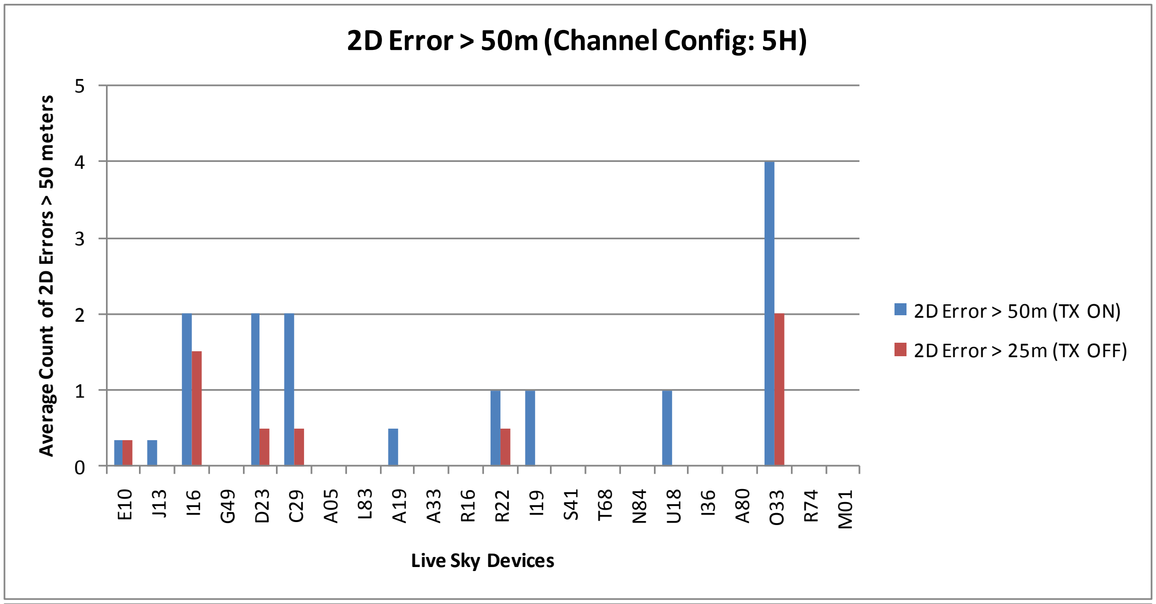
The following charts show a different of view of the 2D error performance of devices under test, with and without the blocker on. The 2D error performance is analyzed and plotted per device and as expected device to device performance varies across device manufacturers and models.

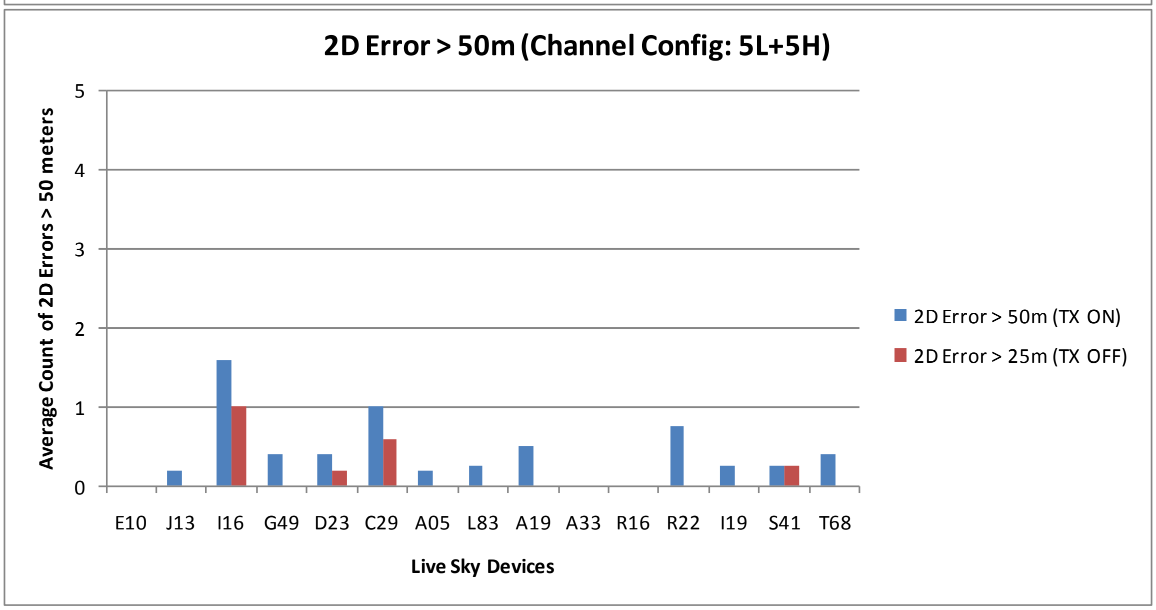





2D Error > 25m (Channel Config: 5L+5H)
Average Count of 2D Errors > 25 meters
0
1
2
3
4
5
E10
J13
I16
G49
D23
C29
A05
L83
A19
A33
R16
R22
I19
S41
T68
Live Sky Devices
2D Error > 25m (TX ON)
2D Error > 25m (TX OFF)


2D Error > 50m (Channel Config: 5L)
Average Count of 2D Errors > 50 meters
0
1
2
3
4
5
E10
J13
I16
G49
D23
C29
A05
L83
A19
A33
R16
R22
I19
S41
T68
N84
U18
I36
A80
O33
R74
M01
Live Sky Devices
2D Error > 50m (TX ON)
2D Error > 25m (TX OFF)


2D Error > 50m (Channel Config: 5H)
Average Count of 2D Errors > 50 meters
5
4
3
2
1
0
E10
J13
I16
G49
D23
C29
A05
L83
A19
A33
R16
R22
I19
S41
T68
N84
U18
I36
A80
O33
R74
M01
Live Sky Devices
2D Error > 50m (TX ON)
2D Error > 25m (TX OFF)

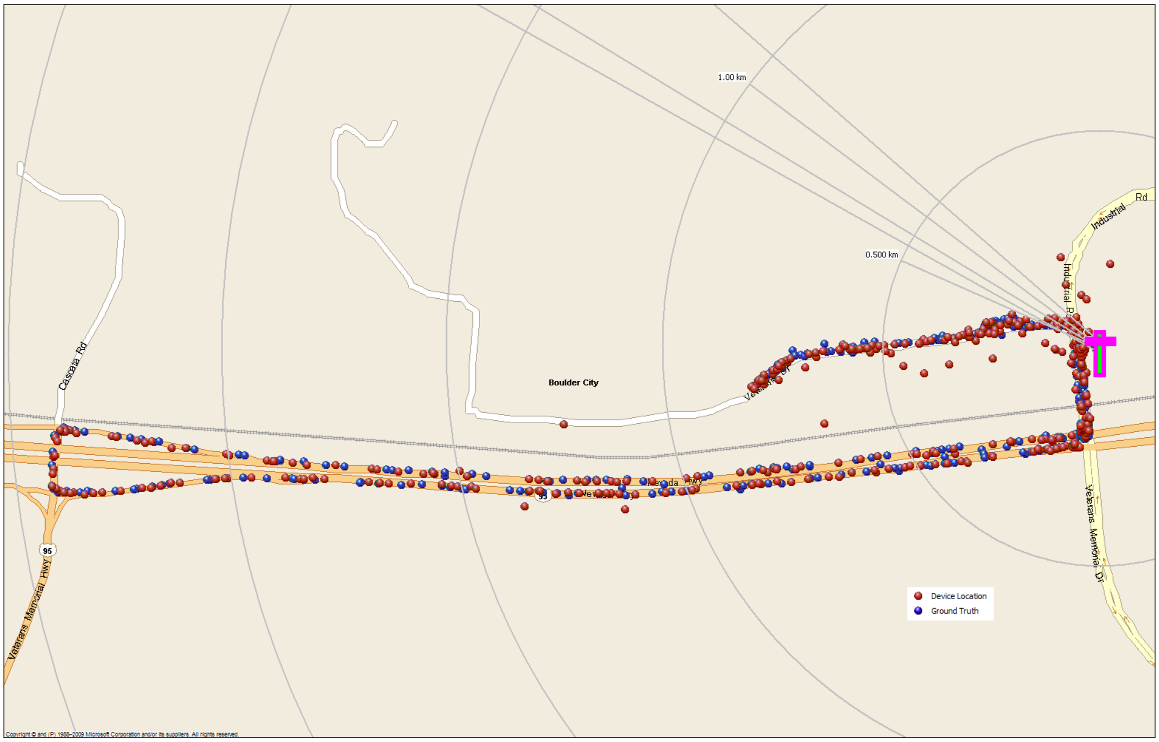

2D Error > 50m (Channel Config: 5L+5H)
Average Count of 2D Errors > 50 meters
5
4
3
2
1
0
E10
J13
I16
G49
D23
C29
A05
L83
A19
A33
R16
R22
I19
S41
T68
Live Sky Devices
2D Error > 50m (TX ON)
2D Error > 25m (TX OFF)

6.2. Dynamic Test Results

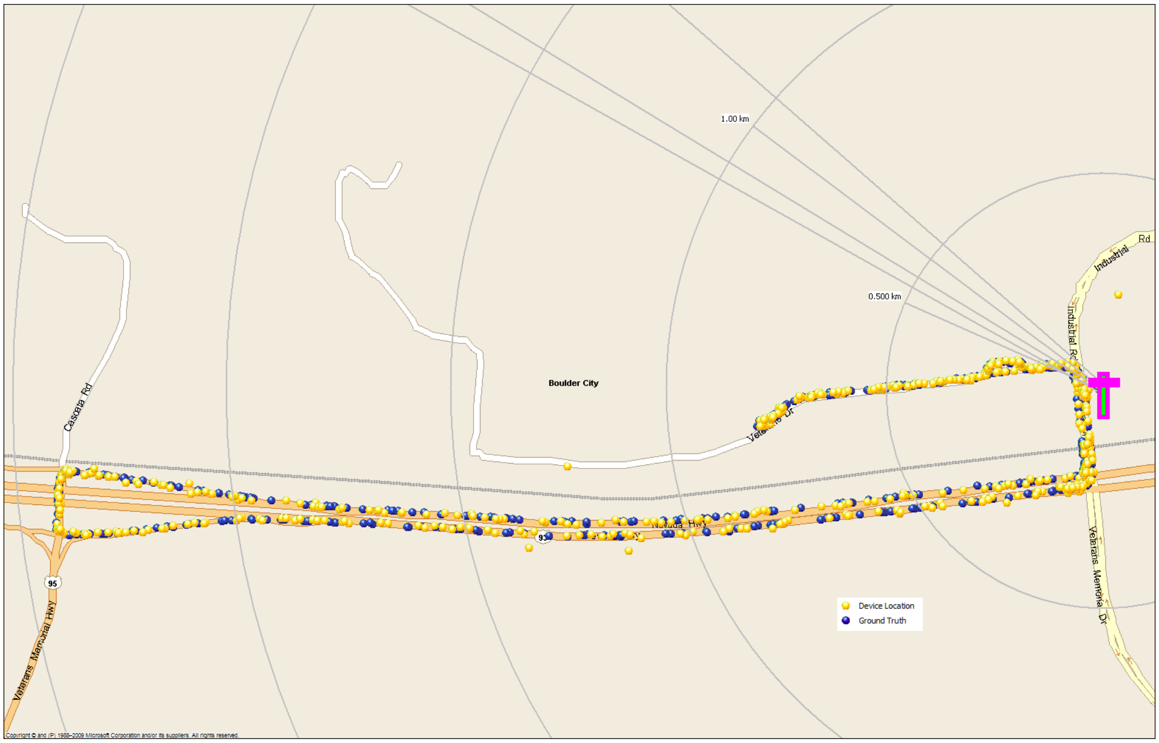
The following maps have been selected to illustrate typical device performance for each test location. Representative samples for each test transmit case, upper band, lower band and both upper and lower bands are included.

i. Channel Configuration: 5L & 5H
   - May 24, 2011 (EIRP / carrier = 59 dBm)

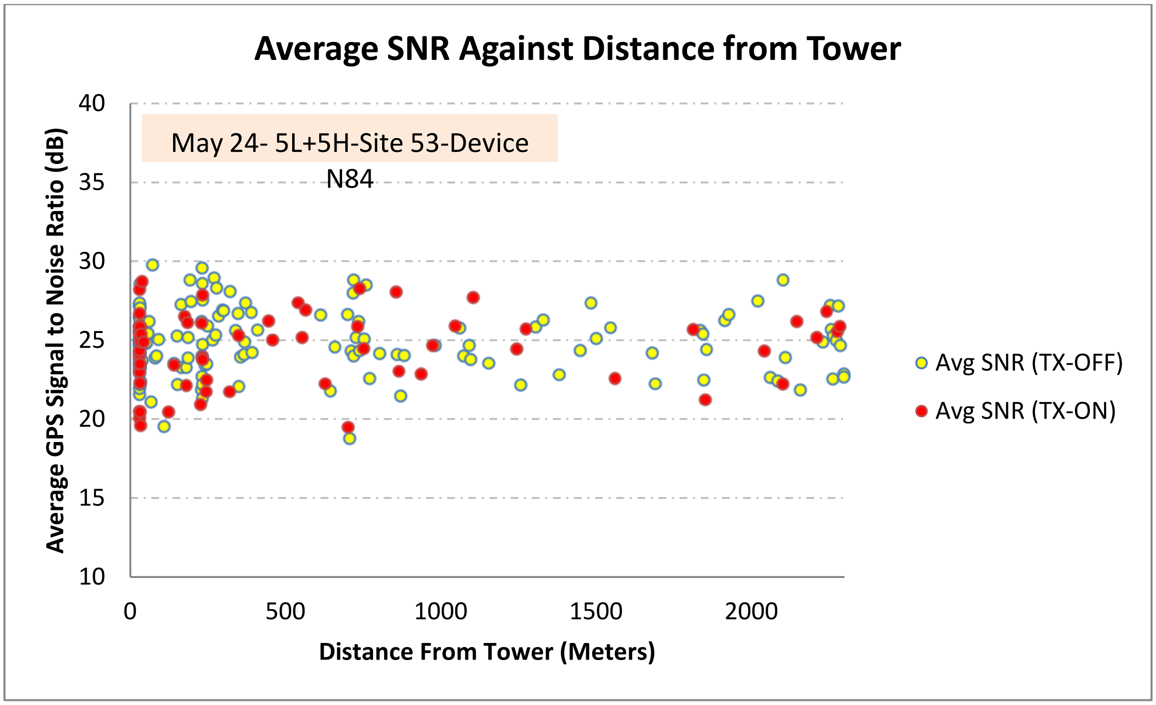
Site-53 Dual May 24 Device-U18 TX-ON



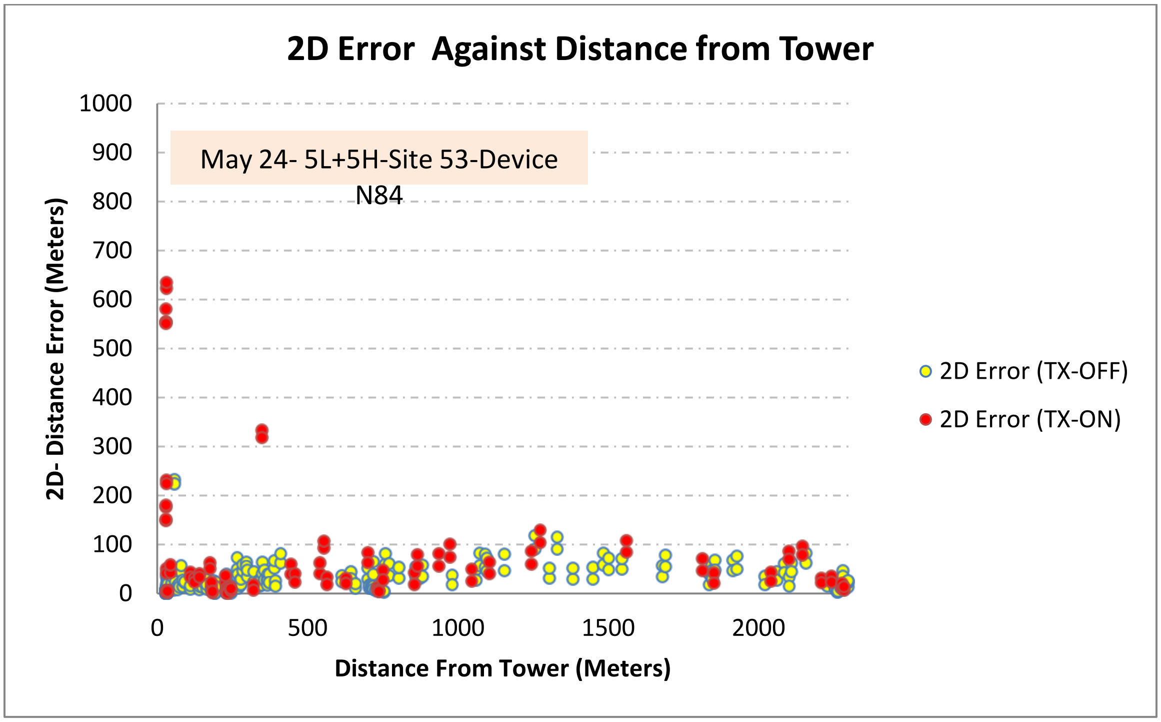
Site-53 Dual May 24 Device-U18 TX-OFF



Site-53 Dual May 24 Device–N84 Average SNR

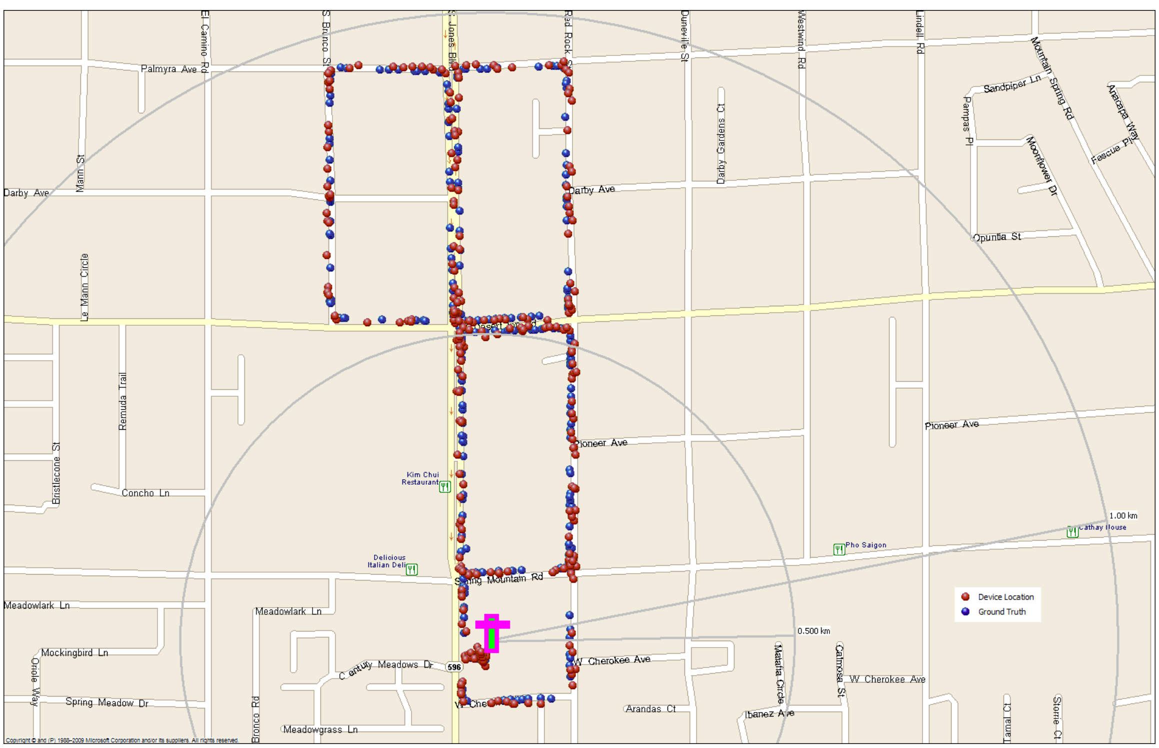


Site-53 Dual May 24 Device-N84 2D Error

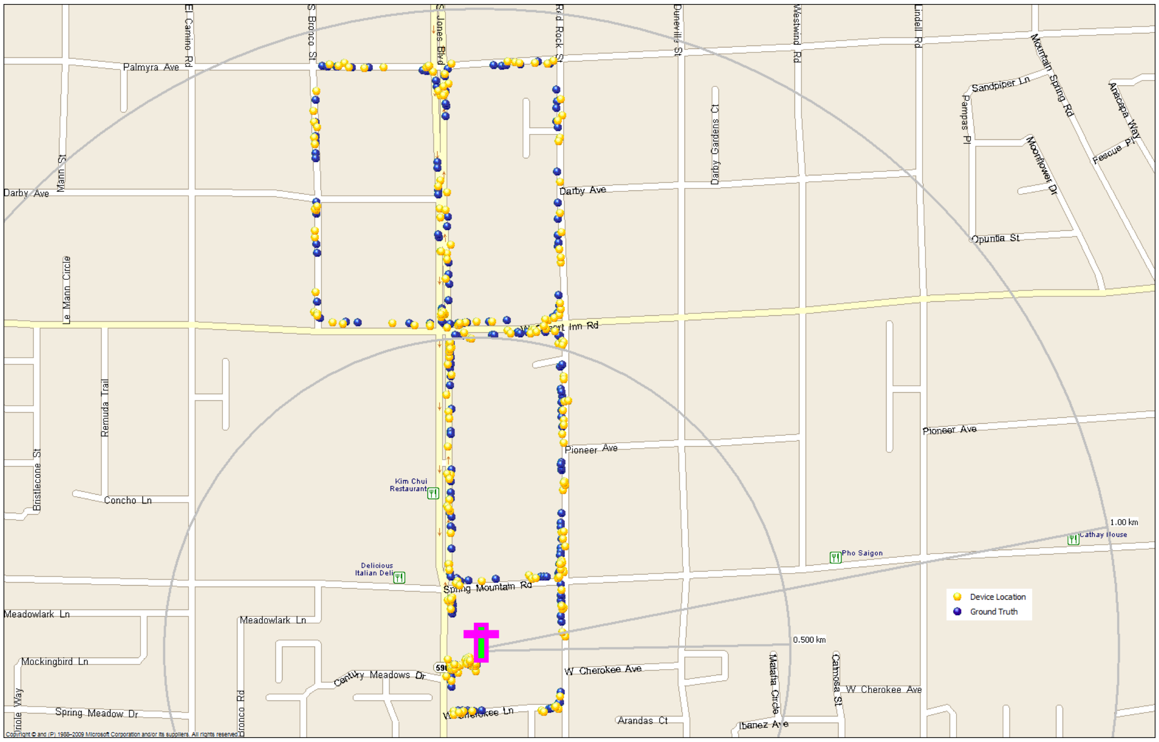


ii. Channel Configuration: 5L
  – May 17, 2011 (EIRP / carrier = 59 dBm)

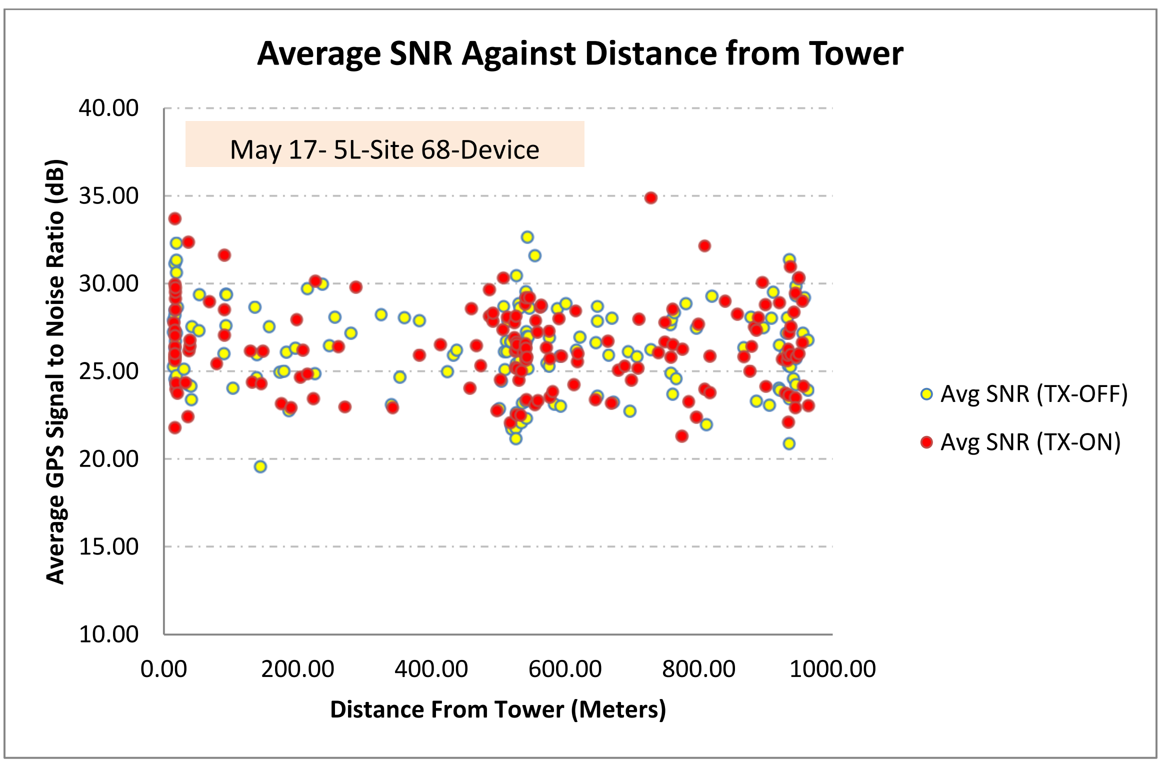
Site-68 Lower May 17 Device-N12 TX-ON



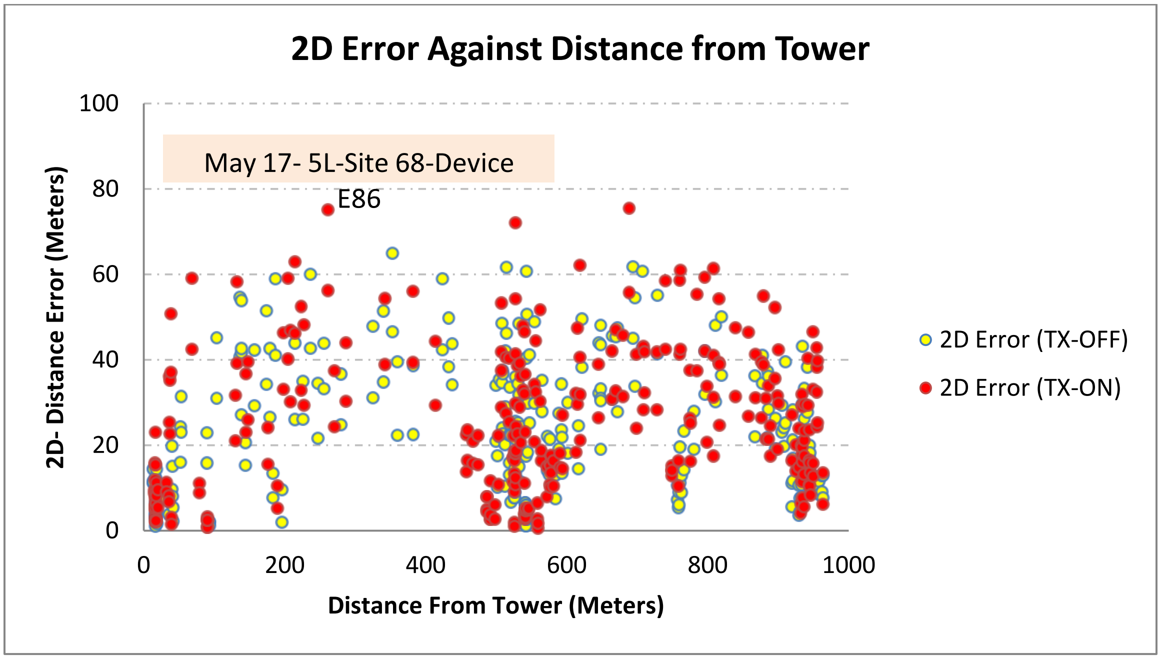
Site-68 Lower May 17 Device-N12 TX-OFF



Site-68 Lower May 17 Device–E86 Average SNR

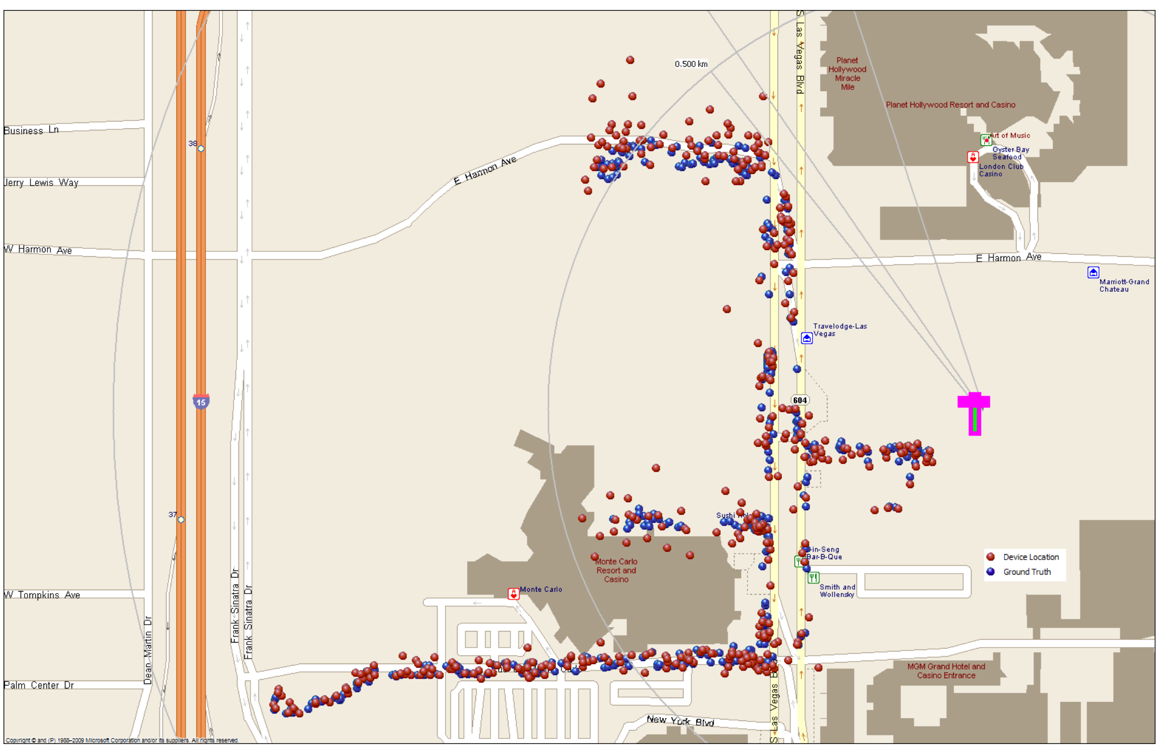


Site-68 Lower May 17 Device–E86 2D Error

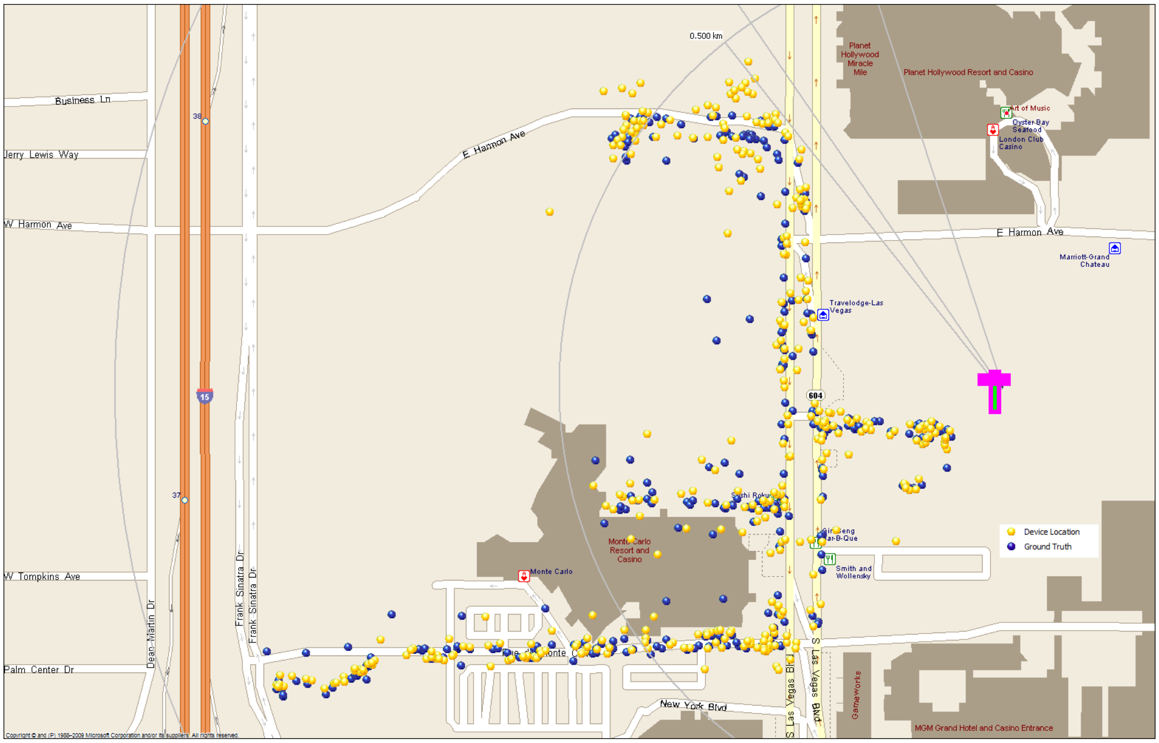


– May 17, 2011 (EIRP / carrier = 59 dBm)

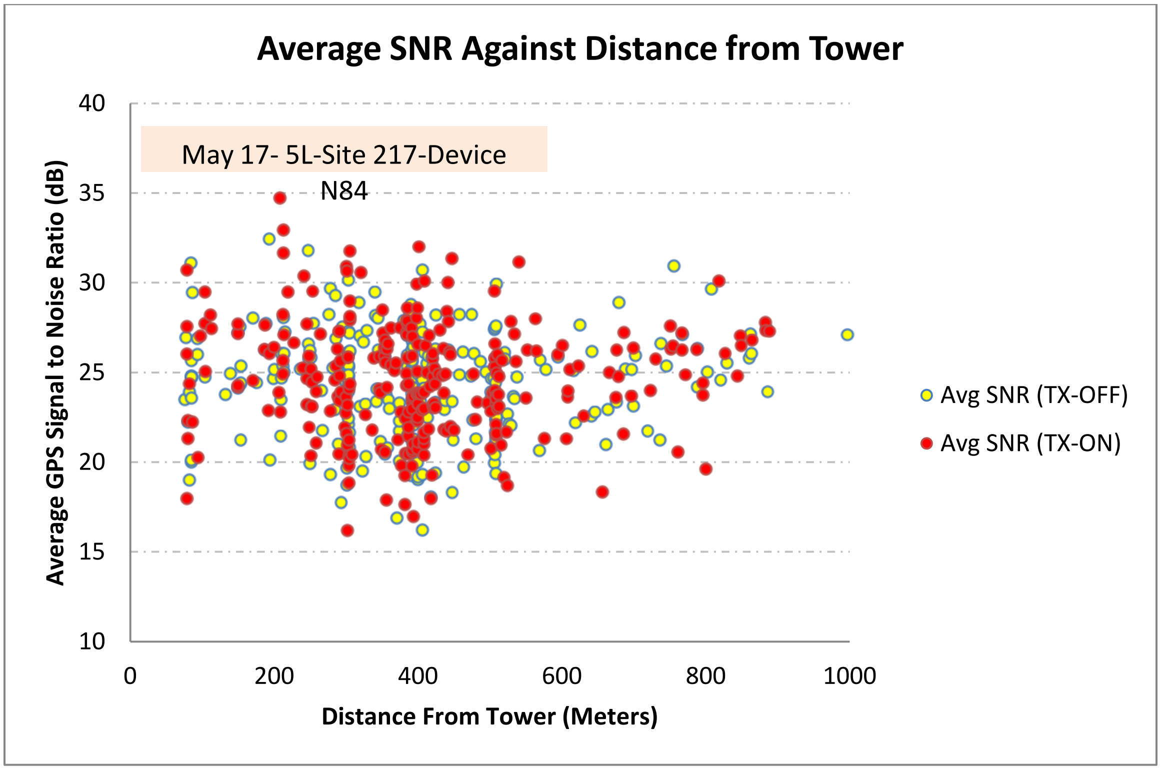
Site-217 Lower May 17 Device-U18 TX-ON



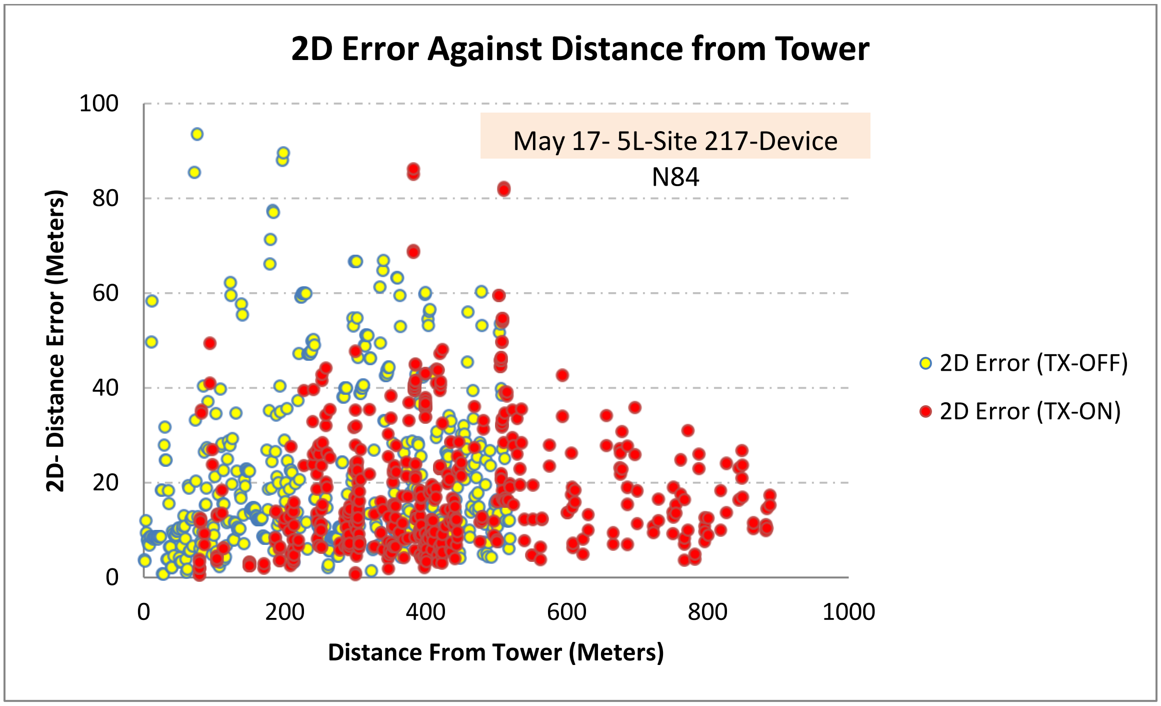
Site-217 Lower May 17 Device-U18 TX-OFF



Site-217 Lower May 17 Device–N84 Average SNR

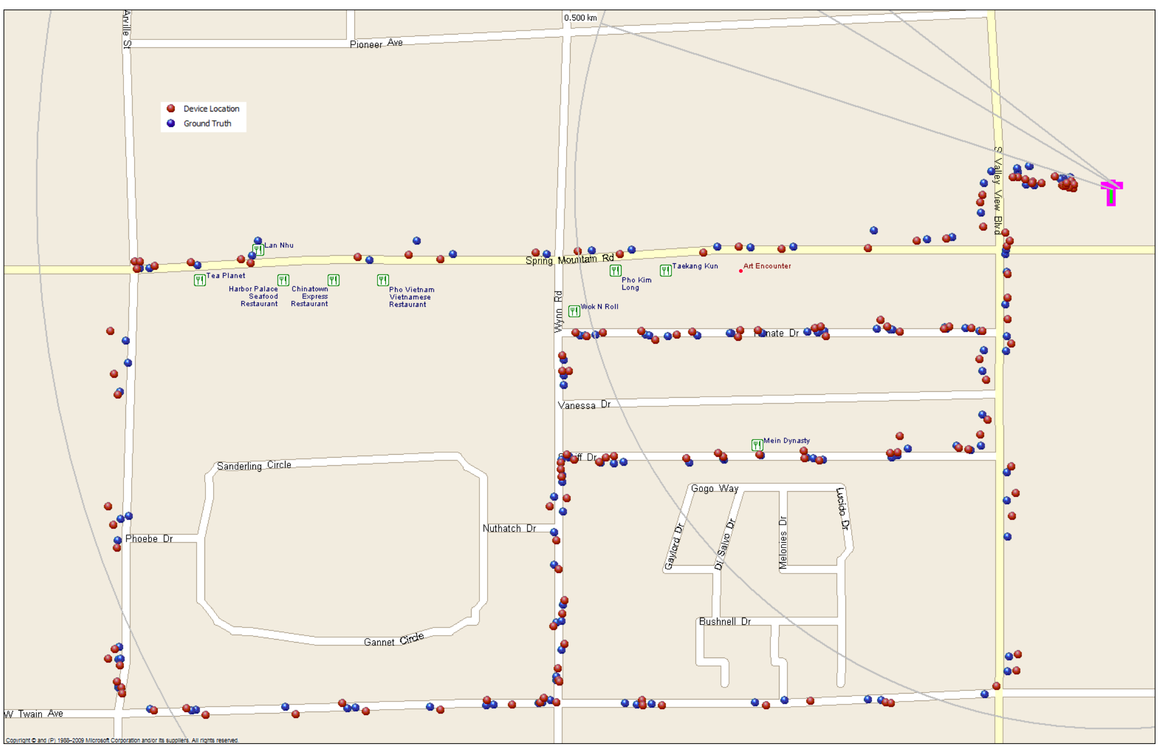


Site-217 Lower May 17 Device–N84 2D Error



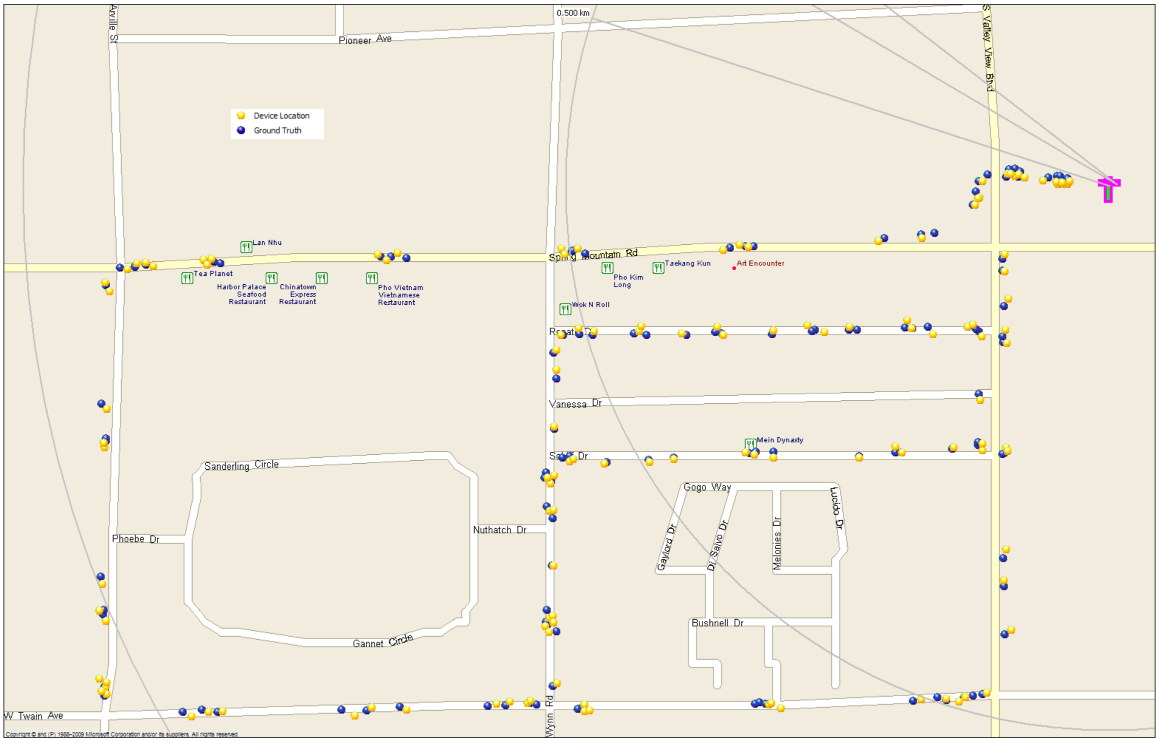
– May 23, 2011 (EIRP / carrier = 62 dBm)

Site-160 Lower May 23 Device-N12 TX-ON

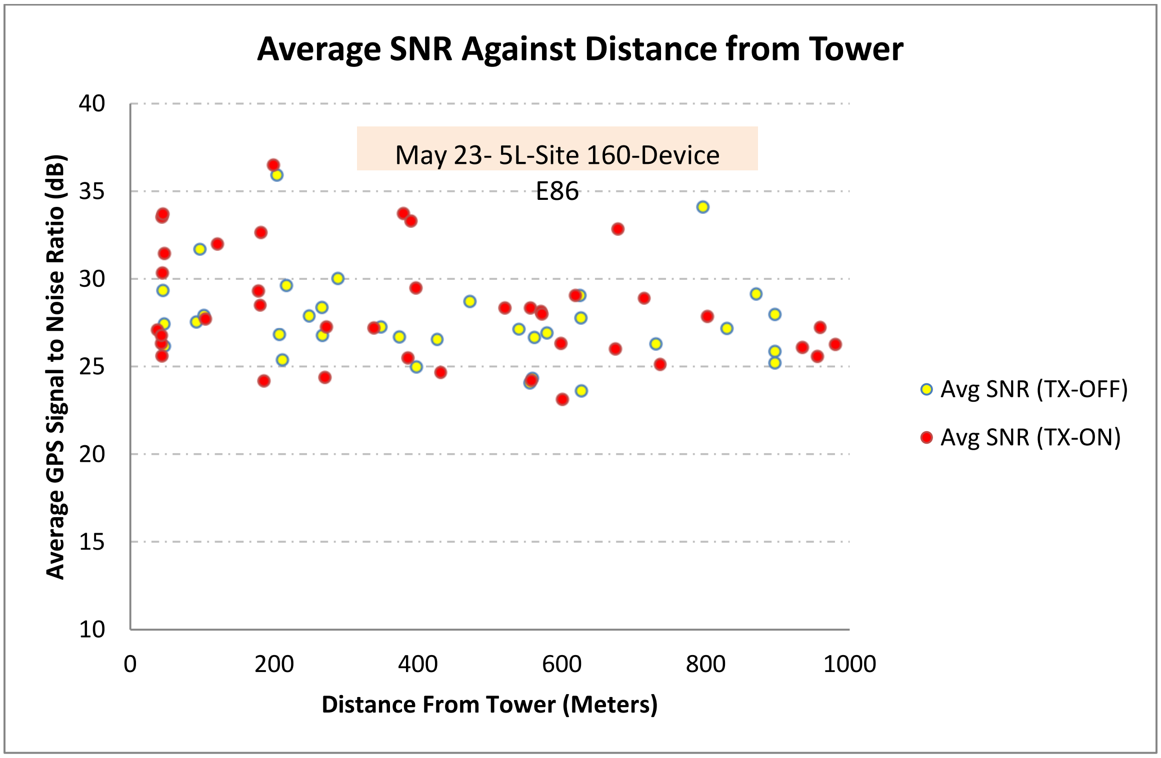


Appendix

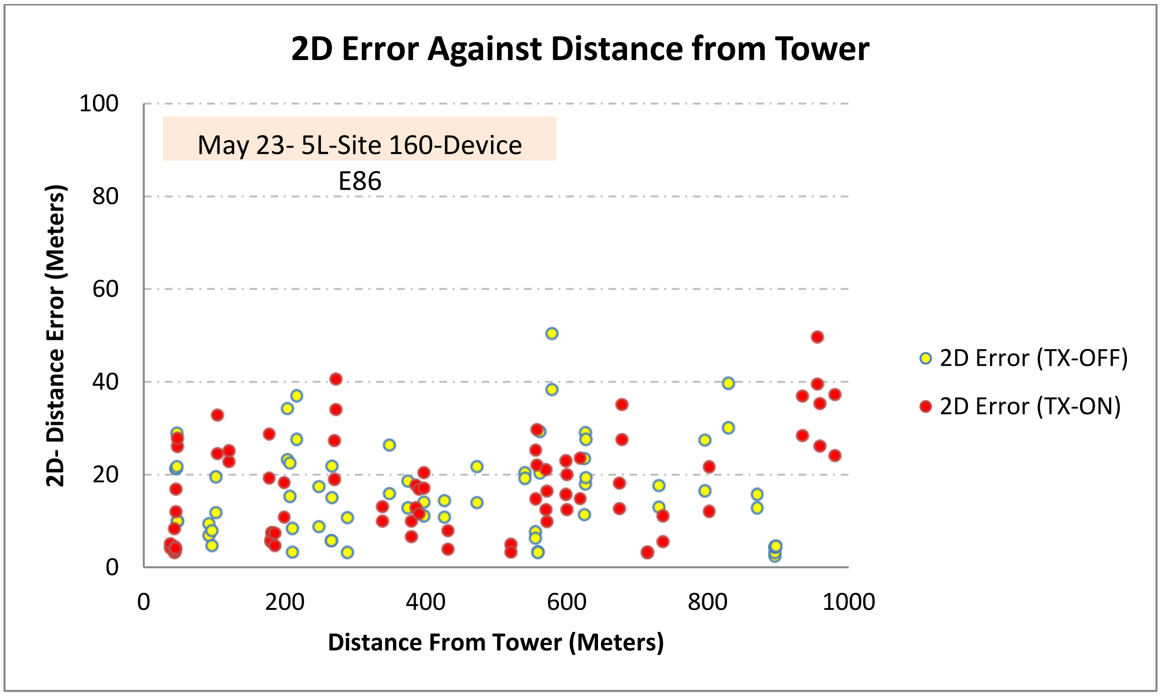
Site-160 Lower May 23 Device-N12 TX-OFF



Site-160 Lower May 23 Device–E86 Average SNR



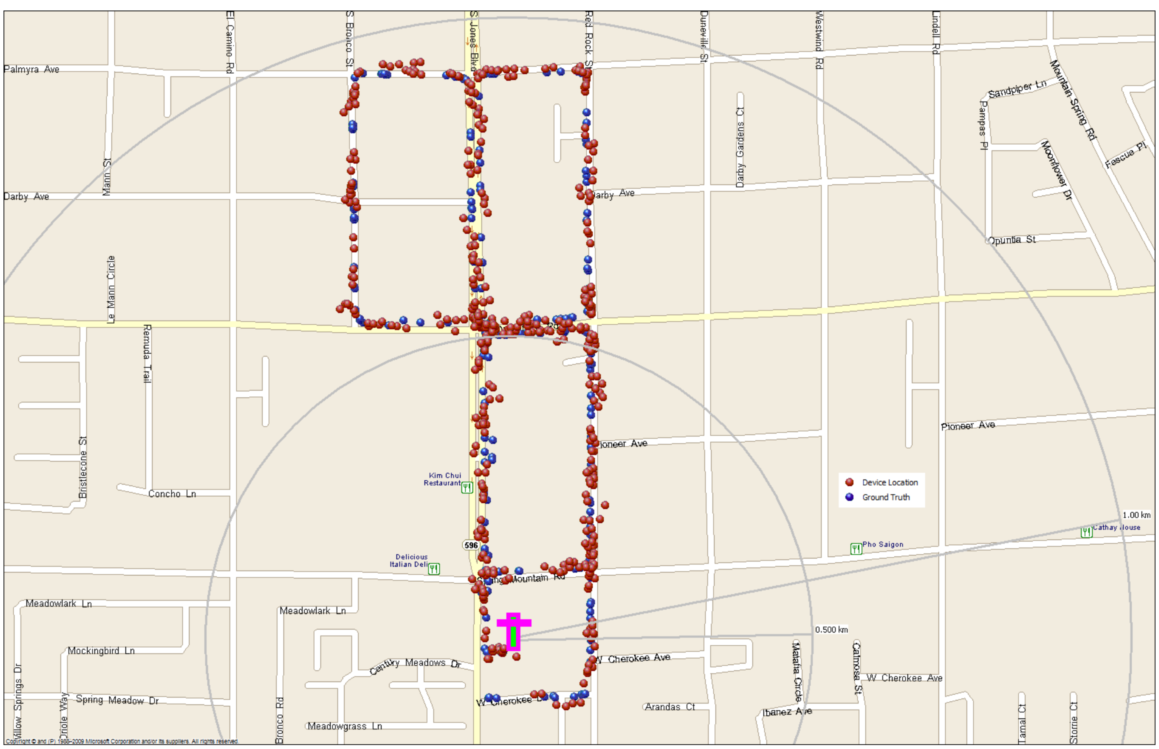
Site-160 Lower May 23 Device–E86 2D Error



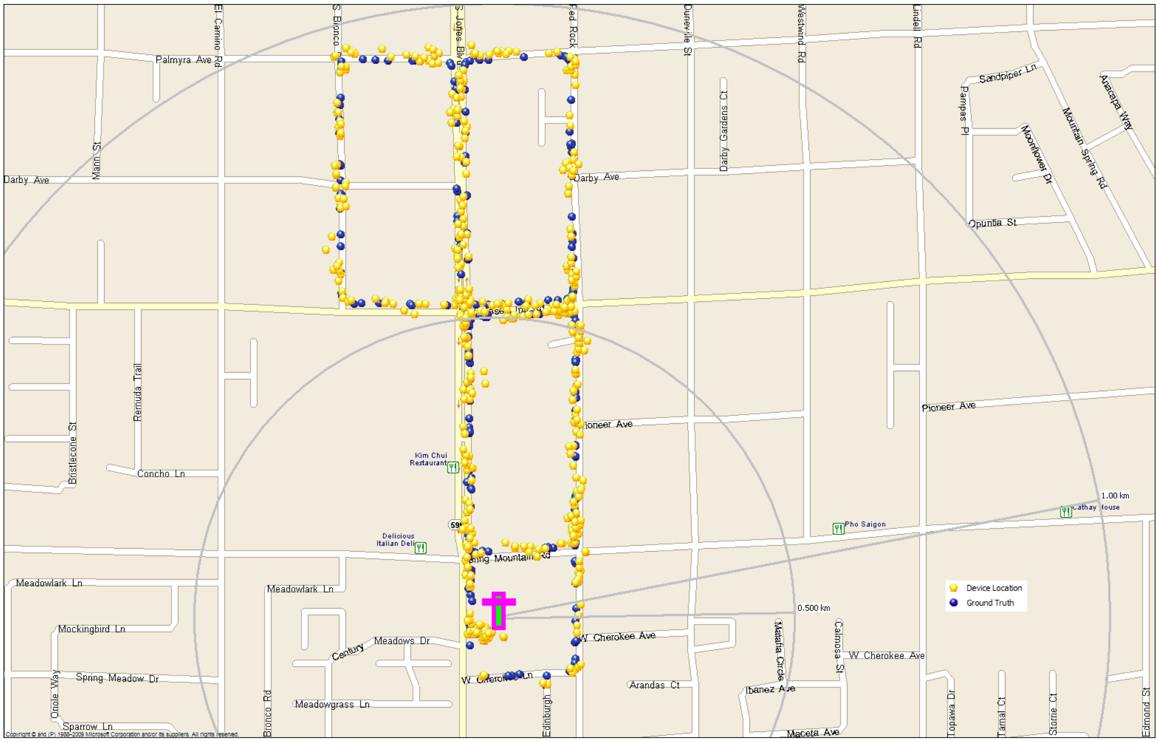
iii Channel Configuration: 5H

– May 16, 2011 (EIRP / carrier = 60 dBm)

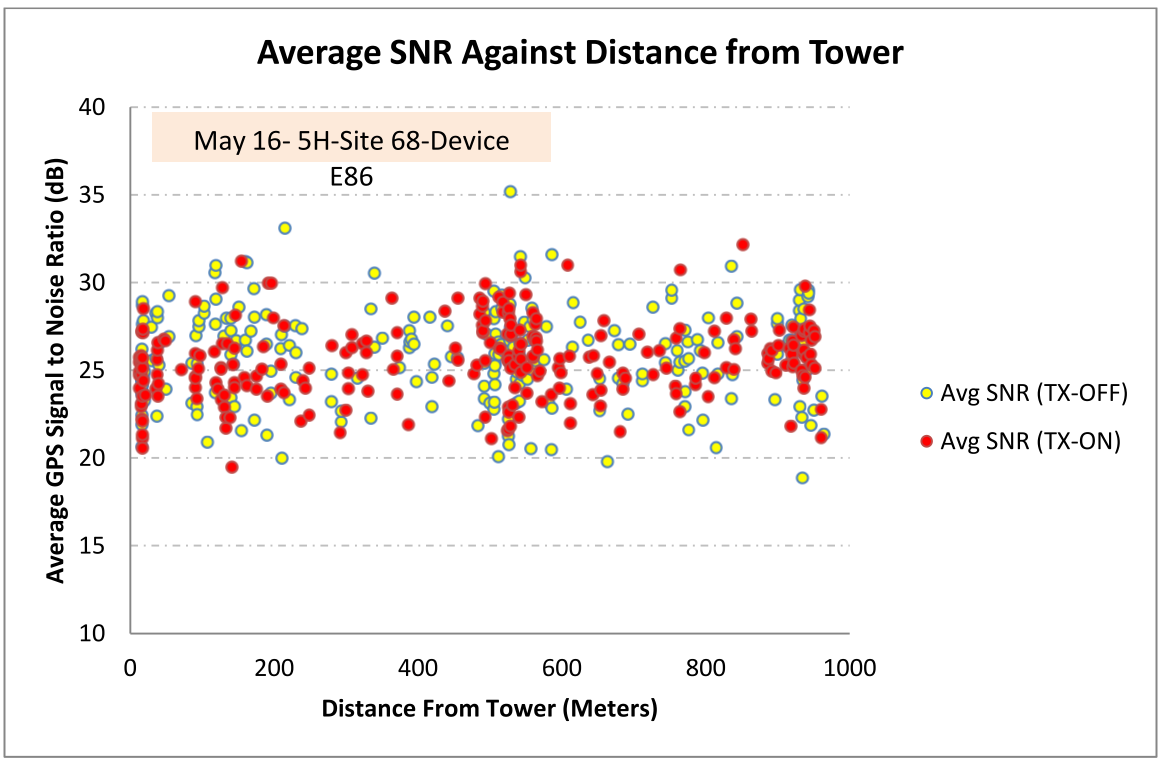
Site-68 Upper May 16 Device-I88 TX-ON



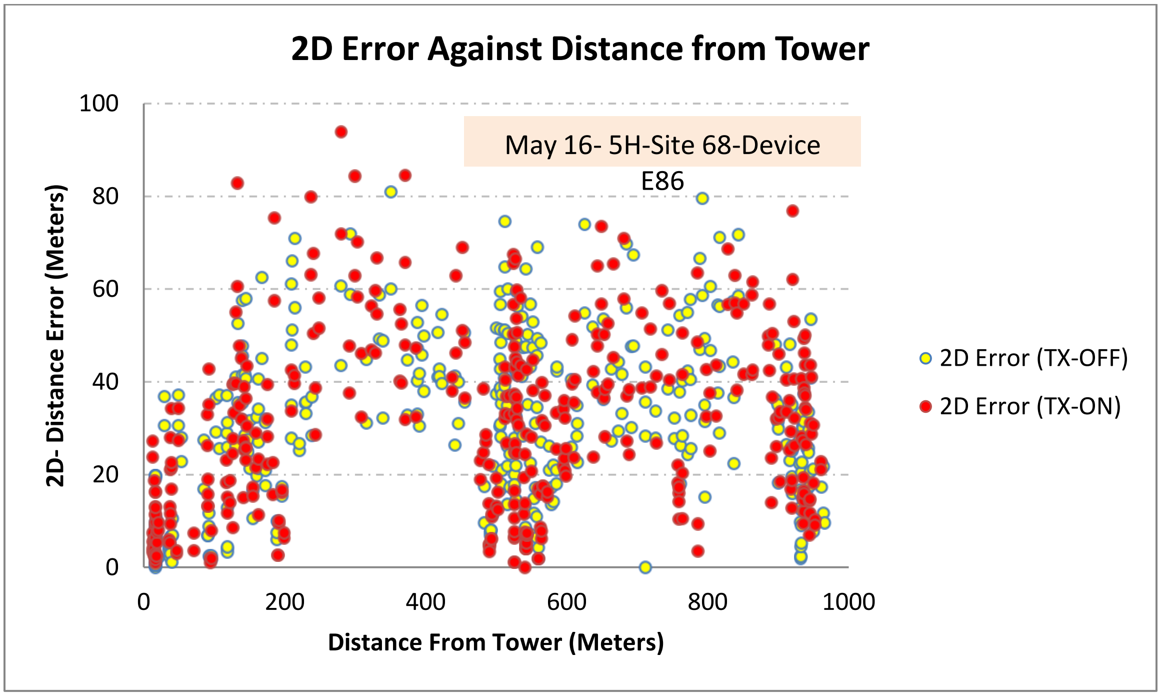
Site-68 Upper May 16 Device-I88 TX-OFF



Site-68 Upper May 16 Device–E86 Average SNR

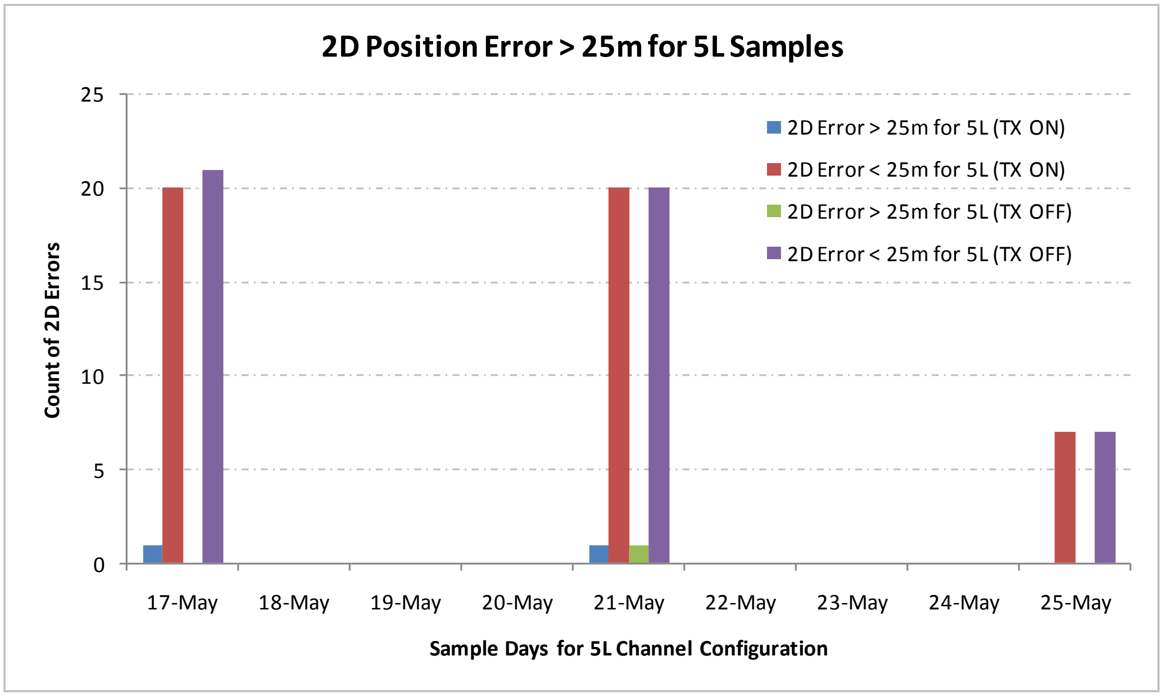


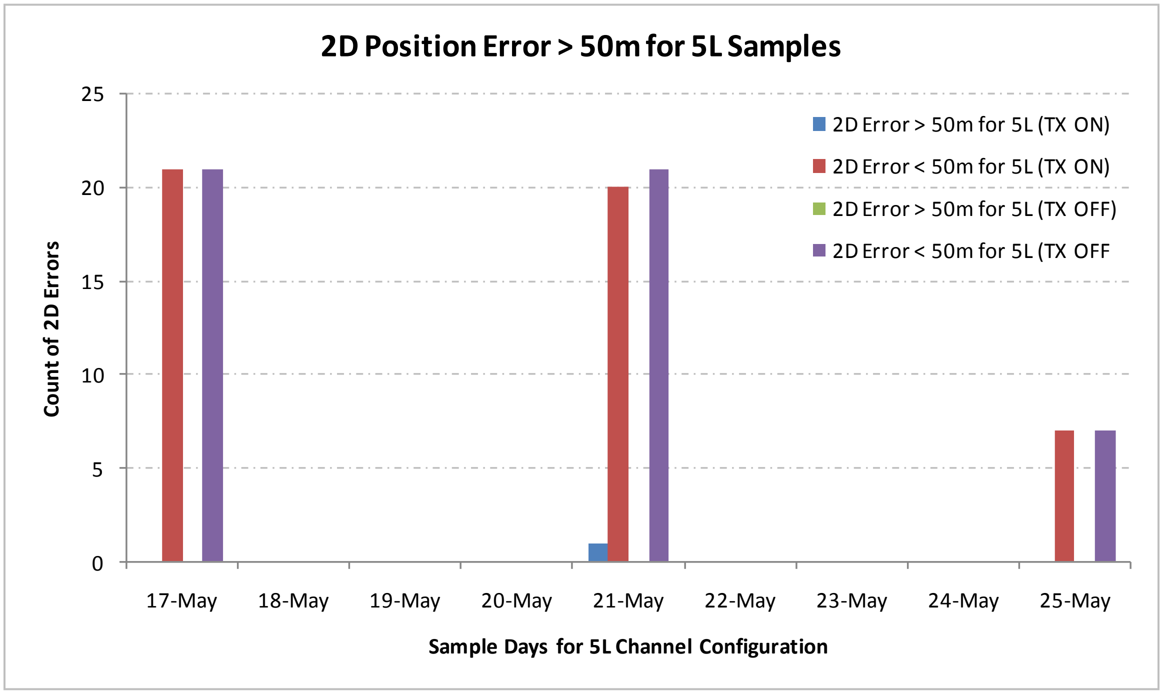
Site-68 Upper May 16 Device–E86 2D Error

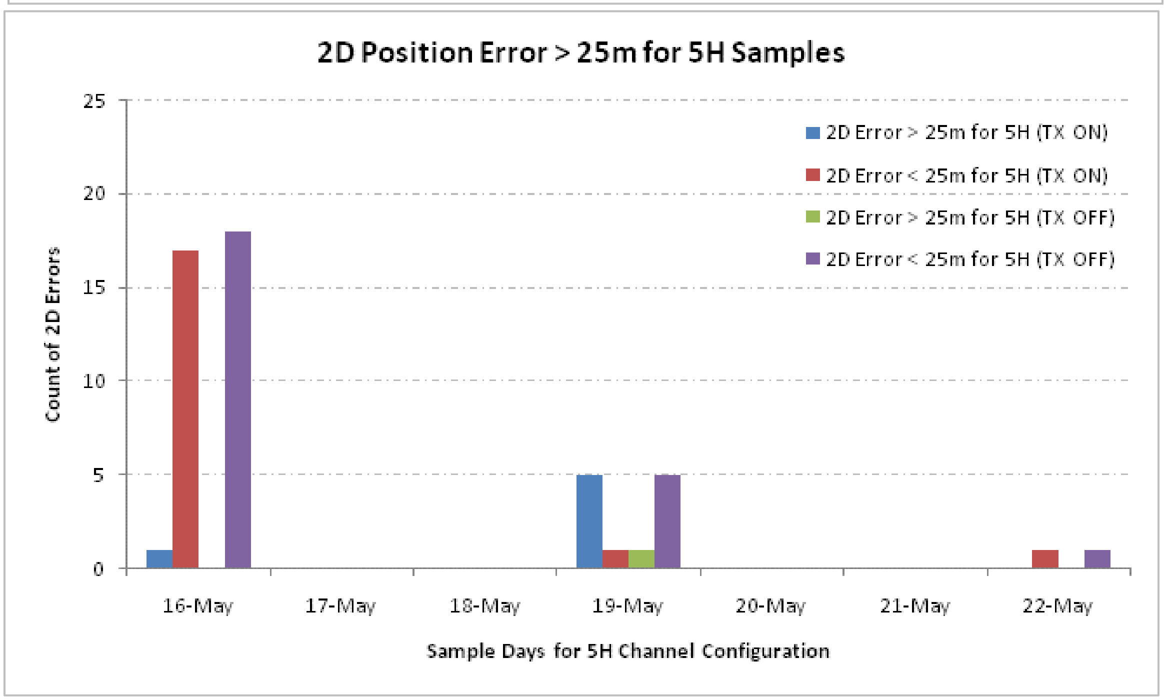


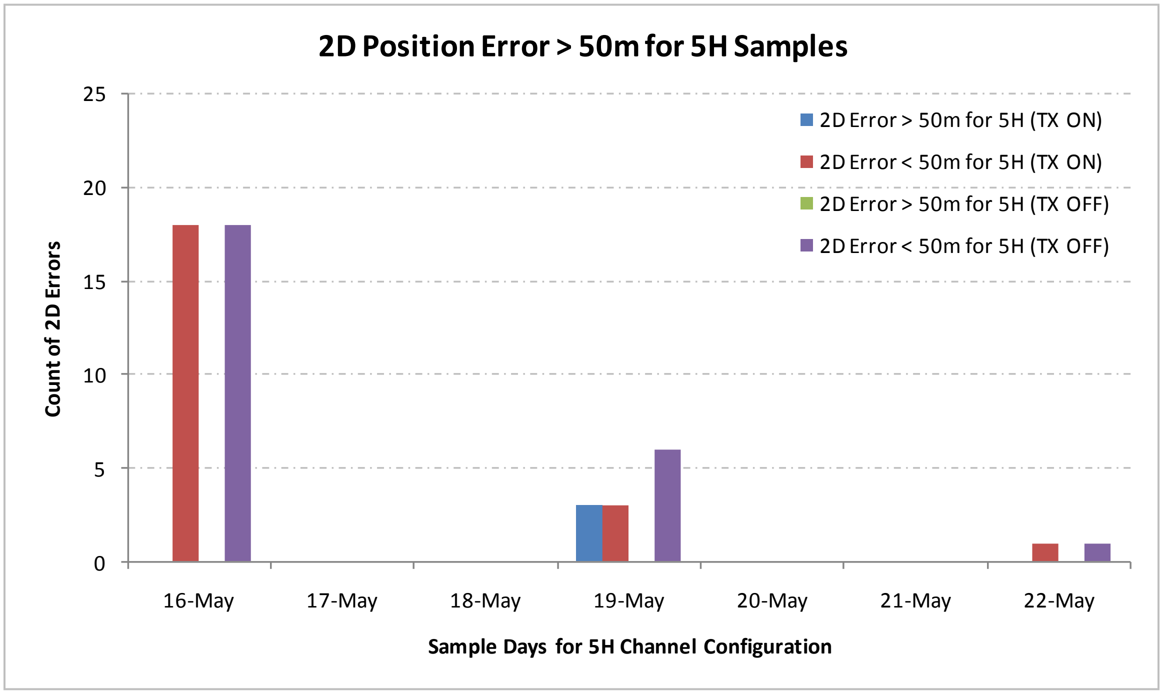
6.3.In-building Results

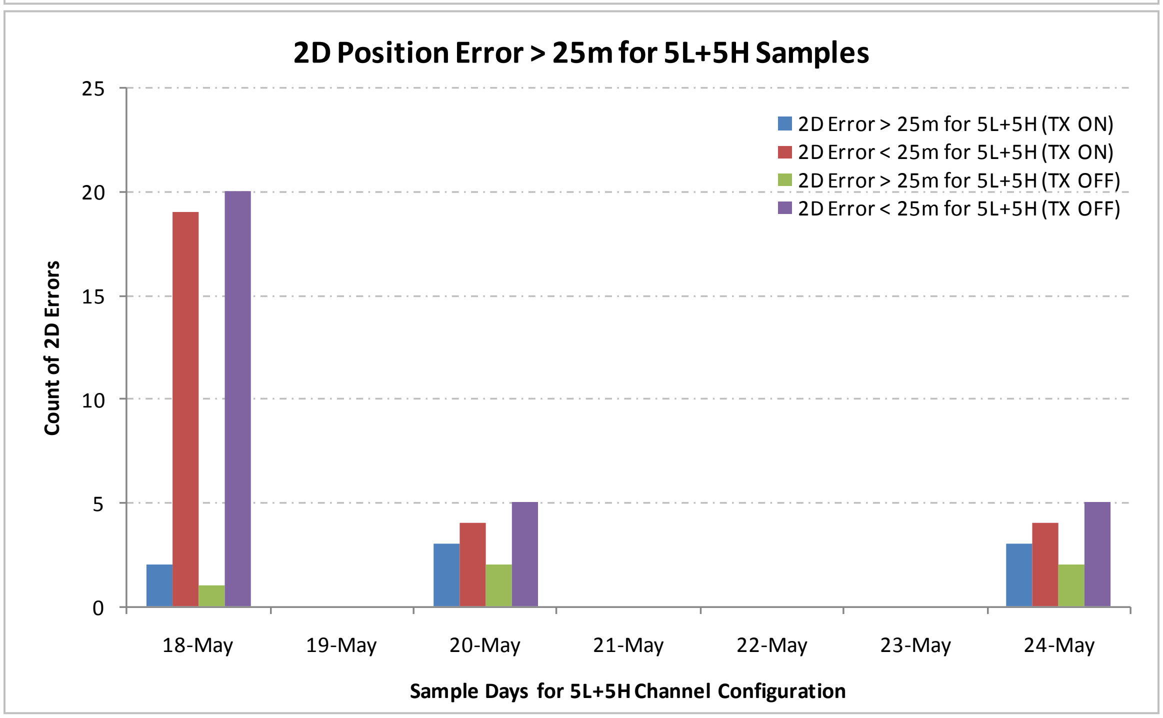
The following graphs provide an integrated summary of the in-building 2D Error performance over a limited set of devices for a given LightSquared channel configuration, named as follows: 5 MHz Low (5L), 5 MHz High (5H), 5 MHz Low + High (L+H).

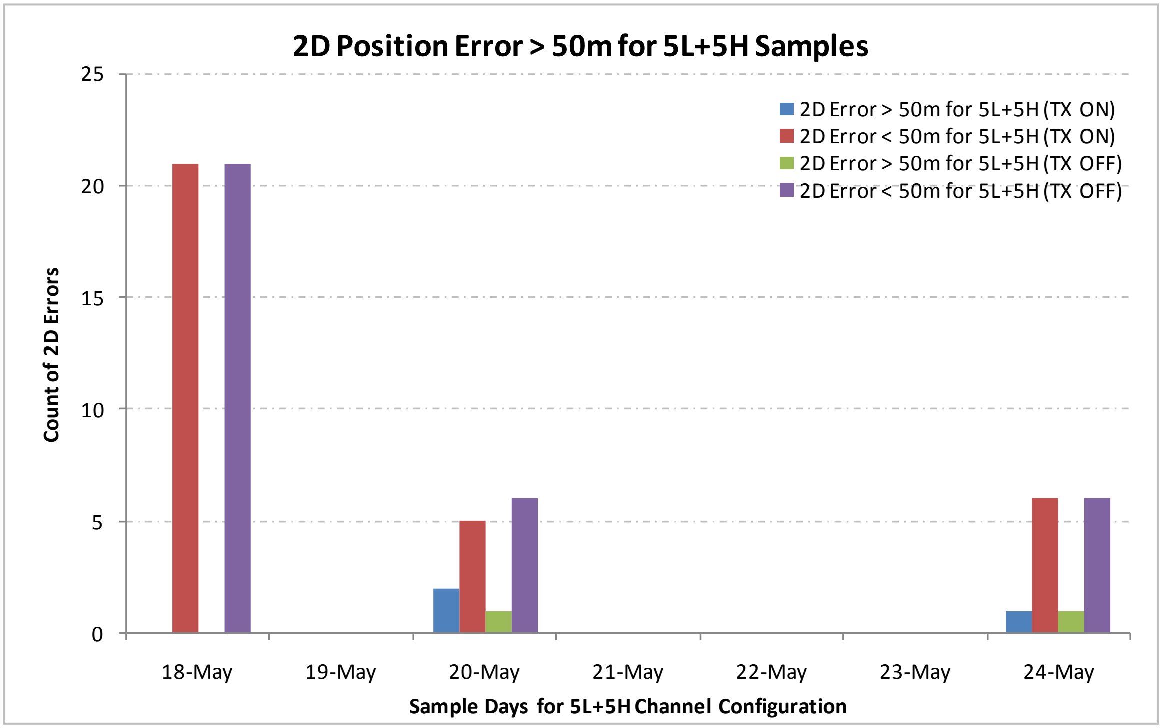



2D Position Error > 50m for 5L Samples
25
20
15
10
5
0
Count of 2D Errors
2D Error > 50m for 5L (TX ON)
2D Error < 50m for 5L (TX ON)
2D Error > 50m for 5L (TX OFF)
2D Error < 50m for 5L (TX OFF
17-May
18-May
19-May
20-May
21-May
22-May
23-May
24-May
25-May
Sample Days for 5L Channel Configuration


2D Position Error > 25m for 5H Samples
25
20
15
10
5
0
Count of 2D Errors
2D Error > 25m for 5H (TX ON)
2D Error < 25m for 5H (TX ON)
2D Error > 25m for 5H (TX OFF)
2D Error < 25m for 5H (TX OFF)
16-May
17-May
18-May
19-May
20-May
21-May
22-May
Sample Days for 5H Channel Configuration


2D Position Error > 50m for 5H Samples
25
20
15
10
5
0
Count of 2D Errors
2D Error > 50m for 5H (TX ON)
2D Error < 50m for 5H (TX ON)
2D Error > 50m for 5H (TX OFF)
2D Error < 50m for 5H (TX OFF)
16-May
17-May
18-May
19-May
20-May
21-May
22-May
Sample Days for 5H Channel Configuration


2D Position Error > 25m for 5L+5H Samples
25
20
15
10
5
0
Count of 2D Errors
2D Error > 25m for 5L+5H (TX ON)
2D Error < 25m for 5L+5H (TX ON)
2D Error > 25m for 5L+5H (TX OFF)
2D Error < 25m for 5L+5H (TX OFF)
18-May
19-May
20-May
21-May
22-May
23-May
24-May
Sample Days for 5L+5H Channel Configuration


2D Position Error > 50m for 5L+5H Samples
25
20
15
10
5
0
Count of 2D Errors
2D Error > 50m for 5L+5H (TX ON)
2D Error < 50m for 5L+5H (TX ON)
2D Error > 50m for 5L+5H (TX OFF)
2D Error < 50m for 5L+5H (TX OFF)
18-May
19-May
20-May
21-May
22-May
23-May
24-May
Sample Days for 5L+5H Channel Configuration

7. Conclusions

The static tests generally reflect the results of the laboratory tests. It is noteworthy that the static tests were conducted at sites that were selected because they were deemed hot sites in terms of measured blocker power on the ground. For the lower channel (5L), there was little systematic variation in the probability of successful position fix (as defined by a position error less than 25 m and 50) between the time epochs when the transmitter was on and off.

In the cases when an upper channel is involved, whether singly or with the lower channel, there was a systematic increase in the frequency with which the position error exceeded the thresholds of 25 m and 50m. However, it is noteworthy that, even in these cases (5H+5L or 5H channels) the frequency of "good fixes" is still at about 80% or higher of the frequency of the same with the blocker off.

In the case of the Dynamic tests, for the rural site #53, with the (5H + 5L) channel configuration, while there is a noticeable increase in the frequency of obviously erroneous fixes, it is also apparent that the results were not catastrophic over the entire route. It is noteworthy that this site showed good propagation out to several kilometers and was the hottest of all sites in terms of power on the ground.

In the case of the singleton lower channel (5L), there is no observable impact of the blocker power at any of the sites. This includes suburban site #68, which was also a site with better than average propagation. Even in the case of the 5H channel configuration, at site 68, the impact of the presence of the blocker is not very evident.

In contrast, in the dense urban site #217, which was the "coldest" site in terms of power on the ground, there were many clearly erroneous fixes both with and without the blocker (with 5L channel configuration). This was clearly owing to an insufficient number of satellites visible with an adequate signal level.

Appendix C.4.1

Statement of Quality: ETS Lindgren

ETS·LINDGREN
An ESCO Technologies Company

Date: June 14, 2011

Purpose: This statement of quality describes the ETS-Lindgren, Inc. testing facilities, work performed, and data collection as submitted to Lightsquared for the L-Band GPS impact evaluation.

ETS-Lindgren was contracted by Lightsquared to conduct a series of tests to be performed in an AMS 8800 Chamber (AMS = Antenna Measurement System). All tests were in accordance with test procedures as provided by Lightsquared.

Tests were performed by ETS-Lindgren lab technicians and in accordance with documented lab procedures. All testing was in performed as directed by Lightsquared and in close coordination with Spirent Communications (providing requisite test equipment and associated software for specific test equipment).

Any and all data has been provided to Lightsquared for review and associated validation of accuracy based on Lightsquared engineering resources and/or consultants. Data has been provided in the format requested by Lightsquared. Lightsquared is in agreement with the data output as generated by software tools used. No modifications, by ETS-Lindgren, have been performed on any data as generated by software tools used for data collection.

Roger Hatch
Director,
Service Operations
512-531-6400

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info@ets-lindgren.com • www.ets-lindgren.com

Appendix C.4.2

Statement of Quality:Intertek

731 Enterprise Drive
Lexington, KY 40510

Telephone: 859-226-1000
Facsimile: 859-226-1040
www.intertek-etlsemko.com

Intertek

Evaluation Report for:

LightSquared

Pertaining to:

GPS-LightSquared Technical Working Group Analysis

Evaluation to 3GPP Band 24 (MSS L-band) ATC impact to Cellphone GPS Receivers

Version 1.1 April 29, 2011

Date: June 13, 2011 Job: G100417002

Prepared By: ______________________________ Date: 6/13/2011
Justin Harbour, Staff Engineer

Approved By: ______________________________ Date: 6/13/2011
Gwyn F. McNew, Engineering Manager

Intertek Testing Services NA, Inc.

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1. Introduction

1.1. Evaluation Standards

The EUT was evaluated to applicable and requested sections Evaluation of 3GPP Band 24 (MSS L-band) ATC impact to Cellphone GPS Receivers, Version 1.1 dated April 29, 2011.

1.2. Project Description

The LightSquared GPS-LightSquared Technical Working Group Analysis is an ongoing investigation into the potential effects of Band 24 LTE on the neighboring GPS spectrum.

1.3. Report Status

This report is a final report. It contains all results for the evaluation for the product described in section 1.2 and characterized in section 1.1 of this report.

1.4. Evaluation Equipment

Table 1.4.1 contains a summary of the test equipment used in this evaluation. The test equipment used was based on the recommended equipment from the supplied testplan, Evaluation of 3GPP Band 24 (MSS L-band) ATC impact to Cellphone GPS Receivers, Version 1.1 dated April 29, 2011.

Table 1.4.1 - Evaluation Equipment Summary
Band-24 Chain—GPS Chain

Number required	Equipment	Manufacturer	Model
2	Vector Signal Generator (used to generate LTE signals for Base Station)	Agilent	E4438C w/ Options: 005 – Hard Drive 602 – Dig Bus Baseband 1E5 – High Stability Time Base 503 – 250 kHz to 3 GHz
1	LTE Signal Generator (used to generate LTE signals for UE)	Agilent	E4438C
2	Amplifier	Comtech	ARD8829 50 or ARD88285 50
2	Band Pass Filter	Lightsquared	1531MHz and 1550.2MHz
2	RF Isolator	MECA	CN 1.500
2	Power Combiner	MECA	H2N - 1.500V
1	Directional Coupler	Mini Circuits	ZGDC20-33HP
Multiple	Cable	Microwave Systems	LMR200
2	Transmission Antenna and Reference/Calibration antenna	AH Systems	SAS-751 Horn 9.5dBi gain
1	Power meter reference and calibration	Agilent	E4419B
1	GPS Simulator	Spirent	Spirent GSS6700, GSS6560, or GSS5060
1	Transmission Antenna	ETS-Lindgren	3201 Conical Antenna (RHCP)
Multiple	Cable	Microwave Systems	LMR200
N/A*	Power meter reference and calibration	Agilent	E4419B
N/A*	Reference/Calibration antenna	AH Systems	SAS-751 Horn 9.5dBi gain

1.5.Sample Selection

The samples evaluated were commercially available devices provided to Intertek by the Light Squared on 4/18/2011. Testing was conducted by Justin Harbour and Ben Coolbear between the dates of 4/18/2011 and 6/13/2011.

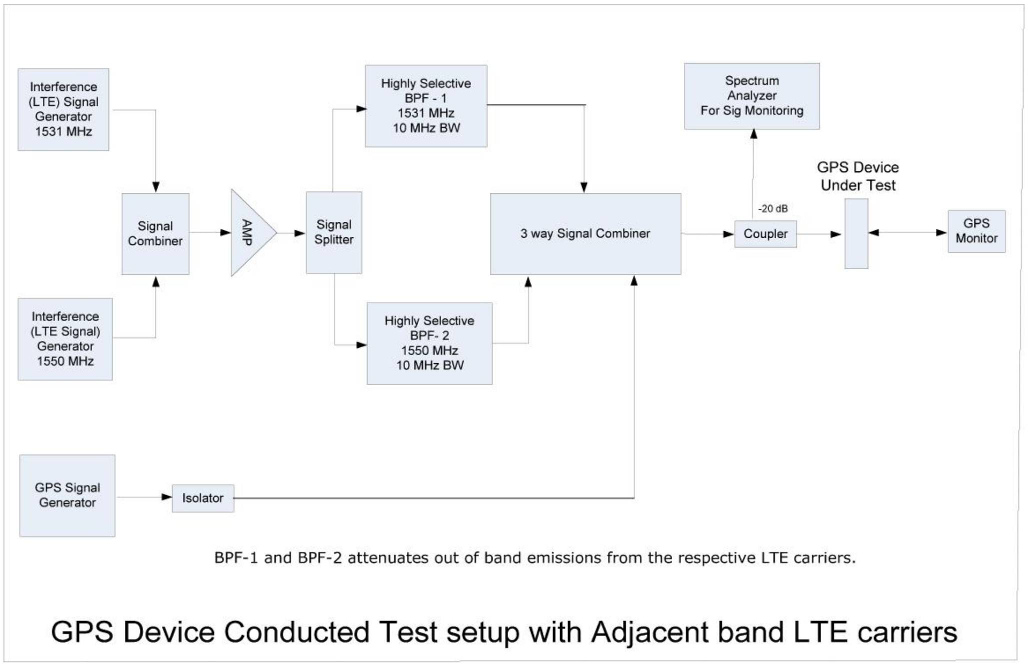
1.6.Test Requirements

Test requirements are stated in the applicable and requested sections Evaluation of 3GPP Band 24 (MSS L-band) ATC impact to Cellphone GPS Receivers, Version 1.1 dated April 29, 2011.

2. ATC Impact on Cellphone GPS Receiver Tests

Testing was all performed with equipment configured as detailed in Diagram 2.1. Equipment used for specific tests is routed via the Spirent testing software, Remote Control Client for PLTS. Detailed testing procedures can be found in Evaluation of 3GPP Band 24 (MSS L-band) ATC impact to Cellphone GPS Receivers, Version 1.1 dated April 29, 2011.

Diagram 2.1 - Test Equipment Configuration



2.1.Detail of Complete Device Testing (Max Power -15 dBm)

2.1.1.

Summary Results Details of the testing completed to date are found in the Test Results table below. This includes low, high and both bands of the LTE interferer active and Max Power up to -15 dBm.

2.1.2.

Test Results See Appendix A - Test Results Summary Max Power -15 dBm for Details.

2.2. Detail of Complete Device Testing (Max Power 0 dBm)

2.2.1.

Summary Results Details of the testing completed to date are found in the Test Results table below. This includes low band only of the LTE interferer active and Max Power up to 0 dBm.

2.2.2.

Test Results See Appendix B - Test Results Summary Max Power 0 dBm for Details.

Appendix A - Test Results Summary Max Power -15 dBm

Device Testing Status - 110613.xls

		Conducted	Radiated	Test	2.4.2.1				2.4.2.2			2.4.2.3 @ -135			2.4.2.3 @ -149			2.4.2.3 @ -152			2.4.2.4			2.4.2.5		
				LTE Channel	Low	High	Both		Low	High	Both	Low	High	Both	Low	High	Both	Low	High	Both	Low	High	Both	Low	High	Both
CD-02	Received	Yes	Yes		C	C	C	-155.5	C	C	C	W	W	W	W	W	W	C	C	C	C	C	C	C	C	C
CD-03	Received	Yes	Yes		C	C	C	-154	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CD-04	Received	Yes	Yes		C	C	C	-155	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CD-05	Received	Yes	Yes		C	C	C	-155	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CD-06	Received	Yes	Yes		C	C	C	-153				C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CD-07	Received	Yes	Yes		C	C	C	-154.5	C	C	C	W	W	W	W	W	W	C	C	C	C	C	C	C	C	C
CD-08	Received	Yes	Yes		C	C	C	-155.5	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CD-09	Received	Yes	Yes		C	C	C	-156.5	C	C	C	W	W	W	W	W	W	C	C	C	C	C	C	C	C	C
CD-10	Received	Yes	Yes		C	C	C	-157				C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CD-11	Received	Yes	Yes		C	C	C	-155				C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CD-12	Received	Yes	Yes	No longer in house	C	C	C	-155.5	C	C	C	C	R	C	C	R	C	C	C	C	C	C	C	C	C	C
CD-14	Received	Yes	Yes	Not working								W	W	W	W	W	W									
CD-15	Received	Yes	Yes	Resolved	C	C	C	-156.5	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CD-16	Received	Yes	Yes	Expected Monday	C	C	C	-157.5	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CD-18	Received	Yes	Yes		C	C	C	-157.5				C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CD-20	Received	Yes	Yes		C	C	C	-157.5	C	C	C	W	W	W	W	W	W	C	C	C	C	C	C	C	C	C
CD-21	Received	Yes	Yes		C	C	C	-156	C	C	C	C	R	R	C	C	C	C	C	C	C	R	R	C	R	C
CD-22	Received	Yes	Yes		C	C	C	-155.5	C	C	C	W	W	W	W	W	W	C	C	C	C	C	C	C	C	C
CD-23	Received	Yes	Yes		C	C	C	-153				C	C	C	R	R	R	R	R	R	C	C	C	C	C	C
CD-24	Received	Yes	Yes		C	C	C	-155.5	C	C	C	W	W	W	W	W	W	C	C	C	C	C	C	C	C	C
CD-25	Received	Yes	Yes		C	C	C	-155	C	C	C	C	C	R	C	C	R	C	C	C	C	C	R	C	C	C
CD-26	Received	Yes	Yes		C	C	C	-154.5				C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CD-27	Received	Yes	Yes		C	C	C	-153				C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CD-28	Received	Yes	Yes	Fixed				-154.5																		
CD-30	Received	Yes	Yes		C	C	C	-154	C	C	C	W	W	W	W	W	W	C	C	C	C	C	C	C	C	C
CD-31	Received	Yes	Yes		C	C	C	-154.5	C	C	C	W	W	C	W	W	W	C	C	C	C	C	C	C	C	C
CD-32	Received	Yes	Yes		C	C	C	-155.5	C	C	C	W	W	W	W	W	W	C	C	C	C	C	C	C	C	C
CD-33	Received	Yes	Yes		C	C	C	-156	C	C	C	W	W	W	W	W	W	C	C	C	C	C	C	C	C	C
CD-34	Received	Yes	Yes		C	C	C	-155	C	C	C	W	W	W	W	W	W	C		C						
CD-35	Received	Yes	Yes	Skipping				-155.5				W	W	W	W	W	W									
CD-36	Received	Yes	Yes		C	C	C	-155.5	C	C	C	W	W	W	W	W	W	C	C	C	C	C	C	C	C	C
CD-47	Received	Yes	Yes		C	C	C	-157	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CD-48	Received	Yes	Yes		C	C	C	-156.5	C	C	C	W	W	W	W	W	W	C	C	C	C	C	C	C	C	C

		2.4.3.1			2.4.2.1			2.4.2.3 @ -135			2.4.2.3 @ -149			2.4.2.3 @ -152			2.4.2.4			2.4.2.5		
		Low	High	Both	Low	High	Both	Low	High	Both	Low	High	Both	Low	High	Both	Low	High	Both	Low	High	Both
CD-02																						
CD-03																						
CD-04																						
CD-05																						
CD-06																						
CD-07																						
CD-08																						
CD-09																						
CD-10																						
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CD-27																						
CD-28																						
CD-30																						
CD-31																						
CD-32																						
CD-33																						
CD-34																						
CD-35																						
CD-36																						
CD-47																						
CD-48						C		C														

Completion (%)	Total	3GPP2	3GPP
Conducted	49.5%	61.6%	13.6%
Radiated	3.8%	0.0%	15.1%
Total	27.0%	31.3%	14.3%

Appendix B - Test Results Summary Max Power 0 dBm

Device Testing Status LOW - 110613.xls

GPS-LightSquared Technical Working Group

Cellular Task Group

Wireless Devices Test Status

CDXX Name	Received	Test Ready		Test Type	Conducted - 3GPP2							
		Conducted	Radiated	Test	2.4.2.1	2.4.2.2		2.4.2.3 @-135	2.4.2.3 @-149	2.4.2.3 @-152	2.4.2.4	2.4.2.5
				LTE Channel	Low	Level	Low	Low	Low	Low	Low	Low
CD-02	Received	Yes	Yes		C	-155.5	C	C	C	C	C	C
CD-03	Received	Yes	Yes		C	-154	C	C	C	C	C	C
CD-04	Received	Yes	Yes		C	-155	C	C	C	C	C	C
CD-05	Received	Yes	Yes		C	-155	C	C	C	C	C	C
CD-06	Received	Yes	Yes		C	-153	C	C	C	C	C	C
CD-07	Received	Yes	Yes	Skipped due to registration issue		-154.5						
CD-08	Received	Yes	Yes		C	-155.5	C	C	C	C	C	C
CD-09	Received	Yes	Yes		C	-156.5	C	C	C	C	C	C
CD-10	Received	Yes	Yes		C	-155	C	C	C	C	C	C
CD-11	Received	Yes	Yes		C	-155	C	C	C	C	C	C
CD-12	Received	Yes	Yes		C	-155.5	C	C	C	C	C	C
CD-15	Received	Yes	Yes		C	-156.5	C	C	C	C	C	C
CD-16	Received	Yes	Yes		C	-157.5	C	C	C	C	C	C
CD-18	Received	Yes	Yes		C	-157.5	C	C	C	C	C	C
CD-20	Received	Yes	Yes		C	-157.5	C	C	C	C	C	C
CD-21	Received	Yes	Yes		C	-156	C	C	C	C	C	C
CD-22	Received	Yes	Yes		C	-155.5	C	C	C	C	C	C
CD-23	Received	Yes	Yes	Skipped due to registration issue		-153						
CD-24	Received	Yes	Yes		C	-155.5	C	C	C	C	C	C
CD-25	Received	Yes	Yes		C	-155	C	C	IP	C	C	C
CD-26	Received	Yes	Yes		C	-154.5	C	C	C	C	C	C
CD-27	Received	Yes	Yes		C	-153	C	C	C	C	C	C
CD-28	Received	Yes	Yes		C	-154.5	C	C	C	C	C	C
CD-30	Received	Yes	Yes		C	-154	C	C	C	C	C	C
CD-31	Received	Yes	Yes		C	-154.5	C	C	C	C	C	C
CD-32	Received	Yes	Yes		C	-155.5	C	IP	C	C	C	C
CD-33	Received	Yes	Yes		C	-156	C	C	C	C	C	C
CD-34	Received	Yes	Yes		C	-155						
CD-36	Received	Yes	Yes		C	-155.5	C			C		
CD-47	Received	Yes	Yes			-157						
CD-48	Received	Yes	Yes			-156.5						

The sensitivity level was re-evaluated for sample CD-10 due to problems running test 2.4.2.2 with the amplifier. The new sensitivity

For sample CD-31, Test 2.4.2.2 and 2.4.2.3@-152 both failed with no passing level. The amplifier appears to be desensing the GPS reciever, thus interferring with the test. Because these tests are performed close to the GPS sensitivity level, it appears that the amplified noise is interferring with the reciever.

Appendix C.4.3

Statement of Quality: PC Test

PCTEST Engineering Laboratory, Inc.

STATEMENT OF QUALITY

Date: June 13, 2011

PURPOSE: This Statement of Quality describes the PCTEST Engineering Lab facilities, test equipment, and data collection measured and submitted to LightSquared for the L-Band GPS Impact Evaluation. This Statement of Quality is only applicable to the L-Band GPS Impact Evaluation final data that was submitted to LightSquared on May 31, 2011.

PCTEST Engineering Laboratory was established in 1989 on the principle of providing manufacturers / carriers with a much needed independent facility, fully capable of testing to a comprehensive set of technical requirements and telecommunication industry standards. PCTEST is an ISO/IEC 17025 accredited independent laboratory uniquely capable of testing to governmental and wireless industry technical requirements.

PCTEST was contracted by LightSquared, under Purchase Order No. 7988, to conduct a series of radiated tests inside the PCTEST ETS Anechoic Chamber in accordance with the described test methodology document of Reference [1] Evaluation of 3GPP Band 24 (MSS L-band) ATC impact to Cell phone GPS Receivers, Version 1.1, dated April 29, 2011.

PCTEST set up the RF path to conduct the overload testing of the cell phone-based GPS receivers in proximity to a simulated LTE Band 24 Base Station. Vector Signal Generators were used to emulate the LTE signal. This set up was in accordance with Section 2.3 of the Lab Test Methodology, Section title, Lab Environment, GPS Device Radiated Test Setup with Adjacent band LTE carriers.

Tests were executed by PCTEST engineers in accordance with Section 2.4 of the Lab Test Methodology document, using the calibrated test equipment noted in Reference [3] of this Statement of Quality. All collected test results were compiled using the Spirent 8100-A500 UMTS Location Test System and Spirent software applications noted below:

Application	Version
TestDrive ULTS	6.00.110
TestDrive OTA	6.00.110
ULTS Remote Control Client	Various Versions used V1.6.6 (latest)
AirAccessHS	4.21.100
SimGEN	V2.90 SR02

PCTEST provided all test results to Spirent and LightSquared for evaluation. There were no PCTEST transcribing requirements for the data collected. The Spirent software output the data in a format that was approved by LightSquared.

REFERENCE:

[1] LightSquared Laboratory Test Methodology; Evaluation of 3GPP Band 24 (MSS L-band) ATC Impact to Cell phone GPS Receivers, Version 1.1, dated April 29, 2011

[2] LightSquared AGPS Cellular Test Algorithm, Version A4, dated May 17, 2011: –based on "Evaluation of 3GPP Band 24 (MSS L-band) ATC Impact to Cell phone GPS Receivers" v1.0

[3] PCTEST Engineering Lab; Equipment List, Version 1.0, dated June 13, 2011

PCTEST ENGINEERING LABORATORY, INC.

PCTEST Equipment List

Manufacturer	Model	Description	Cal Due	Serial Number
Rohde & Schwarz	ZVC	Vector Network Analyzer	5/18/2012	100056
Spirent	GSS6700	Multi-GNSS Simulator	9/23/2011	1201160
Spirent	SR3420	Wireless Network Emulator	9/24/2011	UNE330Q5
Agilent	3499C	Microwave Multiplexer Switch / Control	N/A	MY42000548
Rohde & Schwarz	FSP-7	Spectrum Analyzer	8/13/2011	100990
ETS-Lindgren	3126-1550	GPS Sleeve Dipole (CF1550)	10/13/2012	55089
ETS Lindgren	3164-08	Quad Ridge Horn Antenna	N/A	105955
ETS-Lindgren	3102	Conical Log Spiral	N/A	103959
ETS-Lindgren	3102	Conical Log Spiral	N/A	105699
EMCO	2090	Multi-Device Controller	N/A	104681
ETS-Lindgren	109643	Limiting Amplifier	N/A	128207
Amplifier Research	80S1G4	80W Amplifier	N/A	0336144
Amplifier Research	60S1G3M3	60W Amplifier	N/A	303037
Agilent	E4438C	ESG Vector Signal Generator	10/26/2011	MY42082659
Agilent	E4438C	ESG Vector Signal Generator	12/21/2011	MY45093855
MECA	H2N-1.500V	Power Divider / Combiner	N/A	N/A
MECA	802-4-1.500V	Power Divider / Combiner	N/A	N/A
Mini-Circuits	ZGDC20-33HP+	Bi-Directional Coupler	N/A	0173
MECA	CN-1.500	Circulator	N/A	N/A
MECA	CN-1.500	Circulator	N/A	N/A
RF MORECOM	RMC1531B10M01	Filter	N/A	11030003
RF MORECOM	RMC1550B10M01	Filter	N/A	11030001
Bird Electronic Corp	100-SA-MFN-06	100W 6dB Attenuator	N/A	N/A
MCL	BW-S6W2	2W 3dB Attenuator	N/A	N/A
MCL	BW-S6W2	2W 3dB Attenuator	N/A	N/A
MCL	BW-N6W5	5W 6dB Attenuator	N/A	N/A
Various	N/A	Low-loss RF Cables	N/A	N/A

NOTES:

1. The Agilent Switch (only used in the original baselines), RF cables, attenuators, isolators, combiners, amplifiers, etc, are excluded from calibration. These devices were calibrated within the configuration during the range calibration.
2. The LightSquared filters were not identified to have a calibration reference (calibration label). The LightSquared Filters were swept with a calibrated VNA by PCTEST and data results were provided to LightSquared for approval.
3. The communications antenna, limiting amplifier, etc. are not used in measurement, and do not require calibration.

Randy Ortanez
President

2

CAB/CB n.b. 0982 CE 0982 CTIA Authorized Test Lab LAB CODE 20020221-00

Appendix C.5

Qualcomm L-Band Interferer Test Report and Mitigation

April 19, 2011

Contact Point:

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408-216-6996

Abstract

This report summarizes the results of testing performed by Qualcomm to assess the potential impact of LightSquared's LTE base stations operating on BC24 (L band) on GPS receivers in mobile phones. This report will also suggest some methods and techniques for mitigation for future devices.

1. Introduction

The Qualcomm GNSS test engineering group has tested multiple Qualcomm reference designs for their resilience to LightSquared terrestrial (LTE) base station blockers. Each reference design is a mobile phone designed for Qualcomm internal test and integration. Each such phone uses a different Qualcomm chipset. The selected chipsets comprise several different generations of the GPS signal processing engine, deployed over more than 100 million mobile phones.

Observed performance differences may be due not only to chipset differences but also front-end component differences. Qualcomm does not manufacture the front-end components.

While testing efforts are still in progress, the purpose of this report is to provide a preliminary snapshot of test results along with the associated test methodology. At this time, testing has been restricted to GPS only and Glonass testing may be implemented at a future date. The term GNSS is used in this report generically for any GPS or GPS/Glonass receiver.

2. MSS/ATC Blockers

LightSquared's planned frequency plan for each phase of their deployment is identified in Table 1.

Table 1 LightSquared frequency plan

Phase	Channel Bandwidth	Channel #1			Channel #2		
		$EARFCN_{DL}$	Center Frequency (MHz)		$EARFCN_{DL}$	Center Frequency (MHz)	
			DL	HL		DL	HL
0	5 MHz	7977	1552.7	1654.2	N/A		
1	5 MHz	7977	1552.7	1654.2	7738	1528.8	1630.3
2	10 MHz	7952	1550.2	1651.7	7760	1531.0	1632.5

With sufficient filtering at the LightSquared BS and UE, emission in the GNSS band can be controlled without compromising performance of the MSS/ATC data service. That emission will not be considered further here.

However, from the perspective of the established GNSS user base, the LightSquared terrestrial base stations represent a new interferer. Assessing the impact of that on GPS receiver performance is the subject of the next two sections of this report.

Interference from the base station downlink carriers in the LightSquared phase 2 deployment has been tested. Each of the two carriers is presently being modeled as AWGN with 9 MHz bandwidth. One signal generator with arbitrary waveform generation capability is used to generate both carriers, as shown in the standalone test set-up of Figure 1. To filter out any local oscillator feed thru and emission in the GNSS band, the signal generator output is passed through high-Q base station filters provided by LightSquared.

Future test plans include replacing the AWGN carriers with OFDM waveforms and adding coverage of uplink bands and other deployment phases.

3. Standalone GPS Tests

Using the set-up shown in Figure 1, position-level sensitivity as a function of LightSquared jammer power was measured. With the same set-up, it is also possible to investigate other key performance indicators such as time-to-fix and fix accuracy. The tests were performed at room temperature.

These standalone GPS tests are performed with the mobile's cellular (wireless wide-area network, or WWAN) communications function disabled. No time or frequency aiding is available from the network.

A full constellation of GPS satellites is simulated, such that typically 8 satellites are in view at any instant of time. All satellites have the same power and the user location is fixed throughout the test. The jammer power is swept from −80 dBm to −30 dBm in 10 dB increments, and the following steps are repeated for each jammer power:

1. Ephemeris, almanac, position, and time are deleted.
2. The satellite power is set to −120 dBm and a tracking session is initiated. The mobile is allowed 13 minutes to decode almanac and ephemeris with no jammer present.
3. The LightSquared base station jammer is turned on.

4. A GPS tracking session is re-initiated (hot start) with fixes generated once per second.
5. The satellite power is decreased in 1 dB steps with a 2 minute dwell at each power level. The satellite power is stepped down in this way from −120 dBm to −160 dBm.

The results are shown in Figure 2 and Figure 3, using two different definitions of sensitivity. Each of the 4 curves shows the performance of a different phone reference platform, and each reference platform uses a different chipset.

In Figure 2, sensitivity is defined as the lowest satellite power that gives 100% fix yield for the 2 minute dwell. This definition is relaxed in Figure 3 to allow 50% fix yield for the dwell.

The addition of a fix accuracy requirement is being considered, to ensure that fixes at sensitivity are not corrupted by large errors. However, no such constraint is applied in the results reported here, although the mobile is configured to not report a fix if the estimated standard deviation of horizontal error exceeds 250 m.

Figure 1 Equipment set-up for standalone sensitivity tests

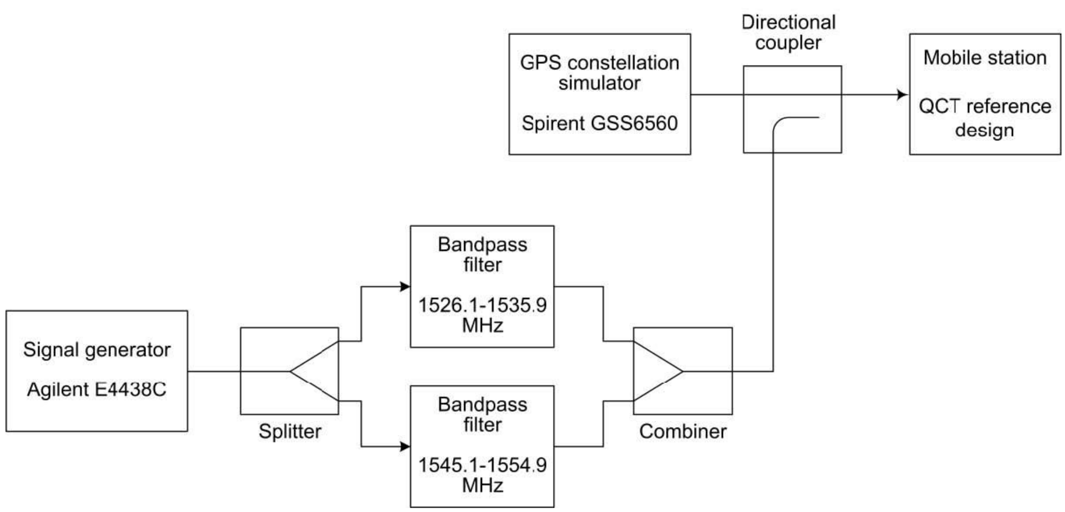


Figure 2 Standalone GPS sensitivity as a function of MSS/ATC power for 4 different platforms

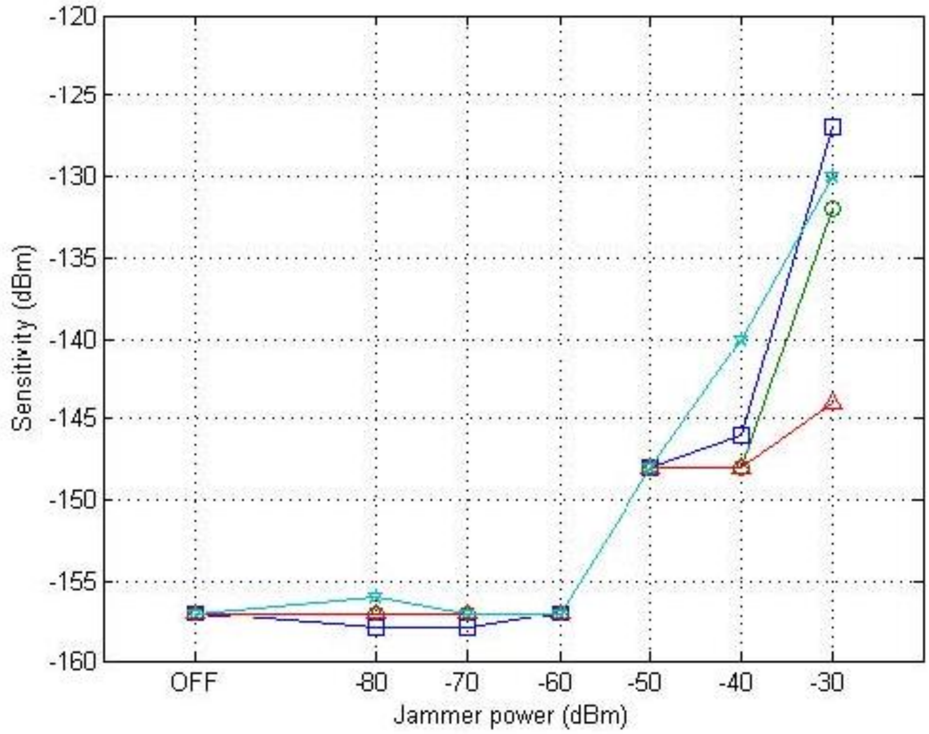
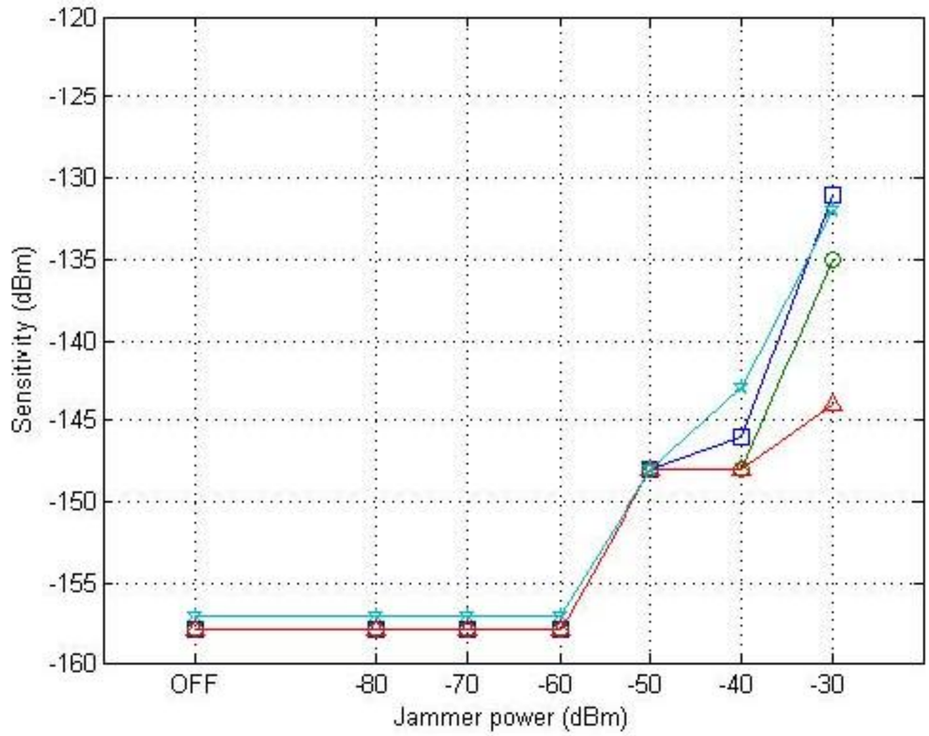


Figure 3 Sensitivity with yield requirement relaxed to 50% for 4 different platforms



Notes:

1. As mentioned at the beginning of this report, the testing is preliminary, and validation of the test setup and methodology, especially at high jammer powers, is still ongoing.

2. It is also important to note that while the above tests sweep jammer power over a range of values, which is a generally-accepted way to characterize any receiver's susceptibility to a jammer, the actual received power distribution in a cellular network is statistical. Specficially, the probability of a mobile user seeing -30 dBm jammer power may be a very small percentage, especially when operating close to GPS sensitivity level.

4. A-GPS tests

To characterize assisted GPS performance, the standard TIA-916/3GPP2 C.S0036-0 MS-assisted GPS sensitivity test in a CDMA network was performed, while injecting the LightSquared base station jammer.

This is a conducted test that simulates 4 satellites at equal power. The position server provides assistance data for these satellites and an additional 5 satellites that are not simulated. A sequence of voice calls is established. During each call, an MS-assisted session is initiated, and the mobile is allowed 16 s to execute its satellite search and transmit the measurement results to the position server. The measurement results—code phase, Doppler frequency, and satellite power—must pass prescribed accuracy checks.

The standard test was modified as follows:

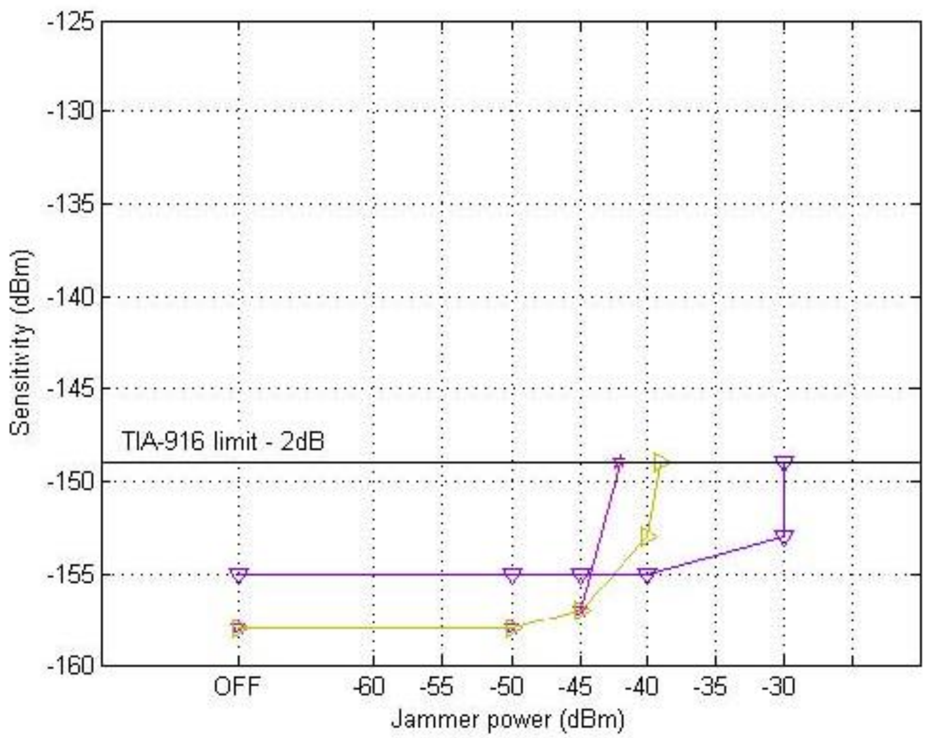
- The LightSquared jammer was coupled into the GPS receiver. This is the same jammer used in the standalone testing.
- A portion of the cellular reverse link was also coupled into the GPS receiver, simulating 10 dB antenna isolation. This is standard procedure in Qualcomm testing. It predicts performance in the CTIA certification test which uses a radiated version of the TIA-916 test.
- The voice call is carried out at maximum reverse link power. The standard does not specify this power.
- A maximum of 40 sessions were allowed in which to satisfy the required statistical bounds on measurement accuracy. The standard itself does not impose an upper limit on the number of sessions attempted.

The jammer power was swept from −50 dBm to −30 dBm in 5 dB steps. For each jammer power, the simulated satellite power was adjusted (with 1 dB resolution) until the breaking point was discovered. The maximum satellite power attempted was −125 dBm.

The line markers in Figure 4 give the weakest satellite power for which the test passes. That power is effectively the TIA-916 sensitivity of the mobile.

The standard does not call for finding the threshold of failure in this way. Rather, it just requires a passing result when the satellite power is −147 dBm. This requirement has been tightened to −149 dBm, as shown by the limit line in Figure 4. The markers intersecting that limit line were determined by setting satellite power to −149 dBm and adjusting jammer power (with 1 dB resolution) until the breaking point was found.

Figure 4 CDMA MS-assisted GPS sensitivity as a function of MSS/ATC power



Notes:

1. As mentioned earlier, the testing is preliminary, and validation of the test setup and methodology, especially at high jammer powers, is still ongoing.

2. The same point about the statistical distribution of jammer power applies here too. In addition, in an indoor environment, at low GPS received signal levels, the jammer power would also be less.

5. Strategies for Mitigation – Framework

For future devices, there are a number of approaches to be considered to improve performance and robustness of a GPS/GNSS receiver in the presence of this L-Band terrestrial downlink.

The proposed requirements could be summarize as follows.

- Downlink (DL) jammer level: up to -30 dBm in band 1525 – 1555MHz (see Table 1 “LightSquared frequency plan” for exact frequencies)
- DL only present, no L-band uplink on the phone – those can be considered separately
- Requirement for GPS+Glonass support
- Consideration of both External LNA (two filter) and no External LNA (one filter) RF front end scenarios
- GPS RX degradation through (1) high level of Jammer (saturation, reciprocal mixing, etc.) and (2) phase 1 and 2 of deployment considers 2 simultaneous channels which could generate IM3 falling into GPS L1 band

- No requirement for or account taken of (a) wideband GPS receivers that use +/-10 MHz or (b) Compass B1 centered at 1561 MHz – which may be deployed in China in 2013-2014 time-frame.

Preliminary measurement results on various representative Qualcomm platforms (see Figures 2 and 3 of earlier section) indicate that typically up to -60dBm jammer power in this band can be tolerated without violating sensitivity requirements.

As a first approach, these results suggest that an additional rejection of 30dB may be required to support up to -30dBm jammer at the antenna connector.

This does not take into account any relaxation or adjustment for the statistical distribution of received power, as mentioned above.

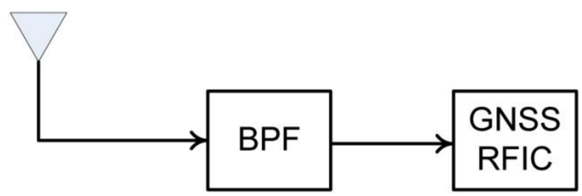
6. Possible Solutions – Front End (FE) Filter Considerations for L-Band Downlink

There are some possibilities that can be considered based on the preliminary test results that have been obtained.

6.1. Configuration without eLNA:

The following figure illustrates the typical configuration without an off chip LNA (external LNA, eLNA). Only one external band-pass filter is used in this low cost configuration. Typically, SAW technology is used for the external band-pass filter.

Figure 5 FE configuration without eLNA



Two options are possible.

- Option 1: Stay with SAW technology typically used in current GPS FE solutions
  - Current GPS FE filters typically provide only a few dB (e.g. 3dB) rejection at 1555MHz while featuring ~1dB insertion loss in the GPS band. Significant rejection (>40dB) is achieved below ~1543MHz (at room temp)
  - Due to process and temperature variation in SAW filters a guard band (between pass-band and stop-band) of at least 20 - 25MHz is required to guarantee low insertion loss.
  - The gap between GPS L1 band and 1555MHz is only ~19MHz. Guaranteeing >30dB below 1555MHz would likely cause the insertion loss in the GPS band to increase by a few tenths of a dB (e.g. 0.3-0.5dB). For low-cost devices without eLNA, higher insertion loss is typically acceptable.
  - If insertion loss is too big, the out of band rejection spec could be iterated or relaxed – potentially taking into account received jammer power distributions as mentioned above.

- Option 2: Switch to different filter technology that provides steeper stop band rejection (e.g. FBAR or BAW)
  - For example, FBAR/BAW is known to achieve low insertion loss while providing very steep stop-band rejection, e.g. insertion loss could be less than 1.2dB while

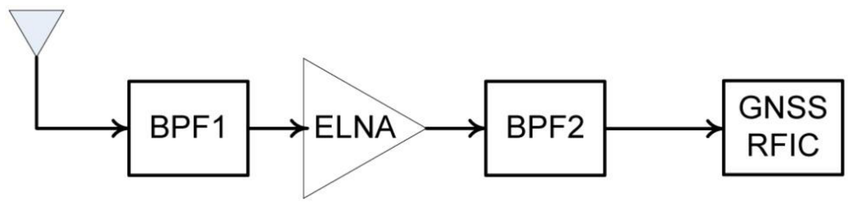
achieving >45dB rejection at ~1% of the pass band frequency over process and temperature. 1555MHz is 19MHz below passband which corresponds to ~1.2% and seems feasible.

– FBAR or BAW technology is typically more expensive than SAW. The cost impact could be on the order of 5 cents, depending on volume.

6.2.Configuration with eLNA:

To achieve best sensitivity or combat insertion losses due to long traces, an off chip LNA (external LNA, eLNA) is commonly used in Smartphones, as shown in the configuration below:

Figure 6 FE configuration with eLNA



An eLNA configuration typically uses one filter prior to eLNA and another filter post eLNA. The required attenuation of >30dB below 1555MHz can be distributed between BPF1 and BPF2 while keeping in mind:

- BPF1 needs to provide sufficient rejection to eliminate the risk IM3 in the eLNA (simultaneous presence of LightSquared channel 1 and channel 2 can cause the IM3 product to fall into the GPS band)
- Maintaining low insertion loss prior to the eLNA will ensure optimum GPS sensitivity

Since the filtering load is distributed across two filters, it is expected this could be achieved using SAW filters, while maintaining minimal overall system noise figure impact. Alternatively, using FBAR/BAW (or similar) with low insertion loss and high stop-band rejection as BPF1 while leaving BPF2 as is would represent a possible solution.

6.3.Summary of Mitigation Approaches

As stated above, although the testing initiatives have not been concluded, the preliminary results suggest that additional 30dB attenuation is needed compared to a typical existing solution (applies to both eLNA and no eLNA). This does not take into account any relaxation or adjustment for the statistical distribution of received power. The stopband is very close to the pass-band with a frequency offset of only ~1.2% of passband. Very likely, for a single filter front end topology, SAW technology may not be enough of a robust solution over process and temperature. FBAR/BAW based filters may be a potential candidate due to their low insertion loss and high stopband rejection. Going with FBAR/BAW may add cost to the GPS solution, possibly on the order of ~5 cents more than SAW. Filter vendors should be able to assess the feasibility of such solutions and provide a better estimate on the associated cost.

Appendix C.6

Verizon Wireless Test Procedure

Purpose

Test and verify the impact of LightSquared L-Band GPS interference on cellular 911 calls GPS location results

Location

Clark County Las Vegas, NV

LightSquared Site ID	Latitude	Longitude	Antenna Height AGL (ft)	Number of Sectors	Azimuths (degrees)	City
LVGS0053-C1	35.9697	-114.8681	60	2	30, 270	Rural
LVGS0068-C1	36.1245	-115.2244	55	3	0, 120 ,240	Suburban
LVGS0160-C1	36.127	-115.189	50	3	0, 120, 240	Urban
LVGS0217-C1	36.1065	-115.1705	235	2	0, 240	Dense Urban

Test devices:

2 LAD units will be set-up to automatically generate test calls from each test point.

Test Procedure:

- Pre-test requirement   30 to 45 minutes prior to the start of the testing
    - Each ground truth test point will be verified using a dGPS unit and documented for results analysis
    - LAD units will be "powered on" - after approx. 15 minute synch time, a call will be made to Intrado NOC to verify calls are being generated with location results: Intrado NOC - 800-514-1851
- Generate 5 calls with each phone for each 15 minute on/off session.
- All test calls will be static calls from a specific test point identified in each test day schedule

Test Schedule:

Test Day	Date	Frequency Bands to be tested		Sites to be tested			
		1526.3-1531.3 MHz LOWER BAND	1550.2-1555.2 MHz UPPER BAND	Site #68	Site #160	Site #217	Site #53
1	5/23/2011	x		x		x	
2	5/24/2011	x	x		x		x
3	5/25/2011	x			x		x
4	5/26/2011	x	x	x	x		
5	5/27/2011	x	x				x

Appendix

Test points selected for each site:

Site #	Test Point 1		Test Point 2		Test Point 3	
	Lat	Long	Lat	Long	Lat	Long
68	36.12439	-115.22443	36.1289	-115.22516	36.1264	-115.22524
217	36.103167	-115.176833	36.106106	-115.171069		
160	36.12625	-115.18973	36.12629	-115.19093	36.12626	-115.18975
53	35.97004	-114.87093	35.96985	-114.87211		

Appendix C.7

Commercial Deployment: Daily Log of Power

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/16/2011	217	Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	59
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	59
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	59
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	59
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	59
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	59
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	59
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	59
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	59
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	59
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	59
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	59
			5:45:00 AM	Turn off site	
			6:00:00 AM		
Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP

					(dBm) / Sector
5/16/2011	068	Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	OFF due to config issues
			12:15:00 AM	Turn off site	N/A
			12:30:00 AM	Turn on site	59.5
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	59.5
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	59.5
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	59.5
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	59.5
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	59.5
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	59.5
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	59.5
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	59.5
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	59.5
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	59.5
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/17/2011	217	Lower 5 MHz (CF= 1528.8 MHz)	12:00:00 AM	Turn on site	59
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	59
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	59
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	59
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	59
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	59
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	59
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	59
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	59
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	59
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	59
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	59
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/17/2011	068	Lower 5 MHz (CF= 1528.8 MHz)	12:00:00 AM	Turn on site	59
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	59
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	59
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	59
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	59
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	59
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	59
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	59
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	59
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	59
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	59
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	59
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/18/2011	217	Lower 5 MHz (CF= 1528.8 MHz) & Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	59
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	59
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	59
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	59
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	59
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	59
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	59
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	59
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	59
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	59
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	59
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/18/2011	068	Lower 5 MHz (CF= 1528.8 MHz) & Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	Site Outage due to rectifier problem
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	59
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	59
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	59
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	59
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	59
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	59
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/19/2011	160	Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	59
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	59
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	59
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	59
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	59
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	59
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	59
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	59
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	59
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	59
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	59
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/19/2011	053	Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	59
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	59
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	59
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	59
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	59
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	59
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	59
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	59
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	59
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	59
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	59
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/20/2011	160	Lower 5 MHz (CF= 1528.8 MHz) & Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	59
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	59
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	59
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	59
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	59
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	59
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	59
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	59
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	59
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	59
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	59
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/20/2011	053	Lower 5 MHz (CF= 1528.8 MHz) & Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	59
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	59
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	59
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	59
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	59
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	59
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	59
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	59
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	59
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	59
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	59
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/21/2011	217	Lower 5 MHz (CF= 1528.8 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	59
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/21/2011	068	Lower 5 MHz (CF= 1528.8 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	59
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/22/2011	217	Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/22/2011	068	Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/22/2011	160	Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/23/2011	217	Lower 5 MHz (CF= 1528.8 MHz)	12:00:00 AM	Turn on site	Site had an amber alarm and did not transmit 00:00-00:15
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/23/2011	068	Lower 5 MHz (CF= 1528.8 MHz)	12:00:00 AM	Turn on site	62.6
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62.6
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62.6
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62.6
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62.6
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62.6
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62.6
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62.6
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62.6
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62.6
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62.6
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62.6
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/23/2011	160	Lower 5 MHz (CF= 1528.8 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/24/2011	160	Lower 5 MHz (CF= 1528.8 MHz) & Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	62.6
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62.6
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62.6
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62.6
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62.6
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62.6
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62.6
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62.6
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62.6
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62.6
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62.6
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62.6
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/24/2011	053	Lower 5 MHz (CF= 1528.8 MHz) & Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Cabling error	N/A
			12:15:00 AM	Turn off site	
			12:30:00 AM	Cabling error	N/A
			12:45:00 AM	Turn off site	
			1:00:00 AM	Cabling error	N/A
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/25/2011	160	Lower 5 MHz (CF= 1528.8 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/25/2011	053	Lower 5 MHz (CF= 1528.8 MHz)	12:00:00 AM	Turn on site	62.2
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62.2
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62.2
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62.2
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62.2
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62.2
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62.2
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62.2
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62.2
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62.2
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62.2
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62.2
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/26/2011	160	Lower 5 MHz (CF= 1528.8 MHz) & Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/26/2011	068	Lower 5 MHz (CF= 1528.8 MHz) & Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/26/2011	217	Lower 5 MHz (CF= 1528.8 MHz) & Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM	Turn off site	
			5:30:00 AM	Turn on site	62
			5:45:00 AM	Turn off site	
			6:00:00 AM		

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/27/2011	53	Lower 5 MHz (CF= 1528.8 MHz) & Upper 5 MHz (CF= 1552.7 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM		
			5:30:00 AM		
			5:45:00 AM		
			6:00:00 AM	Turn off site	

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/27/2011	068	Lower 5 MHz (CF= 1528.8 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM		
			5:30:00 AM		
			5:45:00 AM		
			6:00:00 AM	Turn off site	

Date	Site	Channels	Time (Local PDT)	Site Operator	EIRP (dBm) / Sector
5/27/2011	217	Lower 5 MHz (CF= 1528.8 MHz)	12:00:00 AM	Turn on site	62
			12:15:00 AM	Turn off site	
			12:30:00 AM	Turn on site	62
			12:45:00 AM	Turn off site	
			1:00:00 AM	Turn on site	62
			1:15:00 AM	Turn off site	
			1:30:00 AM	Turn on site	62
			1:45:00 AM	Turn off site	
			2:00:00 AM	Turn on site	62
			2:15:00 AM	Turn off site	
			2:30:00 AM	Turn on site	62
			2:45:00 AM	Turn off site	
			3:00:00 AM	Turn on site	62
			3:15:00 AM	Turn off site	
			3:30:00 AM	Turn on site	62
			3:45:00 AM	Turn off site	
			4:00:00 AM	Turn on site	62
			4:15:00 AM	Turn off site	
			4:30:00 AM	Turn on site	62
			4:45:00 AM	Turn off site	
			5:00:00 AM	Turn on site	62
			5:15:00 AM		
			5:30:00 AM		
			5:45:00 AM		
			6:00:00 AM	Turn off site	

Appendix C.8

Verizon Field Test Report

“This report is pending completion and submission by Verizon Wireless”

Appendix D.1

List of Devices and Receivers Tested

Aviation

- Canadian Marconi GLSSU 5024
- RTCA DO-208 Compliant Airborne Receiver
- Garmin GNS 430W
- Garmin GNS 480
- Novatel G-II WAAS Ground Reference Station
- Rockwell Collins GNLU-930 Multimode Receiver
- Local Area Augmentation system (LAAS) Ground Facility (LGF) Receiver
- Zyfer Timing Receiver

Cellular

- Apple iPhone 3S (GSM)
- Apple iPhone 4 (CDMA)
- HTC Desire 6275
- HTC A6366
- HTC ADR6200
- HTC ADR63002
- HTC ADR63003
- HTC ADR6400L
- LG Lotus
- LG Rumor
- LG VN250
- LG VS740
- LG VX5600
- LG VX8360
- LG VX8575
- LG VX9200
- Motorola A855
- Motorola W755
- Motorola DROID X

- Motorola VA76R
- Sony Ericsson W760
- Nokia 6350
- Nokia 6650
- Nokia E71-2
- RIM 8330C
- RIM 8530
- RIM 9350
- RIM 9630
- RIM 9650
- Elite RIM 9800
- Touch Samsung SPH-M900
- Samsung SCH-R330
- Samsung SCH-R630
- Samsung SCH-R880
- Samsung SCH-U310
- Samsung SCH-U350
- Samsung SCH-U640
- Samsung SCH-U750
- Samsung SCH-I500 (VZ)
- Samsung SCH-I500 (USC)
- Samsung SGH-I617

General Location and Navigation

- Garmin® Forerunner® 110
- Garmin Forerunner 305
- Garmin eTrex® H
- Garmin Dakota® 20
- Garmin Oregon® 550
- Garmin GTU™ 10
- BI® ExacuTrack® One
- General Motors OnStar® System
- Garmin GVN 54

- TomTom® XL335
- TomTom ONE® 3RD Edition
- TomTom GO® 2505
- Garmin nüvi® 2X5W
- Garmin nüvi 13XX
- Garmin nüvi 3XX
- Garmin nüvi 37XX
- Hemisphere GPS® Outback S3 (Low Precision Ground Agricultural Navigation) (Tested by the Timing sub-team)
- Trimble® iLM® 2730 (with Mobile Mark Option J antenna)
- Trimble TVG 850 (with Mobile Mark Option E glass-mount antenna)
- e-Ride Opus 5SD
- Hemisphere GPS® Vector MV101 (Tested by the Timing sub-team)
- Motorola® APX7000
- Motorola APX6000
- Trimble Placer™ Gold
- Motorola MW810
- Garmin GPSMAP 496
- Garmin aera® 5xx
- Garmin GPSMAP 696

High Precision and Networks

- Deere iTC
- Deere SF-3000
- Deere SF-3050
- Hemisphere R320
- Hemisphere S3
- Leica GR10
- Leica GS15
- Leica GX 1230
- Leica SR530
- Leica Uno
- NovAtel OEM4
- NovAtel OEM628

- NovAtel OEMSTAR
- NovAtel OEMV1
- NovAtel OEMV2G
- NovAtel OEMV3G
- Septentrio AsteRx3
- Septentrio PolaRx3e
- Topcon GR-3
- Topcon GR-5
- Topcon HiPer Ga
- Topcon HiPer II
- Topcon MC-R3 (1)
- Topcon MC-R3 (2)
- Topcon NET-G3A
- Topcon SGR-1
- Trimble 5800
- Trimble AqGPS 252
- Trimble AqGPS 262
- Trimble AqGPS Ezguide 500
- Trimble CFX 750
- Trimble FMX
- Trimble GeoExplorer 3000 series GeoXH
- Trimble GeoExplorer 3000 series GeoXT
- Trimble GeoExplorer 6000 series GeoXH
- Trimble GeoExplorer 6000 series GeoXT
- Trimble Juno SB
- Trimble MS990
- Trimble MS992
- Trimble NetR5 (Zephyr 1 Antenna)
- Trimble NetR5 (Zephyr 2 Antenna)
- Trimble NetR9 (Zephyr 1 Antenna)
- Trimble NetR9 (Zephyr 2 Antenna)
- Trimble R8 GNSS

Space Based Receivers

- TriG (NASA Nextgeneration Space Receiver)
- IGOR (Space Receiver)

NASA/JPL also tested the following high precision receivers; the results of these tests have been shared with the HPT&N sub-team for its consideration:

- JAVAD Delta G3T (High Precision IGS)
- Ashtech Z12 (High Precision IGS)

Timing Receivers

- FEI-Zyfer AccuSync II
- FEI-Zyfer UNISync GPS/PRS
- Symmetricom Symmetricom
- Symmetricom Time Provider 1000/1100
- Symmetricom Time Source 3500
- Symmetricom Time Source N
- Trimble Accutime Gold
- Trimble Mini Thunderbolt
- Trimble Resolution SMT
- Trimble Resolution T
- TruePosition GPS Timing Receiver

Appendix G.1

General Location and Navigation Test Plan

Detailed Test Plan

General Location / Navigation Sub-Group

Version 2.1

May 19, 2011

Introduction

The following detailed test plan describes the equipment, setup and methods for measuring the susceptibility of various GPS receivers to interference from LightSquared LTE transmitters operating in the Mobile Satellite Service (MSS) L-band. Any modifications to or deviations from this test plan must be approved by the members of the General Location / Navigation Sub-Group.

Test Equipment and Setup

Overview:

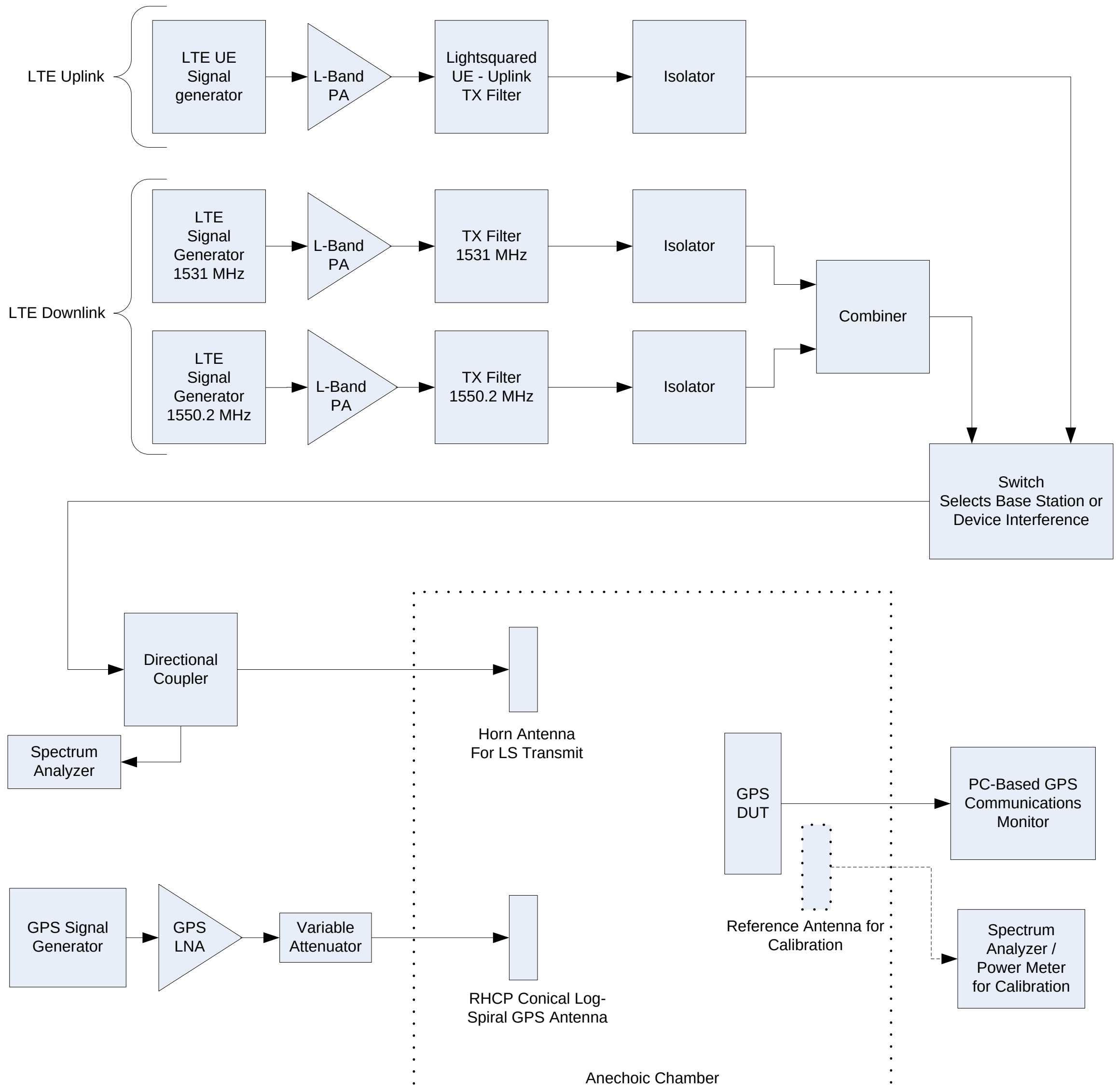
The general parameters for test are to provide an interfering set of signals at the LightSquared downlink and uplink frequencies in the presence of a controlled set of GPS signals. Figure 1 illustrates the basic test setup for testing interference from the LightSquared downlink.

All tests contained in this document shall be performed as radiated tests in an RF chamber. (Acceptable chambers include FCC-approved or equivalent RF anechoic or semi-anechoic chamber. Or, a GigaHertz Transverse Electromagnetic (GTEM) cell may be substituted for select tests with the approval of the sub-group.) The test lab shall calibrate the chamber with the understanding that all power references in this document are specified as radiated power (EIRP) incident on the DUT. It is not anticipated that the power level from the LightSquared downlink source at the receiver will be high enough to require additional isolation from the other sources. Also, if the test lab chooses to use computer-controlled RF switches (as indicated in the block diagram) to reduce test time, high quality mechanical RF switches rated for at least 18GHz shall be used (e.g. Agilent 44476A Microwave Multiplexer Module or equivalent).

In order to maintain consistency and ensure uniform product set-up between DUTs and manufacturers, all tests shall be run in accordance with ANSI C63.4. The FCC specifies ANSI C63.4 for all radiated tests.

Specific manufacturers and models of test equipment are mentioned throughout this document. These are provided for reference. The test lab may make equivalent equipment substitutions with approval from the General Navigation Sub-group.

Figure 1 – Simplified Test Equipment Block Diagram: Radiated Immunity Tests



LightSquared Downlink Source:

Recommended Test Equipment

The test equipment recommended for simulating this source is listed in Table 1. Equivalent equipment may be substituted with the permission of the sub-group members (except where noted).

Table 1: Test Equipment – LS Downlink

Equipment	Manufacturer	Model	QTY
Vector Signal Generator	Agilent	E4438C	2
Signal Studio for 3GPP LTE FDD	Agilent	N7624B	2
Amplifier	Amplifier Research	AR 50S1G4A	2
Band Pass Filter	RF Morecomm	RMC1531B10M01	1
	RF Morecomm	RMC1550B10M01	1
RF Isolator	MECA	CN 1.500	2
Power Combiner	MECA	H2N - 1.500V	1
Directional Coupler	Mini Circuits	ZGDC20-33HP	1
TX Antenna	ETS-Lindgren	3115	1

Test Equipment Setup

Two vector signal generators capable of producing LTE modulation shall be used to simulate the LightSquared downlink transmitters at 1531 MHz and 1550 MHz. The signal bandwidth shall either bet 5 MHz or 10 MHz depending on whether Phase 0, 1, or 2 signals are being tested. Table 2 provides the LTE signal setup parameters. The signals shall be amplified and filtered using the LightSquared provided transmit filters. The signals shall then be combined and fed to the transmit antenna. The transmit antenna shall be linearly polarized. During the Interference Susceptibility Test, either the Transmit Antenna or the DUT shall be rotated to find the angle of maximum susceptibility. This angle shall be documented for each DUT and used for the remainder of the tests.

Table 2: LTE Downlink Signal Setup Parameters

Parameter	Setting	Comment
Center Frequency	1552.7 MHz	Phase 0
	1528.8 MHz & 1552.7 MHz	Phase 1
	1531 MHz and @ 1550.2 MHz	Phase 2
Release	3GPP R8	
Duplexing	FDD	
Modulation	OFDM/OFDMA	
Frame Duration	10 ms	
Sub frame Duration	1.0 ms	
Subcarrier Modulation	QPSK	For PCH , PDCCH, PDSCH
Subcarrier Size	15 KHz	
Channel Bandwidth	5 MHz	Phase 0 / 1
	10 MHz	Phase 2
PRB Bandwidth	0.180 MHz	
Sampling Rate	7.68 MHz	Phase 0 / 1
	15.36 MHz	Phase 2
FFT Size	512	Phase 0 / 1
	1024	Phase 2
Dummy Data	PN9	

Calibration

The power of the sources shall be measured at the directional coupler as well as at the reference antenna in order to establish the losses due to the equipment setup. The net loss shall be documented in the test report. The reference antenna shall then be removed from the anechoic chamber and the DUT shall be substituted in its place. The reference antenna may be substituted with a field measuring probe and test chamber may be calibrated according to EN 61000-4-3.

LightSquared Uplink Source:

Recommended Test Equipment

The test equipment recommended for simulating this source is listed in Table 3. Equivalent equipment may be substituted with the permission of the sub-group members (except where noted).

Table 3: Test Equipment – LS Uplink

Equipment	Manufacturer	Model	QTY
Vector Signal Generator	Rohde & Schwarz	CMU200A	1
Amplifier	Amplifier Research	AR 50S1G4A	1
Band Pass Filter	K&L Microwave	K&L 4CP120-1632.5/E10.3-0/0	2
	K&L Microwave	K&L 4CP120-1651.7/E10.3-0/0	2
RF Isolator	MECA	CN 1.500	2
Power Combiner	MECA	H2N - 1.500V	1
Directional Coupler	Mini Circuits	ZGDC20-33HP	1
TX Antenna, Horn	ETS-Lindgren	3115	1

Test Equipment Setup

A vector signal generator capable of producing LTE modulation shall be used to simulate the LightSquared uplink transmitter. The low, middle, and high channel shall be simulated. Table 4 provides the LTE signal setup parameters. The signal shall be amplified and filtered using a LightSquared provided transmit filter. The signal shall then be fed to the transmit antenna. The transmit antenna shall be linearly polarized. During the Interference Susceptibility Test, either the TX Antenna or the DUT shall be rotated to find the angle of maximum susceptibility. This angle shall be documented for each DUT and used for the remainder of the tests.

Table 4: LTE Uplink Signal Setup Parameters

Parameter	Setting	Comment
Center Frequency	1632.5 MHz	Low / Middle / High, according to test plan.
Release	3GPP R8	
Duplexing	FDD	
Modulation	OFDM / OFDMA	
Allocation	1 Lower-most RB Freq. = 1628 - 1628.180 MHz	
RB Bandwidth	180 kHz	
UE Power	+23 dBm	
Subcarrier Modulation	QPSK	
Dummy Data	PN9	

Calibration

The source power shall be measured at the directional coupler as well as at the reference antenna in order to establish the losses due to the equipment setup. The net loss shall be documented in the test report. The reference antenna shall then be removed from the chamber and the DUT shall be substituted in its place. The reference antenna may be substituted with a field measuring probe and test chamber may be calibrated according to EN 61000-4-3.

GPS Simulator Source:

Recommended Test Equipment

The test equipment recommended for simulating this source is listed in Table 5. Equivalent equipment may be substituted with the permission of the sub-group members (except where noted). *Reference power levels shall be determined in the chamber by assuming a 0 dBic RHCP reference antenna for the DUT.*

Table 5: Test Equipment – GPS Signals

Equipment	Manufacturer	Model	QTY
Satellite Simulator	Spirent	GSS 6700*	1
Record Playback System	Spirent	GSS 6400*	1
Active GPS Patch Antenna for Live Test Recording	CTI	GPS-WP/UNI	1
GPS Transmit Antenna, RHCP Conical Log-Spiral	ETS-Lindgren	3102L	1
GPS Low Noise Amplifier	Mini-Circuits	ZHL-1217HLN	1
Step Attenuator	JFW Industries	50R-019-SMA	1
		50R-243	1
GPS Communications Monitor	Provided by DUT Manufacturer	N/A	1

** Substitutes are not allowed for this equipment.*

Static Use Case Simulator Setup: A Spirent GSS 6700 shall be used to simulate the following satellite signals under static conditions.

Exactly 5 GPS satellites transmitting C/A code only

Highest elevation satellite at maximum power (-119.5 dBm) (per GPS SPS, including maximum satellite antenna gain- DO-229D 2.1.1.10)

Lowest elevation satellite at minimum power (-128.5 dBm) (per GPS SPS, including minimum satellite antenna gain - DO-229D 2.1.1.10)

The other three (3) satellites shall be 3 dB higher than the satellite at minimum power (-125.5 dBm)

HDOP range from 1.4 to 2.1

For the Static Interference Susceptibility Tests only (Sections IV.A. and IV.B.), the aforementioned Satellite signal power levels shall be amended so that all 5 satellites are transmitting at -128.5dBm.

Dynamic Use Case Simulator Setup: A Spirent GSS 6700 shall be used to simulate the following satellite signals under dynamic conditions.

Exactly 6 GPS satellites transmitting C/A code only

HDOP range from 1.4 to 2.1

Reference signal power for all satellites: -128.5 dBm

Trajectory Description: A rectangular trajectory with rounded corners similar to the trajectory described in section 5.6.4.1 of 3GPP TS 34.172 v10.0.0. This scenario is a rectangle 940m by 1440m with various linear acceleration and deceleration profiles and an angular acceleration of 2.4 m/s^2 in the turns.

The beginning of the scenario shall include 90s of static position simulation to be used for satellite acquisition.

Dynamic Use Case Record Playback System Setup: Representative signals for each of the following scenarios shall be recorded using a Spirent GSS 6400 Record Playback System to ensure that the same scenario can be replayed consistently for all tests. A calibrated RHCP patch antenna shall be used to collect the data and shall be oriented in a manner consistent the use case being recorded, as specified below. Detailed instructions on recording live signals are included in Appendix B for reference.

General Use Case 1: Suburban
The DUT is mounted on the dash of a vehicle which is moving in a suburban, tree lined environment. The DUT will experience frequent changes of direction, obscuration of signals by the roof of the car, and mild dynamics. This use case shall be recorded with a predetermined route specified by the sub-group.

General Use Case 2: Urban Canyon
The DUT is mounted on the dash of a vehicle which is moving in an urban canyon environment. The DUT will experience frequent changes of direction, obscuration of signals by the roof of the car, and mild dynamics. This use case shall be recorded in either Chicago, New York, or San Francisco. The sub-group shall make the final determination about the test location and define the specific test route.

Outdoor Use Case: Deep Forest
The DUT is held in the hand of a moving user while walking in a deep forest environment when leaves are on the trees. The DUT will experience some dynamics associated with walking. This use case shall be recorded with a predetermined route specified by the sub-group.

Fitness Use Case: Arm Swing Environment
The DUT is mounted on the arm of a user who is swinging his/her arms in a manner consistent with distance running. The DUT will experience frequent heading changes and the signal will be obscured by the body at times. Stressful dynamics are associated with the arm swing. This use case shall be recorded with a predetermined route specified by the sub-group.

Calibration

The source power shall be measured at the output of the GPS satellite simulator as well as at the reference antenna in order to establish the losses due to the equipment setup. Due to the low signal power in the GPS band, a Network Analyzer should be substituted into the test setup and used for calibration. The net loss shall be documented in the test report. The Network Analyzer shall be removed from the setup. Likewise, the reference antenna shall then be removed from the anechoic chamber and the DUT shall be substituted in its place. The reference antenna may be substituted with a field measuring probe and test chamber may be calibrated according to EN 61000-4-3.

Test Plan Summary

The number of tests and configurations required for each DUT is quite large due to many variables and constraints that require investigation. There are several key test variations that substantially increase the total number of tests performed, and so these deserve special consideration. The sub-group believes that it is important to characterize and understand these variations; however, the extremely tight schedule under which we are operating precludes this possibility. Consequently, configurations for Phase 0 and Phase 2 LightSquared Downlink signals will not be applied to every test. These configurations will only be tested during the Interference Susceptibility test as indicated in Table 6. Further, testing of the interference from the LightSquared uplink (both stand-alone and in tandem with the downlink) will be a secondary priority to the downlink testing. Nevertheless, the uplink signals must be evaluated during the static susceptibility test at a minimum. Finally, the LightSquared transmit antenna polarization shall be evaluated in the horizontal and vertical polarizations only during the Interference Susceptibility test on a per-DUT basis. All subsequent tests on that particular DUT shall be run with the transmit antenna in the polarization that caused the worst performance. The sub-group realizes that omitting these test variations limits our ability to fully explore the effects of intermodulation and overload on the GPS receivers under test, but sees no other alternative given our time constraints.

The test matrices in Tables 6 and 7 provide a concise summary of the tests that can be run within the time constraints imposed on the group. Details relating to specific tests can be found in Sections IV and V. The members of the General Navigation sub-group, in conjunction with the test lab, may choose to omit some test cases for certain devices. Such decisions shall be based on test data indicating that a particular test does not yield useful data. Additionally, device manufacturers and the test lab may choose to omit certain tests based on the time and schedule constraints imposed upon the sub-team. The test lab shall note all deviations from the test plan in the final test report and shall also keep the General Location / Navigation Sub-Team apprised of any deviations on a weekly basis.

For reference, a complete list of devices to be tested can be found in Appendix A.

Table 6: Test Matrix – Downlink Tests

		LightSquared Interference - Downlink			
		Phase 0a 5 MHz BW	Phase 0b [1] 10 MHz BW	Phase 1 --> 5 MHz	Phase 2 --> 10 MHz
	Test Item	1552.7 MHz	1531 MHz	1552.7 MHz 1528.8 MHz	1531 MHz 1550.2 MHz
Static Test Cases	Interference Susceptibility Test	X	X	X	X
Static Test Cases	Interference Susceptibility Test (Acquisition Sensitivity)	No Time	No Time	X	No Time
Static Test Cases	TTFF - Cold Start	No Time	No Time	X	No Time
Static Test Cases	TTFF - Warm Start	No Time	No Time	X	No Time
Static Test Cases	WAAS Demodulation Test - Cold Start to Differential Fix	No Time	No Time	X	No Time
Dynamic Test Cases	Simulated Position and Velocity Tests	No Time	No Time	X	No Time
Dynamic Test Cases	Naviation Position and Velocity Tests	No Time	No Time	X	No Time
Dynamic Test Cases	TTFF - Cold Start	No Time	No Time	X	No Time
Dynamic Test Cases	TTFF - Warm Start	No Time	No Time	X	No Time

[1] Lightsquared requested a change to the Phase 0b signal parameters on the afternoon of 5/17/2011. The updated signal parameters are reflected in Table 6, above. Previously, the Phase 0b signal had a 1528.8 MHz center frequency and a 5 MHz bandwidth. The following devices were tested prior to this change and have not been retested due to time constraints: nuvi 265W, nuvi 1390, nuvi 360, nuvi 3790.

Table 7: Test Matrix – Uplink Tests

		LightSquared Interference - Uplink			
		Phase 0/1 --> 5 MHz BW [1]		Phase 2 --> 10 MHz BW	
	Test Item	1654.2 MHz	1630.3 MHz	1632.5 MHz	1651.7 MHz
Static Test Cases	Interference Susceptibility Test	No Time	X	No Time	No Time
Static Test Cases	Interference Susceptibility Test (Acquisition Sensitivity)	No Time	No Time [2]	No Time	No Time
Static Test Cases	TTFF - Cold Start	No Time	No Time [2]	No Time	No Time
Static Test Cases	TTFF - Warm Start	No Time	No Time [2]	No Time	No Time
Static Test Cases	WAAS Demodulation Test - Cold Start to Differential Fix	No Time	No Time [2]	No Time	No Time
Dynamic Test Cases	Simulated Position and Velocity Tests	No Time	No Time [2]	No Time	No Time
Dynamic Test Cases	Naviation Position and Velocity Tests	No Time	No Time [2]	No Time	No Time
Dynamic Test Cases	TTFF - Cold Start	No Time	No Time [2]	No Time	No Time
Dynamic Test Cases	TTFF - Warm Start	No Time	No Time [2]	No Time	No Time

[1] *Whereas Lightsquared requested a change to the Phase 0b downlink signal parameters on the afternoon of 5/17/2011, no change was made to the uplink signal parameters.*

[2] *While the other uplink tests in this matrix had been bypassed prior to testing start due to time limitations imposed on the sub-group, these tests were removed during the first week of testing (5/16/11) as it became apparent that we would not have time to complete them.*

Static Tests

Interference Susceptibility Test

Test Setup**:** The device under test (DUT) shall be exposed to modified test signals per Section II.D.2.f. Use a communications monitor (provided by manufacturer) to record the baseline C/N_0 reported by the GPS receiver.

Measurement Parameters**:** Measure and record interfering simulated LightSquared transmitter power levels that result in 1dB, 3dB, 6dB, 10dB, and 20dB degradations in average reported C/N_0, as well as a complete loss of fix.

Key Performance Indicator (KPI): Average C/N_0 Degradation from Baseline (dB-Hz)

Interference Susceptibility Test (Acquisition Sensitivity)

Test Setup**:** The device under test (DUT) shall be exposed to test signals per Section II.D.2. Use a communications monitor (provided by manufacturer) to delete ephemeris (including predicted ephemeris) and restart the acquisition engine to simulate a *Warm Start* condition. Then iterate the GPS signal level to find the baseline Acquisition sensitivity (minimum level at which the receiver can acquire a 3D fix within 3 minutes) reported by the GPS receiver. (Note, ephemeris must be deleted and the acquisition engine restarted prior to each iteration/trial).

Measurement Parameters**:** Measure and record the acquisition sensitivities that result from the LightSquared transmitter power levels measured in Section 0, above. Also, record the average C/N_0 reported by the DUT after it has acquired a fix. *(Any TTFF test that runs more than 3 minutes shall be aborted and the test operator shall note that the device failed to acquire a fix.)*

Key Performance Indicator (KPI): Acquisition Sensitivity (dBm)

TTFF (Time to First Fix) - Cold Start

Test Setup**:** The device under test (DUT) shall be exposed to test signals per Section II.D.2. Use a communications monitor (provided by manufacturer) to delete ephemeris (including predicted ephemeris), time, position, and almanac. Then restart the acquisition engine to simulate a *Cold Start* condition. The command to *Cold Start* the device shall be issued in the 10^{th} second of the GPS minute (as reported by the Spirent GSS 6700). Measure the TTFF with no interference present and record this as the baseline *(record 3 samples)*.

Measurement Parameters**:** Measure and Record the TTFF's that result from the LightSquared transmitter power levels measured in Section IV.A.2 *(record 3 samples at each level)*. Also, record the average C/N_0 reported by the DUT after it has acquired a 3D fix. *(Any TTFF test that runs more than 3 minutes shall be aborted and the test operator shall note that the device failed to acquire a fix.)*

Key Performance Indicator (KPI): TTFF (s)

TTFF - Warm Start

Test Setup**:** The device under test (DUT) shall be exposed to test signals per Section II.D.2. Use a communications monitor (provided by manufacturer) to delete ephemeris (including predicted ephemeris) and restart the acquisition engine to simulate a *Warm Start* condition. The command to *Warm Start* the device shall be issued in the 10^{th} second of the GPS minute (as reported by the Spirent GSS 6700). Measure the TTFF with no interference present and record this as the baseline *(record 3 samples).*

Measurement Parameters**:** Measure and Record the TTFF's that result from the LightSquared transmitter power levels measured in Section IV.A.2 *(record 3 samples at each level).* Also, record the average C/N_0 reported by the DUT after it has acquired a 3D fix. *(Any TTFF test that runs more than 3 minutes shall be aborted and the test operator shall note that the device failed to acquire a fix.)*

Key Performance Indicator (KPI): TTFF (s)

WAAS Demodulation Test

Test Setup**:** The device under test (DUT) shall be exposed to test signals per Section II.D.2 with the addition of a WAAS PRN and Signal in Space. Use a communications monitor (provided by manufacturer) to delete ephemeris (including predicted ephemeris), time, position, and almanac. Then restart the acquisition engine to simulate a *Cold Start* condition. The command to *Cold Start* the device shall be issued in the 10^{th} second of the GPS minute (as reported by the Spirent GSS 6700). Measure the TTFF – 3D Differential with no interference present and record this as the baseline *(record 3 samples).*

Measurement Parameters**:** Measure and Record the TTFF's that result from the LightSquared transmitter power levels measured in Section IV.A.2 *(record 3 samples at each level).* Also, record the average C/N_0 reported by the DUT after it has acquired a fix. *(Any TTFF test that runs more than 5 minutes shall be aborted and the test operator shall note that the device failed to acquire a fix.)*

TTFF – Differential (Time to First Differential Fix)

WAAS Satellite Bit Error Rate Degradation
(some receivers may not support this test)

Loss of Frame Synchronization - increase in age of differential correction
(some receivers may not support this test)

Average C/N_0 reported by the DUT

LightSquared Transmit Power Level

Key Performance Indicator (KPI): TTFF - Differential (s)

Dynamic Tests

Simulated Position and Velocity Tests

Test Setup**:** The device under test (DUT) shall be exposed to simulated GPS signals per Section II.D.3. Use a communications monitor (provided by manufacturer) to measure and record the parameters detailed in the Measurement Parameters Section at 1 Hz intervals. Record baseline measurements without interference from the LightSquared transmitter. When collecting data with the LightSquared transmitter interference, allow the DUT to acquire a 3D fix during the first 90s of the scenario. Enable the LightSquared transmitter (at the appropriate level) as soon as the device acquires a 3D fix.

***Measurement Parameters*:** Collect the following data (at 1Hz intervals) for each DUT in the presence of the LightSquared transmitter at the power levels measured in Section IV.A.

Reported position including latitude, longitude, and altitude

Reported velocity

Reported Time

Reported C/N_0 for each satellite

Key Performance Indicators (KPIs): Position, Velocity, and Time (PVT) Error with respect to the truth as reported by the GPS satellite simulator, and C/N_0 degradation. (A *.csv file with the aforementioned data shall be provided as part of the final test report.)

Navigation Position and Velocity Tests

***Test Setup*:** The device under test (DUT) shall be exposed to pre-recorded test signals per Section II.D.4. *The recorded scenario shall be played back per the appropriate test case, as indicated in Appendix A.* Use a communications monitor (provided by manufacturer) to measure and record the parameters detailed in the Measurement Parameters Section at 1 Hz intervals. Record baseline measurements without interference from the LightSquared transmitter. When collecting data with the LightSquared transmitter interference, allow the DUT to acquire a 3D fix during the first 5 minutes of the pre-recorded scenario. Enable the LightSquared transmitter (at the appropriate level) 5 minutes into the pre-recorded scenario (as reported by the GSS-6400).

***Measurement Parameters*:** Collect the following data (at 1Hz intervals) for each DUT in the presence of the LightSquared transmitter at the power levels measured in Section IV.A.

Reported position including latitude, longitude, and altitude

Reported velocity

Reported Time

Reported C/N_0 for each satellite

Key Performance Indicators (KPIs): Position, Velocity, and Time (PVT) Error with respect to the baseline, and C/N_0 degradation. (A *.csv file with the aforementioned data shall be provided as part of the final test report.)

TTFF – Cold Start (May need to skip this test due to time constraints)

Test Setup: The device under test (DUT) shall be exposed to pre-recorded GPS signals per Section II.D.4. The recorded scenario shall be played back per the appropriate test case, as indicated in Appendix A. Use a communications monitor (provided by manufacturer) to delete ephemeris (including predicted ephemeris), time, position, and almanac. Then restart the acquisition engine to simulate a **Cold Start** condition. The command to **Cold Start** the device shall be issued 10 s after the playback is started. Measure the TTFF over several iterations on the DUT (with no interference present) and record that level as the baseline TTFF.

Measurement Parameters: Measure and Record the TTFF's that result from the LightSquared transmitter power levels measured in Section IV.A.2. Also, record the C/N_0 reported by the DUT after it has acquired a fix. (*Any TTFF test that runs more than 3 minutes shall be aborted and the test operator shall note that the device failed to acquire a fix.)*

Key Performance Indicator (KPI): TTFF (s)

TTFF – Warm Start (May need to skip this test due to time constraints)

***Test Setup*:** The device under test (DUT) shall be exposed to pre-recorded GPS signals per Section II.D.4. *The recorded scenario shall be played back per the appropriate test case, as indicated in Appendix A.* Use a communications monitor (provided by manufacturer) to delete ephemeris and restart the acquisition engine to simulate a *Warm Start* condition. The command to *Warm Start* the device shall be issued 10 s after the playback is started. Measure the TTFF over several iterations on the DUT (with no interference present) and record that level as the baseline TTFF.

***Measurement Parameters*:** Measure and Record the TTFF's that result from the LightSquared transmitter power levels measured in Section IV.A.2. Also, record the C/N_0 reported by the DUT after it has acquired a fix. *(Any TTFF test that runs more than 3 minutes shall be aborted and the test operator shall note that the device failed to acquire a fix.)*

Key Performance Indicator (KPI): TTFF (s)

Appendix A

Device Under Test Assignments and Categorization

Device Category	Manufacturer	Model	Communications Monitor Specs			Static Test Cases						Dynamic Test Cases				
			Interface Capability	Manufacturer Support for Communications Monitor	Logging Capability Built into Unit	Interference Susceptibility Test	Interference Susceptibility Test (Acquisition Sensitivity)	TTFF - Cold Start	TTFF - Warm Start	WAAS Demodulation Test - Cold Start to Differential Fix	Simulated Position and Velocity Tests	Dynamic Use Case	Naviation Position and Velocity Tests	TTFF - Cold Start	TTFF - Warm Start
Fitness	Garmin	Forerunner 110	Y	Y	Y	Y	Y	Y	Y	N	Y	Fitness Use Case: Arm Swing Environment	Y	N	N
		Forerunner 305	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	N	N
		EDGE 500	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	N	N
		EDGE 800	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	N	N
Outdoor	Garmin	ETREX-H	Y	Y	Y	Y	Y	Y	Y	Y	Y	Outdoor Use Case: Deep Forest	Y	Y	Y
		Dakota 20	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y
		Oregon 550	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y
		GPSMAP 62	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y
		Astro 220	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y
		Rino 530HCx	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y
Tracking	Garmin	GTU 10	Y	Y	N	Y	Y	Y	Y	N	Y	General Use Case 1: Suburban	Y	Y	Y
		DC40	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
	BI Incorporated	BI ExacuTrack® One	Y	Y	N	Y	Y	Y	Y	N	Y		Y	Y	Y
Marine	Garmin	GPS 17X (NMEA)	Y	Y	Y	Y	Y	Y	Y	Y	Y	None			
		GPSMAP 441	Y	Y	Y	Y	Y	Y	Y	Y	Y				
		GPSMAP 740	Y	Y	Y	Y	Y	Y	Y	Y	Y				
		GPSMAP 541	Y	Y	Y	Y	Y	Y	Y	Y	Y				
		GPSMAP 546	Y	Y	Y	Y	Y	Y	Y	Y	Y				
	Furuno	GP 33	Y	Y	N	Y	Y	Y	Y	Y	Y				
Automotive (in dash)	GM	OnStar Model TBD				Y	Y	Y	Y	N	Y	General Use Case 2: Urban Canyon	Y	Y	Y
	Garmin	GVN 54	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
PND	TomTom	XL335	Y	Y	N	Y	Y	Y	Y	N	Y	General Use Case 1: Suburban General Use Case 2: Urban Canyon	Y	Y	Y
		ONE 3RD Edition	Y	Y	N	Y	Y	Y	Y	N	Y		Y	Y	Y
		GO 2505	Y	Y	N	Y	Y	Y	Y	N	Y		Y	Y	Y
		VIA 1400/1405 or VIA 1500/1505	Y	Y	N	Y	Y	Y	Y	N	Y		Y	Y	Y
		XXL 530/530S or XXL 540/540S	Y	Y	N	Y	Y	Y	Y	N	Y		Y	Y	Y
		GO 720, GO 920	Y	Y	N	Y	Y	Y	Y	N	Y		Y	Y	Y
		GO 730, GO 930	Y	Y	N	Y	Y	Y	Y	N	Y		Y	Y	Y
	Garmin	nűvi 2X5W	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
		nűvi 13XX	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
		nűvi 3XX	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
		nűvi 37XX	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
		Zumo 550	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
		StreetPilot c330	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
		zumo 220	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
		nuvi 760	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
Fleet Management	Trimble	iLM2730 (with Mobile Mark Option J antenna)	Y	Y	N	Y	Y	Y	Y	Y	Y	General Use Case 1: Suburban General Use Case 2: Urban Canyon	Y	Y	Y
		TVG-850 (with Mobile Mark Option E glass-mount antenna)	Y	Y	N	Y	Y	Y	Y	Y	Y		Y	Y	Y
		MTS521 (with CAT Shark Fin antenna)	Y	Y	N	Y	Y	Y	Y	Y	Y		Y	Y	Y
		DCM300G (with Taoglas Combo antenna)	Y	Y	N	Y	Y	Y	Y	Y	Y		Y	Y	Y
	e-Ride	Opus 5SD	Y	Y	N	Y	Y	Y	Y	Y	Y		Y	Y	Y
First Responder Location	Motorola	APX7000	N	Y	N	Y	Y	Y	Y	N	Y	General Use Case 1: Suburban	Y	Y	Y
	Motorola	APX6000	N	Y	N	Y	Y	Y	Y	N	Y		Y	Y	Y
Emergency Vehicles (post-OEM mounted in vehicle)	Trimble	Placer Gold	Y	Y	N	Y	Y	Y	Y	Y	Y	General Use Case 2: Urban Canyon	Y	Y	Y
	Motorola	MW810	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
		ML910	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
		DMR / MotoTRBO	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
		External Antenna / LNA	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	Y
Portable Aviation (non-TSO)	Garmin	GPSMAP 496	Y	Y	Y	Y	Y	Y	Y	Y	Y	None			
		aera® 5xx	Y	Y	Y	Y	Y	Y	Y	Y	Y				
		GPSMAP 696	Y	Y	Y	Y	Y	Y	Y	Y	Y				
	Honeywell Bendix/King	AV8OR	Y			Y	Y	Y	Y	Y	Y				

** NOTES **

1. Please note that items listed in gray are devices that the sub-group believes should be tested, but are probably not feasible due to the extremely short time frame imposed on us.
2. The PND and Fleet Management device categories require testing in both the Suburban and Urban Canyon dynamic use cases. If time constraints prevent testing both use cases, the Urban Canyon use case shall be prioritized.

Appendix B

Procedure for Record and Playback of Live GPS Signals with the GSS6400 Spirent Record Playback System

1. Introduction

The purpose of this document is to define a set of test procedures and conditions for using the Spirent GSS6400 Record/Playback system to collect live GPS signals and replay them with high fidelity in a controlled laboratory environment.

This document will not detail the user interface specifics of the GSS6400 as it is assumed that the reader has some familiarity with this product. This document will refer only to the settings and functions of the GSS6400 that were used to record and validate via playback a GPS test scenario in a laboratory environment.

The overarching goal is to provide a GPS signal playback configuration that closely approximates in the laboratory the signal conditions that a GPS device under test would encounter if the testing were being conducted live on location in the field.

2. Setup for Recording Test Signals

A. GSS6400 Setup

1. GSS6400 components:
   - GSS6400 unit
   - GSS6400 external antenna (CTI, GPS-WP/UNI)
   - GSS6400 12V power cable (the internal battery provides approximately 40 minutes of runtime on a full charge)
2. The GSS6400 shall use Software version 10.11.16 (or greater) and shall be preset to its default settings.
3. **Note** Please verify that the GSS6400 has sufficient disc space available for recording. 20GB for each hour of planned recording should be sufficient.

B. Test Platform Setup

1. Connect the GSS6400 to 12 volt vehicle power using the provide 12V power cable. (For Outdoor and Fitness use cases, ensure that the internal battery is charged.)
2. Connect the reference GPS antenna to the GSS6400 and position it according to the appropriate use case.

   General Use Case 1 and 2, Urban / Suburban

   The GSS6400 GPS antenna shall be affixed to the center of the dash about 2 inches from the base of the windshield. The GSS6400 shall be placed on the seat or floorboard of the car.

   Outdoor Use Case (deep forest)

   The GSS6400 GPS antenna shall be affixed to a dummy DUT and held in the tester’s hand while walking the test route. The GSS6400 shall be placed in a backpack worn by the tester.

Fitness Use Case (Arm Swing Environment)

The GSS6400 GPS antenna shall be affixed to a dummy DUT worn on the tester's wrist while jogging the test route. The GSS6400 shall be placed in a backpack worn by the tester.

3. Secure GSS6400 unit, cables, and antenna so that they do not move during the test (except when required by test setup – e.g. Arm Swing Test).
4. Configure a reference GPS receiver in the same orientation as the GSS6400 antenna, maintaining a separation distance of at least 12". The Reference Receiver shall log data to be used to validate the recording and to calibrate the RF chamber for playback.

C. Recording the Signals

1. **Begin Logging**
   - Power on the GSS6400 and start a new recording.
   - Power on the *Reference Receiver* and start logging.
2. **Initial Acquisition**

   Begin each recording session by maintaining a stationary position and providing the GSS6400 Antenna and *Reference Receiver* with a clear, unobstructed view of the sky for 15 minutes.
3. **Record the pre-planned test route**

   After the initial 15 minute acquisition period, continue recording and drive, walk, or run the prescribed test route.
4. **Stop Recording and Save Data**

   Stop recording on the GSS 6400 and the *Reference Receiver* and save/archive the data files to an external storage medium to make room for subsequent recordings.

3. Test Environment Setup

The playback testing should be performed in a RF chamber as specified in Section II.D.4 of the Detailed Test Plan.

The GSS6400 settings should remain at default values for the validation and playback testing. Since the GSS6400 is designed to playback with the same signal strength that it received during the recording, the signal level is too low for playback in a radiated environment. Consequently, a low-noise amplifier (Mini-Circuits ZHL-1217HLN or similar) is recommended. Further, the signal level shall be adjusted using a post-LNA attenuator as the software attenuation feature on the GSS 6400 is unreliable (the attenuator value on the GSS-6400 shall be set to zero (0).

4. Validation of the Recording

Each recording should be validated as soon as possible to ensure there were no anomalies or errors introduced by the test equipment or test environment. Precise calibration of the GPS signal levels is not required at this point.

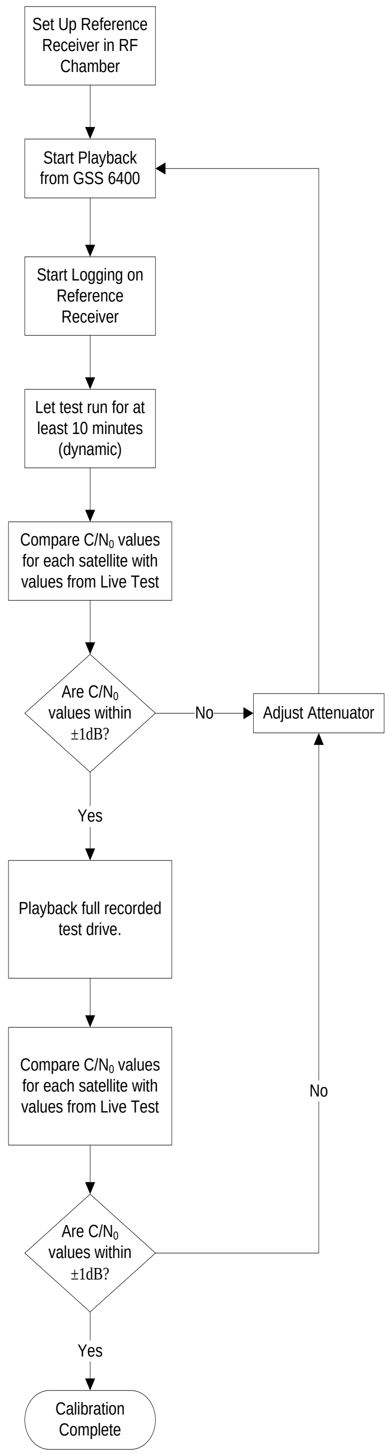
The *Reference Receiver* (for the use case in question) shall be mounted in the test chamber. Then use a communications monitor (provided by manufacturer) to delete ephemeris (including predicted ephemeris), time, position, and almanac. Restart the acquisition engine to simulate a ***Cold Start*** condition, then enable logging. Once logging has commenced, start the playback of the GPS recording and verify that the *Reference Receiver* acquires a 3D fix.

At the completion of the playback, stop the logging on the Reference Receiver. Using the log files from the playback and from the live recording, plot and compare the reported positions. The two position plots should be substantially the same – this validates that the GPS recording is good to use. If large discrepancies are observed (e.g. very large position jumps or large gaps in the logged position data), the recorded data may be corrupt.

5. Calibrating the EMI Chamber Playback Configuration

The flow chart in Figure B1 shows the process of calibrating the re-radiated GPS signal with the *Reference Receiver* used during the recording process.

Figure B1: Process for Calibrating Recorded, Re-radiated GPS Signals



Appendix C

Test Routes for Dynamic GPS Testing

1. Introduction

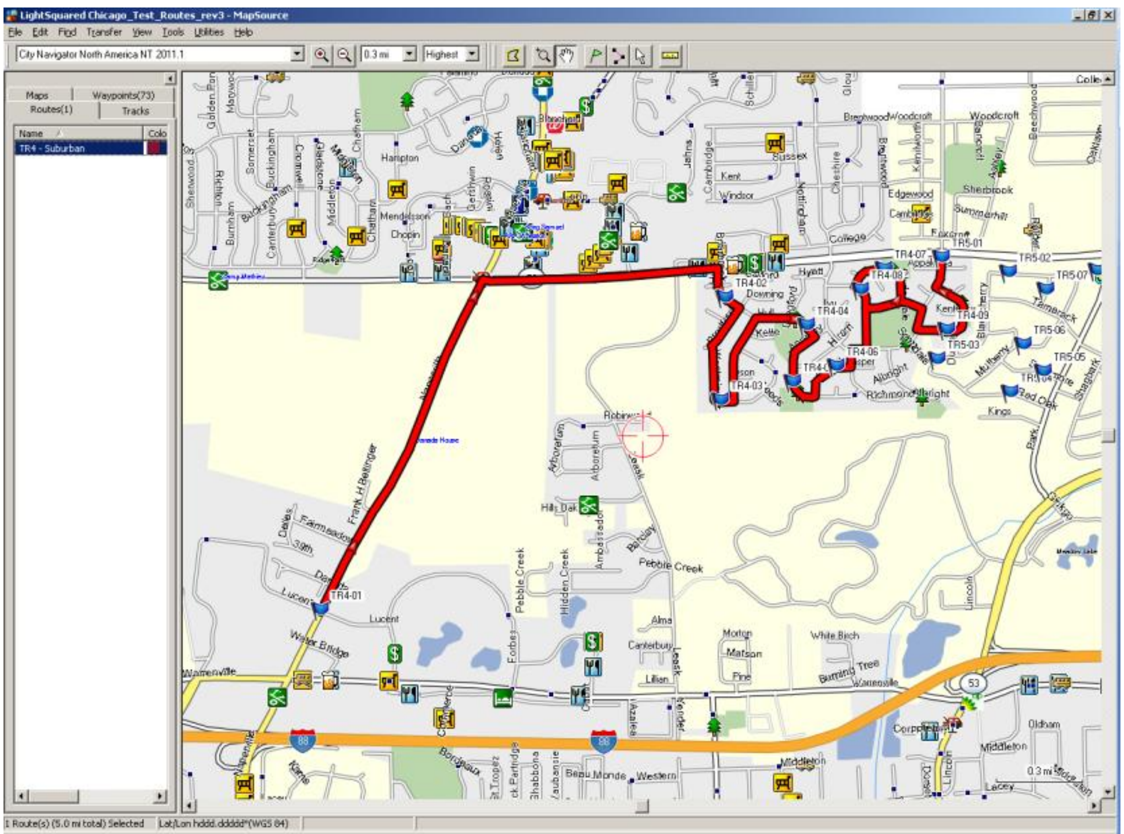
Appendix C details the test routes to be used for recording dynamic GPS data for playback testing in the lab. Coordinates are provided in the WGS-84 reference system.

There are four general use cases called out in the test plan: General Navigation Use Case 1 (Suburban),General Navigation Use Case 2 (Urban Canyon), Outdoor Use Case (Deep Forest), and Fitness Use Case (Arm Swing). The test routes for each of these use cases are provided below. Any deviations from the prescribed routes (due to construction or road closures, for example) shall be noted in the final test report.

2. General Navigation Test Case #1 (Suburban)

The suburban test routes consist of 3 contiguous test route segments through tree lined streets in residential neighborhoods.

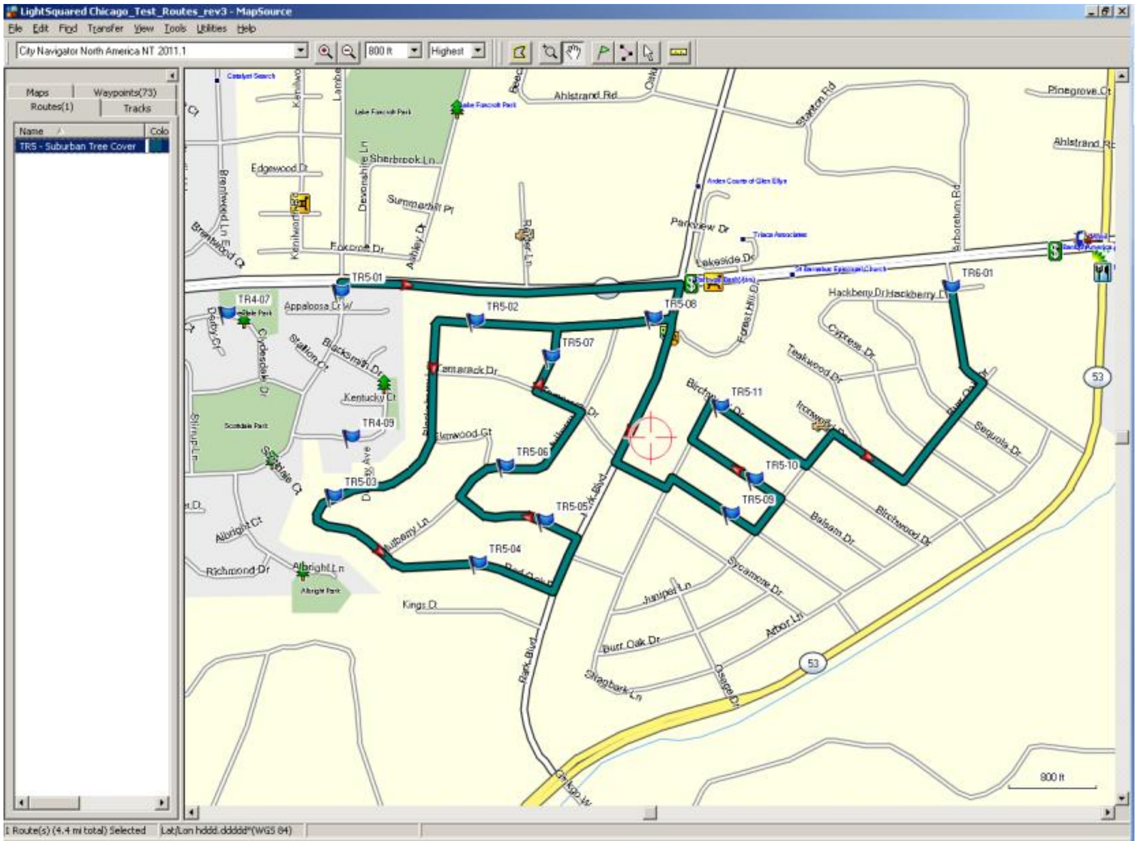
A. Suburban Test Route Segment 1 Map Image



B. Suburban Test Route Segment 1 Driving Directions

	Maneuver / Waypoint	Cumulative Distance	Leg Distance	Coordinates
1	TR4-01	0 ft		N41.81229 W88.11524
2	Get on Naperville Rd and drive northeast	0 ft	0 ft	N41.81229 W88.11524
3	Turn right onto Butterfield Rd	1.3 mi	1.3 mi	N41.82886 W88.10537
4	Turn right onto S Hull Dr	2.0 mi	0.7 mi	N41.82941 W88.09108
5	TR4-02	2.1 mi	0.1 mi	N41.82788 W88.09062
6	Get on S Hull Dr and drive southeast	2.1 mi	0 ft	N41.82788 W88.09062
7	Turn right onto S Bradford Dr	2.2 mi	285 ft	N41.82744 W88.08975
8	Turn left onto Westminster St	2.3 mi	0.2 mi	N41.82555 W88.09147
9	Turn left onto Durham Dr	2.5 mi	0.2 mi	N41.82285 W88.09130
10	TR4-03	2.5 mi	133 ft	N41.82273 W88.09088
11	Get on Durham Dr and drive east	2.5 mi	0 ft	N41.82273 W88.09088
12	Turn left onto Kingston Dr	2.6 mi	214 ft	N41.82276 W88.09010
13	Turn right onto E Hull Dr	2.9 mi	0.3 mi	N41.82693 W88.08877
14	TR4-04	3.1 mi	0.2 mi	N41.82647 W88.08567
15	Get on E Hull Dr and drive southeast	3.1 mi	0 ft	N41.82647 W88.08567
16	Turn right onto Appleby Dr	3.1 mi	227 ft	N41.82598 W88.08516
17	TR4-05	3.3 mi	0.2 mi	N41.82367 W88.08649
18	Get on Appleby Dr and drive south	3.3 mi	0 ft	N41.82367 W88.08649
19	Turn left onto Jasper Dr	3.4 mi	502 ft	N41.82302 W88.08516
20	TR4-06	3.5 mi	0.1 mi	N41.82445 W88.08385
21	Get on Jasper Dr and drive east	3.5 mi	0 ft	N41.82445 W88.08385
22	Turn left onto Richmond Dr	3.6 mi	240 ft	N41.82448 W88.08297
23	Turn right onto Scottdale Cir	3.6 mi	329 ft	N41.82538 W88.08297
24	Turn left onto Stirrup Ln	3.7 mi	257 ft	N41.82538 W88.08203
25	Turn right onto Shetland Dr	3.8 mi	0.1 mi	N41.82740 W88.08207
26	Turn left onto Clydesdale Dr	3.9 mi	0.1 mi	N41.82774 W88.07992
27	TR4-07	4.1 mi	0.1 mi	N41.82931 W88.08094
28	Get on Clydesdale Dr and drive west	4.1 mi	0 ft	N41.82931 W88.08094
29	Turn left onto Stirrup Ln	4.2 mi	0.1 mi	N41.82851 W88.08276
30	TR4-08	4.2 mi	136 ft	N41.82827 W88.08238
31	Get on Stirrup Ln and drive southeast	4.2 mi	0 ft	N41.82827 W88.08238
32	Turn left onto Shetland Dr	4.3 mi	350 ft	N41.82740 W88.08207
33	Turn right onto Scottdale Cir	4.5 mi	0.2 mi	N41.82740 W88.07864
34	Turn left onto Blacksmith Dr	4.5 mi	388 ft	N41.82637 W88.07898
35	TR4-09	4.6 mi	503 ft	N41.82624 W88.07715
36	Get on Blacksmith Dr and drive east	4.6 mi	0 ft	N41.82624 W88.07715
37	Turn right onto Scottdale Cir	4.9 mi	0.2 mi	N41.82847 W88.07782
38	TR4-10	5.0 mi	526 ft	N41.82986 W88.07748

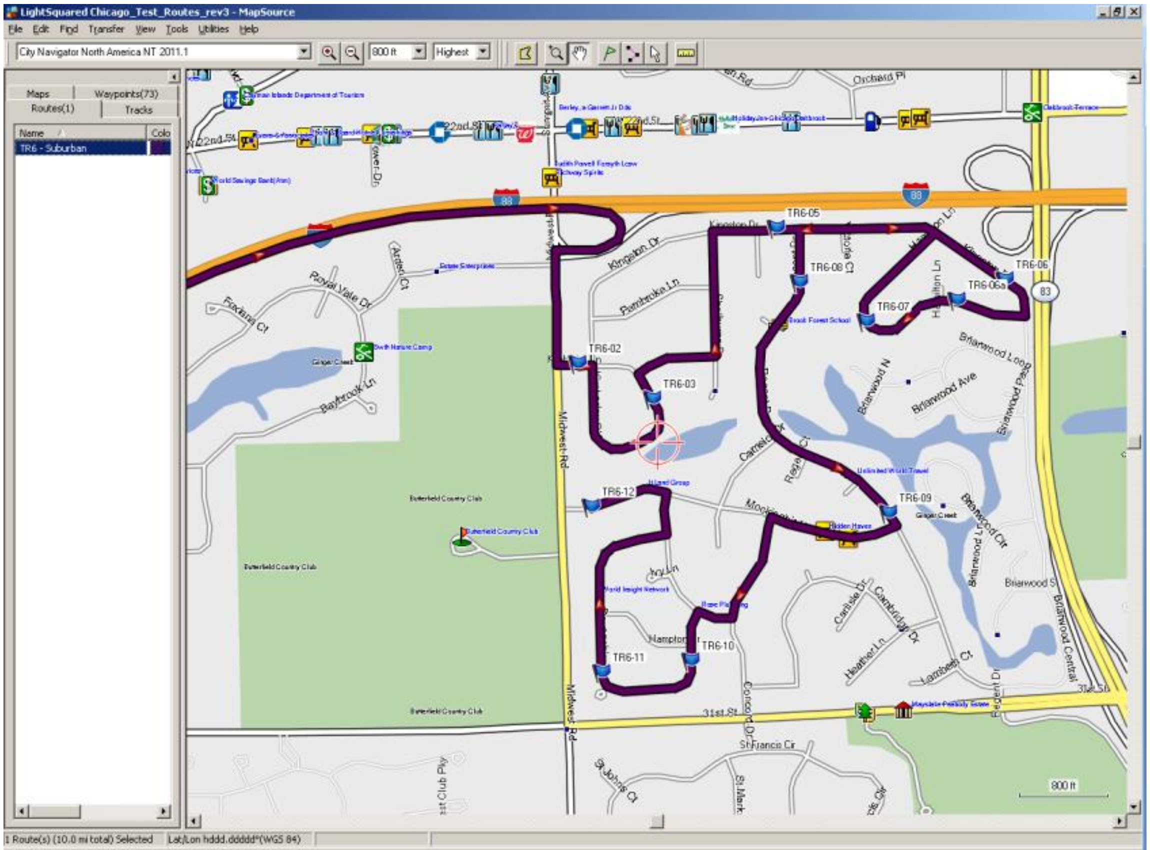
C. Suburban Test Route Segment 2 Map Image



D. Suburban Test Route Segment 2 Driving Directions

	Maneuver / Waypoint	Cumulative Distance	Leg Distance	Coordinates
1	TR5-01	0 ft		N41.82986 W88.07748
2	Get on Scottdale Cir and drive north	0 ft	0 ft	N41.82986 W88.07748
3	Turn right onto Butterfield Rd	103 ft	103 ft	N41.83014 W88.07748
4	Turn right onto Park Blvd	0.6 mi	0.5 mi	N41.83010 W88.06718
5	Turn right onto Hackberry Dr	0.6 mi	321 ft	N41.82924 W88.06744
6	TR5-02	0.9 mi	0.3 mi	N41.82914 W88.07339
7	Get on Hackberry Dr and drive west	0.9 mi	0 ft	N41.82914 W88.07339
8	Turn left onto Blackcherry Ln	1.0 mi	307 ft	N41.82920 W88.07452
9	TR5-03	1.4 mi	0.4 mi	N41.82477 W88.07770
10	Get on Blackcherry Ln and drive southwest	1.4 mi	0 ft	N41.82477 W88.07770
11	Turn left onto Red Oak Dr	1.4 mi	270 ft	N41.82422 W88.07821
12	TR5-04	1.7 mi	0.3 mi	N41.82313 W88.07330
13	Get on Red Oak Dr and drive east	1.7 mi	0 ft	N41.82313 W88.07330
14	Turn left onto Park Blvd	1.8 mi	0.1 mi	N41.82246 W88.07104
15	Turn left onto Sycamore Dr	1.9 mi	525 ft	N41.82379 W88.07031
16	TR5-05	2.0 mi	297 ft	N41.82416 W88.07128
17	Get on Sycamore Dr and drive northwest	2.0 mi	0 ft	N41.82416 W88.07128
18	Turn right onto Mulberry Ln	2.1 mi	0.1 mi	N41.82482 W88.07387
19	TR5-06	2.2 mi	500 ft	N41.82552 W88.07247
20	Get on Mulberry Ln and drive east	2.2 mi	0 ft	N41.82552 W88.07247
21	Turn left onto S Tamarack Dr	2.4 mi	0.2 mi	N41.82693 W88.07018
22	Turn right onto Butternut Ln	2.5 mi	418 ft	N41.82744 W88.07156
23	TR5-07	2.5 mi	317 ft	N41.82824 W88.07109
24	Get on Butternut Ln and drive northeast	2.5 mi	0 ft	N41.82824 W88.07109
25	Turn right onto Hackberry Dr	2.6 mi	296 ft	N41.82903 W88.07091
26	TR5-08	2.8 mi	0.2 mi	N41.82920 W88.06798
27	Get on Hackberry Dr and drive east	2.8 mi	0 ft	N41.82920 W88.06798
28	Turn right onto Park Blvd	2.8 mi	148 ft	N41.82924 W88.06744
29	Turn left onto Tamarack Dr	3.0 mi	0.3 mi	N41.82568 W88.06915
30	Turn left onto Shagbark Ln	3.1 mi	482 ft	N41.82504 W88.06761
31	Turn right onto Tamarack Dr	3.2 mi	105 ft	N41.82529 W88.06744
32	TR5-09	3.3 mi	0.1 mi	N41.82434 W88.06562
33	Get on Tamarack Dr and drive southeast	3.3 mi	0 ft	N41.82434 W88.06562
34	Turn left onto Juniper Ln	3.3 mi	238 ft	N41.82396 W88.06490
35	Turn left onto Balsam Dr	3.4 mi	365 ft	N41.82478 W88.06413
36	TR5-10	3.4 mi	257 ft	N41.82519 W88.06490
37	Get on Balsam Dr and drive northwest	3.4 mi	0 ft	N41.82519 W88.06490
38	Turn right onto Shagbark Ln	3.6 mi	0.1 mi	N41.82624 W88.06684
39	Turn right onto Birchwood Dr	3.6 mi	382 ft	N41.82718 W88.06623
40	TR5-11	3.6 mi	100 ft	N41.82702 W88.06594
41	Get on Birchwood Dr and drive southeast	3.6 mi	0 ft	N41.82702 W88.06594
42	Turn left onto Juniper Ln	3.8 mi	0.2 mi	N41.82559 W88.06336
43	Turn right onto Ironwood Dr	3.9 mi	371 ft	N41.82641 W88.06254
44	Turn left onto Burr Oak Dr	4.0 mi	0.1 mi	N41.82521 W88.06040
45	Turn left onto Arboretum Rd	4.2 mi	0.2 mi	N41.82765 W88.05799
46	TR5-12	4.4 mi	0.2 mi	N41.82997 W88.05894

E. Suburban Test Route Segment 3 Map Image

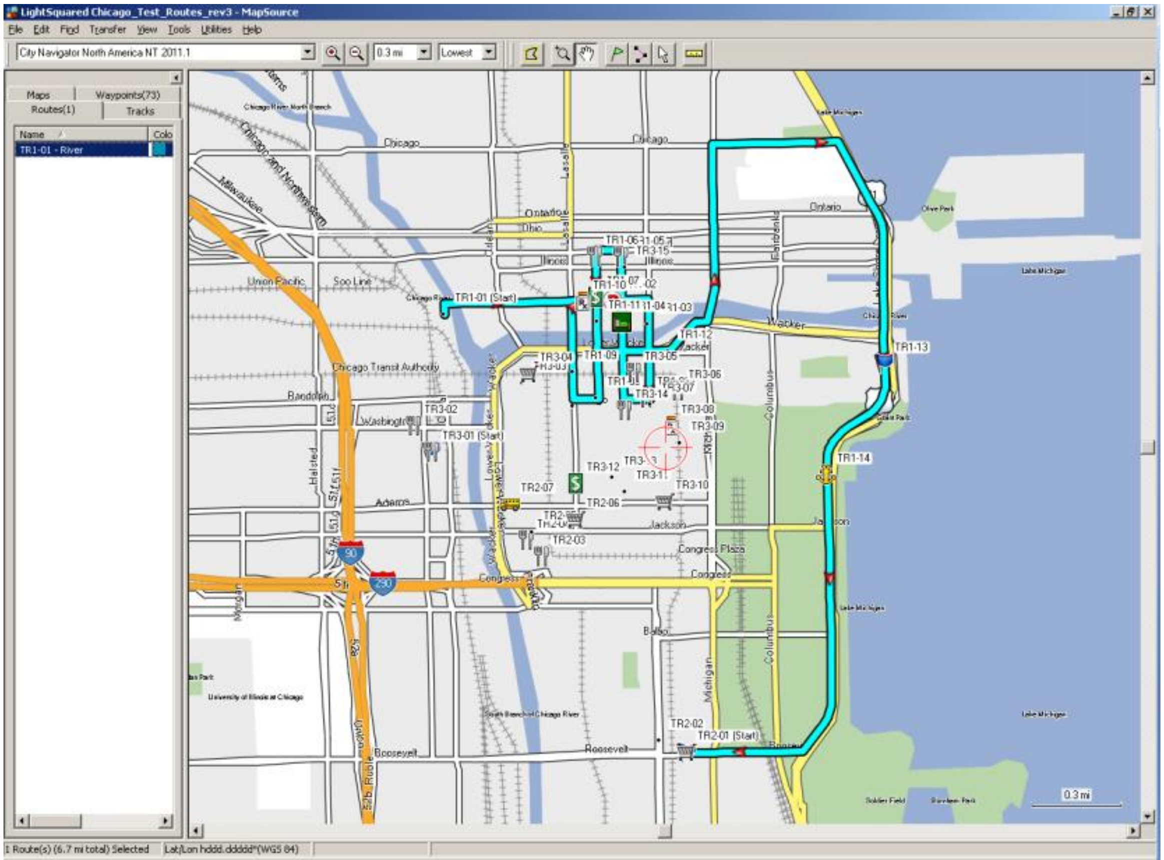


F. Suburban Test Route Segment 3 Driving Directions

	Maneuver / Waypoint	Cumulative Distance	Leg Distance	Coordinates
1	TR6-01	0 ft		N41.82997 W88.05894
2	Get on Arboretum Rd and drive north	0 ft	0 ft	N41.82997 W88.05894
3	Turn right onto Butterfield Rd	271 ft	271 ft	N41.83070 W88.05911
4	Take the I-355 S ramp to the right towards Jolie	1.5 mi	1.5 mi	N41.83280 W88.03049
5	Take the I-88 E/I-88 W ramp to the right towards	1.9 mi	0.4 mi	N41.82740 W88.02886
6	Take the I-88 E ramp to the left towards Chicago	2.1 mi	0.2 mi	N41.82435 W88.02898
7	Keep left onto I-88 E	4.1 mi	2.0 mi	N41.83619 W88.00087
8	Take the Midwest Rd ramp to the right	5.7 mi	1.6 mi	N41.84431 W87.97165
9	Turn left onto Midwest Rd	5.9 mi	0.2 mi	N41.84328 W87.97225
10	Turn left onto Kimberley Ln	6.1 mi	0.2 mi	N41.84044 W87.97221
11	TR6-02	6.2 mi	174 ft	N41.84044 W87.97157
12	Get on Kimberley Ln and drive east	6.2 mi	0 ft	N41.84044 W87.97157
13	Turn right onto Kimberley Cir	6.2 mi	118 ft	N41.84044 W87.97113
14	TR6-03	6.5 mi	0.3 mi	N41.83957 W87.96932
15	Get on Kimberley Cir and drive northwest	6.5 mi	0 ft	N41.83957 W87.96932
16	Turn right onto Charleton Pl	6.5 mi	268 ft	N41.84023 W87.96976
17	Turn left onto Shelburne Dr	6.7 mi	0.1 mi	N41.84066 W87.96744
18	Turn right onto Kingston Dr	6.9 mi	0.2 mi	N41.84375 W87.96753
19	TR6-05	7.0 mi	521 ft	N41.84377 W87.96561
20	Get on Kingston Dr and drive east	7.0 mi	0 ft	N41.84377 W87.96561
21	TR6-06	7.4 mi	0.4 mi	N41.84252 W87.95873
22	Get on Kingston Dr and drive southeast	7.4 mi	0 ft	N41.84252 W87.95873
23	Turn right onto Hamilton Ln	7.4 mi	387 ft	N41.84165 W87.95813
24	TR6-06a	7.5 mi	0.1 mi	N41.84201 W87.96017
25	Get on Hamilton Ln and drive west	7.5 mi	0 ft	N41.84201 W87.96017
26	TR6-07	7.7 mi	0.2 mi	N41.84149 W87.96290
27	Get on Hamilton Ln and drive northwest	7.7 mi	0 ft	N41.84148 W87.96290
28	Turn left onto Kingston Dr	7.9 mi	0.2 mi	N41.84371 W87.96083
29	Turn left onto Regent Dr	8.1 mi	0.2 mi	N41.84379 W87.96491
30	TR6-08	8.2 mi	495 ft	N41.84243 W87.96491
31	Get on Regent Dr and drive south	8.2 mi	0 ft	N41.84243 W87.96491
32	TR6-09	8.7 mi	0.5 mi	N41.83677 W87.96222
33	Get on Regent Dr and drive southeast	8.7 mi	0 ft	N41.83677 W87.96222
34	Turn right onto Mockingbird Ln	8.7 mi	117 ft	N41.83650 W87.96199
35	Turn left onto Concord Dr	8.9 mi	0.2 mi	N41.83671 W87.96577
36	Turn right onto Ivy Ln	9.1 mi	0.2 mi	N41.83422 W87.96693
37	Turn left onto Devonshire Dr	9.2 mi	294 ft	N41.83439 W87.96796
38	TR6-10	9.3 mi	475 ft	N41.83312 W87.96817
39	Get on Devonshire Dr and drive south	9.3 mi	0 ft	N41.83312 W87.96817
40	TR6-11	9.4 mi	0.2 mi	N41.83286 W87.97085
41	Get on Devonshire Dr and drive north	9.4 mi	0 ft	N41.83286 W87.97085
42	Turn left onto Ivy Ln	9.8 mi	0.3 mi	N41.83628 W87.96890
43	Turn left onto Mockingbird Ln	9.8 mi	379 ft	N41.83731 W87.96890
44	TR6-12	10.0 mi	0.1 mi	N41.83693 W87.97116

3. General Navigation Test Case #2 (Urban Canyon)

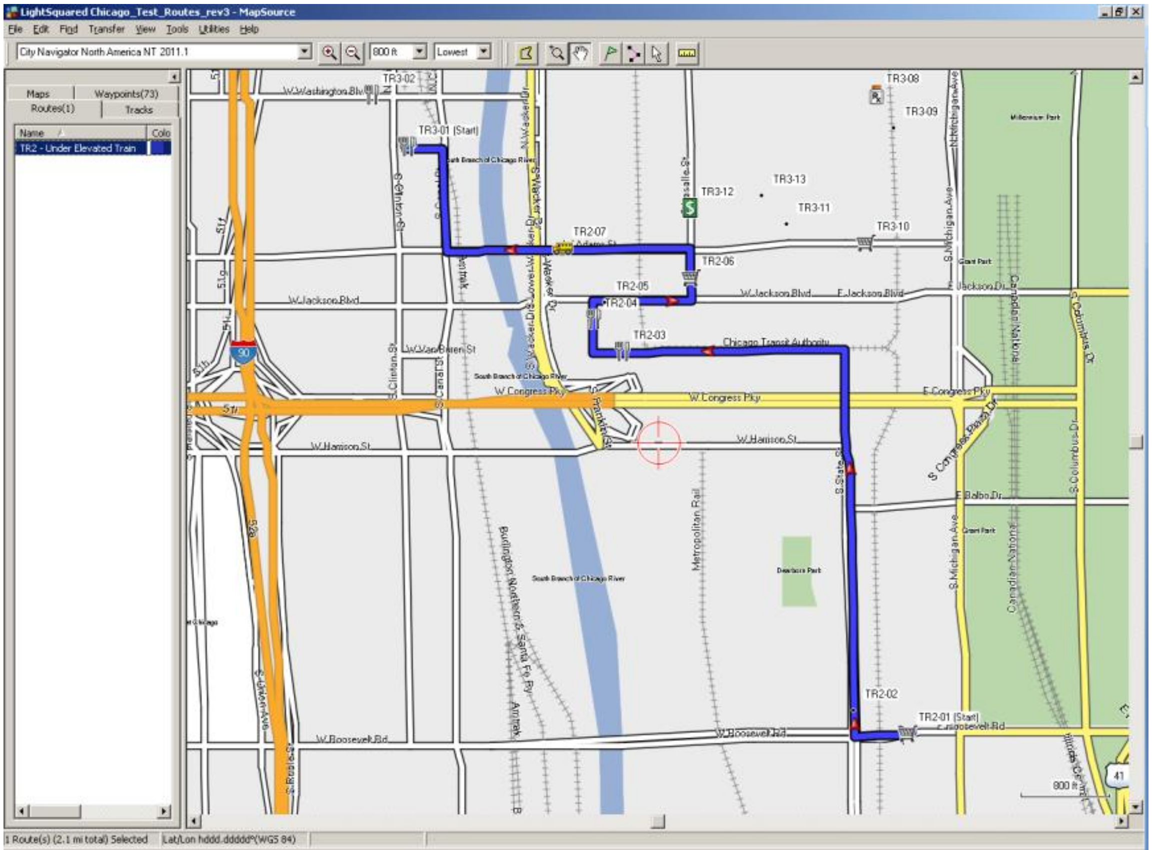
A. Urban Canyon Test Route Segment 1 Map Image



B. Urban Canyon Test Route Segment 1 Driving Directions

	Maneuver / Waypoint	Cumulative Distance	Leg Distance	Coordinates
1	TR1-01 (Start)	0 ft		N41.88855 W87.63997
2	Get on N Canal St and drive north	0 ft	0 ft	N41.88855 W87.63997
3	Turn right onto W Kinzie St	188 ft	188 ft	N41.88907 W87.64000
4	TR1-02	0.5 mi	0.5 mi	N41.88920 W87.63009
5	Get on W Kinzie St and drive east	0.6 mi	10 ft	N41.88922 W87.63009
6	Turn right onto N State St	0.7 mi	0.1 mi	N41.88928 W87.62803
7	TR1-03	0.7 mi	451 ft	N41.88808 W87.62803
8	Get on N State St and drive south	0.7 mi	12 ft	N41.88808 W87.62798
9	Turn right onto W Randolph St	1.0 mi	0.2 mi	N41.88447 W87.62790
10	TR1-03a	1.0 mi	74 ft	N41.88452 W87.62811
11	Get on W Randolph St and drive west	1.0 mi	16 ft	N41.88447 W87.62811
12	Turn right onto N Dearborn St	1.1 mi	362 ft	N41.88447 W87.62944
13	TR1-04	1.3 mi	0.3 mi	N41.88817 W87.62953
14	Get on N Dearborn St and drive north	1.3 mi	3 ft	N41.88817 W87.62954
15	TR1-05	1.6 mi	0.2 mi	N41.89130 W87.62961
16	Get on N Dearborn St and drive north	1.6 mi	7 ft	N41.89130 W87.62964
17	Turn left onto W Grand Ave	1.6 mi	126 ft	N41.89164 W87.62966
18	Turn left onto N Clark St	1.7 mi	397 ft	N41.89164 W87.63112
19	TR1-06	1.7 mi	125 ft	N41.89134 W87.63116
20	Get on N Clark St and drive south	1.7 mi	16 ft	N41.89134 W87.63110
21	TR1-07	1.8 mi	0.1 mi	N41.88937 W87.63107
22	Get on N Clark St and drive south	1.8 mi	9 ft	N41.88937 W87.63104
23	Turn right onto W Randolph St	2.2 mi	0.3 mi	N41.88447 W87.63090
24	TR1-08	2.2 mi	51 ft	N41.88452 W87.63103
25	Get on W Randolph St and drive west	2.2 mi	16 ft	N41.88447 W87.63103
26	Turn right onto N Lasalle St	2.2 mi	373 ft	N41.88447 W87.63240
27	TR1-09	2.3 mi	482 ft	N41.88576 W87.63240
28	Get on N Lasalle St and drive north	2.3 mi	12 ft	N41.88576 W87.63245
29	Turn right onto W Kinzie St	2.6 mi	0.2 mi	N41.88920 W87.63253
30	TR1-10	2.6 mi	191 ft	N41.88915 W87.63189
31	Get on W Kinzie St and drive east	2.6 mi	16 ft	N41.88920 W87.63189
32	Turn right onto N Clark St	2.7 mi	233 ft	N41.88920 W87.63103
33	TR1-11	2.7 mi	372 ft	N41.88821 W87.63099
34	Get on N Clark St and drive south	2.7 mi	12 ft	N41.88821 W87.63103
35	Turn left onto W Wacker Dr	2.8 mi	0.1 mi	N41.88675 W87.63099
36	TR1-12	3.0 mi	0.2 mi	N41.88679 W87.62682
37	Get on E Wacker Dr and drive east	3.1 mi	14 ft	N41.88683 W87.62683
38	Turn left onto N Upper Michigan Ave	3.2 mi	0.2 mi	N41.88821 W87.62455
39	Turn right onto E Chicago Ave	3.8 mi	0.6 mi	N41.89675 W87.62425
40	Turn right onto US 41 S	4.2 mi	0.4 mi	N41.89688 W87.61687
41	TR1-13	5.0 mi	0.8 mi	N41.88617 W87.61412
42	Get on N Lake Shore Dr and drive south	5.0 mi	0 ft	N41.88617 W87.61412
43	TR1-14	5.4 mi	0.4 mi	N41.88083 W87.61751
44	Get on S Lake Shore Dr and drive south	5.4 mi	2 ft	N41.88083 W87.61750
45	Turn right onto E Roosevelt Rd	6.3 mi	0.9 mi	N41.86752 W87.61893
46	TR1-15	6.7 mi	0.4 mi	N41.86744 W87.62575

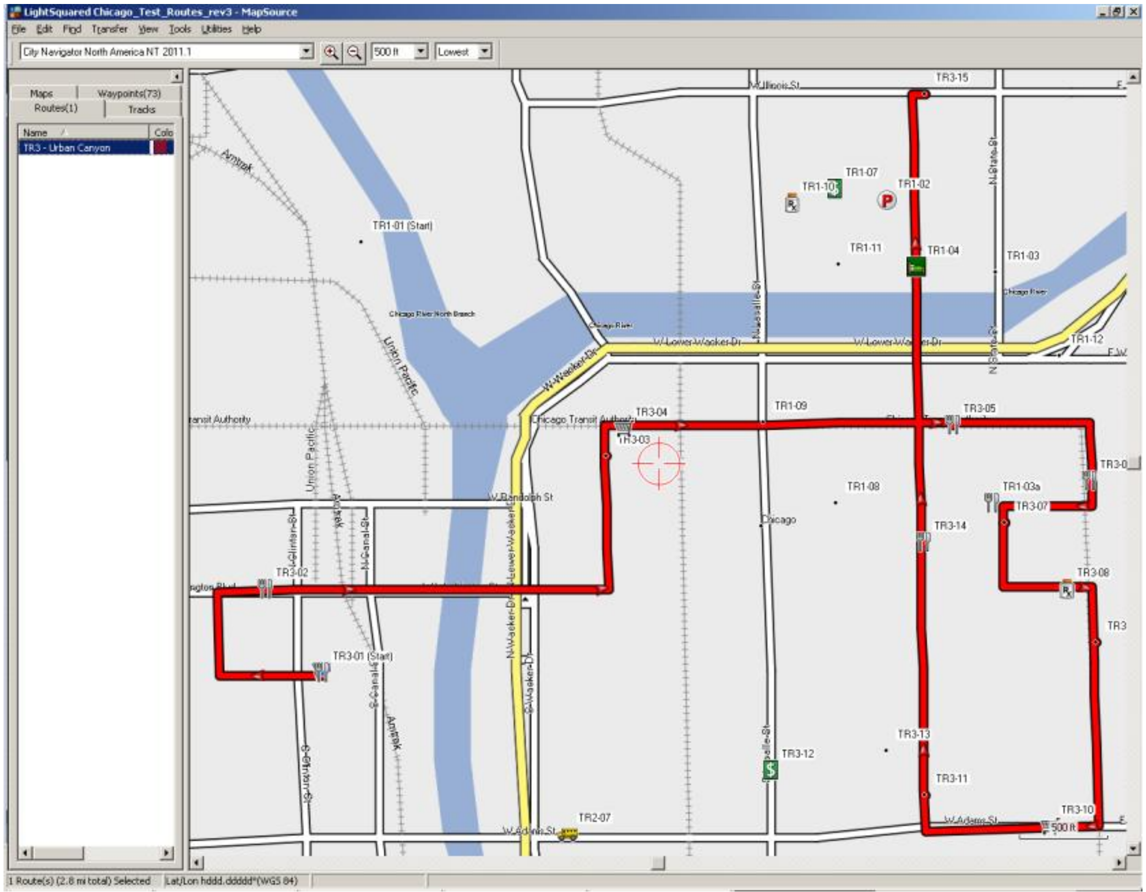
C. Urban Canyon Test Route Segment 2 Map Image


LightSquared Chicago_Test_Routes_rev3 - MapSource
City Navigator North America NT 2011.1
TR2 - Under Elevated Train
TR3-01 (Start)
TR3-02
TR3-08
TR3-09
TR3-10
TR3-11
TR3-12
TR3-13
TR2-01 (Start)
TR2-02
TR2-03
TR2-04
TR2-05
TR2-06
TR2-07
W Jackson Blvd
W Congress Pky
W Harrison St
W Roosevelt Rd
Chicago Transit Authority
1 Route(s) (2.1 mi total) Selected

D. Urban Canyon Test Route Segment 2 Driving Directions

	Maneuver / Waypoint	Cumulative Distance	Leg Distance	Coordinates
1	TR2-01 (Start)	0 ft		N41.86748 W87.62575
2	Get on E Roosevelt Rd and drive west	16 ft	16 ft	N41.86744 W87.62575
3	Turn right onto S State St	448 ft	432 ft	N41.86739 W87.62734
4	TR2-02	0.1 mi	239 ft	N41.86804 W87.62734
5	Get on S State St and drive north	0.1 mi	4 ft	N41.86804 W87.62735
6	Turn left onto W Van Buren St	0.7 mi	0.6 mi	N41.87692 W87.62764
7	TR2-03	1.1 mi	0.3 mi	N41.87688 W87.63429
8	Get on W Van Buren St and drive west	1.1 mi	16 ft	N41.87684 W87.63429
9	Turn right onto S Franklin St	1.1 mi	245 ft	N41.87684 W87.63519
10	TR2-04	1.2 mi	309 ft	N41.87765 W87.63515
11	Get on S Franklin St and drive north	1.2 mi	12 ft	N41.87765 W87.63519
12	Turn right onto W Jackson Blvd	1.2 mi	172 ft	N41.87812 W87.63519
13	TR2-05	1.3 mi	121 ft	N41.87808 W87.63481
14	Get on W Jackson Blvd and drive east	1.3 mi	16 ft	N41.87812 W87.63481
15	Turn left onto S Lasalle St	1.4 mi	0.1 mi	N41.87812 W87.63223
16	TR2-06	1.4 mi	213 ft	N41.87868 W87.63223
17	Get on S Lasalle St and drive north	1.4 mi	9 ft	N41.87868 W87.63227
18	Turn left onto W Adams St	1.5 mi	267 ft	N41.87941 W87.63227
19	TR2-07	1.7 mi	0.2 mi	N41.87941 W87.63609
20	Get on W Adams St and drive west	1.7 mi	16 ft	N41.87937 W87.63609
21	Turn right onto S Canal St	1.9 mi	0.2 mi	N41.87932 W87.63957
22	Turn left onto W Madison St	2.0 mi	0.2 mi	N41.88186 W87.63970
23	TR2-08	2.1 mi	296 ft	N41.88190 W87.64073

E. Urban Canyon Test Route Segment 3 Map Image



F. Urban Canyon Test Route Segment 3 Driving Directions

	Maneuver / Waypoint	Cumulative Distance	Leg Distance	Coordinates
1	TR3-01 (Start)	0 ft		N41.88190 W87.64073
2	Get on W Madison St and drive west	16 ft	16 ft	N41.88186 W87.64073
3	Turn right onto N Jefferson St	0.1 mi	525 ft	N41.88186 W87.64266
4	Turn right onto W Washington Blvd	0.2 mi	470 ft	N41.88314 W87.64270
5	TR3-02	0.2 mi	252 ft	N41.88319 W87.64180
6	Get on W Washington Blvd and drive east	0.2 mi	6 ft	N41.88317 W87.64180
7	Turn left onto N Franklin St	0.6 mi	0.3 mi	N41.88319 W87.63532
8	TR3-03	0.7 mi	0.1 mi	N41.88525 W87.63536
9	Get on N Franklin St and drive north	0.7 mi	12 ft	N41.88525 W87.63541
10	Turn right onto W Lake St	0.8 mi	172 ft	N41.88572 W87.63541
11	TR3-04	0.8 mi	121 ft	N41.88568 W87.63502
12	Get on W Lake St and drive east	0.8 mi	16 ft	N41.88572 W87.63502
13	TR3-05	1.1 mi	0.3 mi	N41.88572 W87.62884
14	Get on W Lake St and drive east	1.1 mi	16 ft	N41.88576 W87.62884
15	Turn right onto N Wabash Ave	1.2 mi	0.1 mi	N41.88576 W87.62627
16	TR3-06	1.3 mi	341 ft	N41.88486 W87.62627
17	Get on N Wabash Ave and drive south	1.3 mi	12 ft	N41.88486 W87.62622
18	Turn right onto E Randolph St	1.3 mi	141 ft	N41.88447 W87.62622
19	Turn left onto N State St	1.4 mi	455 ft	N41.88447 W87.62790
20	TR3-07	1.4 mi	106 ft	N41.88422 W87.62785
21	Get on N State St and drive south	1.4 mi	12 ft	N41.88422 W87.62790
22	Turn left onto E Washington St	1.5 mi	360 ft	N41.88323 W87.62790
23	TR3-08	1.6 mi	342 ft	N41.88319 W87.62670
24	Get on E Washington St and drive east	1.6 mi	16 ft	N41.88323 W87.62670
25	Turn right onto N Wabash Ave	1.6 mi	128 ft	N41.88323 W87.62622
26	TR3-09	1.7 mi	329 ft	N41.88237 W87.62614
27	Get on N Wabash Ave and drive south	1.7 mi	15 ft	N41.88237 W87.62619
28	Turn right onto E Adams St	1.9 mi	0.2 mi	N41.87954 W87.62609
29	TR3-10	1.9 mi	254 ft	N41.87954 W87.62700
30	Get on E Adams St and drive west	1.9 mi	9 ft	N41.87952 W87.62699
31	Turn right onto S Dearborn St	2.0 mi	0.1 mi	N41.87945 W87.62936
32	TR3-11	2.1 mi	214 ft	N41.88001 W87.62936
33	Get on S Dearborn St and drive north	2.1 mi	10 ft	N41.88001 W87.62939
34	TR3-14	2.3 mi	0.3 mi	N41.88392 W87.62940
35	Get on N Dearborn St and drive north	2.3 mi	12 ft	N41.88392 W87.62944
36	Turn right onto W Illinois St	2.8 mi	0.5 mi	N41.89083 W87.62961
37	TR3-15	2.8 mi	72 ft	N41.89083 W87.62936

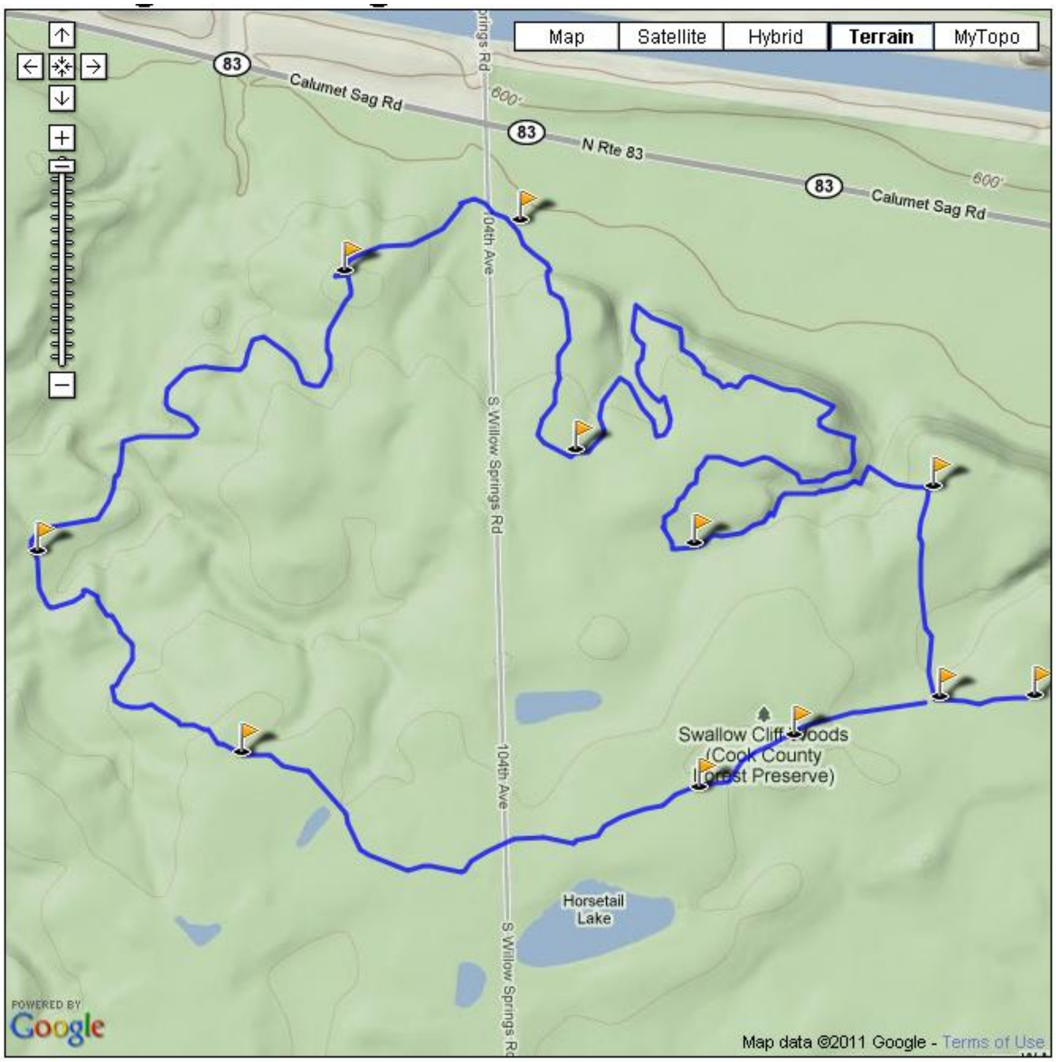
4. Outdoor Test Case (Deep Forest)

This test case assumes that all trees in this area are fully in leaf.

Location: Cook County Forest Preserve's *Swallow Cliffs Woods*

Palos Park, IL 60464

A. Deep Forest Test Route Map Image



**Note: Map image and directions sourced from Backpacker / Trimble Outdoors:*
http://bp2.trimbleoutdoors.com/ViewTrip.aspx?tripId=23837

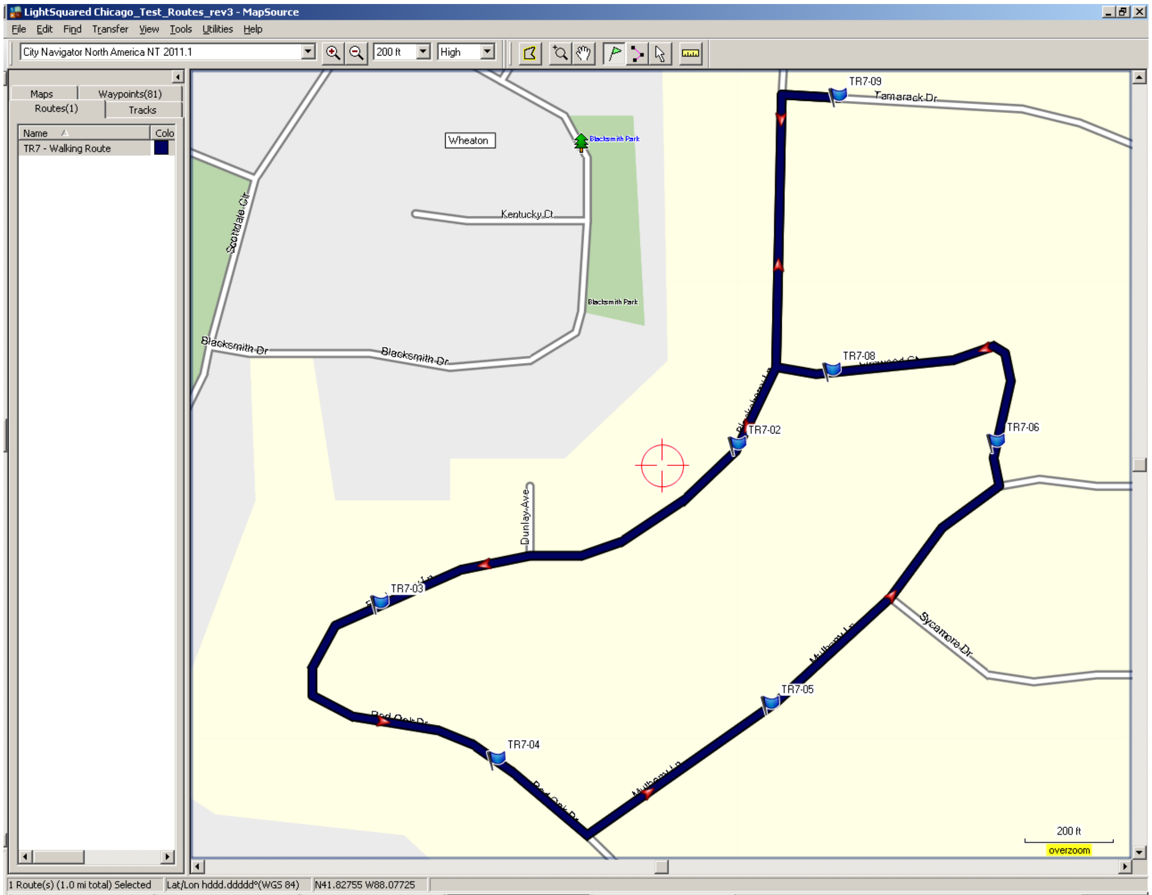
B. Deep Forest Test Route Walking Directions

Maneuver	Coordinates	
Start: Take R onto Brown Trail from lot	N41.674030	W87.860046
Swing Right @ 3-way and descend through first bog	N41.674011	W87.862587
Stay left on footpath; bear right into ravine, then follow gulch left.	N41.678280	W87.862793
Turn left at top of ravine; loop around on Yellow-blazed trail back to Swallow Cliffs	N41.677109	W87.869232
Zigzag along cliffs and bear right for descent to Teason's Woods	N41.678989	W87.872467
Turn right then go uphill	N41.683651	W87.873970
Crest knoll and take left and meander along cliffs	N41.682621	W87.878731
Left following yellow blazes	N41.676952	W87.887070
Reach ridge crest and take left at Y to skirt shoreline of Horsetail Lake	N41.672871	W87.881516
Stay left on yellow trail	N41.672173	W87.869133
Left at Y onto Brown Trail for .2 mi. to close loop	N41.673218	W87.866547

5. Fitness Test Case (Arm Swing Environment)

This test case assumes that all trees in this area are fully in leaf.

A. Arm Swing Test Route Map Image



B. Arm Swing Test Route Jogging Directions

	Maneuver / Waypoint	Cumulative Distance	Leg Distance	Coordinates
1	TR7-01	0 ft		N41.82789 W88.07426
2	Get on Tamarack Dr and drive west	0 ft	0 ft	N41.82789 W88.07426
3	Turn left onto Blackcherry Ln	116 ft	116 ft	N41.82791 W88.07469
4	TR7-02	0.2 mi	0.2 mi	N41.82575 W88.07502
5	Get on Blackcherry Ln and drive southwest	0.2 mi	0 ft	N41.82575 W88.07502
6	TR7-03	0.3 mi	0.2 mi	N41.82477 W88.07770
7	Get on Blackcherry Ln and drive southwest	0.3 mi	0 ft	N41.82477 W88.07770
8	Turn left onto Red Oak Dr	0.4 mi	270 ft	N41.82422 W88.07821
9	TR7-04	0.5 mi	411 ft	N41.82382 W88.07683
10	Get on Red Oak Dr and drive southeast	0.5 mi	0 ft	N41.82382 W88.07683
11	Turn left onto Mulberry Ln	0.5 mi	248 ft	N41.82336 W88.07615
12	TR7-05	0.6 mi	473 ft	N41.82415 W88.07477
13	Get on Mulberry Ln and drive northeast	0.6 mi	0 ft	N41.82415 W88.07477
14	Turn left onto Elmwood Ct	0.7 mi	0.1 mi	N41.82551 W88.07306
15	TR7-06	0.7 mi	96 ft	N41.82577 W88.07308
16	Get on Elmwood Ct and drive northwest	0.7 mi	0 ft	N41.82577 W88.07308
17	TR7-08	0.9 mi	0.1 mi	N41.82621 W88.07431
18	Get on Elmwood Ct and drive west	0.9 mi	0 ft	N41.82621 W88.07431
19	Turn right onto Blackcherry Ln	0.9 mi	116 ft	N41.82624 W88.07473
20	Turn right onto Tamarack Dr	1.0 mi	0.1 mi	N41.82791 W88.07469
21	TR7-09	1.0 mi	116 ft	N41.82789 W88.07426

Appendix D

Log File Format for Testing V1.0

1. Introduction

In order to simplify the processing to test results, a common log file is proposed. This log file is a simple comma delimited text file that will be very easy for test lab to import into any data processing tool they choose, such as Excel or MATLAB .

A note about time: Time is specified in the table below as GPS time. Currently, there is a 15 second offset between GPS time and UTC time (UTC leads GPS by 15 seconds). Due to issues with devices accurately reporting UTC (the number of leap seconds has changed over the years), an unambiguous time base is GPS time, which is consistent between all units.

2. File Format

Column Number (Letter)	Quantity	Format	Example
1 (A)	Year	xxxx	2011
2 (B)	Month	xx (leading zero optional)	05
3 (C)	Day(GPS Time, no time zone offset)	xx (leading zero optional)	02
4 (D)	Hour (GPS Time, no time zone offset)	xx (24 hour format)	14
5 (E)	Minute (GPS Time, no leap second offset)	xx	27
6 (F)	Second (GPS time, no leap second offset)	xx	59
7 (G)	Fix Indicator 0 – No fix 1 – 2D Fix 2 – 3D Fix 3 – 2D Diff. Fix 4 – 3D Diff. Fix	x	1
8 (H)	Latitude (WGS-84), decimal degrees Blank if no fix	±dd.ddddddd leading zero optional	38.1234567
9 (I)	Longitude (WGS-84), decimal degrees Western hemisphere negative Blank if no fix	±ddd.ddddddd leading zeros optional	-95.1234567
10 (J)	Height Above Ellipsoid (WGS-84), m Blank if no fix	±xxxxx.xx leading zeros optional	325.12
11 (K)	East Velocity, m/s Blank if no fix	±xxxxx.xx leading zeros optional	-23.12
12 (L)	North Velocity, m/s Blank if no fix	±xxxxx.xx leading zeros optional	16.12

13 (M)	Up Velocity, m/s Positive up Blank if no fix	±xxxxx.xx leading zeros optional	-2.46
14 (N)	C/N_0, PRN1 0.00 if PRN is not being tracked	xx.xx	39.83
15 (O)	C/N_0, PRN2 0.00 if PRN is not being tracked	xx.xx	41.25
More columns to enumerate all 32 GPS PRNs			
46 (AS)	C/N_0, PRN32 0.00 if PRN is not being tracked	xx.xx	41.25
47 (AT)	C/N_0, SVID33 (PRN 120) For WAAS 0.00 if PRN is not being tracked	xx.xx	38.71
More columns if needed to enumerate additional WAAS satellites			

Appendix E

LightSquared Transmitter Simulator Test Bed Limits

(provided by Alcatel-Lucent / Bell Labs)

1. Introduction

The following tables have been provided by Bell Labs to show the limits of the test bed with respect to interferer transmit power and simulated distance from an actual LightSquared transmit antenna. Any deviations from this setup and calibration shall be noted in the final test report.

2. Test Bed Limits – Lightsquared Downlink Simulator

Bell Labs LightSquared GPS Test Bed Calibration C.Meyer 11-May-11

Maximum LightSquared TX Power:	**62**	dBm EIRP	**(downlink)**
Test Antenna Separation:	**3**	Meter	
Antenna Front-Back Isolation:	**30**	dB	
Radiating Antenna Gain:	**8.8**	dBi	
Free space loss frequency:	**1550.2**	MHz	
Test Bed Power Meter Offset:	**20**	dB	

Raw Pwr Mtr dBm	LTE TX Power dBm	LTE TX EIRP dBi	Propgation Loss dB	Power at device dBm	Power diff dB	Equivalent Boresight Distance Meters	Equivalent Boresight Distance Feet	Equivalent off-lobe Distance Meters	Notes
-25.0	-5	3.8	45.8	-42.0	104.0	2438	8000	77.1	1
-24.0	-4	4.8	45.8	-41.0	103.0	2173	7130	68.7	
-23.0	-3	5.8	45.8	-40.0	102.0	1937	6355	61.3	
-22.0	-2	6.8	45.8	-39.0	101.0	1726	5664	54.6	
-21.0	-1	7.8	45.8	-38.0	100.0	1539	5048	48.7	
-20.0	0	8.8	45.8	-37.0	99.0	1371	4499	43.4	
-19.0	1	9.8	45.8	-36.0	98.0	1222	4010	38.6	
-18.0	2	10.8	45.8	-35.0	97.0	1089	3574	34.4	
-17.0	3	11.8	45.8	-34.0	96.0	971	3185	30.7	
-16.0	4	12.8	45.8	-33.0	95.0	865	2839	27.4	
-15.0	5	13.8	45.8	-32.0	94.0	771	2530	24.4	
-14.0	6	14.8	45.8	-31.0	93.0	687	2255	21.7	
-13.0	7	15.8	45.8	-30.0	92.0	613	2010	19.4	
-12.0	8	16.8	45.8	-29.0	91.0	546	1791	17.3	
-11.0	9	17.8	45.8	-28.0	90.0	487	1596	15.4	
-10.0	10	18.8	45.8	-27.0	89.0	434	1423	13.7	
-9.0	11	19.8	45.8	-26.0	88.0	386	1268	12.2	
-8.0	12	20.8	45.8	-25.0	87.0	344	1130	10.9	
-7.0	13	21.8	45.8	-24.0	86.0	307	1007	9.7	
-6.0	14	22.8	45.8	-23.0	85.0	274	898	8.7	
-5.0	15	23.8	45.8	-22.0	84.0	244	800	7.7	
-4.0	16	24.8	45.8	-21.0	83.0	217	713	6.9	
-3.0	17	25.8	45.8	-20.0	82.0	194	635	6.1	
-2.0	18	26.8	45.8	-19.0	81.0	173	566	5.5	
-1.0	19	27.8	45.8	-18.0	80.0	154	505	4.9	
0.0	20	28.8	45.8	-17.0	79.0	137	450	4.3	
1.0	21	29.8	45.8	-16.0	78.0	122	401	3.9	
2.0	22	30.8	45.8	-15.0	77.0	109	357	3.4	
3.0	23	31.8	45.8	-14.0	76.0	97	318	3.1	
4.0	24	32.8	45.8	-13.0	75.0	87	284	2.7	
5.0	25	33.8	45.8	-12.0	74.0	77	253	2.4	
6.0	26	34.8	45.8	-11.0	73.0	69	225	2.2	
7.0	27	35.8	45.8	-10.0	72.0	61	201	1.9	
8.0	28	36.8	45.8	-9.0	71.0	55	179	1.7	
9.0	29	37.8	45.8	-8.0	70.0	49	160	1.5	
10.0	30	38.8	45.8	-7.0	69.0	43	142	1.4	
11.0	31	39.8	45.8	-6.0	68.0	39	127	1.2	
12.0	32	40.8	45.8	-5.0	67.0	34	113	1.1	
13.0	33	41.8	45.8	-4.0	66.0	31	101	1.0	
14.0	34	42.8	45.8	-3.0	65.0	27	90	0.9	
15.0	35	43.8	45.8	-2.0	64.0	24	80	0.8	
16.0	36	44.8	45.8	-1.0	63.0	22	71	0.7	
17.0	37	45.8	45.8	0.0	62.0	19	64	0.6	
18.0	38	46.8	45.8	1.0	61.0	17	57	0.5	
19.0	39	47.8	45.8	2.0	60.0	15	50	0.5	
20.0	40	48.8	45.8	3.0	59.0	14	45	0.4	2

Notes:
1 Estimated Minimum RF Test Bed Power, equiv. to > 2.4 km to antenna boresight
2 Estimated Maximum RF Test Bed Power, equiv. to < 15 m to antenna boresight

3. Test Bed Limits – Lightsquared Uplink Simulator

Bell Labs LightSquared GPS Test Bed Calibration C.Meyer 11-May-11

Maximum LightSquared TX Power:	**23**	dBm EIRP	**(uplink)**
Test Antenna Separation:	**3**	Meter	
Antenna Front-Back Isolation:	**n/a**	dB	
Radiating Antenna Gain:	**8.8**	dBi	
Free space loss frequency:	**1632.5**	MHz	
Test Bed Power Meter Offset:	**20**	dB	

Raw Pwr Mtr dBm	LTE TX Power dBm	LTE TX EIRP dBi	Propgation Loss dB	Power at device dBm	Power diff dB	Equivalent Distance Meters	Equivalent Distance Feet	Notes
-25	-5	3.8	46.2	-42.4	65.4	27	90	1
-24	-4	4.8	46.2	-41.4	64.4	24	80	
-23	-3	5.8	46.2	-40.4	63.4	22	71	
-22	-2	6.8	46.2	-39.4	62.4	19	64	
-21	-1	7.8	46.2	-38.4	61.4	17	57	
-20	0	8.8	46.2	-37.4	60.4	15	50	
-19	1	9.8	46.2	-36.4	59.4	14	45	
-18	2	10.8	46.2	-35.4	58.4	12	40	
-17	3	11.8	46.2	-34.4	57.4	11	36	
-16	4	12.8	46.2	-33.4	56.4	10	32	
-15	5	13.8	46.2	-32.4	55.4	9	28	
-14	6	14.8	46.2	-31.4	54.4	8	25	
-13	7	15.8	46.2	-30.4	53.4	7	23	
-12	8	16.8	46.2	-29.4	52.4	6	20	
-11	9	17.8	46.2	-28.4	51.4	5.5	18	
-10	10	18.8	46.2	-27.4	50.4	4.9	16	
-9	11	19.8	46.2	-26.4	49.4	4.3	14	
-8	12	20.8	46.2	-25.4	48.4	3.9	13	
-7	13	21.8	46.2	-24.4	47.4	3.4	11	
-6	14	22.8	46.2	-23.4	46.4	3.1	10	
-5	15	23.8	46.2	-22.4	45.4	2.7	9.0	
-4	16	24.8	46.2	-21.4	44.4	2.4	8.0	
-3	17	25.8	46.2	-20.4	43.4	2.2	7.1	
-2	18	26.8	46.2	-19.4	42.4	1.9	6.4	
-1	19	27.8	46.2	-18.4	41.4	1.7	5.7	
0	20	28.8	46.2	-17.4	40.4	1.5	5.0	
1	21	29.8	46.2	-16.4	39.4	1.4	4.5	
2	22	30.8	46.2	-15.4	38.4	1.2	4.0	
3	23	31.8	46.2	-14.4	37.4	1.1	3.6	
4	24	32.8	46.2	-13.4	36.4	1.0	3.2	
5	25	33.8	46.2	-12.4	35.4	0.9	2.8	
6	26	34.8	46.2	-11.4	34.4	0.8	2.5	
7	27	35.8	46.2	-10.4	33.4	0.7	2.3	
8	28	36.8	46.2	-9.4	32.4	0.6	2.0	
9	29	37.8	46.2	-8.4	31.4	0.55	1.8	
10	30	38.8	46.2	-7.4	30.4	0.49	1.6	
11	31	39.8	46.2	-6.4	29.4	0.43	1.4	
12	32	40.8	46.2	-5.4	28.4	0.39	1.3	
13	33	41.8	46.2	-4.4	27.4	0.34	1.1	
14	34	42.8	46.2	-3.4	26.4	0.31	1.0	
15	35	43.8	46.2	-2.4	25.4	0.27	0.9	
16	36	44.8	46.2	-1.4	24.4	0.24	0.8	
17	37	45.8	46.2	-0.4	23.4	0.22	0.7	
18	38	46.8	46.2	0.6	22.4	0.19	0.6	
19	39	47.8	46.2	1.6	21.4	0.17	0.6	
20	40	48.8	46.2	2.6	20.4	0.15	0.50	2

Notes:
1 Estimated Minimum RF Test Bed Power, equiv. to 90 ft to LTE mobile
2 Estimated Maximum RF Test Bed Power, equiv. to 6 inches to LTE mobile

4. Test Bed Limits – GPS Simulator

Bell Labs LightSquared GPS Test Bed Calibration		
Anecholic chamber GPS Signal Path:	**MH Lab**	**5/18/2011**
SPIRENT 6700 PATH	**Contribution**	**Level (dBm)**
GPS signal	0	-130.0
Spirent gain	10	-120.0
booster amp & path loss	34.32	-85.7
attenuator	0	-85.7
GPS TX antenna gain	3.1	-82.6
path loss (3 meters)	-46	**-128.6**
SPIRENT 6400 PATH	**Contribution**	**Level (dBm)**
GPS signal	0	-130.0
Spirent gain	10	-120.0
booster amp & path loss	34.32	-85.7
attenuator	-10	-95.7
GPS TX antenna gain	3.1	-92.6
path loss (3 meters)	-46	**-138.6**