John Deere Intelligent Solutions Group
4052 114th St., Urbandale, IA 50322 USA

August 11, 2016

Via ECFS

Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: *Office of Engineering and Technology Announces Technical Advisory Council (TAC) Noise Floor Technical Inquiry* (ET Docket No. 16-191)

Dear Ms. Dortch:

Deere & Company ("Deere") hereby responds to the Commission's Public Notice[1] seeking comment on behalf of the Technological Advisory Council ("TAC") on an investigation of "changes and trends to the radio spectrum noise floor to determine if there is an increasing noise problem, and if so, the scope and quantitative evidence of such problem(s)."[2]

Deere offers its enthusiastic support for a fulsome examination of developments in the radio spectrum noise floor. Deere concurs with the expectations already stated by TAC members that the "noise floor in the radio spectrum is rising as the number of devices in use that emit radio energy grows," and that the 'limited available quantitative data" on this virtually certain trend must be addressed in order to ensure the future integrity and utility of an irreplaceable and finite resource -- radio spectrum.[3] Deere also emphasizes that harmful interference due to a rise in the noise floor represents a particular problem for sensitive receivers such as Global Navigation Satellite System ("GNSS") devices, which look for faint signals from power limited spacecraft thousands of miles removed in orbit. For GNSS devices, even a subtle rise in the radio spectrum noise floor in-band may create sufficient interference to degrade performance or render a device inoperable. Moreover, a rise in the

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[1] *See* Office of Engineering and Technology Announces Technological Advisory Council (TAC) Noise Floor Technical Inquiry, Public Notice, DA 16-676 (rel. Jun. 15, 2016) ("Public Notice").

[2] Public Notice at 1.

[3] Public Notice at 1.

noise floor creates in-band, co-channel interference, a problem that cannot be fixed by re-engineering or otherwise modifying the victim receiver.

To assist the Commission and the TAC in developing a methodology for examining changes and trends in the radio spectrum noise floor, for inclusion in the instant record please find attached as **Exhibit 1** a radiofrequency site survey and complementary overview ("RF Survey") conducted by Deere engineers in late 2015. The RF Survey examines the ambient radio spectrum environment at five (5) locations over a period of six (6) weeks, and was undertaken to evaluate possible new corporate sites for Deere's NavCom Technology, Inc. subsidiary, the developer of StarFire high-precision GNSS receivers. The RF Survey offers the Commission and the TAC a reference point with respect to fundamental metrics for a radio spectrum noise floor examination methodology, and in particular a baseline for examination of the noise floor in spectrum below 2 GHz in proximity to GNSS allocations.

Deere appreciates the commitment made by the Commission and the TAC to examine changes and trends in the radio spectrum noise floor, and looks forward to making further contributions to the effort to develop a methodology to study the noise floor that yields meaningful and quantitative information.

Very truly yours,

/s/

Mark Lewellen
Manager of Spectrum Advocacy
Deere & Company

Exhibit 1

Overview of Electromagnetic Environment (EME) Survey

Conducted by NavCom (a John Deere company)

in LA County in Southern California

Introduction: In late 2015, NavCom (a John Deere company) conducted five Electromagnetic Environment (EME) Surveys in southern California. The results are of which are included here.

Background: Established in 1992, NavCom Technology, Inc., a John Deere Company, is a leading provider of advanced GNSS (Global Navigation Satellite System) products such as StarFire™ 3000 and the new StarFire™ 6000. NavCom is located in LA County about 30 minutes south of LAX airport.

As part of the ongoing Research and Development, NavCom maintains an extensive antenna farm on the roof of their building and is continuously receiving GNSS signals in two frequency bands from multiple antennas located on the roof.[1]

In 2015, NavCom investigated several possible new locations, in the same general area, for relocating the facility. The status of the EME in the GNSS bands was one of the factors used in evaluating the new locations.

Objective: NavCom conducted EME Site Surveys at five separate locations. Four possible new locations (Vermont, Utah, Toyota and Pacific Concourse) and their exist location (Madrona) were analyzed.

Approach: The testing was conducted over 6 weeks, with each test taking 4-5 days. As we are only interested in the two GNSS bands, for the first part of the test the spectrum analyzer was set

[1] A satellite navigation or satnav system is a system that uses satellites to provide autonomous geo-spatial positioning. It allows small electronic receivers to determine their location (longitude, latitude, and altitude/elevation) to high precision (within a few metres) using time signals transmitted along a line of sight by radio from satellites. The system can be used for navigation or for tracking the position of something fitted with a receiver (satellite tracking). The signals also allow the electronic receiver to calculate the current local time to high precision, which allows time synchronisation. Satnav systems operate independently of any telephonic or internet reception, though these technologies can enhance the usefulness of the positioning information generated.

A satellite navigation system with global coverage may be termed a global navigation satellite system (GNSS). As of April 2013 only the United States NAVSTAR Global Positioning System (GPS) and the Russian GLONASS are global operational GNSSs. China is in the process of expanding its regional BeiDou Navigation Satellite System into the global Compass navigation system by 2020.[1] The European Union's Galileo is a global GNSS in initial deployment phase, scheduled to be fully operational by 2020 at the earliest (https://en.wikipedia.org/wiki/Satellite_navigation)

to Low Band (1150-1300 MHz) and for the second part it was set to High Band (1500-1650 MHz).[2]

The following metrics were used in the analysis:

- **Average AGC (Average Gain Control)** - This value represents the amount of gain in decibels [dB] which the receiver must provide in order to get the antenna output voltage to the desired level. Lower AGC values indicate that strong interference is present, so it needs to provide less gain. Since the GPS signals are constant power, that means for low AGC we attenuate the GPS signals more which is a negative thing. Each receiver/antenna/cable has its own stable AGC point so only relative comparisons can be made. The correct amount of AGC is dependent on a number of factors so there is no way to specify an absolute value for all setups. So the exact setup was used at all site so a relative comparison could be made.
- **High/Low Band AGC vs. Time** - The receiver AGC is logged every 1 [second] and reports the in-band power for both the High Band and Low Band. When plot vs. time, we can see the entrance/exit of interference sources and their total power relative to the rest of the power in that band. It is a good way of detecting interference sources not always present. Interference which is always present will shift the AGC and keep it constant. Lower numbers are bad.
- **CDF (cumulative distribution function) AGC** - The cumulative distribution function of the AGC data shows the probability of getting a certain level of interference. We desire the AGC to be a high value and never change, but as interference enters/exits the AGC will respond. There is approximately 1-1 mapping of AGC to loss of C/N0.
- **Spectrum Analyzer Data, Power vs Frequency** - These plots show the max and mean spectral data. In an ideal world this plot would be flat inside the receiver filter passband, but in the real world other signals are present which show up. This plot tells us where the signals are in frequency, their bandwidth and their maximum and average power levels.
- **CDF of Spectrum Analyzer Recorded Power** - This is very similar to CDF/AGC (See above), except the receiver filtering is not applied. These show how much total power in each the High and Low Bands the antenna is sending out to the receiver. When comparing, smaller numbers are better. This plot and CDF/AGC represent very similar data measured in two independent ways.

For other than the spectrum analyzer plots, it is difficult to establish an absolute threshold so the report uses the current NavCom location (Madrona) as a baseline and then ranked the other sites as better or worse regarding interference issues.

[2] Three carrier frequencies are centered at 1575.42 MHz (GPS L1 signal), 1227.6 MHz (GPS L2 signal), and 1176.45 MHz (GPS L5 signal).

Overall Results: The data summary contains a table giving the average AGC (Automatic Gain Control) values which indicate the amount of energy present in Upper (L1 / StarFire) and Lower (L2 / L5) GNSS bands. Lower AGC values can indicate the presence of harmful interference. The AGC reacts to the energy present in the spectrum bands as determined by the antenna and Low Noise Amplifier (LNA).

Bottom Line: The Vermont site appears slightly better than the current site (Madrona) regarding with regard to interference. The other three sites all had varying issues.

RF Site Survey December 2015 (Vermont, Utah, Pacific Concourse, Aviation)

Wednesday 23 December 2015

Brian C. Goodrich

Executive Summary

- Vermont as a 10 story building may be subject to 0.5 [cm] sway, making it a risk.
- Vermont may not have adequate room to deploy an antenna farm upon.
- 777 Aviation (Xerox building) was noticeably worse (182%) than other sites. This is reflected in AGC, Spectrum Analyzer and C/N_0 data.
- All other sites (Pacific Concourse, Utah and Vermont) are comparable to our current location in Torrance, within 12%.
- Site rankings can be made for HB and LB individually from Table 1.
- Aviation should be ruled out due to the 2nd test where multiple AGC issues were seen corresponding to large drops in C/N_0. See "***Aviation Round 2 Drops in C/N_0 Corresponding to AGC Events***" for details.
- 2555 W. 190th (ITT) Summary – Questionable at best. Bad positioning event and C/N_0 drops related to AGC activity
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Data Summary

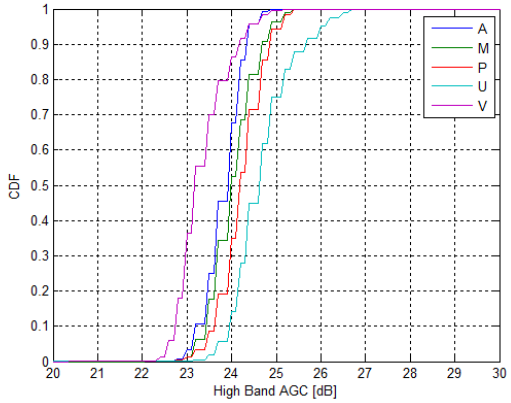
This quantifies the average total noise power (thermal noise plus interference) present; lower numbers indicate more interference and there exists a 1-1 mapping of total noise power to Carrier-to-Noise Ratio (C/N_0) loss. It is important to note that the same receiver, cable, antenna, splitter were used to facilitate direct comparisons.

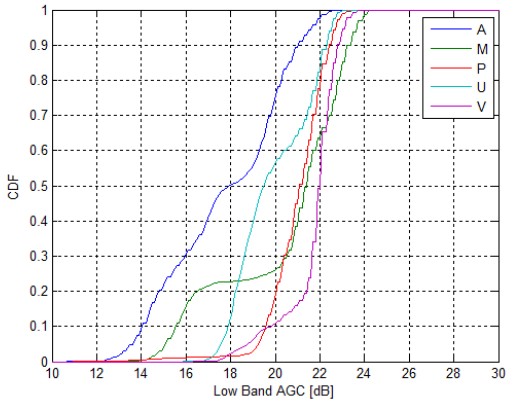
	HB AGC [dB]	LB AGC [dB]
Aviation	23.803594	17.946830
Avi (Test 2)	24.852274	20.788808
ITT (190th)	24.766244	20.522189
Madrona	24.097012	20.564660
Pacific Con.	24.284751	21.058129
Toyota	24.473847	19.355844
Utah	24.740038	19.975878
Vermont	23.403487	21.756599

Table 1: Average SF6000 AGC

High and Low Band Interference Plots

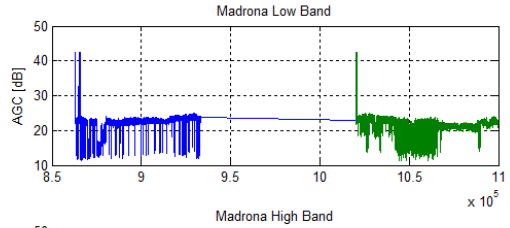
Next we compare the AGC Cumulative Histogram Functions for all the sites. Since absolute AGC can change as a function of temperature, it is possible that absolute measurements cannot be compared with 100% reliability. The testing period involved multiple rainstorms and clear skies. Recall that lower AGC values indicates interference.

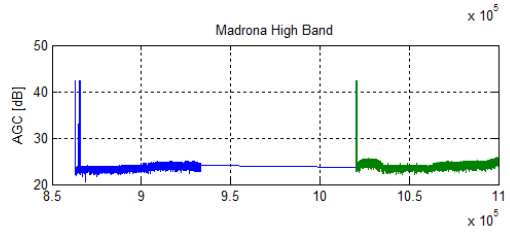


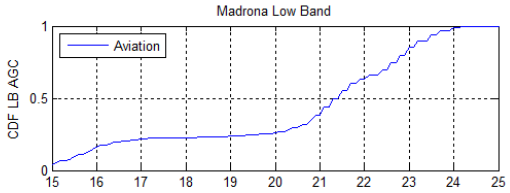

CDF
Low Band AGC [dB]
A
M
P
U
V
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
10
12
14
16
18
20
22
24
26
28
30

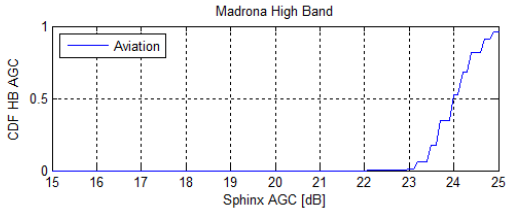
The following section is detailed plots for each of the five sites. Some sites have additional information relating to more detailed looks at interference. It is noted that the work done with regard to Automatic Gain Control (AGC) is beyond what would be expected for a noise study.

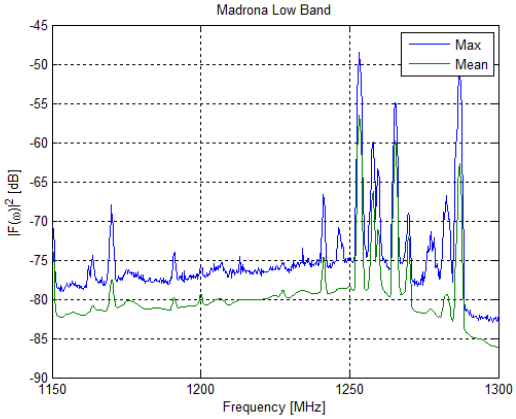
20780 Madrona (ISG-Torrance)

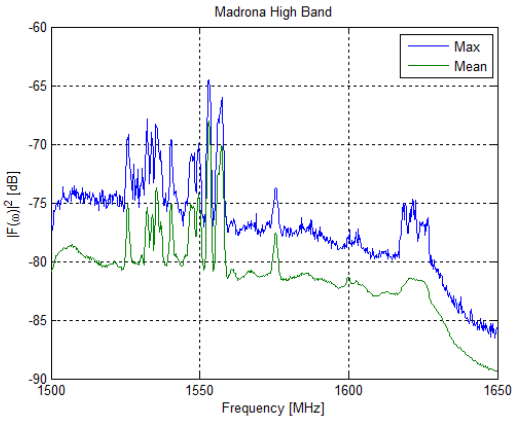


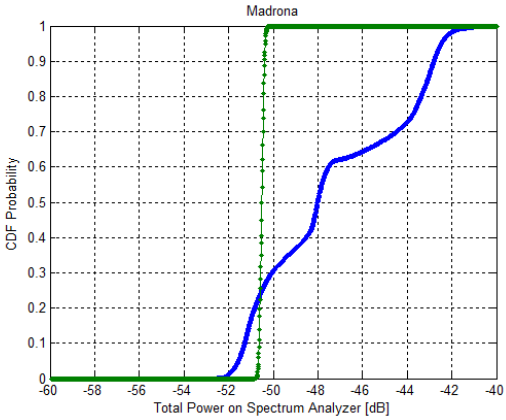






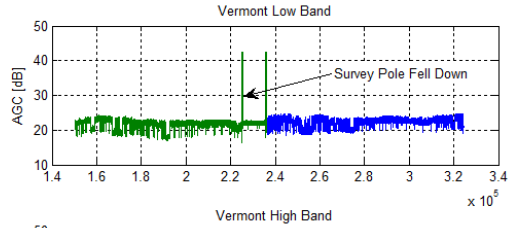


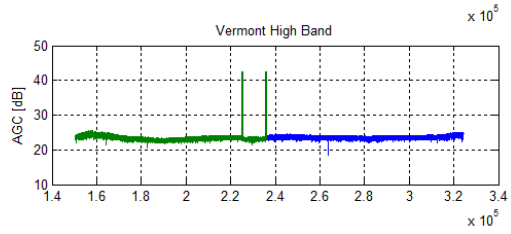


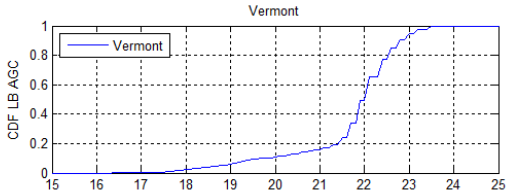


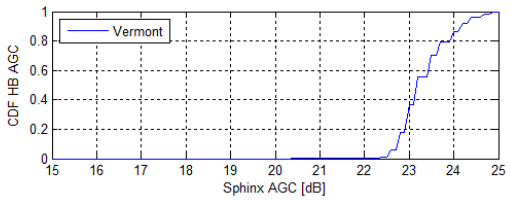
Note: 4 power outages, survey pole fell during rainstorm.

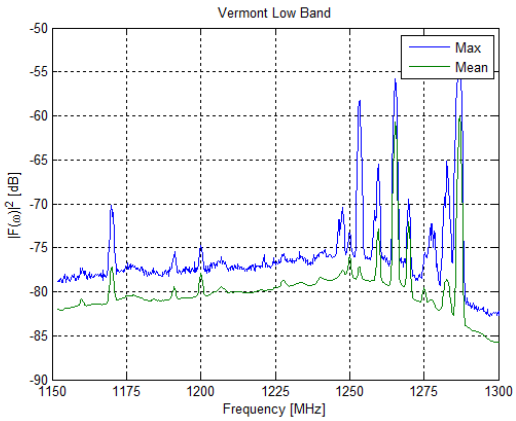
19191 Vermont (Herbalife Building)

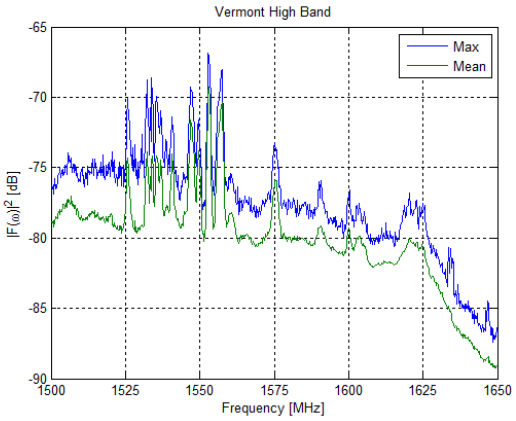


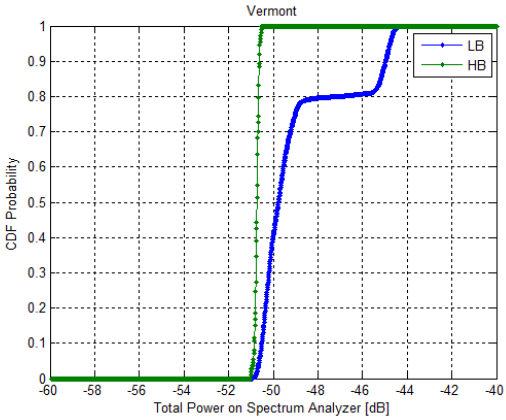






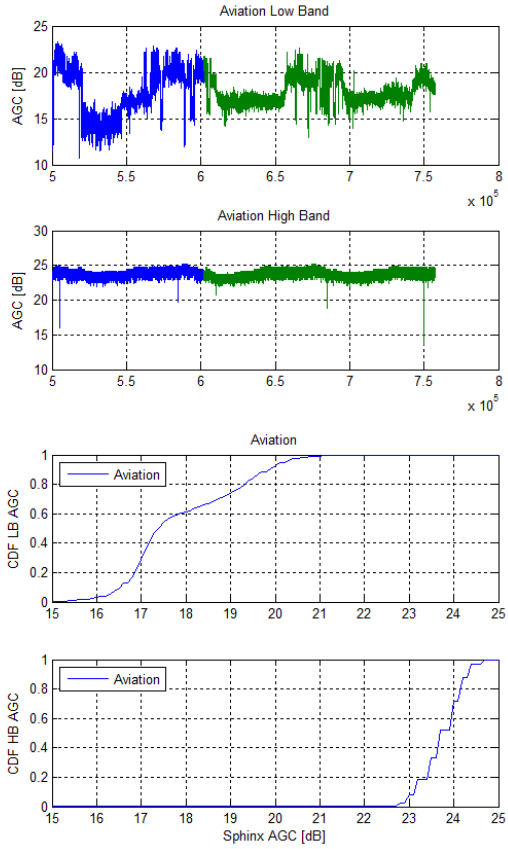


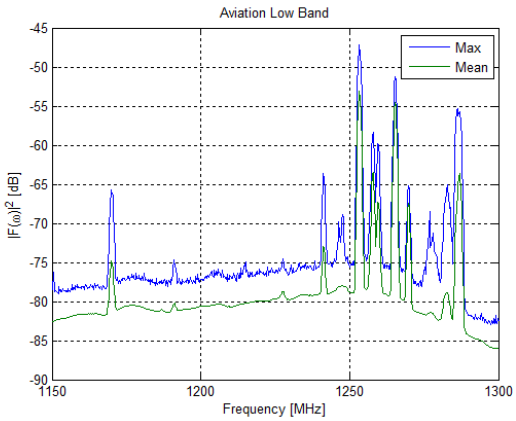


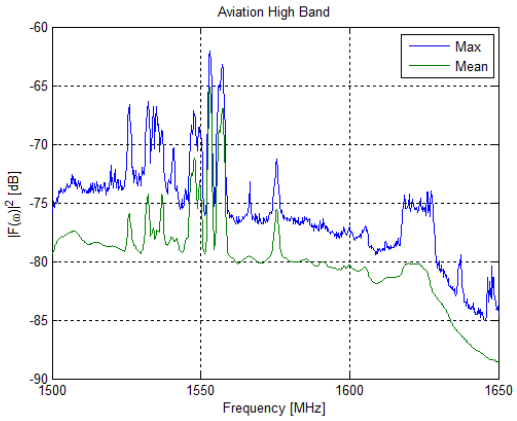


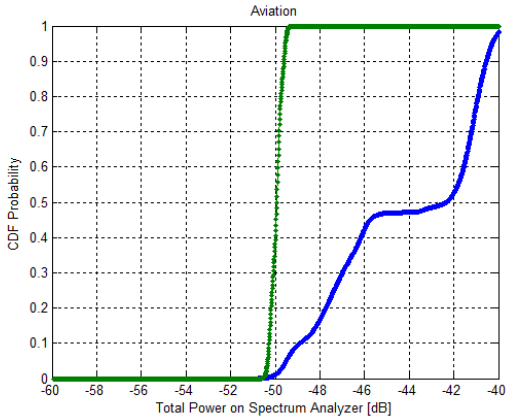
Note: During this test the survey pole fell down towards the end of the first day. That is shown as the two distinct vertical lines in the AGC vs. Time plot below. That data is removed from the analysis.

777 Aviation (Xerox Building)



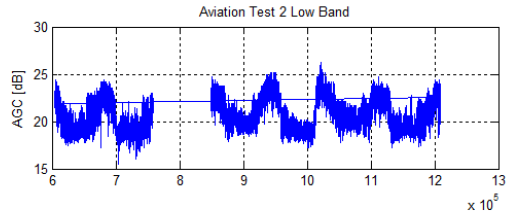


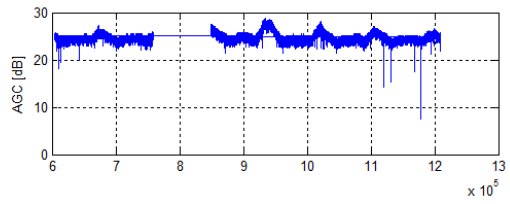


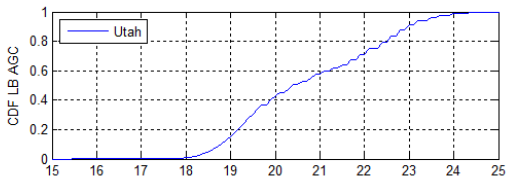


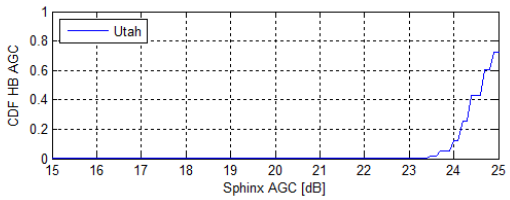
Note: All went smoothly without incident.

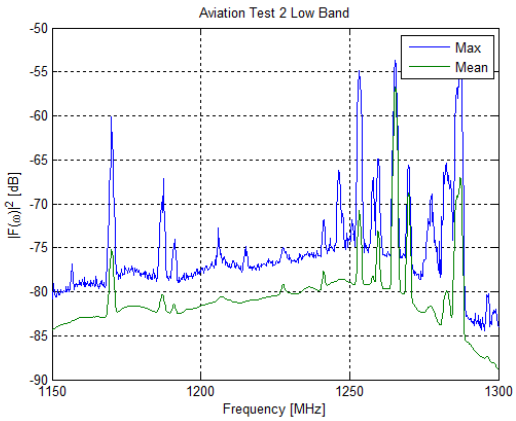
777 Aviation Test #2 (Xerox Building)

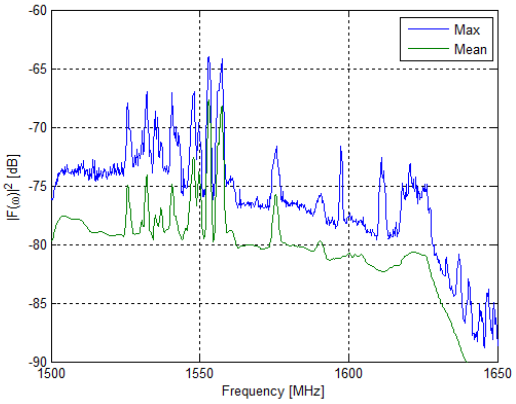


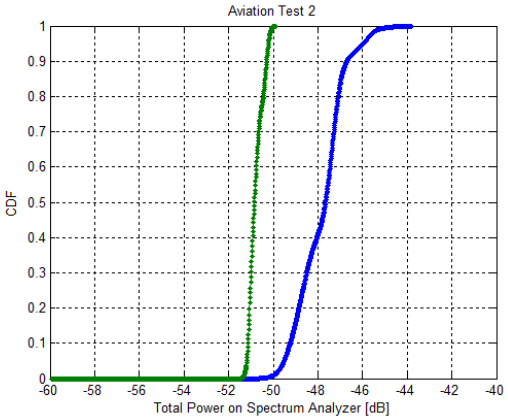




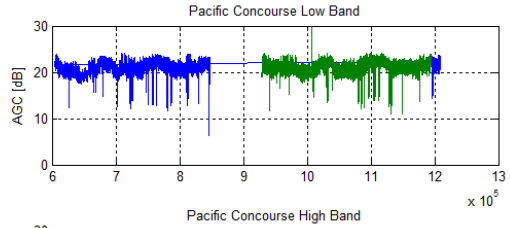


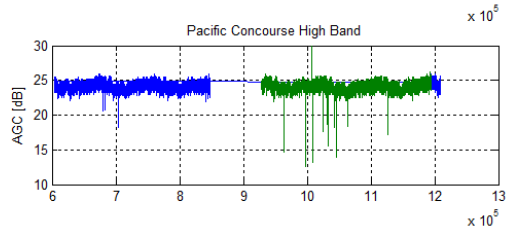


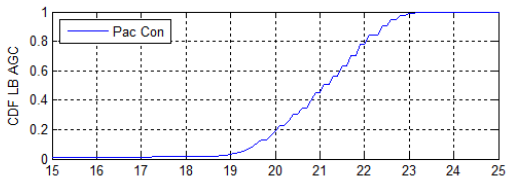


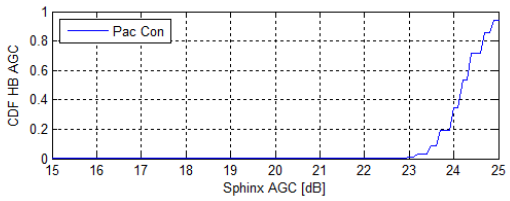


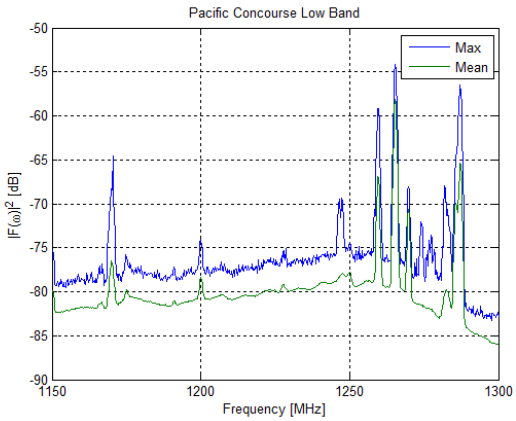
Pacific Concourse (Siemens Building)

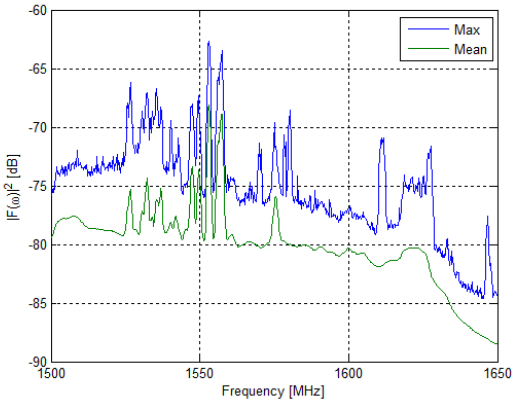


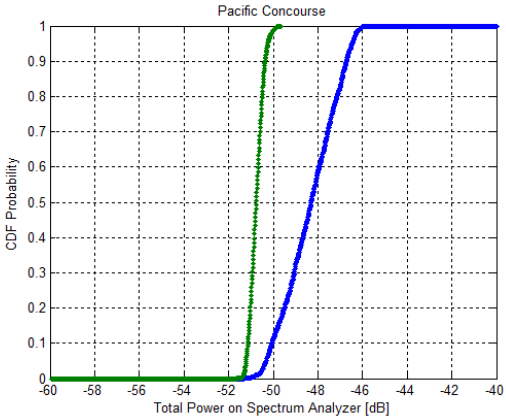










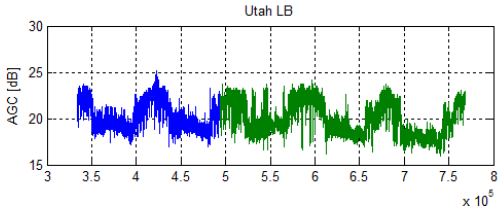


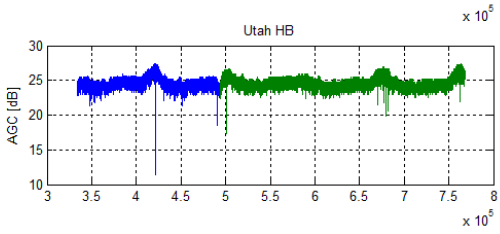
Note: Due to the inability to monitor equipment we have 5 total days of data for this site, opposed to 2 total days at other sites.

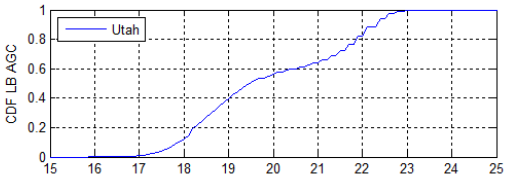
Note: There was a power loss at 401749 which caused a position spike.

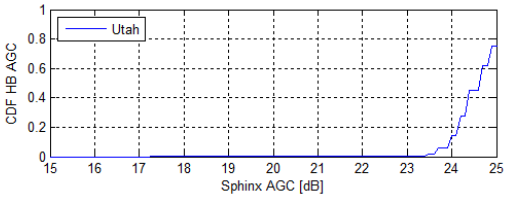
Note: To elevate the antenna above the metal walls, a long extending pole was used. This pole was not 100% rigid and subject to movement in the wind.

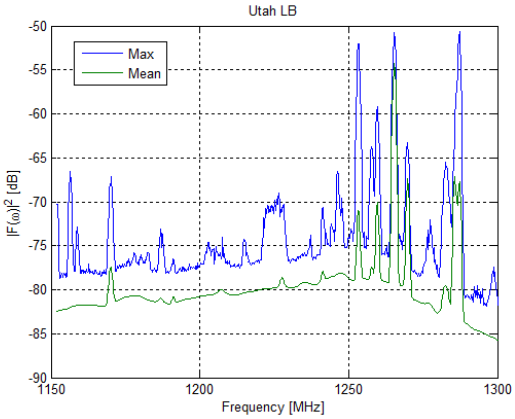
Utah (Unoccupied)

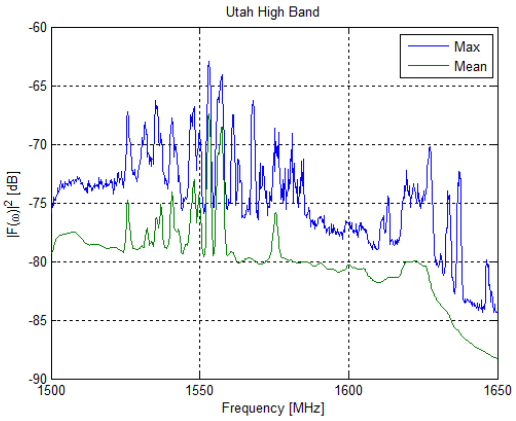


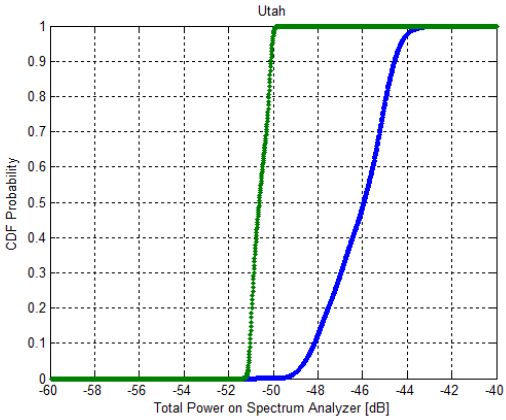




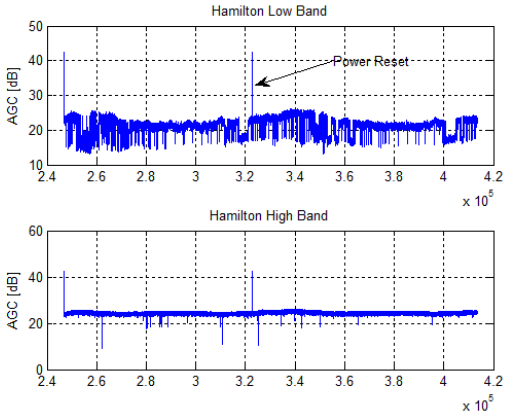


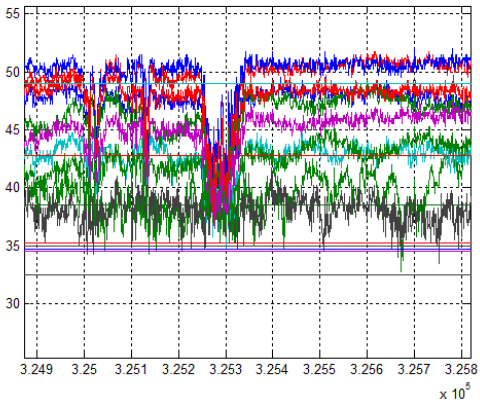




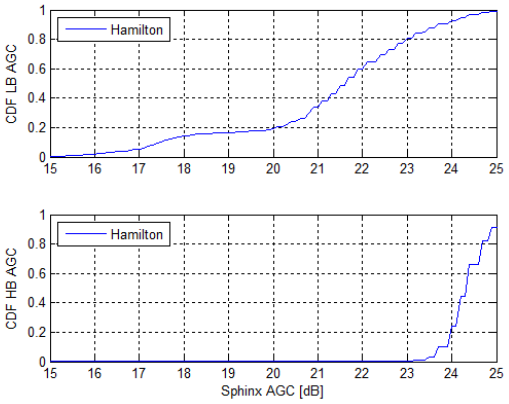


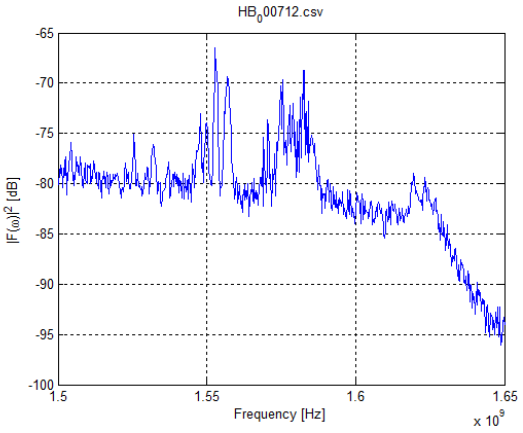
Hamilton (Torrance) ~ Week of March 5th



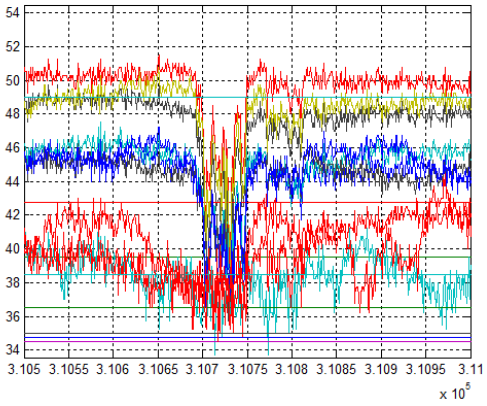


Spectrum During C/N_0 Degradation



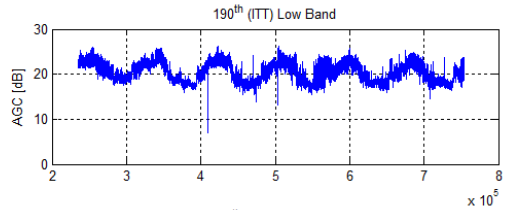


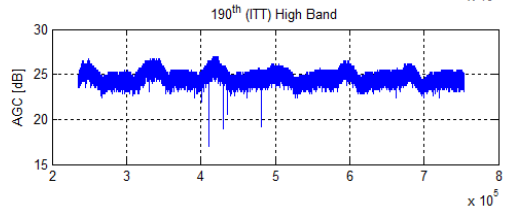
Drops in L_1C/A C/N_0

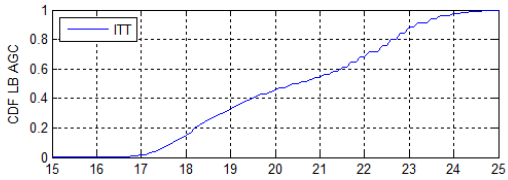


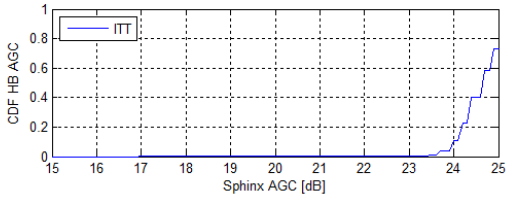
2555 W. 190th Street Torrance (ITT Technical Institute) 6 Days of Data

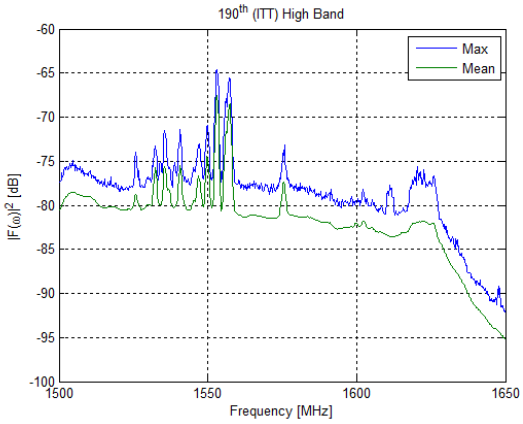
Had one power loss, that portion of data is removed from statistics and plots.

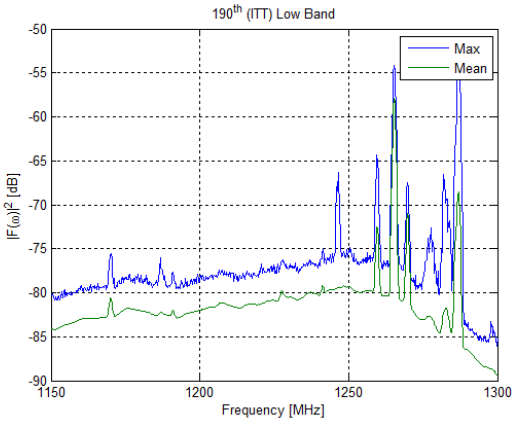


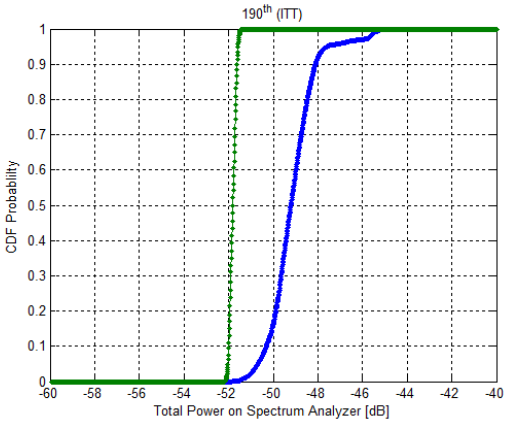




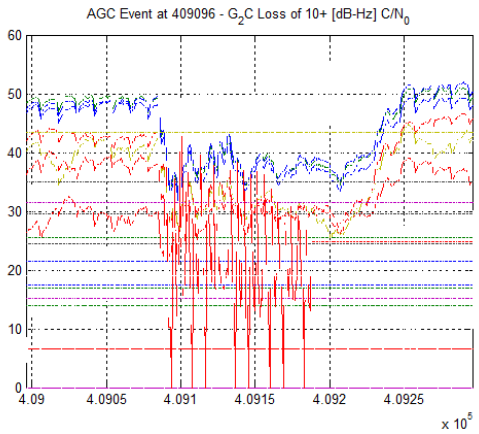


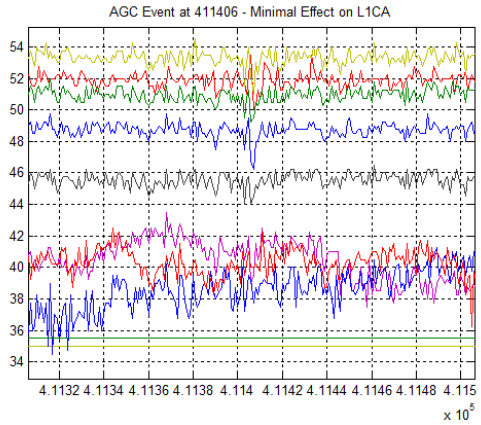


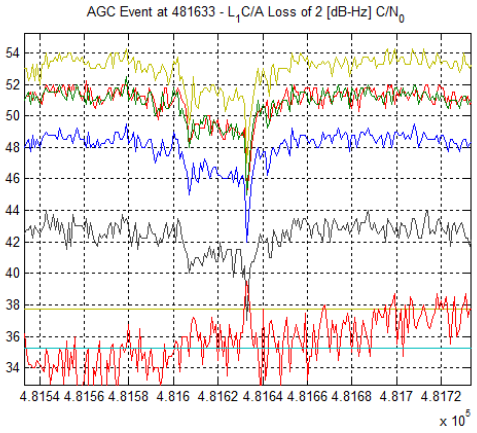


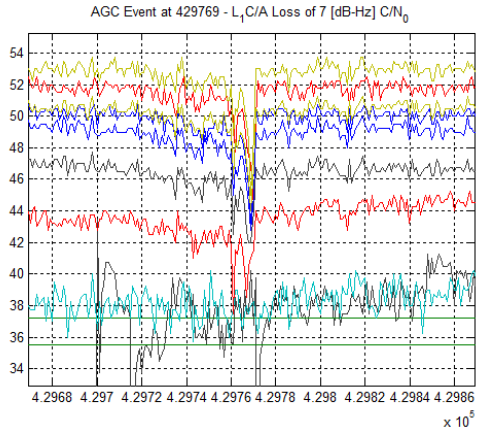


Over the 6 days of testing, we do observe a few drops in C/N_0 corresponding to AGC events. This test was 6 days in duration and there were 6 events (2 on the low band and 4 on the high band). The interfering source is unknown, but here are the effects.

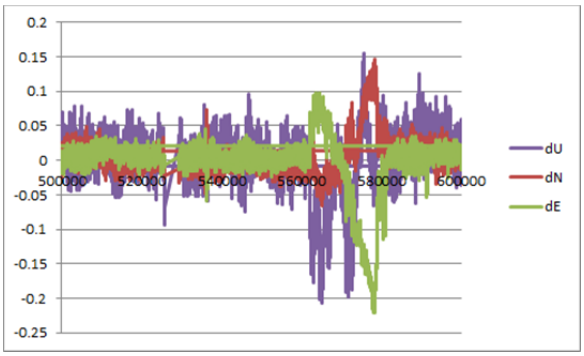


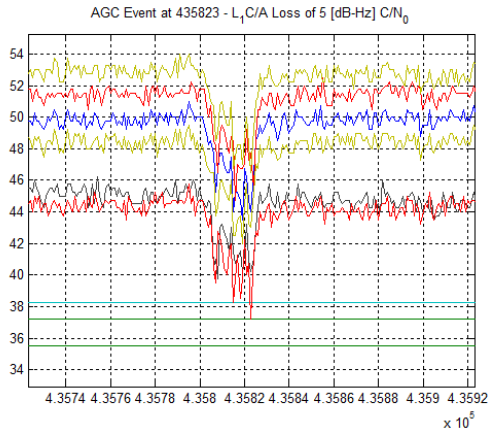


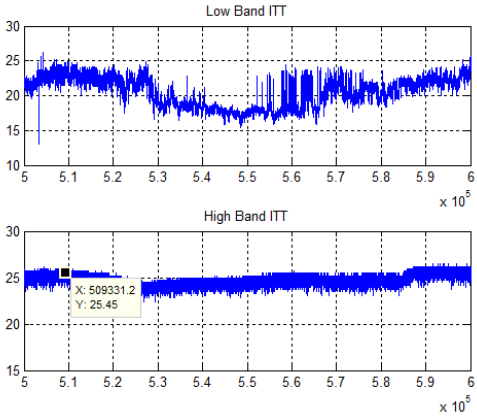




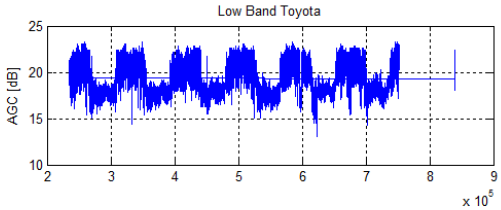
Also we saw the positioning data of SF3 worse than previous tests. There existed a sustained position outlier which appears to correlate to higher activity on the Low Band AGC.

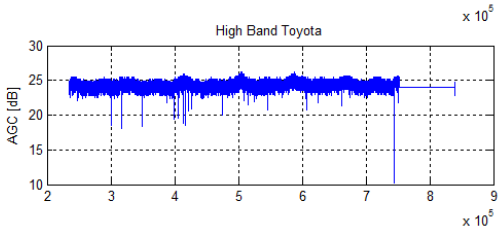


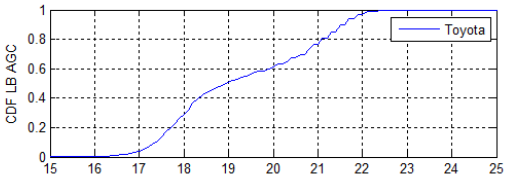


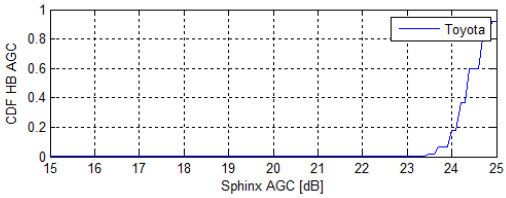


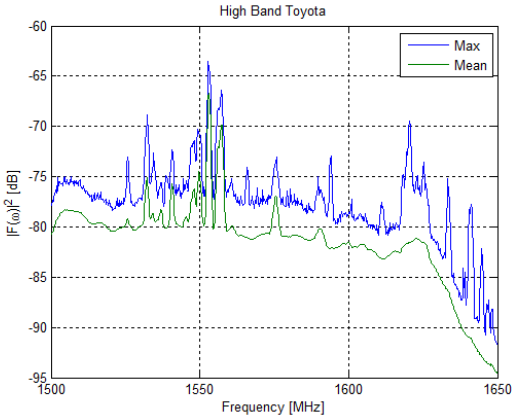
2050 W. 190th Street Torrance (Toyota)

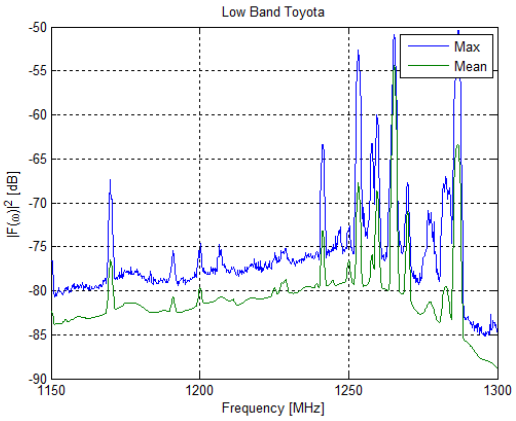


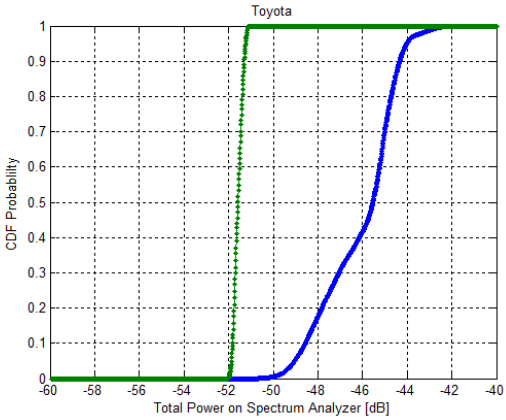


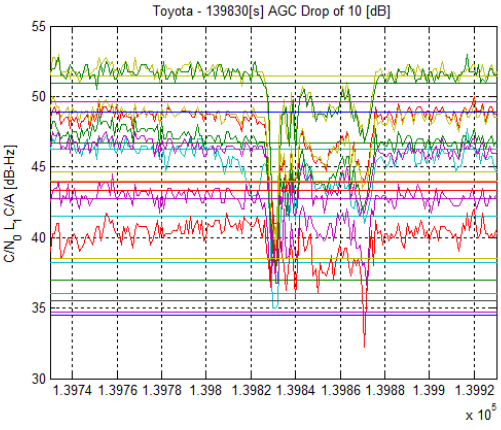


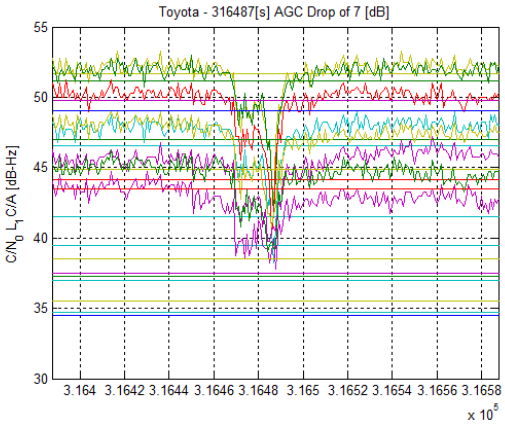






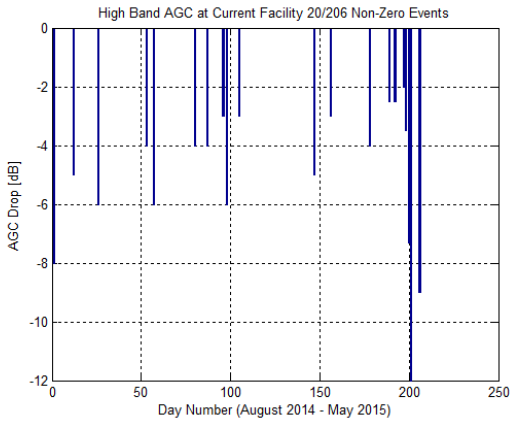






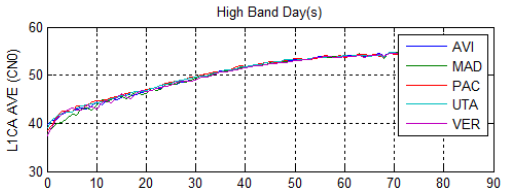
This building has a Toyota regulation that antennas may not be placed higher than the walls on the roof. For this test, they allowed us to place the antenna 6" above the wall; shading in the south direction is expected. See aerial photo on last page for antenna placement.

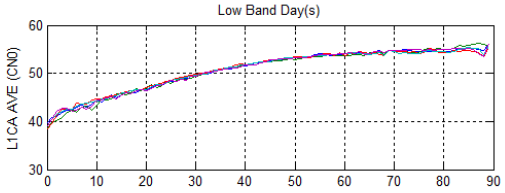
Since we again noticed drops in L_1C/A C/N_0 corresponding to spikes in the High Band AGC, we took a look at data in Torrance. Below is a plot of 206 days of AGC data. Most are 0 which indicates no AGC spikes. Non-zero values indicate one spike in the day or a period of interference, the value corresponds to the dip. No effort was made to investigate these dips or rule them out (i.e. receiver resets).

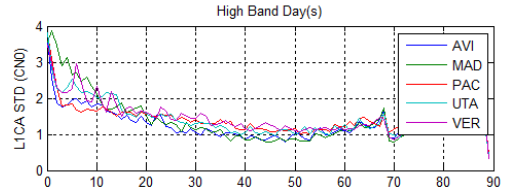


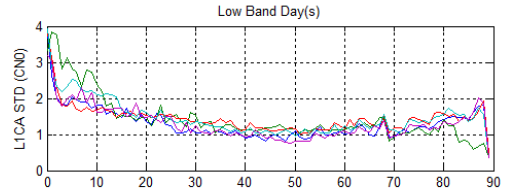
This section slows Carrier To Noise Ratio Plots with all sites shown in each graph.

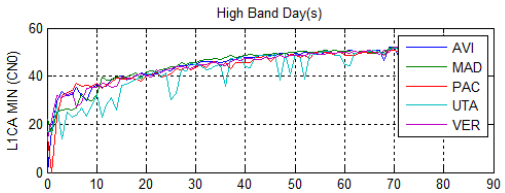
Carrier to Noise Ratio Plots – GPS L1CA (HB)

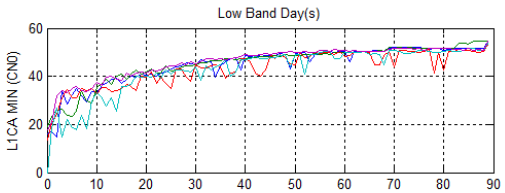


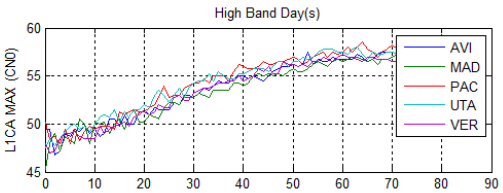


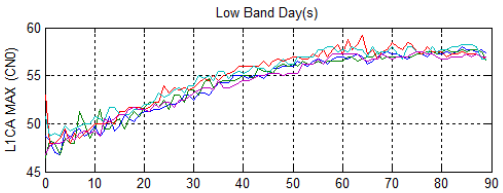




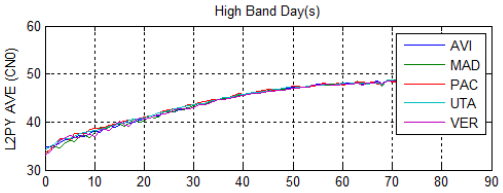


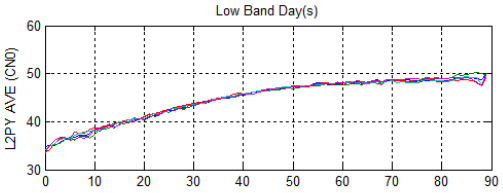


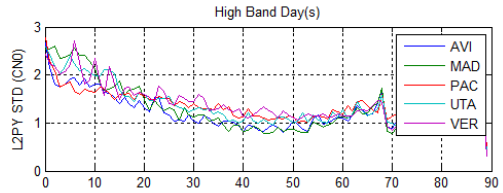


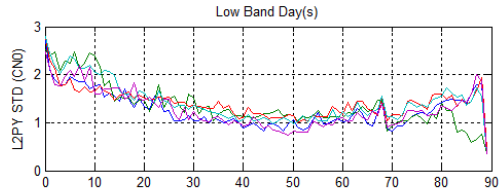


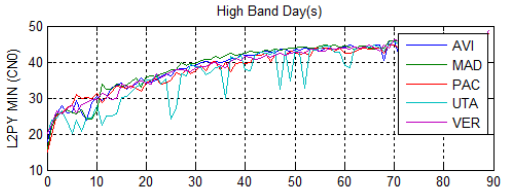
Carrier to Noise Ratio – GPS L2PY (LB)

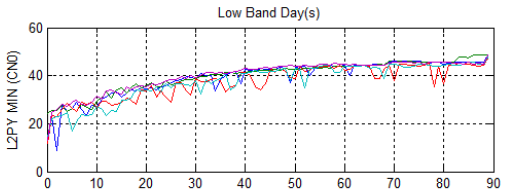


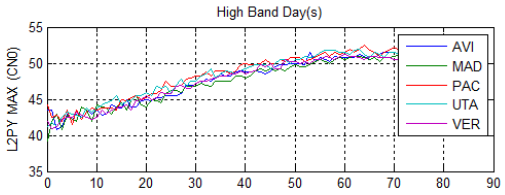


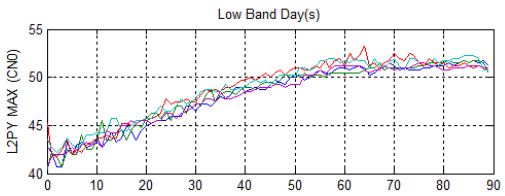


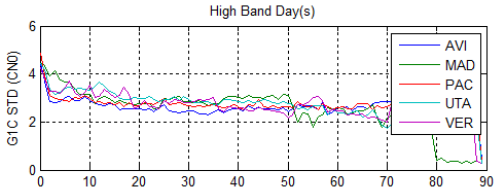


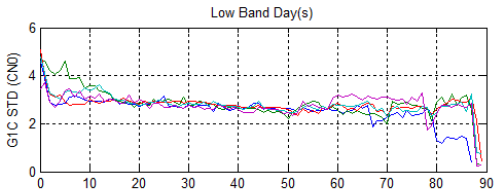


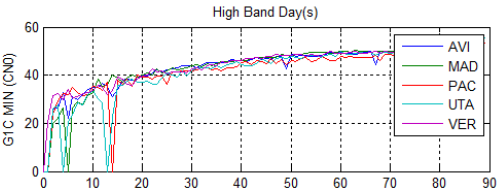


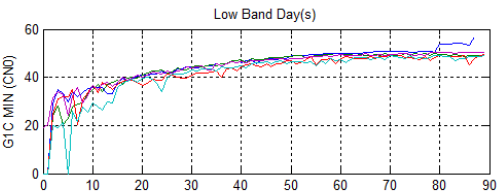




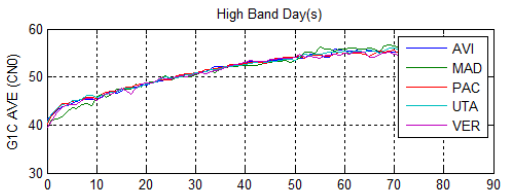


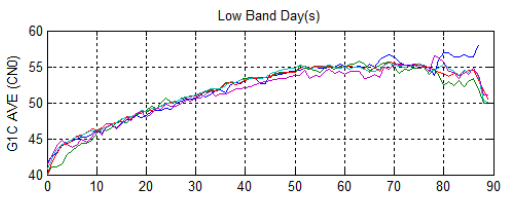


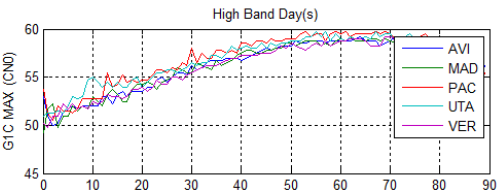


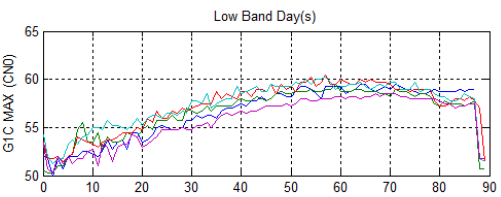


Carrier to Noise Ratio – GLN G1C (HB)

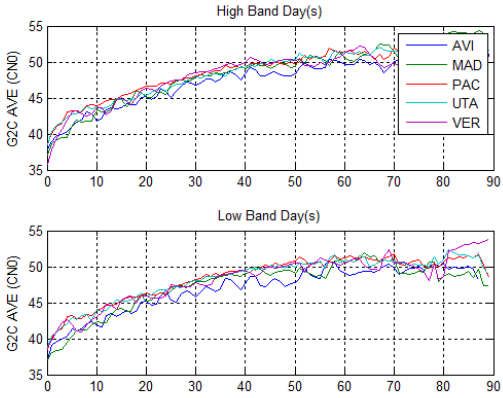


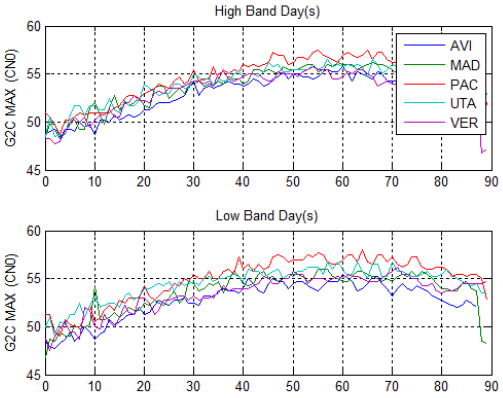


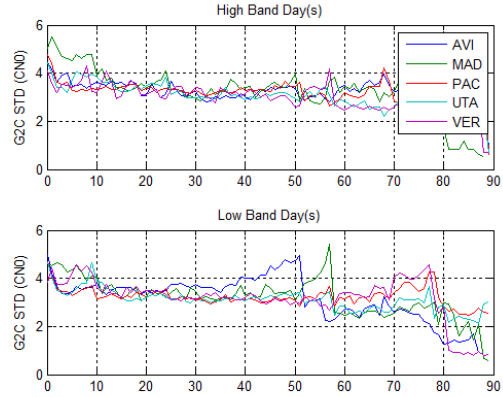


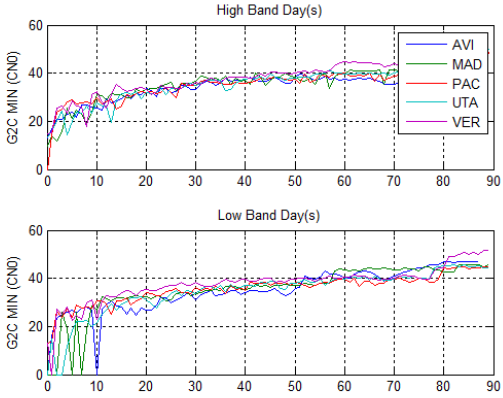


Carrier to Noise Ratio – GLN G2C (LB)

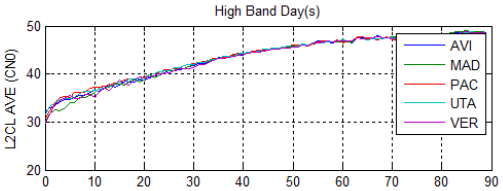


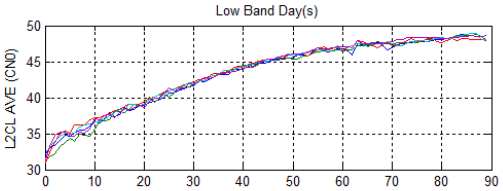


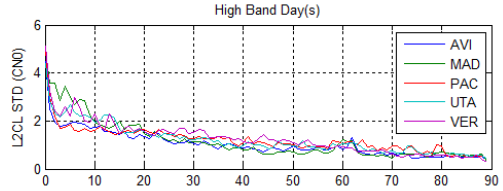


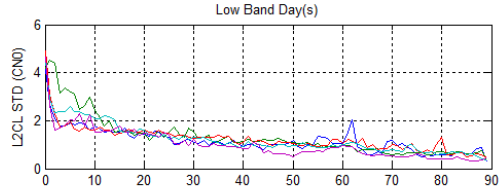


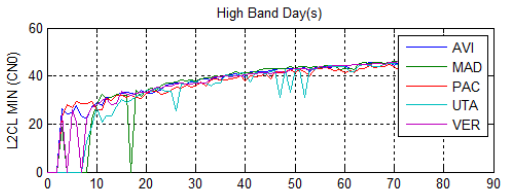
Carrier to Noise Ratio – GPS L2CL (LB)

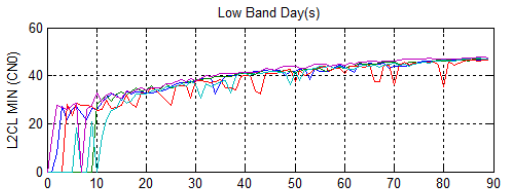


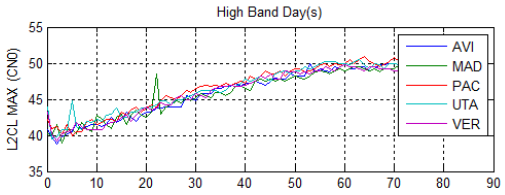


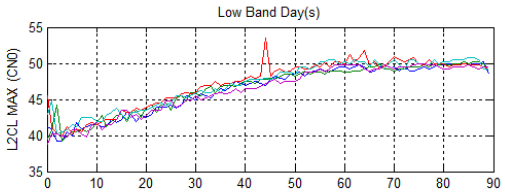


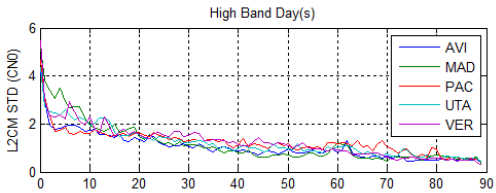


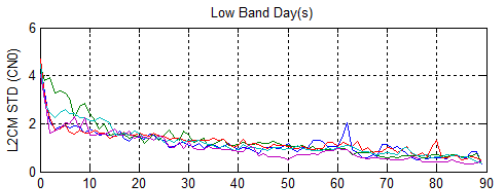


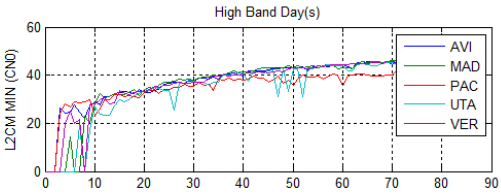


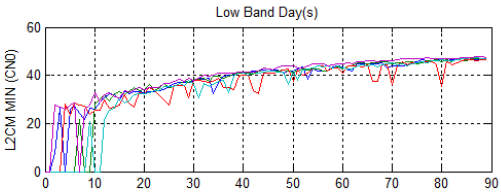




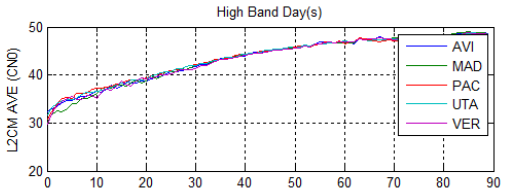


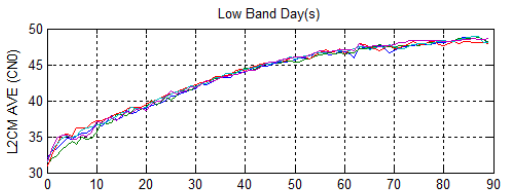


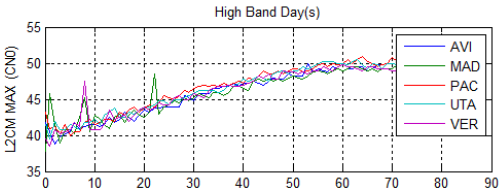


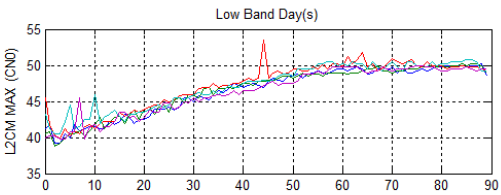


Carrier to Noise Ratio – GPS L2CM (LB)

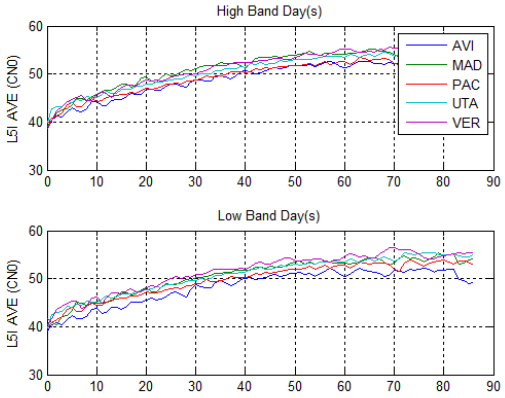


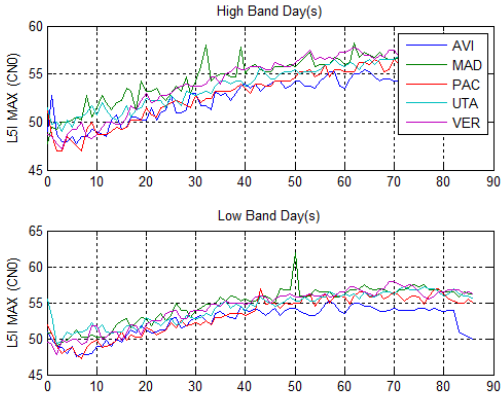


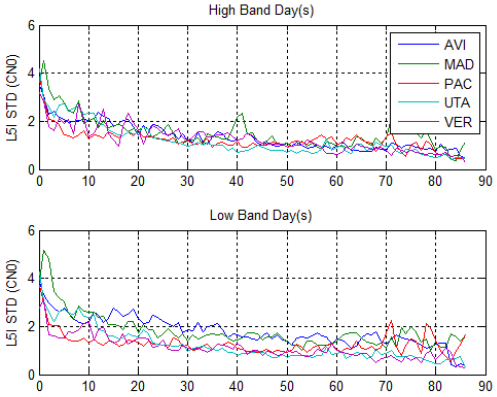


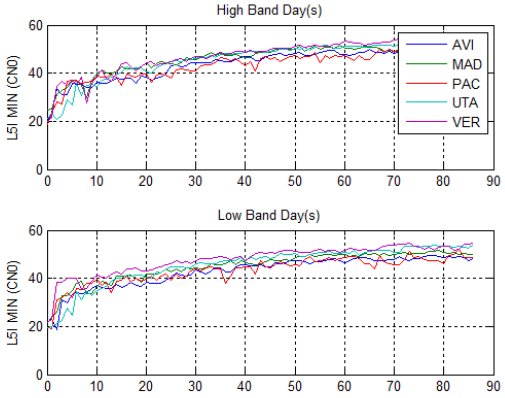


Carrier to Noise Ratio – GPS L5I (LB)

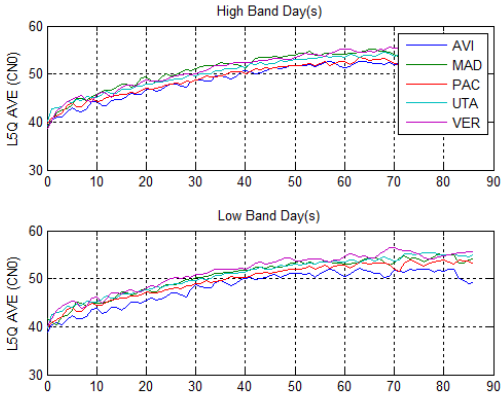


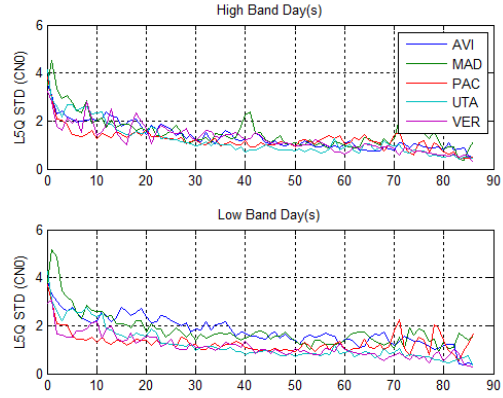


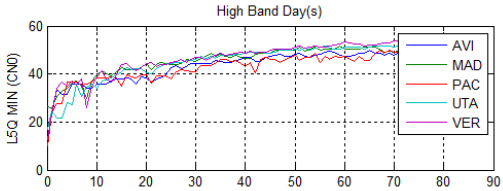


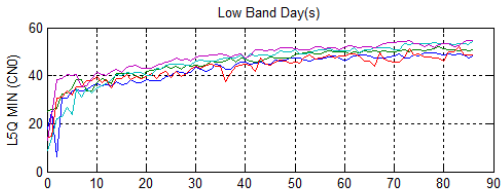


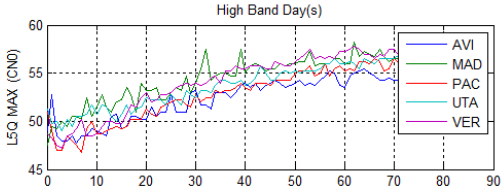
Carrier to Noise Ratio – GPS L5Q (LB)

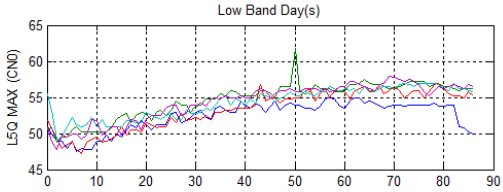




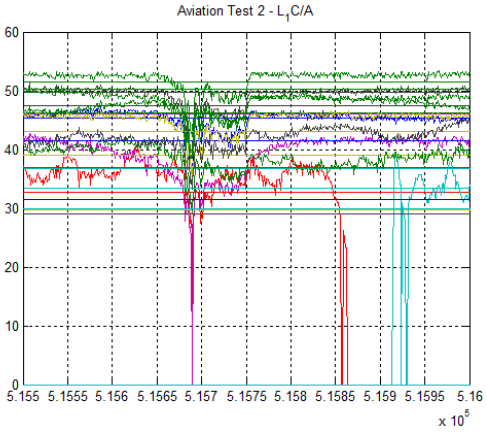

High Band Day(s)
L5Q MIN (CN0)
AVI
MAD
PAC
UTA
VER

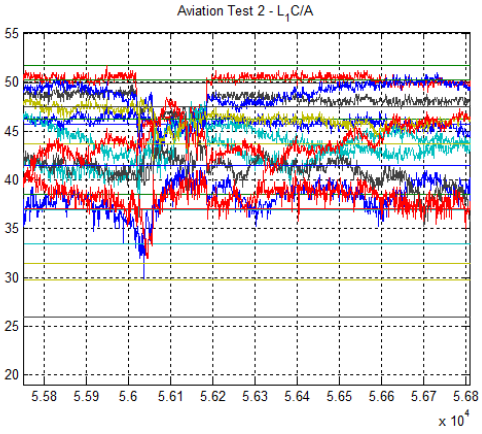

Low Band Day(s)
L5Q MIN (CN0)

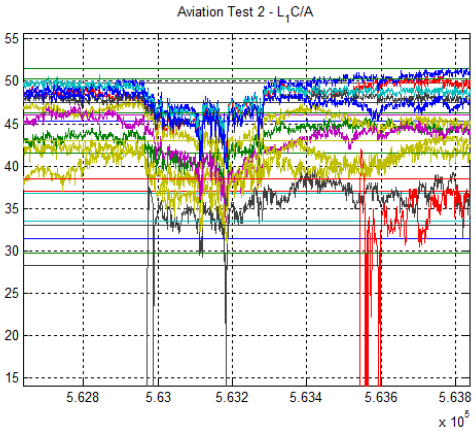

High Band Day(s)
L5Q MAX (CN0)
AVI
MAD
PAC
UTA
VER

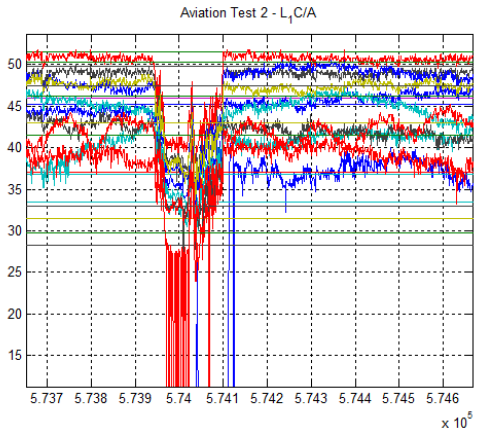

Low Band Day(s)
L5Q MAX (CN0)

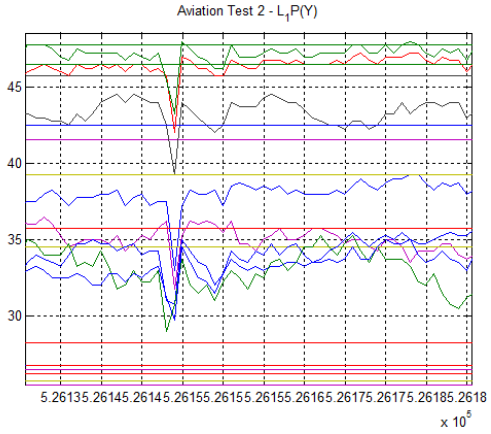
Aviation Round 2 Drops in C/N_0 Corresponding to AGC Events

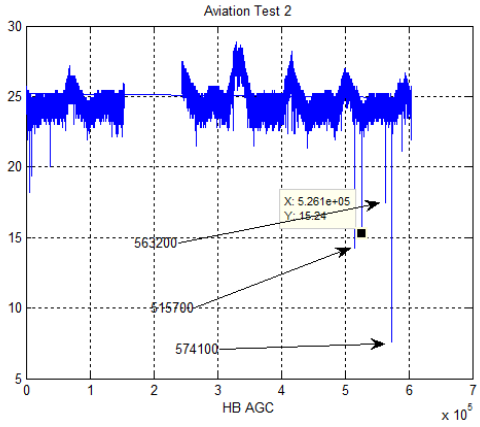












Appendix 1: Interpreting Figures, Tables and Numerical Results

Table 1: Average AGC

This table shows the mean values of the Automatic Gain Control (AGC). This value represents the amount of gain in decibels [dB] which the receiver must provide in order to get the antenna output voltage to the desired level. Lower AGC values indicate that strong interference is present, so it needs to provide less gain. Since the GPS signals are constant power, that means for low AGC we attenuate the GPS signals more which is a negative thing. Each receiver/antenna/cable has its own stable AGC point so only relative comparisons can be made. There is no way to say any AGC >< some value is acceptable.

In addition to 1 [Hz] PVT data, the highly precise carrier phase measurements are used to compute delta positioning (L_1PNav). This means how much relative position the receiver has moved in the last epoch. Since all receivers are stationary we know the truth should be 0. This provides a means to evaluate carrier phase accuracy at each location.

Figure 1 – High/Low Band AGC vs. Time

The receiver AGC is logged every 1 [second] and reports the in-band power for both the High Band and Low Band. When plot vs. time, we can see the entrance/exit of interference sources and their total power relative to the rest of the power in that band. It is a

Figure 2 – CDF AGC

The cumulative distribution function of the same AGC data in Figure 1 shows the probability of getting a certain level of interference. We desire the AGC to be a high value and never change, but as interference enters/exits the AGC will respond. There is a 1-1 mapping of AGC to loss of C/N_0.

Figures 3 & 4– Spectrum Analyzer Data, Power vs Frequency

These plots show the max and mean spectral data. In an ideal world this plot would be flat inside the receiver filter passband but in the real world other signals are present which show up. This plot tells us where the signals are in frequency, their bandwidth and their maximum and average power levels.

Figure 5 – CDF of Spectrum Analyzer Recorded Power

This is very similar to Figure 2, except the receiver filtering is not applied. This reports how much total power in each the High and Low Bands the antenna is sending out to the receiver. When comparing, smaller numbers are better. This plot and Figure 2 represent very similar data measured in two independent ways.

Figure A – Carrier To Noise Ratio Plots – Average

This plot shows the average C/N_0 vs. Elevation for each code type. The higher the better.

Figure B – Carrier To Noise Ratio Plots – Standard Deviation

This plot shows the standard deviation of C/N_0 vs. Elevation for each code type. The lower the better, when interference occurs the C/N_0 will change and be reflected in the standard deviation.

Figure C & D – Carrier To Noise Ratio Plots – Max/Min

These plots show the maximum and minimum recorded C/N_0 for each code type versus elevation angle. One note is when a satellite first comes into view, its C/N_0 may initially be reported too high and if it loses lock, it may drop to near 0.

Appendix 2: Setup Instructions

It is imperative that the same exact equipment be used (cables, splitter, receiver).

Aero Quasar Antenna→Custom 60 ft LMR400 Cable→4-Way GSP Networks Active Splitter

Splitter Port 1 → 3 ft TNC Cable → Rhode & Shwarz FSH6 Spectrum Analyzer → Ethernet → Laptop

Splitter Port 1 → 3 ft TNC Cable → SF6000 Receiver → EdgePort → Laptop

Day #1: Set Spectrum Analyzer to Low Band 1150-1300 [MHz].

Day #2: Set Spectrum Analyzer to High Band 1500-1650 [MHz].

Receiver Logging:

CHNLSTATUS1B (1 Hz), A2DA (1 Hz), PVT2B (1 Hz), MEAS3B (1 Hz), EPHEM1B (On Change), ALM1B (On Change), PANICA (On Change)

Spectrum Analyzer Logging:

.CSV files every 5 [seconds].

Post-Processing Tools

C:\Users\bg54263\Desktop\SiteSurvey_20151210\show_a2da.m – Plots Cumulative Distribution Functions of High Band & Low Band AGC, AGC versus time and computes AGC.

C:\Users\bg54263\Desktop\SiteSurvey_20151210\Process_Spectrum.m – Plots F(ω) max(F(ω)) and mean(F(ω)).

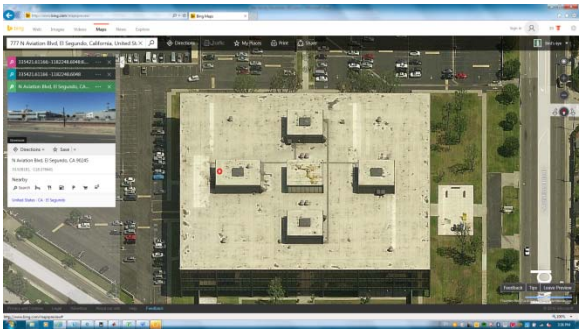
Truth Coordinates

Antenna locations shown using red circles

Aviation

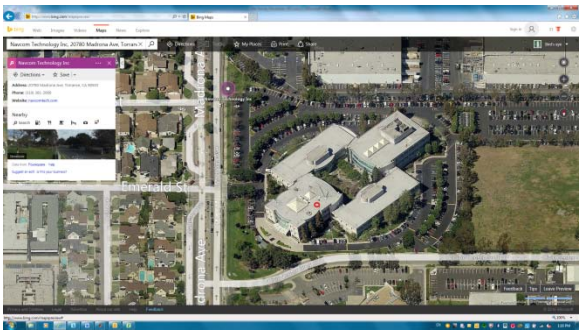
335421.61166:-1182248.6048:8.675452

335421.45019:-1182246.12710179:8.73065 (#2)



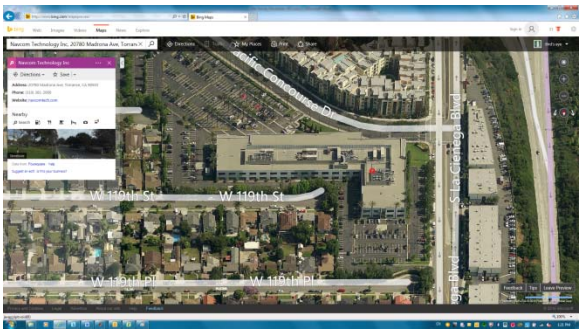
Madrona

335027.72805638:-1182037.5033:8.516549



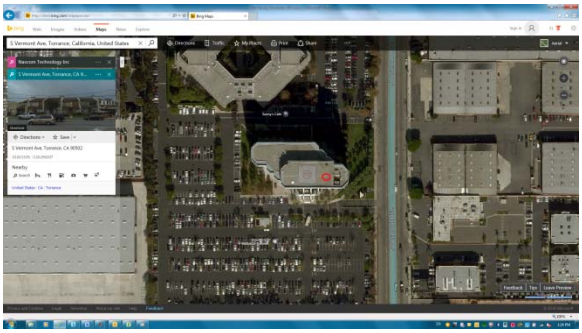
Pacific Concourse (Elevated on 15' Pole)

335532.47020365:-1182214.56185082:6.65891



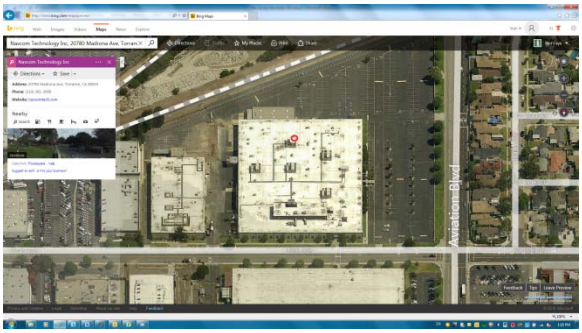
Vermont

335122.77329:-1181728.0265:24.19678



Utah (Elevated on 15' Pole)

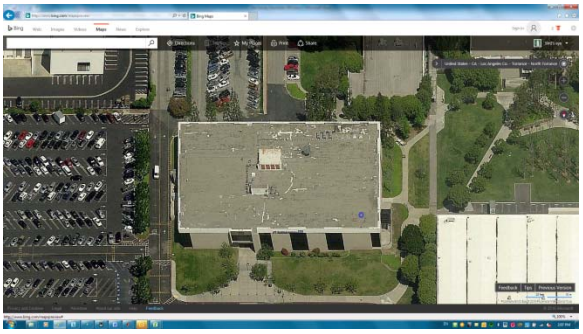
335438.0635942:-1182248.05105419:2.078012



Utah & Pacific Concourse had large metal walls, to avoid blockage and place the receiver in probable antenna farm locations we elevated the antenna using a 15' pole. This placed the receiver ~ 5 feet above the metal walls.

2555 W. 190th Street (ITT)

335134.15709:-1181924.3779:-5.09749



2050 W. 190th Street (Toyota)

335128.49511:-1181853.2775:5.021455