TangiTek CleanSignal™ Technology for GPS Modules and Antennas

Objectives

1. To quantify the signal gain when the **CleanSignal™** enhancement is used with typical GPS units and antennas in an uncontrolled "real world" noisy urban environment.

2. The gain and performance of the GPS units with and without the **CleanSignal™** enhancements are quantified in terms of the reported Signal to Noise Ratio (SNR), Position Dilution Of Precision (PDOP) and the number of satellites (SVs) used in a position fix.

Module and enna used

Testing Conditions

1. The testing environment was sensitive to changes in location, orientation, the time that the test was run, and the use of different hardware parts (GPS units, antennas, cables, cable length, serial adapters, etc.). Different units of the same model part could easily generate different results.

2. In order to compare GPS performance, we needed two identical GPS units – one in stock condition and one enhanced with **CleanSignal™**, running concurrently so that both the units had the same "sky view" of GPS satellites. The data from these GPS units were logged concurrently. This test configuration is referred to as *"Concurrent"* test configuration in this report.

3. Additional test runs were performed when only a single GPS unit or model was available. In these test cases, there is a time variation between when data from the stock configuration was collected vs. when the **CleanSignal™** enhancement was used. This test configuration will be referred to as *"Non-Concurrent"*. Results of such tests are **NOT** presented in this report since the tests are time variant - comparing GPS data from time variant tests, while providing some insights and experience on testing protocols and methodologies, are not very useful.

4. Tests were carried out by using the following **CleanSignal™** configurations:

a. Enhancing just the GPS antenna - hence forth referred to as "*CleanSignal™ Antenna Enhancement*"

b. Enhancing just the GPS module chipset - henceforth referred to as "*CleanSignal™ Chipset Enhancement*" and

c. Enhancing the entire GPS unit and the antenna by using an enclosure with a larger form factor when compared to the original GPS unit and antenna - henceforth referred to as the *"CleanSignal™ System Enhancement"*.

5. For easy logging and processing of GPS data, only GPS units that could output GPS data in NMEA format via a serial connection were used. The NMEA strings reported by the GPS devices in various configurations were recorded and post-processed to get the summary data that were used for comparing the performance. The results of these test configurations are reported in this paper.

6. Table 1 summarizes the test configurations and GPS units used.

Table 1 GPS Units and Test Configurations			
Test #	GPS Unit	Test Configuration(s)	Comments
1	Polstar/Parallax GPS	Concurrent Tests *CleanSignal™ System Enhancement*	• Un-Controlled in-house tests. • The **CleanSignal™** enhancement, in the form of an enclosure, increased the form factor of the GPS unit. • In general **CleanSignal™** provided **1 to 7 db gain** over the stock configuration.
2	Linx GPS Module with Ceramic Patch Antennas	Concurrent Tests *CleanSignal™ Antenna Enhancement* *CleanSignal™ Chipset Enhancement* *CleanSignal™ System Enhancement*	• Un-Controlled in-house tests. • In general **CleanSignal™** provided **1 to 4 db gain** over the stock configuration depending on the enhancement type.

Test 1 – Polstar PMB-648 GPS Modules

Two identical Polstar PMB-648 GPS modules were used for testing purposes. These modules were bought from Parallax Inc and their batch numbers indicate that were manufactured in the same batch. Both the modules use the same circuit board - GM Board Rev 2.3.
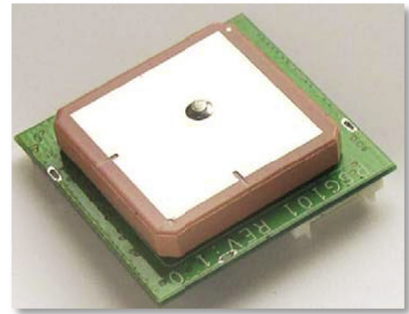
According to the manufacturer, the GPS module has a built-in SiRFstarIII chipset with receivers that can track 20 parallel satellite-tracking channels for fast acquisition and reacquisition. The unit has support for serial NMEA0183 v2.2 data output. The unit was built for car and marine navigation.

Each of the units was connected to a computer using identical KeySpan serial to USB adapters. The data from each device was logged on the same computer using a serial port monitoring application.

One GPS module was connected to the computer in its stock configuration. The **CleanSignal™ System Enhancement** was applied to the other GPS module i.e. the entire GPS module (including antenna and circuit board) was enclosed with **CleanSignal™** technology. A side by side setup of the two configurations is presented in Figure 3. The image below shows both the GPS modules connected to their respective serial to USB adapters. The module on the left is in stock configuration. The module on the right has the **CleanSignal™ System Enhancement**.
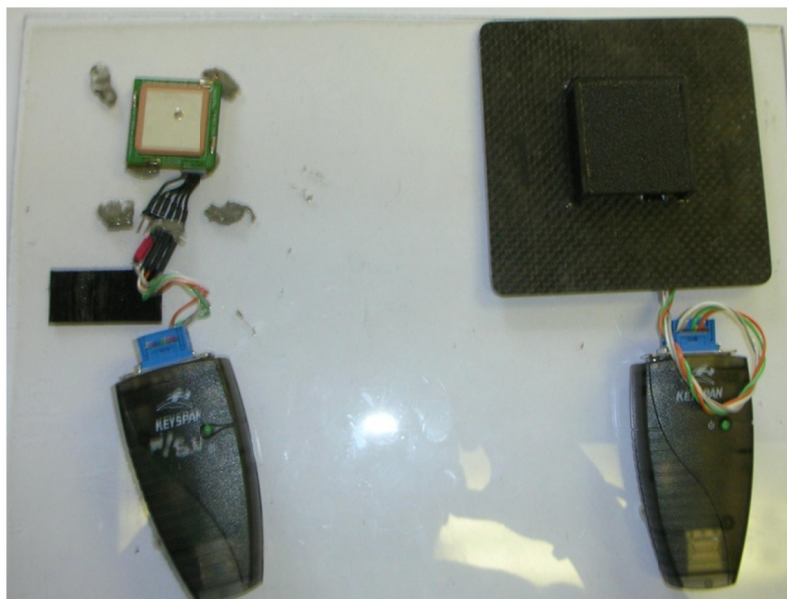

Figure 3 Stock Parallax GPS on the left and CleanSignal™ enhanced GPS on the right

The above setup was mounted on the dash board of a car during a standard round trip between downtown Portland, OR to Wilsonville, OR under real world driving conditions.

Data was actively logged on a computer during this commute. The GPS data from the two configurations were then compared and analyzed. Summary statistics were computed based on the satellites used to obtain a position fix, specifically the satellites in common, for both GPS module configurations.

It was determined that the *CleanSignal™ System Enhancement* provided a **gain in GPS SNR of about 7.58 dB** and had a better standard deviation than the stock configuration. The enhanced GPS module picked up an additional satellite on average and had a lower average PDOP.

The results are presented in the table and graph below.

TestID	Enhancement Type	SNR (dB)			PDOP		SVs Fix	
		Avg.	Std. Dev	Gain	Avg.	Std. Dev	Avg.	Std. Dev
20	CleanSignal™ System Enhancement	49.30	1.88	**7.58**	1.86	0.42	8.27	0.90
	Stock Configuration	41.72	2.25		2.19	0.68	7.16	1.06

Table 2 Comparison of CleanSignal™ System Enhancement and Stock GPS Polstar Module Configurations
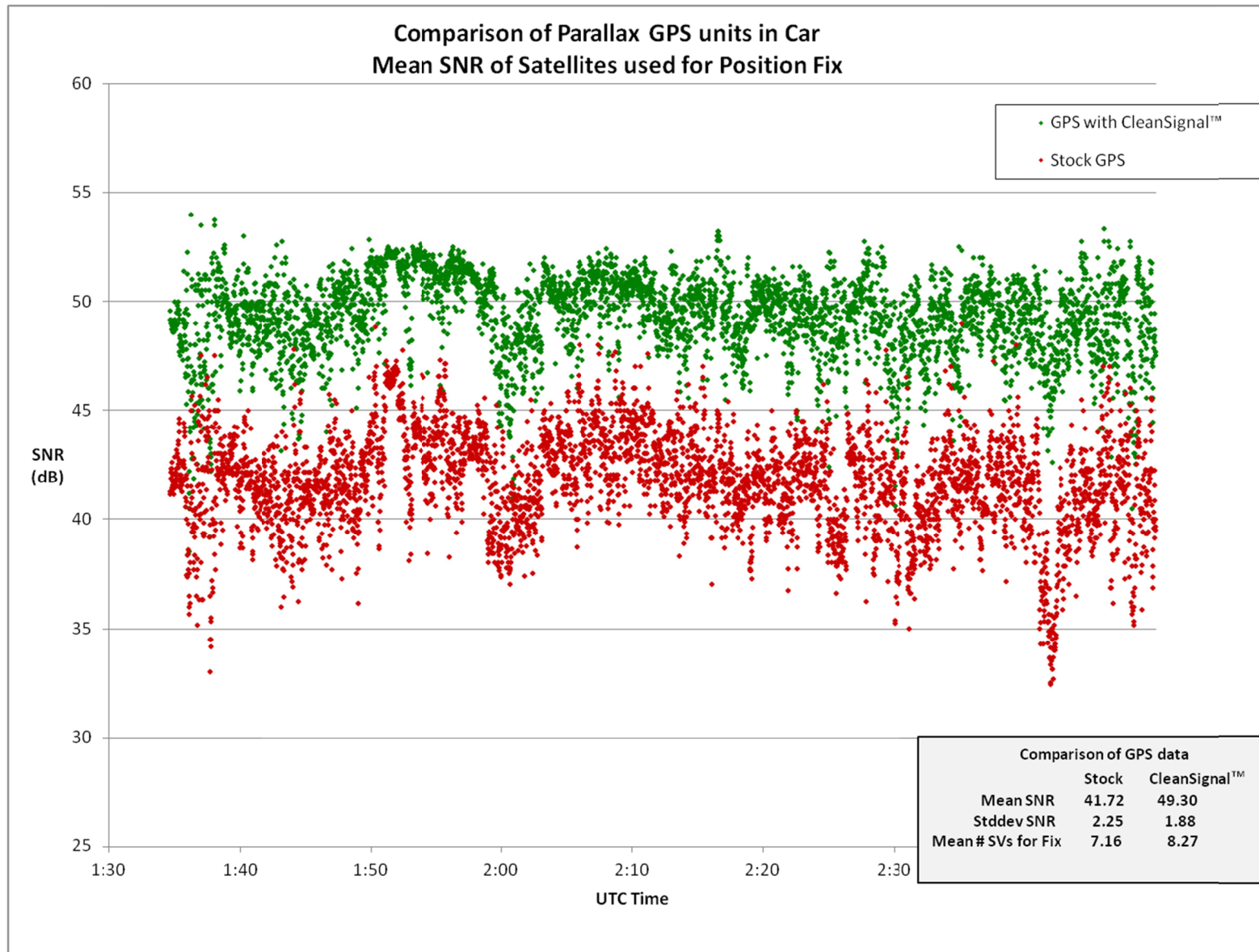
Figure 4 TestID-20 Comparison of CleanSignal™ System Enhancement and stock Parallax GPS units

Test 2 – LINX GPS Modules

Two identical LINX GPS modules (RXM-GPS-SR, both with manufacturing lot #GA 1047) were used for testing purposes. These modules were bought from Linx Technologies. Both the GPS modules were fitted with identical Taoglas - T574N/T574T ceramic patch antennas.

According to the GPS manufacturer, the embeddable SR Series GPS receiver modules are based on the SiRFstar III chipset. The module can acquire and track up to 20 satellites simultaneously. The modules provides standard NMEA GPS data output.

The two modules were assembled on identical custom made breadboards and circuitry as shown below.
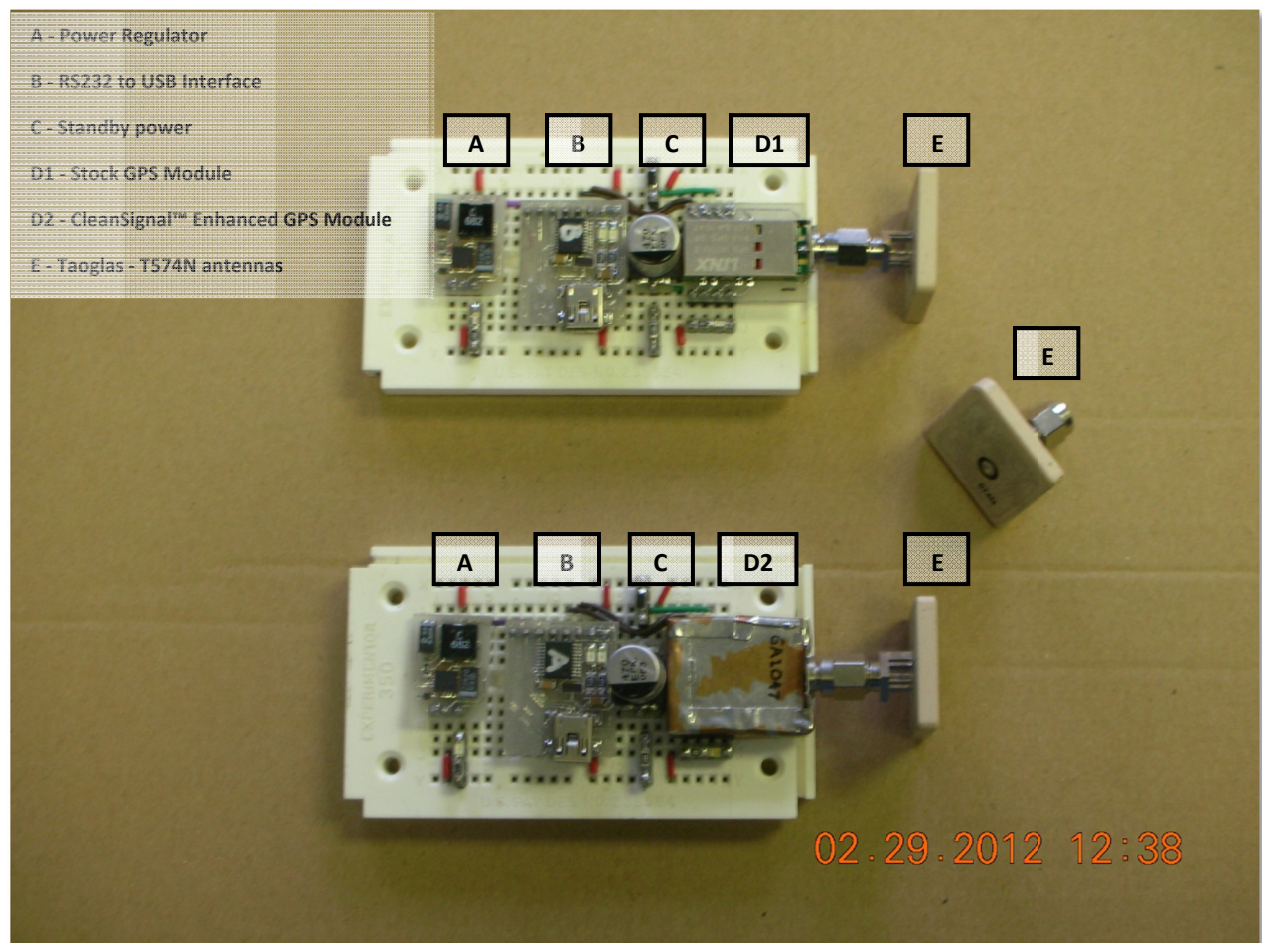

A - Power Regulator

B - RS232 to USB Interface

C - Standby power

D1 - Stock GPS Module

D2 - CleanSignal™ Enhanced GPS Module

E - Taoglas - T574N antennas

Figure 5 Layout of the circuitry used in testing the two Linx GPS Modules

Data from the receivers were logged in a computer using USB interfaces and GPS application software. One GPS module was connected to the computer in its stock configuration. The **CleanSignal™** enhancements were applied to the other GPS module. A side by side setup of the

two GPS modules in **CleanSignal™ Chipset Enhancement** test mode is presented in Figure 5. The figure shows both the GPS modules connected to their respective patch antennas, mounted on their respective breadboards. The module on the top is in stock configuration. The module on the bottom has the chipset enhancement (the antenna for this unit has NOT been modified).

Before incorporating any enhancements, both modules were tested without any to establish baseline performance characteristics of each module and breadboard configuration relative to the other (TestID #5). Baseline tests performed on the same day shows that one module on average had a SNR of 28.21 dB while the other had an average SNR of 30.69 dB (2.48 dB difference).

It was noticed that one GPS module and breadboard configuration always underperformed the other by about **1.50 dB to 2.50 dB** on average, across tests, when comparing GPS SNR data.

It was decided that any enhancements would be made to the module with the slight handicap. Our goal was to prove that the **CleanSignal™** enhancements actually provided a tangible performance increase (in SNR) even when applied to a module known to be underperforming in our baseline tests.

Several configurations of the **CleanSignal™** enhancement were tested in comparison to the stock GPS module configuration. Below is a description of the test configurations and results.

Antenna Enhancement Tests

In these tests, both the GPS module chipsets were NOT enhanced with **CleanSignal™**. However, one GPS module's antenna (T547N/T547T) was enhanced using a 3'' x 3'' copper backplane and the other GPS module's antenna was enhanced using a 3'' x 3'' **CleanSignal™** backplane. Basically we were trying to determine the performance of a GPS unit whose antenna was enhanced using a **CleanSignal™** backplane against a GPS unit with a copper backplane of identical dimensions as shown in Figure 6.

Tests were performed for both the T547N and T547T antennas.

Figure 6 Antenna backplanes used in testing – 3'' x 3'' Copper (left side) and CleanSignal™ (right side)

The *CleanSignal™ Antenna Enhancement* gave an average of **1.56 dB** improvement/gain in GPS SNR values over the copper antenna backplane configuration as shown in Table 3.

		SNR (dB)			PDOP		SVs Fix	
TestID	Enhancement Type	Avg.	Std. Dev	Gain	Avg.	Std. Dev	Avg.	Std. Dev
6 (574T)	CleanSignal™ Antenna Enhancement 3 x 3 CleanSignal™ backplane	35.74	2.46	**1.54**	4.44	2.75	5.29	0.91
	Stock Configuration 3 x 3 copper backplane	34.20	2.36		4.32	2.40	4.96	0.73
7 (574T)	CleanSignal™ Antenna Enhancement 3 x 3 CleanSignal™ backplane	38.19	1.34	**1.31**	1.82	0.16	8.93	0.48
	Stock Configuration 3 x 3 copper backplane	36.88	1.41		1.81	0.17	8.96	0.52
11 (574N)	CleanSignal™ Antenna Enhancement 3 x 3 CleanSignal™ backplane	37.65	3.54	**1.83**	3.00	1.50	5.74	1.13
	Stock Configuration 3 x 3 copper backplane	35.82	3.32		2.80	1.27	6.05	1.17

Table 3 Comparison of CleanSignal™ and Copper (3'' x 3'') Antenna Backplane Enhancement

The plot of the comparison for some of these tests is available in Appendix A.

Across the above tests the *CleanSignal™ Antenna Enhancement* improves the GPS SNR by about **1.56 dB** on average. Since the enhancement was applied to the unit with the handicap, we can safely conclude that **CleanSignal™** could get about **1 to 3 dB of gain** in SNR over traditional copper antenna enhancements for GPS units.

Chipset Enhancement Tests

In these tests, the *CleanSignal™ Chipset Enhancement* was applied to the chipset of one GPS module while the other was left in stock configuration. The ceramic patch antennas of both GPS modules were left in stock configuration as shown in the Figure 7, below.

Figure 7 Stock LINX GPS configuration on left, CleanSignal™ Chipset Enhancement on the right

Data was collected during routine commutes to and from work, and from a stationery position in the office.

A comparison of data from various tests is enumerated in Table 4 below. The plots of the comparison of GPS SNR for various tests are available in Appendix A.

TestID	Enhancement Type	SNR (dB)			PDOP		SVs Fix	
		Avg.	Std. Dev	Gain	Avg.	Std. Dev	Avg.	Std. Dev
12	CleanSignal™ Chipset Enhancement	30.74	3.57	**0.48**	2.31	0.68	7.31	1.08
	Stock Configuration	30.26	3.23		2.57	0.90	6.83	1.09
13	CleanSignal™ Chipset Enhancement	32.32	2.60	**1.00**	2.19	0.67	6.96	0.82
	Stock Configuration	31.32	2.44		1.90	0.54	7.60	0.60
15	CleanSignal™ Chipset Enhancement	32.87	1.81	**2.14**	2.06	0.36	8.78	0.65
	Stock Configuration	30.73	1.67		2.01	0.35	11.11	0.31
16	CleanSignal™ Chipset Enhancement	33.51	2.39	**2.15**	4.53	1.28	4.73	0.49
	Stock Configuration	31.36	2.89		4.98	1.90	4.24	0.64
17	CleanSignal™ Chipset Enhancement	33.21	2.12	**2.45**	4.68	0.76	4.57	0.66
	Stock Configuration	30.76	2.35		5.23	0.86	3.81	0.42
18	CleanSignal™ Chipset Enhancement	31.70	3.45	**0.07**	4.39	0.65	4.81	0.45
	Stock Configuration	31.63	3.03		4.79	1.03	4.43	0.75

Table 4 Comparison of CleanSignal™ Chipset Enhancement and Stock GPS Module

Across these tests, the *CleanSignal™ Chipset Enhancement* gives an average improvement of **1.38 dB in SNR**, with a maximum improvement/gain of about **2.45 dB** in test 17.

Since the enhancement was applied to the unit with the handicap, we can safely conclude that we could get about **2 to 4 dB of gain** in SNR over the stock GPS modules.

System Enhancement Tests

In this test, the ***CleanSignal™ System Enhancement*** was applied to one GPS module while the other was left in stock configuration. The "system enhancement" includes a **CleanSignal™** enclosure around the GPS receiver module along with an antenna enhancement using a 1.25" x 1.25" **CleanSignal™** backplane. The other GPS module was left is stock configuration, but its antenna was fitted with a 1.25" x 1.25" copper backplane.

Figure 8 Antenna backplanes used in testing – 1 1/4" x 1 1/4" Copper (left side) and CleanSignal™ (right side)

The **system enhancement** gave about **3.4 dB** in SNR improvement over the stock configuration as shown in Table 5 below. Since the ***CleanSignal™ System Enhancement*** was applied to the unit with the handicap, we can safely conclude that we could get about **3 to 5 dB of gain** in SNR over the stock GPS modules.

The plots of the comparison of GPS SNR for various tests are shown in Appendix A.

Table 5 Comparison of CleanSignal™ System Enhancement and Stock GPS Module								
TestID	**Enhancement Type**	**SNR (dB)**			**PDOP**		**SVs Fix**	
		Avg.	**Std. Dev**	**Gain**	**Avg.**	**Std. Dev**	**Avg.**	**Std. Dev**
19	**CleanSignal™ System Enhancement**	35.33	4.45	**3.40**	3.45	1.46	5.42	1.15
	Stock Configuration	31.93	4.31		3.94	1.60	4.95	1.03

Conclusions

Several different GPS modules and antennas were tested with and without **CleanSignal™** enhancements in different configurations. The tests conducted were uncontrolled and in real world noisy environments.

The **CleanSignal™** enhancement for GPS antenna units gave an average SNR improvement of about **1 dB to 8 dB** during testing depending on GPS module, antenna and type of **CleanSignal™** enhancement used.

The *CleanSignal™ Antenna Enhancement* gave about **1 to 3 dB** of improvement in SNR.

The *CleanSignal™ Chipset Enhancement* gave about **2 to 4 dB** of improvement in SNR.

The *CleanSignal™ System Enhancement* gave about **3 to 8 dB** of improvement in SNR.

Additional controlled laboratory testing and third party testing with improved protocols are recommended.
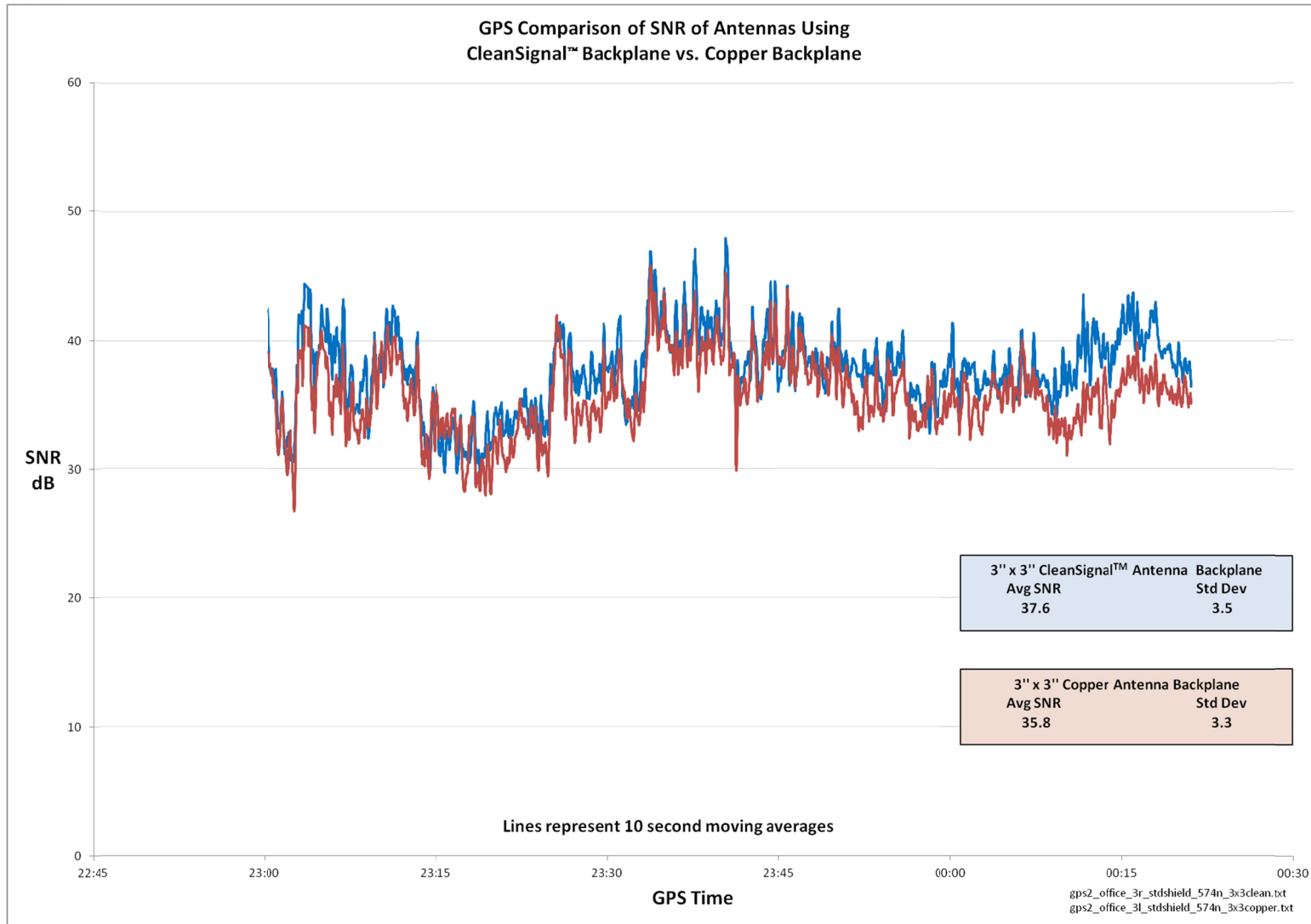
Appendix A

**GPS Comparison of SNR of Antennas Using
CleanSignal™ Backplane vs. Copper Backplane**

3'' x 3'' CleanSignal™ Antenna Backplane	
Avg SNR	**Std Dev**
37.6	3.5

3'' x 3'' Copper Antenna Backplane	
Avg SNR	**Std Dev**
35.8	3.3

Lines represent 10 second moving averages

gps2_office_3r_stdshield_574n_3x3clean.txt
gps2_office_3l_stdshield_574n_3x3copper.txt

Figure 9 TestID-11 Comparison of GPS SNR - CleanSignal™ Antenna Backplane vs. Copper Antenna Backplane

GPS Comparison of SNR
CleanSignal™ GPS Chipset Enhancement vs. Stock Configuration

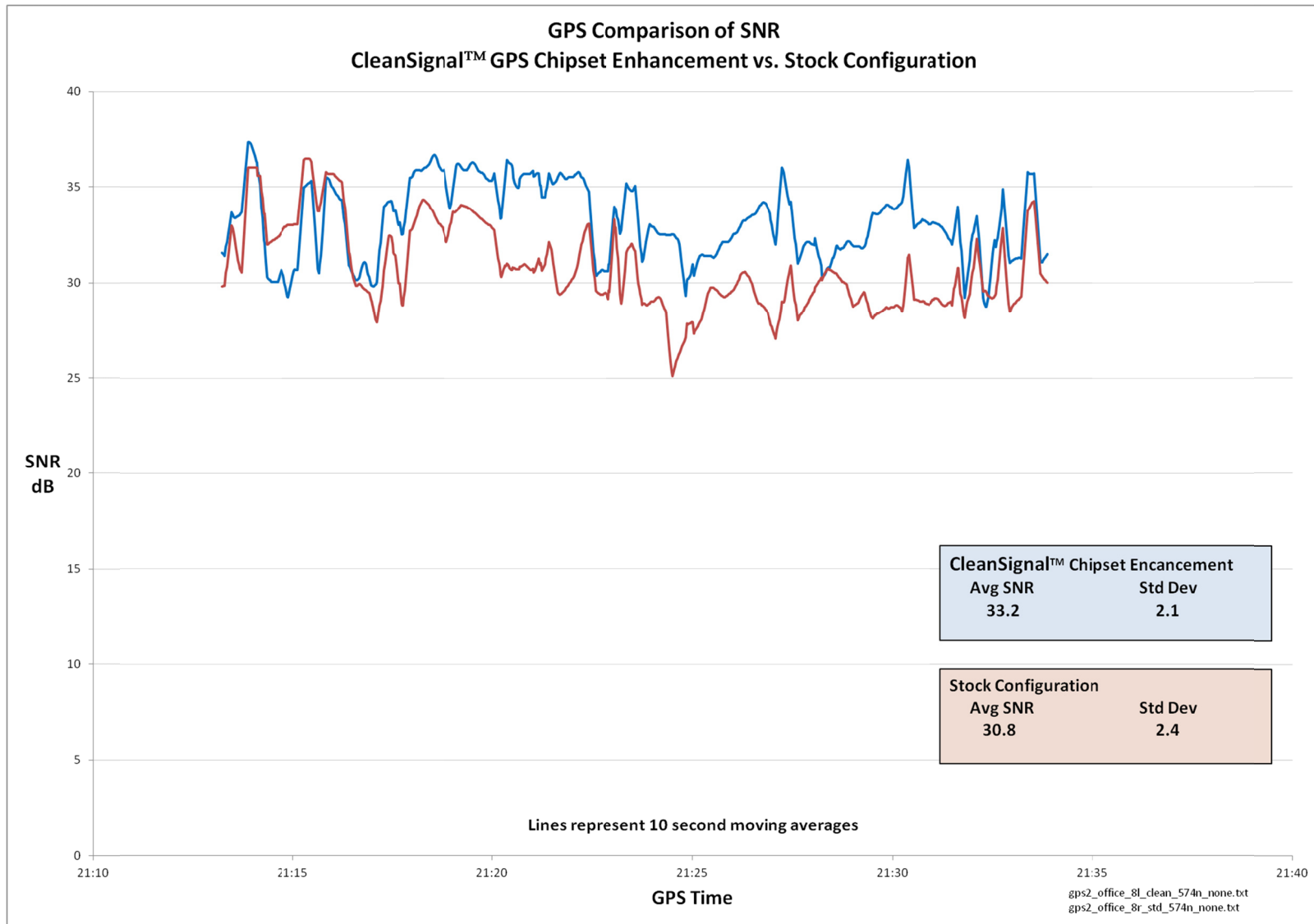CleanSignal™ Chipset Enhancement
Avg SNR	Std Dev
33.5	2.4

Stock Configuration
Avg SNR	Std Dev
31.4	2.9

Lines represent 10 second moving averages

gps2_office_7r_clean_574n_none.txt
gps2_office_7l_std_574n_none.txt
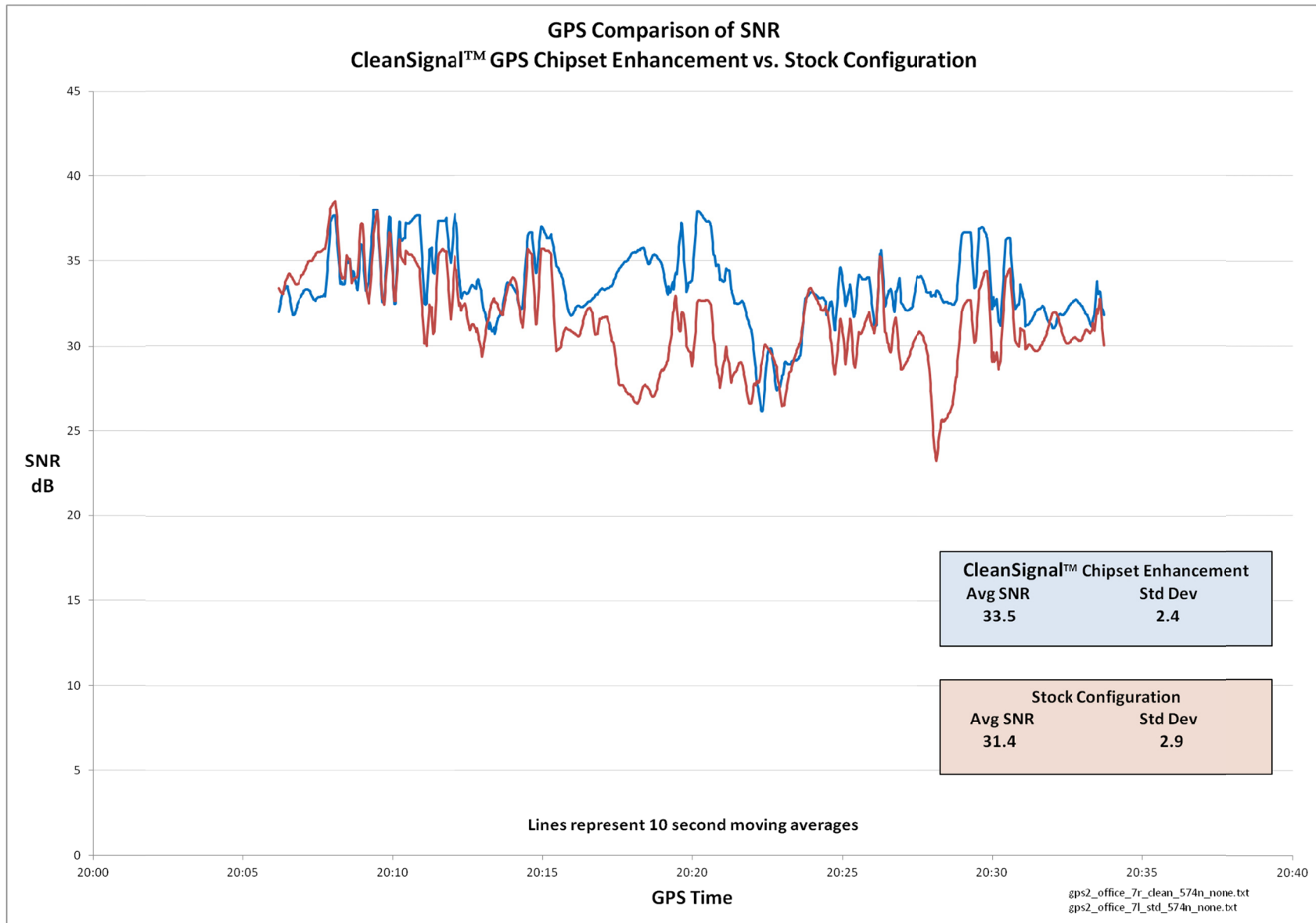
Figure 10 TestID-16 Comparison of GPS SNR - CleanSignal™ GPS Chipset Enhancement vs. Stock GPS Configuration

Figure 11 TestID-17 Comparison of GPS SNR - CleanSignal™ GPS Chipset Enhancement vs. Stock GPS Configuration
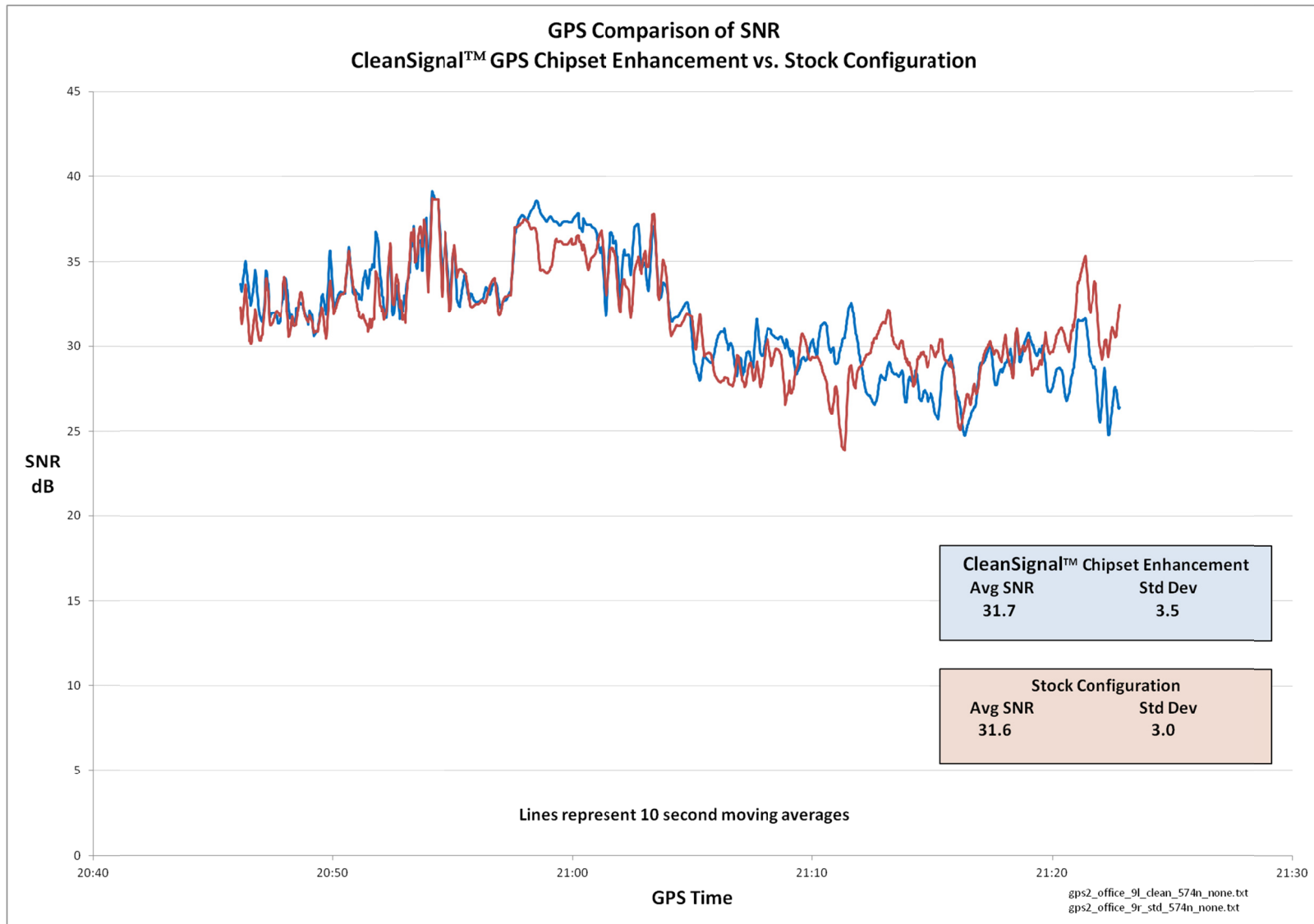
Figure 12 TestID-18 Comparison of GPS SNR - CleanSignal™ GPS Chipset Enhancement vs. Stock GPS Configuration
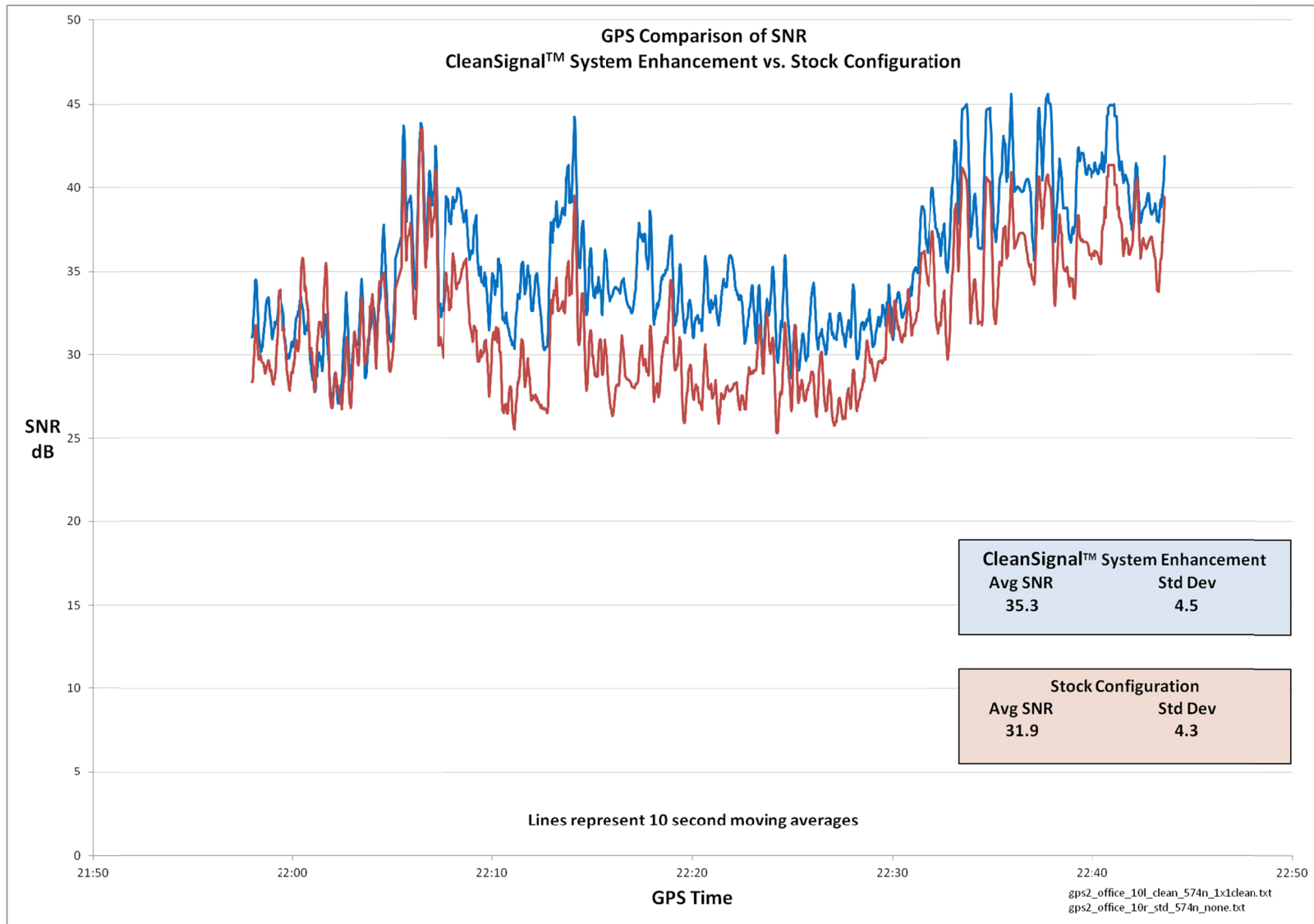
Figure 13 TestID-19 Comparison of GPS SNR - CleanSignal™ System Enhancement vs. Stock GPS Configuration

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