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GPS Ionospheric Scintillation & Tec Monitor
(User's Manual)

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GSV4004B

GPS IONOSPHERIC SCINTILLATION & TEC MONITOR (GISTM)

USER'S MANUAL

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GETTING STARTED

INTRODUCTION

This manual covers the operation of GPS Silicon Valley's GPS Ionospheric Scintillation and TEC Monitor (GISTM) system Model GSV4004B. The GSV4004B, with its optional antenna, consists of three major components: an L1/L2 GPS Antenna (NovAtel's Model 532, 533 or GPS702), a GPS receiver (NovAtel's EuroPak-3M) and a power supply with various interconnecting cables. The EuroPak-3M enclosure houses the GPS receiver and a low phase noise oven-controlled crystal oscillator (OCXO) that is required for monitoring phase scintillation. The GPS receiver, the Euro-3M, with modified software (firmware), can track up to 11 GPS signals signal at the L1 frequency (1575.42 MHz) and the L2 frequency (1227.6 MHz). It measures phase and amplitude (at 50-Hz rate) and code/carrier divergence (at 1-Hz rate) for each satellite being tracked on L1, and computes TEC from combined L1 and L2 pseudorange and carrier phase measurements. The 11^{th} and 12^{th} dual channels are configured as SBAS satellite tracking channels, and to measure a noise floor for C/N_0 and S4 correction computations. The 11^{th} dual channel is designated as Channels 10 and 11. The 12^{th} dual channel is designated as Channel 12. The last half of the 12^{th} dual channel is the noise floor channel. Thus, there are 10 GPS channels (Channel 0 through Channel 9) and 3 SBAS-GEO channels (Channels 10, 11 and 12). Scintillation measurements are also available on all 3 SBAS-GEO channels. However, the phase scintillation parameters are somewhat degraded because the SBAS networks are steering the phase of the signal.

Older optional firmware loads assigned only one SBAS-GEO channel with 11 GPS channels. That option is no longer available.

See Appendix A for specifications for the EuroPak-3M receiver and the L1/L2 antennas. Two CDROMs are distributed with the GSV4004B – a NovAtel CDROM and a GSV Utilities CDROM. A preliminary manual for the EuroPak-3M is included on the GSV Utilities CDROM. However, this EuroPak-3M manual should only be used for the hardware and installation descriptions. The NovAtel data logs from the GSV4004B are based upon NovAtel's OEM4 receiver, as the GSV4004B firmware is based upon OEM4 firmware. The OEM4 manuals are also included on the GSV Utilities CDROM. This GSV4004B manual only augments the NovAtel manuals.

The primary purpose of the GSV4004B GISTM is to collect ionospheric scintillation and TEC data for all visible GPS satellites (up to 10), and up to 3 SBAS-GEO satellites, and output data logs, called ISMRB or ISMRA, to a serial port in either binary or ASCII format. Either of two (NovAtel GPSolution4 or SLOG) programs can be used to control the GSV4004B operations, but SLOG is recommended for collecting scintillation logs. The GSV4004B's Data Logging operation can be controlled to collect the ISMR data logs that are generated every minute. Details of the ISMR data are presented in the GSV4004B Scintillation/TEC Log section. Another off-line PC-based program, ISMVIEW4.EXE, may be used to review the ISMR data. Raw 50-Hz phase and amplitude data logs are also available.

In addition, data extraction programs are supplied for extracting records from the binary files. They are described within. Example source C++ code is also supplied so the users can write their own extraction programs.

This manual augments the NovAtel manuals provided with the GSV4004B. Minimum PC requirements are specified in those manuals. If the high-speed phase and amplitude data logs are to be collected, GSV recommends using an external high-speed serial port device as a buffer between the GSV4004B and the PC. The GSV4004B can have serial port output rates as high as 230 kBaud. An example of such a high-speed serial device is the Inside Out Networks Edgeport USB Expansion Module (www.ionetworks.com). Test results have indicated that certain PC serial ports cannot cope with the high-speed logs.

From time-to-time, there may be GSV4004B firmware upgrades. If there is an upgrade, it will be distributed free of charge, most likely via email. A section in the manual is devoted to instructions for loading the upgraded firmware.

INSTALLATION

INSTALLING HARDWARE

Figure 1 presents the GSV4004B and an optional antenna (GPS-702 or GPS-702GG)[1]. The GSV4004B Rear Panel is described in the NovAtel manual for the EuroPak-3M enclosure. See the applicable NovAtel manuals for hardware installation instructions.

GSV4004B

GPS-702 or GPS-702GG L1/L2 Antenna

Figure 1. GSV4004B GPS Ionospheric Scintillation and TEC Monitor and Optional Antenna

INSTALLING SOFTWARE

The NovAtel **GPSolution4** software program is distributed on the NovAtel CDROM provided with the GSV4004B. It can be installed using the “autorun” feature on the CDROM. Then, simply execute the program from Windows and follow instructions. Consult the NovAtel manuals for operating instructions.

After installation, set up **GPSolution4** to recognize the special GISTM logs as follows:

1. Open **GPSolution4**, and open the appropriate GSV4004B serial port (computer port, not the receiver port).
2. Select "Update All Convert4 Log Definitions" from the main menu.
3. “Updating Convert4 Conversion Definitions” will appear in the status bar. Once updated, **GPSolution4** and **Convert4** will be aware of the ISM logs.
4. These procedures are not necessary for subsequent execution of **GPSolution4** and **Convert4**.

GPSolution4 is no longer supported by NovAtel, so it is recommended that SLOG and the parsing utilities defined herein be used (or other programs developed by the user). The SLOG and other utility programs are distributed on the second utilities CDROM provided with the GSV4004B. For SLOG and the utility programs, simply copy all files from the CDROM to a sub-directory you have selected on your hard disk. The SLOG program manual and example script files used by SLOG are provided on the CDROM, as is this manual.

[1] The GSV-702 antenna has been discontinued by NovAtel. The GSV-702GG replaces it and covers the GLONASS band. However, GLONASS satellites are not tracked by the GSV4004B.

RUNNING THE GSV4004B

INITIALIZING THE GSV4004B

The GSV4004B initializes itself upon power-up and begins to acquire satellites using default information. It automatically locks to the 10 MHz OCXO internal to the enclosure. However, the following non-factory configuration command should be sent to the receiver to ensure that the GSV4004B provides valid low-phase noise scintillation parameters:

CLOCKADJUST DISABLE

to disable receiver hardware clock adjustments (to GPS time). These clock adjustments could cause jumps in the phase data. The downside to this is that clock drift over a very long period of time could cause the receiver's time offset from GPS to exceed its limits, but unlikely. Since the clock adjustments should be very small, the user may chose to not use this command.

Other specific GSV4004B commands controlling filter bandwidths are described later. Default values are set in the GSV4004B.

RECORDING DATA ON HARD DISK

Either NovAtel's **GPSolution4** or **SLOG** programs can be used to select data logs from the GSV4004B. These logs will be continuously recorded to a specified disk file. (It is recommended that **SLOG** be used to avoid possible Windows crashes. However, **GPSolution4** is excellent for monitoring general receiver performance in a Windows GUI environment, especially during installation. **SLOG** is a Windows based program as well that is executed using the Command Prompt; it does not have a Windows GUI.) The use of **SLOG** is described in the **SLOG Details** Section.

GSV4004B SCINTILATION/TEC LOGS

In addition to the data logs described in the NovAtel manuals, the GSV4004B supports the scintillation/TEC data logs listed in Table I. For each selected data log, you may also select one the following trigger methods:

Table I. Specific GSV4004B Data Logs

LOG	ID	BYTE COUNT	DESCRIPTION
RAWSINB	327	H + 4 + (n * 420)	GISTM 50-Hz phase and amplitude data, and 1-Hz TEC data (rate = 1 per sec)
DETRSINB	326	H + 4 + (n * 420)	GISTM detrended RAWSINB data (rate = 1 per sec)
ISMRB	274	H + 4 + (n*152)	GISTM main data record (rate = 1 per 60 sec)

Note: n is the number of SVs being tracked.

RANGEB and RANGEA Data Logs. These NovAtel logs will be slightly different that specified in the OEM4 manual in that there will be an odd number of observations when a GEO is tracked in the 12th channel (Channel 11a). Nothing is reported for the noise-floor half of the 12^{th} channel (Channel 11b).

DATA LOG FORMATS

These three data logs, ISMRB, RAWSINB and DETRSINB, are peculiar to the GSV4004B. Please refer to NovAtel's GPS OEM4 Receiver User Manuals for detailed descriptions of other data logs.

BINARY LOG STRUCTURE

The structure of the binary messages is given in the NovAtel manuals.

RAWSINB Data Log. The receiver collects raw phase measurements and raw amplitude measurements at 50 Hz rate (i.e. 50 sets of measurements a second) and stores them in the binary **RAWSINB** data log every second on the second. Continuous data will be recorded when the ONTIME trigger is specified with 1.0 second period. Each log contains data blocks for all the satellites being tracked. Each data block contains 50 sets of data; the first set is at time specified in Time of Week (TOW), the second set at TOW+0.02 seconds, and so on. The ADR (phase) in this log is that of the tracking model. It contains frequencies up to the tracking loop bandwidth (default at 10 Hz). This log also includes raw 1-second TEC and ΔTEC data. The format of the **RAWSINB** data logs is given in Table II.

The scale factor of the raw power measurements is meaningless. This is because the actual receiver and antenna gains are unknown. In the end, this does not matter because subsequent detrending and forming of S4 will normalize the measurements.

The raw phase measurements include satellite motion, the rate of change of the ionosphere and satellite and receiver oscillator drift. Thus, observation scintillation in the measurements without detrending is not possible, although the use of FFT programs with windowing may be used without detrending.

DETRSINB Data Log. The **DETRSINB** data log has the Message ID of 326. The data log is the same format as the **RAWSINB** log, with the exception that the data it contains is the receiver-detrended scintillation data, and the scale of the power measurements is Ratio * 1048576 (ratio of raw to low-pass filtered). The **DETRSINB** data logs should not be requested at the same time the **RAWSINB** data logs are requested to prevent port overload. The GSV4004B will ignore the second request unless the original request is canceled (un-logged).

DETRSINB data logs are different if the “60-second averaging” amplitude detrending is selected. If this 60-second averaging is selected, the detrended data is simply the raw data divided by the previous 1-minute raw data average. See more detail on this below under the discussions of the Filter Bandwidth command. Further detrending (by averaging) is recommended to remove the ambiguity between 60-second intervals.

Table II. RAWSINB Data Log - Message ID = 327
Message byte count = H + 4 + (n * 420) (n = the number of SVs being tracked)

Field #	Data	Bytes	Format	Units	Offset
1	header	H			0
2	Number of SV observations	4	integer		H
	For First SV observation				
3	PRN	2	integer		H+4
4	reserved	2			H+6
5	L1 TEC at TOW	4	float	TECU	H+8
6	L1 ∆TEC (1-sec) at TOW	4	float	TECU	H+12
7	First L1 ADR	8	double	cycles	H+16
8	L1 ∆ADR for TOW + 0.00	4	signed integer	millicycles	H+24
9	L1 Power for TOW + 0.00	4	unsigned integer	(nbp-wbp)* /10000	H+28
10	L1 ∆ADR for TOW + 0.02	4	signed integer	millicycles	H+32
11	L1 Power for TOW + 0.02	4	unsigned integer	(nbp-wbp)* /10000	H+36
	...				
107	L1 ∆ADR for TOW + 0.98	4	signed integer	millicycles	H+418
108	L1 Power for TOW+ 0.98	4	unsigned integer	(nbp-wbp)* /10000	H+420
109...	For Next SV Observation				

* See text regarding scale factor (units) for detrended power.

ISMRB Data Log. Both the **RAWSINB** and the **DETRSINB** data logs described above contain only raw or detrended-raw measurements (TEC, TEC-phase, phase and amplitude). They are available for diagnostic or analytical purposes. The user must supply data analysis programs to process this raw data. A data reduction program is supplied with the GSV4004B ISM to convert the data to a convenient ASCII format. However, the receiver automatically reduces these raw measurements every minute on the minute and stores the results in the **ISMRB** data log. The GSV4004B provides continuous data at the specified ONTIME (or ONNEW) trigger with a 60 second period. Each log contains data blocks for the all satellites being tracked, including an SBAS GEO, if one has been assigned and is visible. The format of the **ISMRB** data log is given in Table III.

TEC Calculations TEC (Total Electron Content) is a measure of the number of electrons along the path from the satellite and is reported in TEC Units (TECU = Electrons $*10^{-16}$). The number is proportional to the ionospheric delay between L1 and L2 signals.

$$TEC = [9.483 * (PR_{L2} – PR_{L1} - \Delta_{C/A-P,PRN}) + TEC_{RX} + TEC_{CAL}]\ TECU$$

where:

PR_{L2} is the L2 pseudo-range in meters
PR_{L1} is the L1 pseudo-range in meters
$\Delta_{C/A-P,PRN}$ is the input bias between SV C/A- and P-code code chip transitions in meters (see below)
TEC_{RX} is the TEC result due to internal receiver L1/L2 delay
TEC_{CAL} is the user defined TEC offset

Table III. ISMRB Data Log - Message ID = 274
Message byte count = H + 4 + (n * 152) (n = number of SVs being tracked)

Field #	Data	Bytes	Format	Units	Offset
1	Header	H			0
2	Number of SV observations	4	integer	N/A	H
	For First SV observation				
3	PRN	2	integer	N/A	H+4
4	SV Azimuth angle[1]	4	float	degrees	H+8
5	SV Elevation angle[1]	4	float	degrees	H+12
6	C/N_0	8	double	dB-Hz	H+16
7	Total S4	8	double	dimensionless	H+24
8	Correction to total S4	8	double	dimensionless	H+32
9	1-second phase sigma	8	double	radians	H+40
10	3-second phase sigma	8	double	radians	H+48
11	10-second phase sigma	8	double	radians	H+56
12	30-second phase sigma	8	double	radians	H+64
13	60-second phase sigma	8	double	radians	H+72
14	Average of Code/Carrier divergence	8	double	meters	H+80
15	Sigma of Code/Carrier Divergence	8	double	meters	H+88
16	TEC at TOW - 45	4	float	TECU	H+96
17	ΔTEC from TOW - 60 to TOW - 45	4	float	TECU	H+100
18	TEC at TOW - 30	4	float	TECU	H+104
19	ΔTEC from TOW - 45 to TOW - 30	4	float	TECU	H+108
20	TEC at TOW - 15	4	float	TECU	H+112
21	ΔTEC from TOW - 30 to TOW - 15	4	float	TECU	H+116
22	TEC at TOW	4	float	TECU	H+120
23	ΔTEC from TOW - 15 to TOW	4	float	TECU	H+124
24	L1 Lock time	8	double	seconds	H+128
25	Channel status	4	integer		H+136
26	L2 Lock Time	8	double	seconds	H+140
27	L2 C/N_0	8	double	dB-Hz	H+148
28...	For Next SV Observation				

Note 1: Data may also be included for SVs that are unhealthy. However, the Azimuth and Elevation may be set to 0. All scintillation data will still be valid. The TEC values may be set to 0 because of the unavailability of the Tau_GD value.

TEC_{RX} is the nominal L1/L2 receiver delay (converted to TECU) hard-coded as a data base parameter, and TEC_{CAL} is an input parameter supplied by the user, since the receiver differential delay may change slightly with time, and will be different from unit-to-unit. The units are calibrated against WAAS prior to shipment and the TEC_{CAL} value is indicated on the bottom of the unit and on its shipping carton (for shipments after 1 July 2002). The TEC is also corrected for satellite inter-frequency biases (Tau_GD – see ICD-GPS-200D), but not for the SV C/A-to-P biases. These biases are available on a JPL website (see a later section in this document) and can be input to the GSV4004B during initialization (see below). As an alternative, the values of these biases can be converted to TECU and added to the logged TEC values.

ΔTEC is based upon carrier phase measurements at L1 and L2. For an ionospheric delay measured in L1 carrier cycles, the total electron content becomes

$$\Delta TEC = (1.1723\ \Delta PR_{L1,carrier})\ TECU$$

over the 1-second interval, where

$$\Delta PR_{L1,carrier} = 1.54573\ (\Delta ADR_{L1} - \Delta ADR_{L2})\ cycles$$

measured over the 1-second interval (**RAWSINB** and **DETRSINB**) or over a 15-second interval (**ISMRB**).

Phase. As mentioned above for the **RAWSINB** data log, the receiver collects 50 raw phase measurements a second. The raw phase measurements are first detrended with a 6th-order Butterworth high-pass filter (with a user-specified cutoff frequency). Then, for every minute on the minute, the statistics of the residuals (of the previous 3,000 detrended phase measurements) are computed over periods of 1 second, 3 seconds, 10 seconds, 30 seconds and 60 seconds. Thus, for every 60 seconds, 5 values (**1-sec, 3-sec, 10-sec, 30-sec and 60-sec phase sigma's**) are stored in **ISMRB** data log along with the time tag (in **week number** and **time of week**).

Amplitude. The raw amplitude measurements are detrended (by normalization), either with a 6th-order Butterworth low-pass filter output (with a user-specified cutoff frequency), or with the measurement average over the 60-second interval (if the user-specified cutoff frequency is 0). The latter method is the default method if no cutoff frequency is specified. Then, the **total S4**, which includes S4 due to the effects of ambient noise (and multipath), is computed over the same 60-second interval as the phase parameters. The receiver also computes the **correction to the total S4,** which is the effect of ambient noise, based upon the average of the raw 1-Hz C/N_0 values over the same 60-second intervals.

Code/Carrier Divergence. The receiver also collects raw code/carrier divergence (difference between code and carrier pseudorange) every second. The average and standard deviation of the code/carrier divergence are then computed every minute on the minute. These values are indicative of multipath (and noise) activity and can be used to distinguish between **S4** due to multipath (and noise) and **S4** due to scintillation, since there is no code/carrier divergence due to scintillation. A method for using the code/carrier divergence standard deviation is provided below.

L1 Lock Time. The L1 Lock Time indicates how long the receiver has been locked to the carrier phase on the L1 signal. Since the phase-detrending high-pass filter has to be reinitialized whenever lock is lost, all phase parameters (sigmas) should be discarded for any Lock Time less than 180-240 seconds (for a 0.1 Hz bandwidth) to allow the detrending filter to re-settle. For other bandwidths, this time may vary inverse-proportionally to the bandwidth. For the S4 parameters, it suffices to only discard data for any Lock Time less than 60 seconds. S4 may also be valid for Lock Time less than 60 seconds since the power measurements are non-coherent measurements that do not require phase lock. However, on rare occasions, total signal lock could have been lost, so the use of S4 for Lock Time less than 60 seconds should be used with caution. However, in those cases, the code/carrier divergence measurements could be used to discard the data.

L2 Lock Time. The Lock Time indicates how long the receiver has been locked to the carrier phase on the L2 signal. It is an indicator of the validity of the TEC measurements. As with the L1 phase data, short Lock Time data should be discarded.

GSV4004B SPECIFIC COMMANDS

COMMANDS

The following commands are those in addition to standard NovAtel OEM4 commands:

Filter Bandwidth

This command is used in defining the bandwidths of the phase and amplitude de-trending filters, with default values of 0.1 Hz and 0 Hz for phase and amplitude data, respectively. These default values may be changed using the command:

SinBandWidth <PhaseFilterBW> <AmplitudeFilterBW>

This command allows the user to modify the bandwidths of the 6th-order Butterworth filters: a high-pass filter for detrending raw phase measurements and a low-pass filter for detrending raw amplitude measurements. The bandwidths may be individually varied between 0.01 to 1.0 Hz (phase) and 0 to 1.0 Hz (amplitude). A 0 Hz value for the phase filter bandwidth is not valid. If 0 Hz (default value) is input for the amplitude filter bandwidth, the amplitude detrending is accomplished using a straight 60-second average of the amplitude. This is the most desirable method with long-fade amplitude scintillation is present, since the Butterworth detrending of amplitude tends to become unstable and provides excessively large S4 values. However, the straight averaging method is more susceptible to multipath fading. There is no substitute for a near multipath-free environment.

TEC Calibration Value

This command allows the user to input a TEC Calibration (TEC_{cal}) value. The use of this value is defined below. An input of zero can be used, in which case measurements may be corrected during post-processing.

SinTECCalibration <CalibrationValue>

As an purchased option, a value calibrated against WAAS provided TEC data is indicated on a sticker under the unit and on its shipping carton. Typically, with the default value of 0, the units provide TEC values that are on the order of up to 80 TECU (for the GSV4004B – the values for the GSV4004 and GSV4004A are smaller and sometimes negative). The value entered should be the value given on the sticker. Antennas can have an effect on these values. Of course, the user can perform calibration as well and enter a user-determined value.

C/A-to-P Biases

As described below, the SVs generally have a time-bias between the C/A and P code chip transitions. In order to make the TEC values collected from the GSV4004B more accurate, the user may enter these known biases into the GSV4004B to correct for the biases as TEC data is collected. A specific command has been implemented. The command is

CPOffset <32 offset values>

The 32 offset values (one for each PRN, in meters) are added to the C/A code pseudorange measurements prior to forming the TEC values.

PLL Loop Bandwidths

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Depending upon the environment, it may be necessary to change the L1 and L2 Phase-Lock-Loop bandwidths, as the loops may have problems acquiring the signal. This is because the default bandwidths are set as narrow as possible to provide the best tracking performance at lower signal-to-noise ratios. The default bandwidths are as follows:

L1: 6 Hz
L2 0.2 Hz

The acquisition problem will cause the receiver to "give-up" on a specific signal and never track it, either on L2 alone or on both L1 and L2. If this occurs rarely, nothing should be done. However, if this occurs regularly, the bandwidths should be increased using the LOOPSBANDWIDTH command as follows:

LOOPSBANDWIDTH [L1 PLL Bandwidth] [L2 PLL Bandwidth]

Care should be exercised using this command. It is an undocumented NovAtel command.

Command Procedure

The procedure for entering commands is given in the NovAtel OEM4 manual, Volume 2. They can either be entered using **GPSolution4** or be entered using **SLOG**.

TRACKING SBAS (WAAS, EGNOS, MSAS) SVs

COMMANDS

The 11ath, 11bth and 12th channels of the GISTM are to be used to search for and track specified SBAS GEOs, even if not visible. To utilize this capability, use the standard **Assign** Command as follows:

Assign 10, 11 or 12 <PRN> 0 500

where "10", "11" and "12" denotes the 11ath, 11ath and 12th channels, respectively. A separate command is required for each SBAS GEO. The current set of PRNs for the SBAS satellites are given in Appendix E.

In all cases, the "b" side of the 12th channel is used to compute the "Noise Power." The GISTM will measure or compute scintillation parameters for the specified SBAS GEO.

In both versions of the **SLOG** script described below, only one **Assign** command is included. Add one or two more commands if additional SBAS GEOs are to be assigned. However, it is advisable to comment out (using ; at the beginning of the line) commands dealing with the SBAS GEO if no SBAS GEO is visible so that the receiver is not continually trying to acquire it. This is the **Assign** command described here. Also, if not within an SBAS network, collection and copying of the WAAS18B and WAAS26B logs should be commented out as the data would be useless for the local region where the GSV4004B is located. These logs are collected by GPS Silicon Valley during GSV4004B testing for the purpose of TEC calibration. Software used to process these logs is provided on the Utilities CD, but a manual is not. These logs can be converted to ASCII logs using **Convert4**. The user may process this data to obtain the SBAS networks estimate of TEC by using procedures given in RTCA DO-229C. For a nominal fee, GPS Silicon Valley can provide informal instructions (with some manual manipulation) for using the supplied software (**waasiono.exe** and **VertDelay.exe**).

C/A-TO-P SV BIASES

The GSV4004B measures TEC using pseudorange measurements on the L1 and L2 frequencies. On L1, C/A code measurements are used, while on L2, semi-codeless P code measurements are used. Unfortunately, the satellite Tau_GD values used for correcting TEC are corrections for P code L1/L2 biases in the SV. There can also be a bias in the SV between the C/A code phase and the P code phase. This bias will cause a bias in the TEC output values that is different for each SV. GPS Users involved with the International GPS Service (IGS) recognized this and have been estimating these C/A-to-P code biases. These biases are available in a file on the following University of Berne -- http://www.aiub-download.unibe.ch/CODE/P1C1.DCB. The list will be given in ns as a function of GPS PRN. An example of this file is included on the CDROM provided with the GSV4004B. This information is periodically updated and may not be available, for a period of time, for new PRNs, and may be invalid, for a period of time, for PRNs that have had redundant hardware paths changed.

Table IV provides the set of SV biases collected from the site on December 4, 2006, converted to meters. The number 0 must be inserted for PRNs that do not exist at the time.

Table IV. C/A-to-P SV Biases in Meters (December 4, 2006)

CPOffset	-0.0996 -0.0144 -0.132 0.3336 -0.3258 0.0813 -0.3921 -0.1647 0.0459 -0.561 0.1701 0.4803 0.4569 0.0342 -0.5022 -0.2163 0.4176 -0.1068 -0.6057 -0.4053 -0.1239 0.1566 0.0756 -0.0714 0.1404 0.2901 -0.1149 -0.081 0.165 0.5586 0.5112 0

These biases can be removed by using the CPOffset Command upon GSV4004B initialization to enter the biases, in meters, for each PRN, such as follows:

SLOG DETAILS

SLOG

SLOG can be programmed, via script, to generate new files on a periodic basis (such as a new file every day). Example scripts to do this are given in Appendix B (for recording 60-second data) and Appendix C (for recording 50-Hz data). The following describes these two sets of script – Scint60sec.slg and ScintRaw.slg. **SLOG** revision 6n is required to operate these scripts. Older versions of **SLOG** will not.

SLOG accepts command line options for Com Port number (integer), file logging period in minutes (double) and Site Name (string). That is, the command line is:

SLOG scintXXX.slg [iport] [iperiod] [ssite]

where XXX denotes the script name. If the variables are not specified, the default options are 1, 60 and blank for COM1, 60 minutes, and no site name. The Site Name is the only control the user has over the file names using the script in Appendix B and C. The file name for each period is as follows: Site Name_GPS Week No._Day of Week_Hour of Day.gps, relative to GMT.

Scint60sec.slg

This version of script is designed for recording only the 60-second logs, as opposed to the high-rate 50 Hz data. Either version of script could be used for recording only the 60-second logs. However, ScintRaw.slg always records temporary 50 Hz data logs, even though it only saves them if parameters exceed thresholds. Saving the logs can be controlled with appropriate definition of thresholds, however, temporary data logs are always stored. If the PC serial port cannot handle the high-rate data, this could be a problem. Thus, if the 50-Hz data is not desired, it is better to use a script that only records 60-second logs. An example of such script is given in Appendix B.

ScintRaw.slg

Two of the GSV4004B logs (RAWSINB and DETRSINB) consist of a tremendous amount of data, although they would never be logged simultaneously. Usually, however, these logs do not contain any useful information when there is not any ionospheric scintillation activity. Thus, it is desired that the logging be selective based upon information contained in a much lower rate (once per minute) log (ISMRB), which would be logged at the same time. Unfortunately, this log indicates what had occurred over the previous interval, so some buffering is required.

The following describes suggestions/requirements for logging either RAWSINB or DETRSINB based upon information contained in ISMRB.

<u>ScintRaw Requirements</u> **SLOG** extracts information from the ISMRB logs and displays the information when the "L" key is pressed. This same information can be used to determine if either the RAWSINB or DETRSINB log should be recorded. The parameters of interest are SV Elevation angle, C/N_0, Total S4, 60-second phase sigma, and L1 Lock time. The idea is to compare each of these (for each SV) against a threshold. If either of the Total S4 or 60-second phase sigma thresholds are exceeded for any SV, the RAWSINB or DETRSINB log are recorded for the current period and for N_{Max} 60-second periods to follow, provided all of the other thresholds are exceeded. The thresholds, and the value of N_{Max}, must be specified in the ScintRaw.slg Script file as given in Table V.

The counter N is reset to 0 whenever either $S4_{Min}$ or Sigma_Phi_60_{Min} and all the other thresholds are exceeded for any SV, so that the current and the next N_{Max} logs are recorded. It is also be reset when N_{Max} is reached. An exception to this is applied to data collected from an SBAS GEO – exceeding $S60_{Min}$ is not checked for reasons described below.

Default thresholds (and value of N_{Max}) are all 0, which means that all records would be logged. Default values are used if no values are defined in the ScintRaw.slg Script file.

Table V. Threshold Parameters Specified in ScintRaw Script

Parameter	Threshold	Range	Units
Log Counter N	N_{Max}	0 - 100	Unit-less
SV Elevation Angle	El_{Min}	0 - 90	Degrees
C/N_0	$C/N_{0,Min}$	0 - 60	dB-Hz
Total S4	$S4_{Min}$	0 – 1.5	Unit-less
60-Sec Phase Sigma	$S60_{Min}$	0 - 2	Radians
L1 Lock Time	$Lock_{Min}S4$ or $Lock_{Min}Sig60$	0 – 600	Seconds

Logic for recording raw scintillation logs is as follows:

$$save\_raw = \left(Elev \geq Th\_El\right) \bullet \left(C/N_0 \geq Th\_C/N_0\right) \bullet \begin{bmatrix} \left(L1Lock \geq ThLock\_S4\right) \bullet \left(TotalS4 \geq Th\_S4\right) \\ +\left(L1Lock \geq ThLock\_S60\right) \bullet \left(SigPhi60 \geq Th\_S60\right) \bullet \left(PRN < 33\right) \end{bmatrix}$$

The last term of the logic prevents saving raw data when the Sigma_Phi_60 exceeds the threshold for the SBAS satellite. This is because the SBAS network is controlling the phase of the SBAS signal and that control could easily cause the threshold to always be exceeded.

No raw scintillation logs would be recorded if all the thresholds (not including N_{Max}) were set to their maximum (or large) value. However, temporary raw scintillation logs would continue to be recorded.

In order to prevent logging high-rate data on non-scintillation events (low C/N_0, cycle slips or multipath), the suggested minimum thresholds are as follows: $C/N_{0,Min}$ = 30 dB-Hz, $S4_{Min}$ = 0.35, $S60_{Min}$ = 0.2, $Lock_{Min}S4$ = 60 sec and $Lock_{Min}Sig60$ = 240 sec. The $C/N_{0,Min}$ value could be raised if no SBAS signal is being tracked, or if the SBAS GEO is at a higher elevation angle. The $S4_{Min}$ value is set to minimize triggering on GPS signal multipath.

Example ScintRaw.slg script is presented in Appendix C.

OFF-LINE UTILITY PROGRAMS

The following are a few useful off-line utility programs that extract binary scintillation and TEC data logs into an ASCII format:

- **Parseismr.exe**, Version 1.4.1.0 dated 01/14/04, extracts ISMR records from a binary file and converts them to comma-delimited ASCII records for a specified PRN

  Parseismr <PRN> <inputfile> <outputfile>

  If the PRN is specified as "all" (without the quotes), records for all the PRNs will be extracted, but in time-sequence. The output format, preceded by a comma-delimited header defining the fields, is given in Table VI. A program such as EXCEL can be used to sort versus PRN. ASCII Azimuth and Elevation Angle records for all PRNs can also be extracted without the other data with "azel" in the PRN field. These directions can also be obtained by simply typing the program name. Example parsed ISMR files are included on the GSV Utilities CDROM as *.XLD files.

Table VI. PARSEISMR Extracted Data Fields

Input Field #	Data	Units
1	Week Number (WN)	N/A
2	Time of Week (TOW)	seconds
3	PRN	N/A
4	Receiver Status (See NovAtel Manual)	N/A
5	SV Azimuth angle	degrees
6	SV Elevation angle	degrees
7	C/No	dB-Hz
8	Total S4	dimensionless
9	Correction to total S4	dimensionless
10	1-second phase sigma	radians
11	3-second phase sigma	radians
12	10-second phase sigma	radians
13	30-second phase sigma	radians
14	60-second phase sigma	radians
15	Average of Code/Carrier divergence	meters
16	Sigma of Code/Carrier Divergence	meters
17	TEC at TOW - 45	TECU
18	ΔTEC from TOW - 60 to TOW - 45	TECU
19	TEC at TOW - 30	TECU
20	ΔTEC from TOW - 45 to TOW - 30	TECU
21	TEC at TOW - 15	TECU
22	ΔTEC from TOW - 30 to TOW - 15	TECU
23	TEC at TOW	TECU
24	ΔTEC from TOW - 15 to TOW	TECU
25	L1 Lock time	seconds
26	Channel status	N/A
27	L2 Lock Time	seconds
28	L2 C/N_0	dB-Hz

- **Parsesin.exe**, Version 1.4.1.0 dated 01/22/04, extracts RAWSINB or DETRSINB records and converts them to comma-delimited ASCII records for a specified PRN

Parsesin <PRN> <inputfile> <outputfile> <start_time> <stop_time>

Only a PRN value can be specified (<all> does not work). A PRN value of 0 can be used to display the number of records available for each PRN. <start_time> and <stop_time> are optional, but are useful because of the large data file, and to search for data of interest based upon ISMRB summary results. They are to be entered as GPS Time-of-Week (no Week Number). If <stop_time> is omitted, data will be parsed to the end of file. If <stop_time> is smaller than <start_time>, the program will automatically bridge an end-of-week roll-over. Example **Parsesin** output file data fields (for a DETRSINB file) are given in Table VII, preceded by a two-line header. Example parsed DETRSINB files are included on the GSV Utilities CDROM as *.XLD files. The output ADR values are total ADR values, where the one-second value is combined with each 20-msec value.

Table VII. PARSESIN Extracted Data Fields (Header and First 50 Data Points) (Detrended Log)

Detrended Week Num: 1231 Prn: 3				
GPS TOW	TEC	TECdot	ADR	Power
406681	46.409222	0.003973	0.037000	0.99448967
406681.02	46.409222	0.003973	0.034000	1.00279427
406681.04	46.409222	0.003973	0.030000	1.01049423
406681.06	46.409222	0.003973	0.037000	1.00348759
406681.08	46.409222	0.003973	0.040000	1.01587009
406681.1	46.409222	0.003973	0.040000	1.02810955
406681.12	46.409222	0.003973	0.038000	0.96980095
406681.14	46.409222	0.003973	0.037000	0.97975636
406681.16	46.409222	0.003973	0.033000	0.94889641
406681.18	46.409222	0.003973	0.032000	0.94976807
406681.2	46.409222	0.003973	0.035000	1.0243721
406681.22	46.409222	0.003973	0.035000	1.13061142
406681.24	46.409222	0.003973	0.035000	0.95649433
406681.26	46.409222	0.003973	0.036000	1.03944206
406681.28	46.409222	0.003973	0.037000	1.09727955
406681.3	46.409222	0.003973	0.037000	1.15427113
406681.32	46.409222	0.003973	0.042000	0.9800415
406681.34	46.409222	0.003973	0.043000	1.04520988
406681.36	46.409222	0.003973	0.046000	1.00749397
406681.38	46.409222	0.003973	0.044000	0.95614147
406681.4	46.409222	0.003973	0.039000	1.06119061
406681.42	46.409222	0.003973	0.036000	1.09483337
406681.44	46.409222	0.003973	0.034000	1.05533695
406681.46	46.409222	0.003973	0.032000	0.97684574
406681.48	46.409222	0.003973	0.037000	1.00063229
406681.5	46.409222	0.003973	0.040000	0.94757843

- The Windows-based program **Convert4** is also available as part of the NovAtel **GPSolution4** software package. It can also be used to parse logs from logging files. However, before it is used, **GPSolution4** must be setup and used with the GSV4004B so that a file indicating available receiver logs is recorded in the **GPSolution4/Convert4** folder, including synchronizing to the units data base. This setup is described above for **GPSolution4**.

- **ISMVIEW4.EXE** is an off-line utility program supplied with the GSV4000 that allows the user to review the ISMR data logs and extract ISM data for specified satellite while ignoring other data logs. It is a valuable tool for finding desirable data to be extracted from the logs. ISMVIEW4 is described in Appendix D.

SUGGESTED SCINTILLATION ANALYSIS PROCEDURES

60-SECOND SUMMARY ANALYSIS

For the detailed analysis of the 60-second ISMR summary data, the recommended parsing program is **Parseismr.exe** for obtaining the ISMR records in a comma-delimited format as is shown above in Table VI (using the <all> PRN option). This comma-delimited file can be easily input to and edited in **EXCEL**, the Microsoft spreadsheet program. Editing involves eliminating phase sigma data collected before the phase detrending filter has converged. This can be done by sorting, in ascending order, the Lock Time data in column 25 (column Y) or column 27 (column AA). It is suggested that rows with Lock Time less than 240 seconds be deleted. Next, in order to eliminate non-converged values even further, sort, in descending order, the 60-second phase sigma data in column 15 (column N) and delete rows with very large phase sigma data where convergence has obviously not yet happened. This will eliminate confusion with legitimate scintillation events. Filter convergence is not usually an issue with regard to the amplitude S4 data, especially if the "averaging" detrending option is used. Thus, if the observation of S4 is more important that observation of the phase sigmas, the Lock Time threshold should be set at a lower value, or generate two different spread sheets with different Lock Time thresholds.

Finally, sort, in ascending order, the PRNs in column 3 (column C), Week Number I column 1 (column A) and Time-of-Week in column 2 (column B). The remaining data can then be pasted into the sample spreadsheet provided with the GSV4004B in columns A through AB. Rows at the end of the spreadsheet may have to be deleted in there are fewer rows than previously existed in the spreadsheet. If this is the case, the plots will be automatically adjusted. If there are more rows than previously existed, the series end-points will have to be adjusted accordingly. We also suggest creating two spreadsheets – one for the GPS PRNs and one for the SBAS GEO PRN – since their characteristics differ significantly as discussed below.

The Corrected S4 is obtained by differencing the S4 Correction from the Total S4 is an RSS sense. If the S4 Correction is larger than the Total S4, simply set the Corrected S4 to 0, since the S4 value is obviously due to noise.

The example spreadsheets included on the Utilities CD plot the phase sigmas versus C/N_0 and elevation angle, corrected S4 versus the same and S4 versus an estimate one-sigma pseudorange (code_carrier divergence). Much of the lower-to-moderate S4 for the GPS PRNs at lower elevation angles can be due to multipath. The latter plot helps discriminate the difference between the effects of multipath and amplitude scintillation. When multipath is present, the pseudorange accuracy or the 60-second period is larger than normal (but not always, depending upon multipath characteristics). In the case of the SBAS GEO, the S4 is somewhat immune to multipath because the multipath, although present, varies very slowly and filters out in the detrending. However, because of sometimes much lower C/N_0 conditions, the SBAS GEO Total S4 is more affected by noise. The application of the S4 correction partially eliminates this effect.

Example plots of the phase sigmas for the GPS PRNs and the SBAS GEO are presented in Figures 2 and 3, respectively, for a non-scintillating environment, collected simultaneously. Note that the SBAS values are somewhat higher for two reasons – lower C/N_0 and the fact that the SBAS network is "steering" the phase of the GEO signal with updates of once per second.[2] However, under moderate phase scintillation conditions, the effect of scintillation would still be observable. The phase sigmas for the GPS PRNs are dominated by the GSV4004B OCXO phase noise, the SV frequency standard phase noise and thermal noise at low C/N_0. Generally, the SV frequency standard phase noise is worse than the GSV4004B OCXO phase noise for the

[2] Figure 3 represents phase measurements collected from Inmarsat-3. The newer WAAS GEOs, PRNs 135 and 138, provide much less noisy phase measurements.

shorter averaging times, depending upon the frequency standard technology. In any event, lower than moderate phase scintillation will dominate these effects.

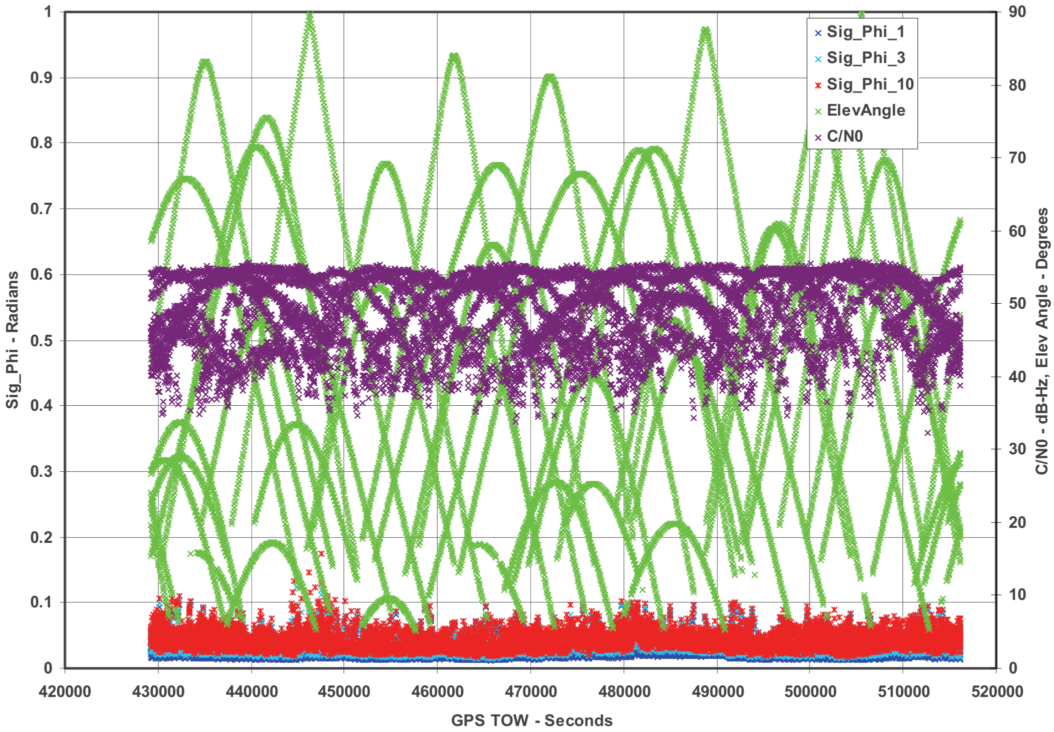


Figure 2. Example Phase Sigma Plots in a Non-Scintillation Environment for GPS PRNs

Example plots of Corrected S4 for the GPS PRNs and the SBAS GEO are presented in Figures 4 and 5, respectively, for a non-scintillating environment, collected simultaneously. Note that larger values are more prevalent for the GPS PRNs than for the SBAS GEO, primarily because of the more rapid changes in the multipath effects. However, the lower values of Corrected S4 are lower for the GPS PRNs because they are generally at higher C/N_0 than is the SBAS GEO.

To illustrate the effects of multipath on Corrected S4, examples of estimated pseudorange errors (code-carrier divergence) are plotted against Corrected S4 for the GPS PRNs and the SBAS GEO in Figures 6 and 7. An example dividing line between points due to multipath and non-multipath is shown. This technique has been successfully used to filter out S4 due to multipath from that due to scintillation in a scintillation environment, since there is very little code/carrier divergence due to scintillation.

Note that the code-carrier measurements on the GPS satellites are somewhat less than on the GEO, but the S4 values on the GEO are somewhat less than on the GPS satellites. Thus, the line equation is different.

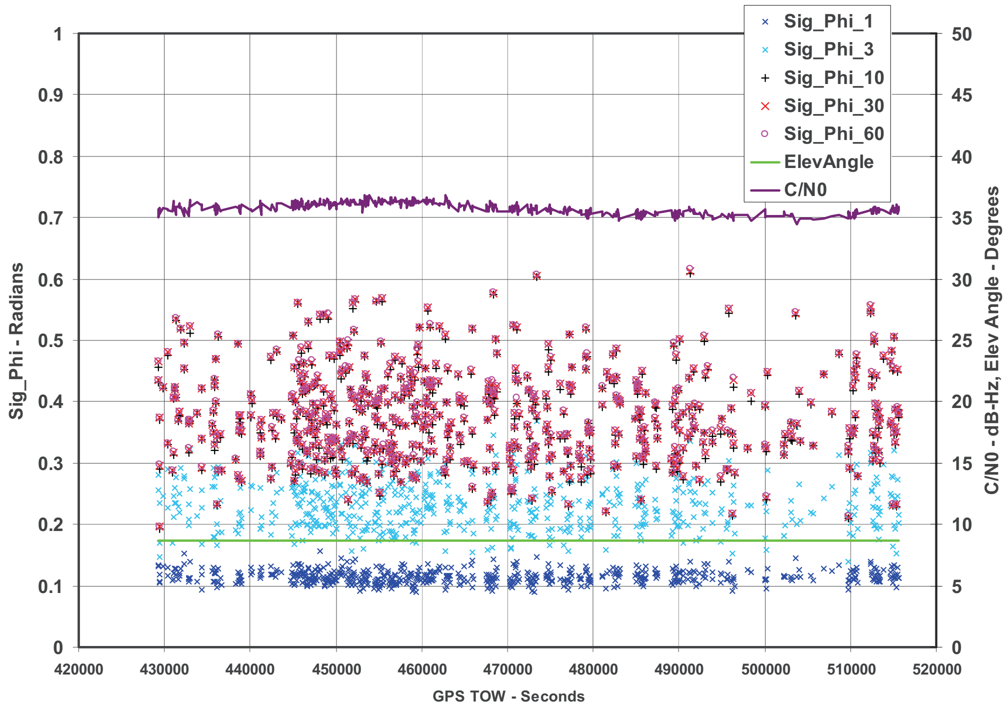


Figure 3. Example Phase Sigma Plots in a Non-Scintillation Environment for an SBAS GEO

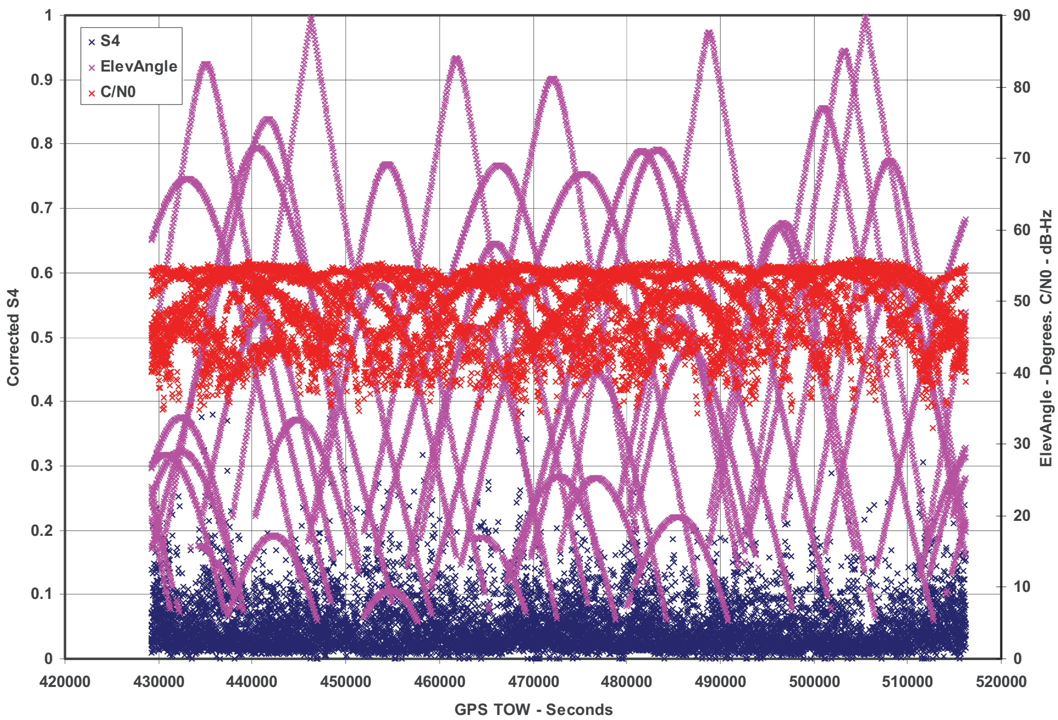


Figure 4. Example Corrected S4 Plots in a Non-Scintillation Environment for GPS PRNs

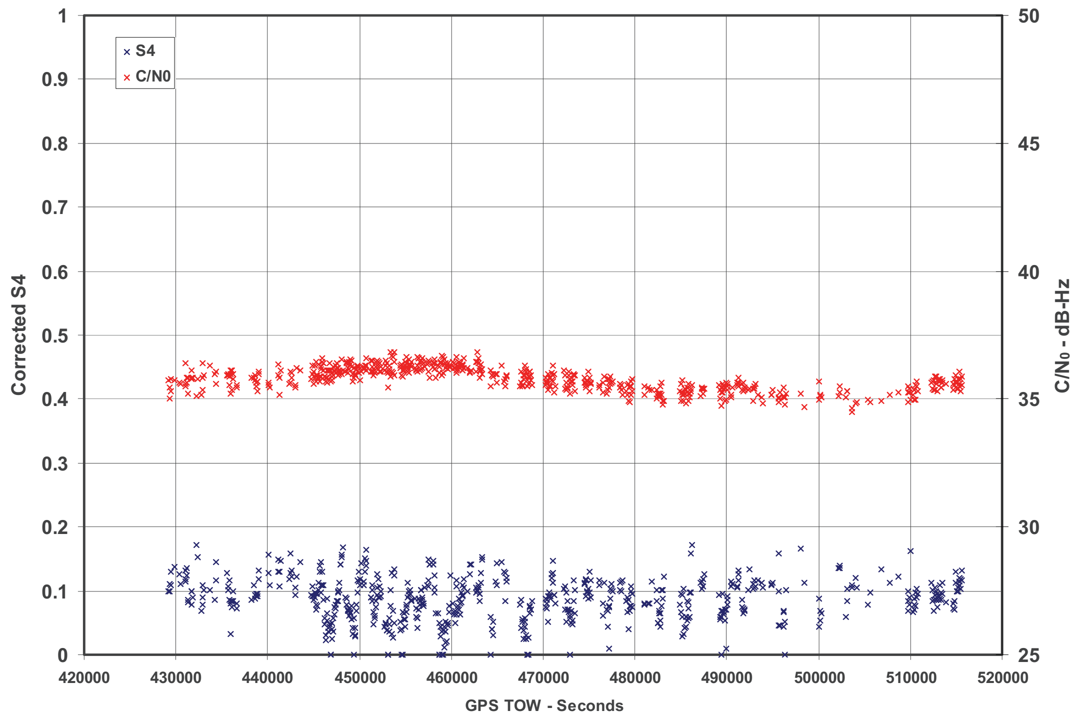


Figure 5. Example Corrected S4 Plots in a Non-Scintillation Environment for an SBAS GEO

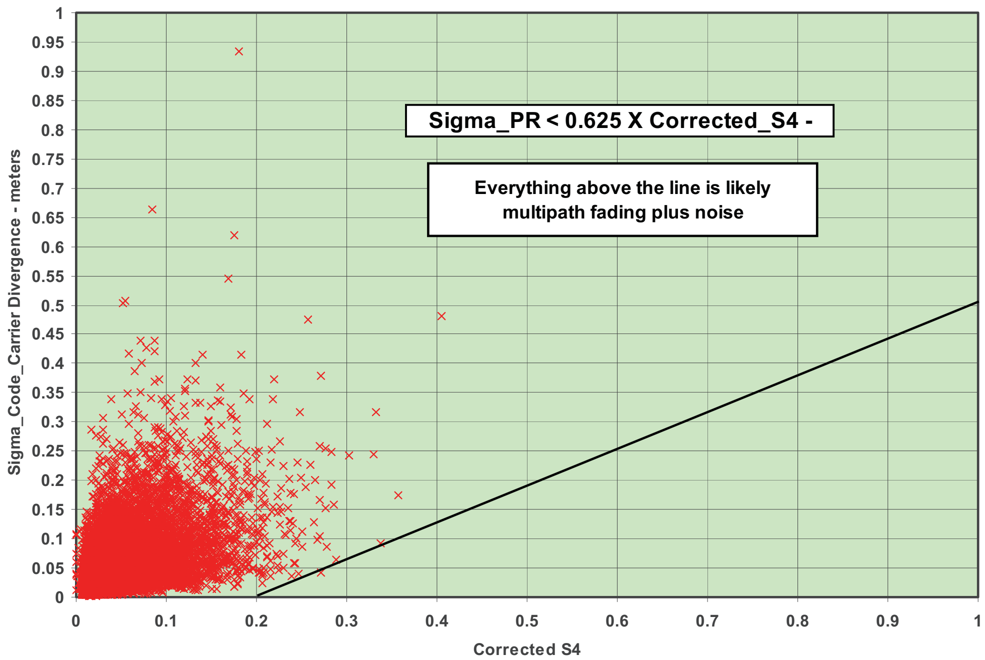


Figure 6. Example Estimated Multipath Error Plotted Against Corrected S4 in a Non-Scintillation Environment for GPS PRNs

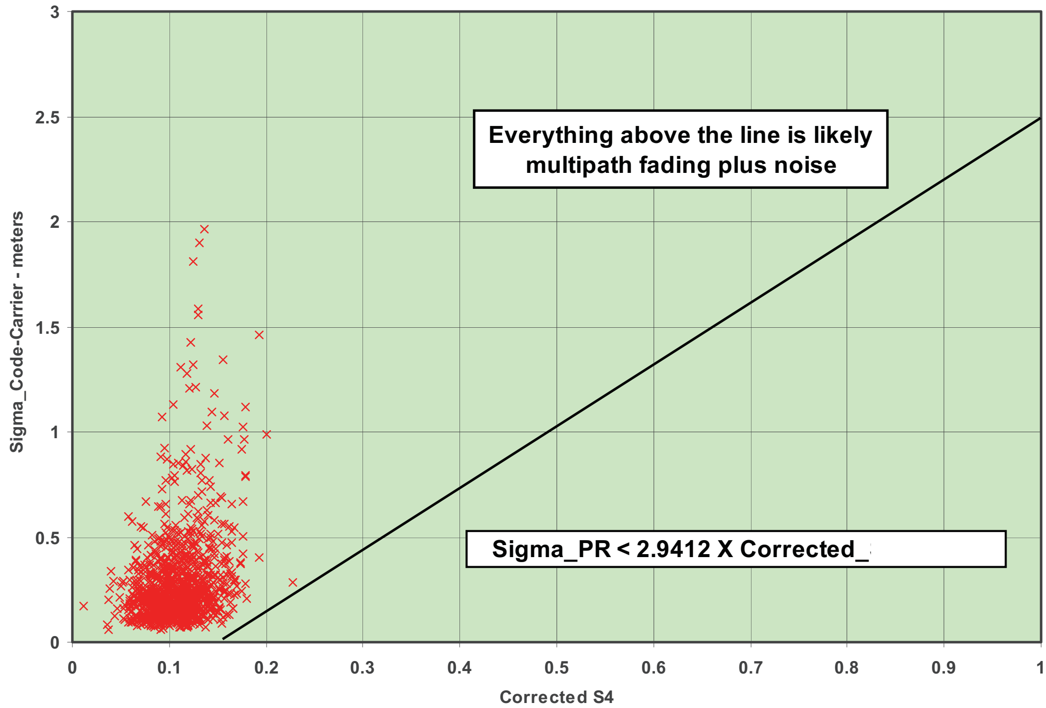


Figure 7. Example Estimated Multipath Error Plotted Against Corrected S4 in a Non-Scintillation Environment for an SBAS GEO

50-Hz SUMMARY ANALYSIS

As indicated above, without setting thresholds for collection of detrended 50-Hz data, the amount of data collected can be very excessive. Figure 8 shows the effect of setting thresholds for PRN 2 for a Total S4 threshold set at 0.3, where four 60-second periods of 50-Hz data was collected. This data corresponds to the Corrected S4 values plotted in Figure 4. N_{Max} was set to 2, so two periods were logged for each of the two events. Each 60 second period was detrended again since the buffered amplitude data is detrended with the previous period's average during the real time collection. The threshold was exceeded on the first period of each event, again, due to multipath excursions.

The detrended phase data for the same period is also plotted, but no thresholds were exceeded. Detrending phase data again is not required since the high-pass filtered data is recorded in real-time. This would also be the case for the amplitude data if the low-pass filter option was selected with a non-zero bandwidth.

If raw data is collected (not detrended), the user can perform any detrending scheme. However, a word of caution is in order. If programs such as MATLAB are used for filtering the raw, problems can be encountered – they are not accurate enough for high-order narrow-bandwidth filtering. This would not be the case if "average" detrending is used for S4 computations.

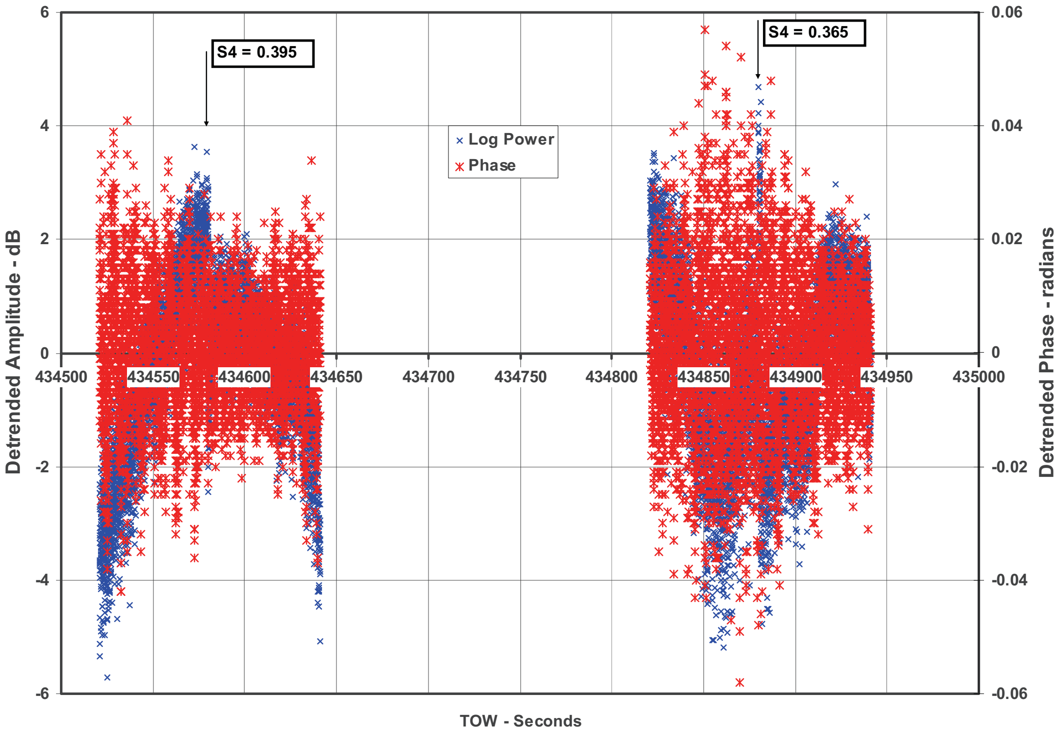


Figure 8. Example Detrended Raw Amplitude and Phase Data in a Non-Scintillation Environment for GPS PRN 2 Where S4 Exceeded 0.3

DIRECTIONS FOR LOADING NEW FIRMWARE

Occasionally, a new version of firmware for the GSV4004B will be distributed. To update GSV4004B receiver to the new version, first launch the application named WINLOAD.EXE. If you had previous versions of WINLOAD.EXE, please discard them in favor of this new version. You should be running at least WINLOAD.EXE, v1.0.0.0 A42 (Alpha Release 42). You can verify this by clicking the "Help->About" menu within WINLOAD.EXE.

When WINLOAD.EXE is started, go to the "Settings->COM Settings" menu and set up the PC's comport for your system. Going with the default settings is recommended, if possible. COM1, 115200 download baud and 9600 connect baud works good on most systems.

Next, go to the file menu, and select "File Open". In the "File Open" dialog window, navigate to the directory containing the new firmware HEX file (if necessary), and then double-click on the HEX file. The "File Open" dialog box will disappear, and the path and file should appear in the console window. Connect your OEM4's COM1 port to the appropriate PC's comport using the "null" modem cable, have power ready, but DO “NOT” apply it to the GSV4004B yet. Click the "Write Flash" button. Double-check that the power is unplugged to the GSV4004B receiver when prompted by the dialog box, click "Ok", and then plug power back into the GSV4004B about three seconds after the status screen says "Searching for card ... timeout in: 15 s". You will get the best results if you apply power at 12 seconds. (If the countdown starts at 60 instead of 15, then wait until it counts down to 57, then apply the power.)

The card will be initialized, and then you will be prompted for the authorization code (authcode) for this particular GSV4004B Card (serial number specific). (Note that there are two serial numbers – one for the enclosure and one for the receiver card. The receiver card serial number is not visible, but is indicated along with the enclosure serial number in the documentation provided with the authcode.) Enter the authcode complete with the commas, making sure that you enter the letters in the authcode in UPPERCASE FORMAT ONLY, and then click OK to begin the firmware update process. (Lowercase or mixed case will not work properly, and you will get an error about an invalid authcode or a failed checksum.)

Note: You have thirty seconds to enter the authcode before WinLoad "times out" and aborts the firmware loading process. It helps to copy the authcode to the clipboard and then paste the authcode to WinLoad's "authcode entry text dialog box" using Ctrl-V to save time, and also to reduce the chance of entering an incorrect authcode due to a typing error.

Once the GSV4004B has been successfully loaded with the new firmware, you “MUST” FRESET the receiver or it may operate erratically, because the NVRAM table has changed, so you must use the FRESET command to "format" the NVRAM table to new firmware’s specifications for reliable operation. You can FRESET the receiver by entering the FRESET command into it using a simple terminal program or by using the "Command Console" window under the **GPSolution4** software.

APPENDIX A – EuroPak-3M and L1/L2 Antenna Data Sheets

NovAtel

Positioning Leadership

Euro-3M

Euro-3M

NovAtel's Euro-3M™ features improved MEDLL performance and signal quality measurements in a Euro format card or a durable, lightweight enclosure with optional internal high precision clock.

Standard and MEDLL versions

Available in two software models, the standard Euro-3M includes 14 channels for tracking L1/L2 GPS signals with NovAtel's patented Narrow Correlator® technology and four channels for wide correlator tracking of L1 GEOs. The MEDLL version provides eight L1/L2 GPS channels and one L1 GEO channel and features a 50 percent improvement in MEDLL performance on a single card, compared to the previous multi-card 8 MHz MEDLL receiver, as shown in Figure 1 (back).

Superior tracking ability

The Euro-3M includes the patent-pending SafeTrak™ algorithm, which detects and eliminates cross-correlation for added tracking reliability. In addition, the Euro-3M features bit synchronization verification, in-band digital pulse blanking on the L2 signal, and includes RFI improvements developed for the U.S. WAAS network. A DO-228 compatible RF deck offers additional protection against out-of-band RF interference.

Raw data and signal quality monitoring

The Euro-3M provides raw GPS and SBAS frame data with parity information and Signal Quality Monitoring (SQM) measurements, which can be used to monitor the quality of the incoming signal and detect satellite failures. Automatic gain control (AGC) data for the L1 and L2 signals is also provided.

Choice of platform

Designed for system integrators, the Euro-3M is available as an OEM engine in the standard Eurocard format or housed in the rugged EuroPak-3M enclosure. Both include three high speed serial ports and auxiliary strobe signals, including a 1PPS output. Also available is the EuroPak-3MT, which provides these same features, as well as an internal high precision clock tightly matched to GPS time, making it an ideal solution for timing applications.

Features	Benefits
50% improvement in MEDLL performance	Reduces multipath effects for accurate range measurements
Real-time Signal Quality Monitoring (SQM) measurements using multiple correlators	Offers the ability to detect satellite failures to ensure exceptional data integrity
In-band digital pulse blanking on the L2 signal	Mitigates pulsed RF interference for increased tracking reliability

Euro-3M

Performance[1]

Tracking Channels

Standard Model	14 L1/L2 GPS + 4 L1 GEO
MEDLL Model	8 L1/L2 GPS + 1 L1 GEO

Position Accuracy

Single Point L1/L2	1.5 m CEP

Measurement Precision[2]

C/A Code	10 cm RMS
P(Y) Code	50 cm RMS (AS on)
L1 Carrier Phase	3 mm RMS (differential channel)
L2 Carrier Phase	5 mm RMS (differential channel)

Data Rate	1 Hz

Time to First Fix

Cold Start[3]	< 100 s

Signal Reacquisition

C/A Code	< 5 s (typical)
P(Y) Code	< 60 s (typical)
SBAS	< 10 s (typical)

Altitude	**3,000 m**

1 Typical values. Performance specifications subject to GPS system characteristics, US DOD operational degradation, ionospheric conditions, satellite geometry, baseline length, and multipath effects.
2 Measurement precision at C/N_0 = 44 dB-Hz.
3 Typical value. No almanac or ephemeris and no approximate time or position.
4 Main data connector extends approximately 7 millimeters past edge of board.
5 Unless otherwise specified, all specifications apply to both the EuroPak-3M and EuroPak-3MT.
6 The EuroPak-3M provides an external oscillator input on this connector while the EuroPak-3MT provides an output from the internal clock.

Euro-3M Engine Physical & Electrical

Size[4]	**160 x 100 x 16 mm**
Weight	**150 g**

Power

Input Voltage	+4.5 to +18 VDC
Power Consumption	6 W (typical)

Antenna LNA Power Output

Output Voltage	+5 VDC
Maximum Current	100 mA

External Oscillator Input

Input Frequency	5 or 10 MHz ± 0.5 ppm
Signal Level	0 to +13 dBm

Communication Ports

- 3 RS-232 or RS-422 serial ports (user-configurable) capable of 9,600 to 230,400 bps

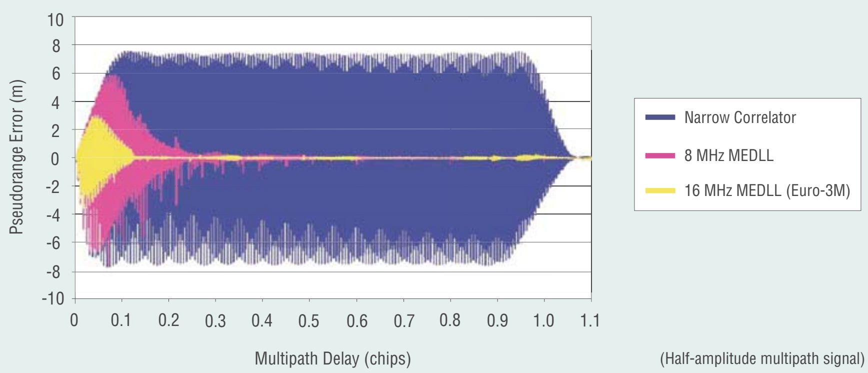
Input/Output Connectors

Main	160-pin five-row male header
Antenna Input	SMB male
External Oscillator Input	SMB male

Environmental

Temperature	
Operating	-40°C to +85°C
Storage	-45°C to +95°C
Humidity	95% non-condensing

Figure 1 - Simulation of Pseudorange Error Due to Multipath



(Half-amplitude multipath signal)

EuroPak-3M/3MT Enclosure Physical & Electrical[5]

Size	**235 x 154 x 71 mm**
Weight	**1.2 kg**

Power

EuroPak-3M	
Input Voltage	+9 to +18 VDC
Power Consumption	6 W (typical)
EuroPak-3MT	
Input Voltage	+11 to +18 VDC
Power Consumption	13 W (typical)

Antenna LNA Power Output

Output Voltage	+5 VDC
Maximum Current	100 mA

External Oscillator Input (EuroPak-3M only)

Input Frequency	5 or 10 MHz ± 0.5 ppm
Signal Level	0 to +13 dBm

Oscillator Output (EuroPak-3MT only)

Output Frequency	10 MHz
Signal Level	+10 dBm ± 3 dB

Phase Noise

0.1 Hz	-55 dBc/Hz	1 kHz	-165 dBc/Hz
1 Hz	-95 dBc/Hz	10 kHz	-165 dBc/Hz
10 Hz	-125 dBc/Hz	100 kHz	-165 dBc/Hz
100 Hz	-155 dBc/Hz		

Communication Ports

- 3 RS-232 serial ports capable of 9,600 to 230,400 bps

Input/Output Connectors

Power	4-pin LEMO
Antenna Input	TNC female
Oscillator[6]	BNC female
COM1	DB-9 male
COM2	DB-9 male
COM3	DB-9 male
I/O	DB-9 female

Environmental

Temperature	
Operating	
EuroPak-3M	-40°C to +60°C
EuroPak-3MT	-20°C to +50°C
Storage	-45°C to +95°C
Humidity	95% non-condensing

For more information, visit our website.

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Email	sales@novatel.ca
Web	www.novatel.com

NovAtel

GPS-702

USERS' GUIDE

The GPS-702 is an active antenna designed to operate at the GPS L1 and L2 frequencies, 1575.42 and 1227.60 MHz. This guide provides the basic information you need to install and begin using your new antenna.

ADDITIONAL EQUIPMENT REQUIRED

The equipment listed below is required to set up the GPS-702:

- A mount, such as a range pole, tribrach, or tripod, with a 5/8" x 11 thread that extends between 3/8" and 7/8" (9 mm and 22 mm)
- A 1" open-end wrench
- Coaxial cable with a male TNC connector
- A device with an antenna input port that both receives the RF signal and provides 4.5 - 18.0 VDC to the antenna (All NovAtel GPS receivers provide the necessary power through their antenna RF connectors.)

SITE SELECTION GUIDELINES

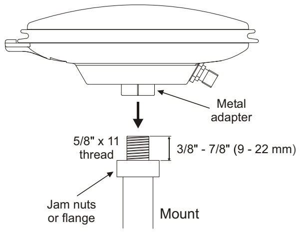
Before installing the antenna, select a site that as closely as possible meets the following conditions for optimal performance:

- An unobstructed line-of-sight from horizon to horizon and at all bearings and elevation angles
- As far as possible from reflective objects, especially those that are above the antenna and any water bodies, which can be a strong source of multipath reflections
- If obstructions and reflective surfaces are within 30 m, ensure the site is as high as possible. Otherwise, mount the antenna as low as possible.

INSTALLING THE ANTENNA

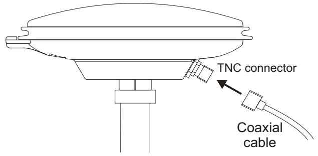
After a site has been selected, install the antenna as follows.

1. Verify that the thread on the mount does not extend more than 7/8" (22 mm) to ensure the plastic inside the antenna receptacle is not damaged when the mount is inserted. If it extends further than 7/8" (22 mm), add two jam nuts to shorten the exposed thread, ensuring the nuts are well-tightened.
2. Align the mount thread with the metal adapter on the bottom of the antenna and rotate the antenna clockwise until it is securely screwed to the mount. Using a wrench, tighten the adapter to the mount.



✉ The metal adapter on the bottom of the antenna is fixed in place. Do not attempt to remove it.

3. Remove the dust cap from the antenna's TNC connector.
4. Attach the male TNC connector of the coaxial cable to the antenna's TNC connector.

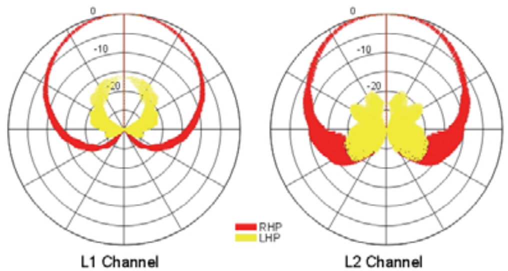


5. Attach the other end of the coaxial cable to the antenna input port of the receiving device, which must provide power as detailed in the *SPECIFICATIONS* section of this guide. All NovAtel GPS receivers provide the necessary power through their antenna RF connectors.

ANTENNA CARE

The GPS-702 is designed to withstand the elements, including rain, snow, and dust. However, to ensure your antenna performs optimally, keep the radome (the top surface of the antenna) clean and brush off any ice and snow. In addition, ensure the TNC connector remains clean and dry and replace the dust cap when a cable is not connected.

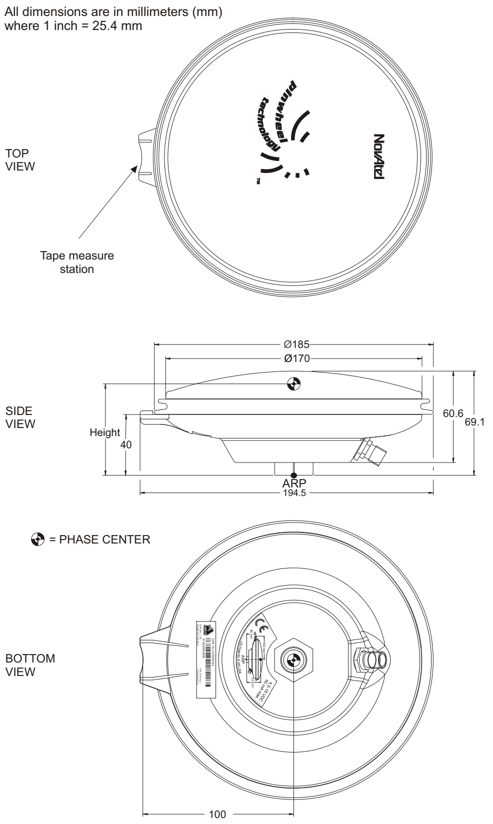
ELEVATION GAIN PATTERN



SPECIFICATIONS

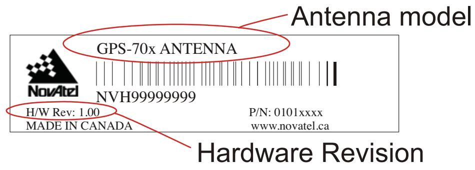
RF	
3 dB pass band (typical)	L1: 1575 -15/+30 MHz L2: 1228 -15/+30 MHz
Out-of-band rejection (typical) -30/+50 MHz -40/+80 MHz	 30 dBc 50 dBc
Gain at zenith (θ = 90°) (min)	L1: +5 dBic L2: +2 dBic
Gain roll-off (zenith to horizon)	L1: 13 dB L2: 11 dB
LNA gain (typical)	27 dB
Polarization	Right-hand circular
Noise figure (typical)	2.0 dB
L1-L2 differential propagation delay (maximum)	5 ns
Nominal impedance	50 Ω
VSWR	≤ 2.0 : 1
POWER	
Input voltage	4.5 - 18.0 VDC
Current (typical)	35 mA
PHYSICAL	
Diameter	185 mm (7.28")
Weight	480 g (16.9 oz)
ENVIRONMENTAL	
Maximum altitude	9000 m (29527.5 ft)
Operating temperature	-40°C to +85°C (-40°F to +185°F)
Storage temperature	-55°C to +85°C (-67°F to +185°F)
Vibration	MIL-STD-810F Method 514.5
Salt spray	MIL-STD-810F Method 509.4
Ingress protection	IPX6, IPX7

MECHANICAL DRAWINGS



PHASE CENTER

Please refer to the Mechanical Drawings on the previous panel and the close-up of the label below before reading this section.



Height = Vertical phase center offset from antenna reference point or antenna reference plane (ARP)

For relative offset numbers and phase center variation (PCV) tables, please visit the U.S. National Geodetic Survey (NGS) website at www.ngs.noaa.gov/ANTCAL/.

For absolute offset numbers and to download PCV tables, please visit the GEO++ website at www.geopp.com.

When using either of the websites mentioned above, look for the NovAtel listing of your antenna model **and** its hardware revision.

Only integer hardware revisions affect the phase center offsets. For example, the numbers given for hardware revision 2.02 are applicable to an antenna labelled H/W Rev: 2.00, 2.04, 2.12 and so on.

Table 1 shows typical absolute and relative offset numbers for the current 702 antenna model.

Table 1: Height

	Absolute (GEO++)	Relative (NGS/IGS)
L1	66 mm (2.60")	83 mm (3.27")
L2	63 mm (2.48")	77 mm (3.03")
Avg.	65 mm (2.56")	N/A

If you need any further advice on this matter, please visit our website at www.novatel.com. Other methods of contacting Customer Service can be found on the last panel of this guide.

WARRANTY POLICY

NovAtel Inc. warrants that its Global Positioning System (GPS) products are free from defects in materials and workmanship, subject to the conditions set forth below, for the following periods of time:

GPSAntenna™ Modules:	One (1) Year
Cables and Accessories:	Ninety (90) Days

Date of sale shall mean the date of the invoice to the original customer for the product. NovAtel's responsibility respecting this warranty is limited solely to product repair at an authorized NovAtel location only. Determination of repair will be made by NovAtel personnel or by technical personnel expressly authorized by NovAtel for this purpose.

The foregoing warranties do not extend to

(i) nonconformities, defects or errors in the products due to accident, abuse, misuse or negligent use of the products or use in other than a normal and customary manner, environmental conditions not conforming to NovAtel's specifications, or failure to follow prescribed installation, operating and maintenance procedures, (ii) defects, errors or nonconformities in the products due to modifications, alterations, additions or changes not made in accordance with NovAtel's specifications or authorized by NovAtel, (iii) normal wear and tear, (iv) damage cause by force of nature or act of any third person, (v) shipping damage; or (vi) service or repair of product by the dealer without prior written consent from NovAtel.

In addition, the foregoing warranties shall not apply to products designated by NovAtel as beta site test samples, experimental, developmental, preproduction, sample, incomplete or out of specification products or to returned products if the original identification marks have been removed or altered.

The warranties and remedies are exclusive and all other warranties, express or implied, written or oral, including the implied warranties of merchantability or fitness for any particular purpose are excluded.

NovAtel shall not be liable for any loss, damage or expense arising directly or indirectly out of the purchase, installation, operation, use or licensing or products or services. In no event shall NovAtel be liable for special, indirect, incidental or consequential damages of any kind or nature due to any cause.

There are no user-serviceable parts in the GPSAntenna and no maintenance is required. If the unit is faulty, replace with another unit and return the faulty unit to NovAtel Inc. You must obtain a RETURN MATERIAL AUTHORIZATION (RMA) number by calling NovAtel Customer Service at 1-800-NOVATEL (U.S. and Canada only) or 403-295-4900 before shipping any product to NovAtel or a dealer. Once you have obtained an RMA number, you will be advised of proper shipping procedures to return any defective product. When returning any product to NovAtel, please return the defective product in the original packaging to avoid damage.

Before shipping any material to NovAtel or Dealer, please obtain a Return Material Authorization (RMA) number from the point of purchase. You may also visit our website at http://www.novatel.com and select *Support | Repair Request* from the side menu.

PATENT NOTICE

NovAtel's 700 series antennas are manufactured and protected under U.S. Patent:

#6,445,354
#6,452,560

QUESTIONS OR COMMENTS

If you have any questions or comments regarding your 700 series antenna, please contact NovAtel Customer Service using one of methods provided below.

Email: support@novatel.ca
Web: www.novatel.com
Phone: 1-800-NOVATEL (U.S. & Canada)
403-295-4900 (International)
Fax: 403-295-4901

OM-20000075 Rev 5 July 31, 2003

L1/L2 Antennas

L1/L2 Antennas

NovAtel's L1/L2 antennas combine exceptional performance with unsurpassed reliability to suit a wide variety of applications.

GPS-702

The GPS-702 includes patented Pinwheel™ technology to provide superior multipath rejection in a compact and lightweight dual-frequency antenna. With a highly stable phase center in the same location for the L1 and L2 signals, the antenna is the perfect choice for high precision applications. The GPS-702 is waterproof to IEC 60529 IPX7 and meets the MIL-STD-810F specification for vibration and salt spray, resulting in an antenna suitable for adverse conditions.

GPS-533

The GPS-533 is a high performance L1/L2 antenna with a built-in choke ring to substantially reduce the effects of multipath, making it ideal for use in a DGPS base station or other demanding applications. The antenna features an integrated protective radome to withstand harsh environments and meets DO-160D standards.

GPS-532 and GPS-532-C

NovAtel's GPS-532 is an aircraft-certified L1/L2 antenna for airborne and other high dynamic applications. Designed to the ARINC 743A standard, the GPS-532 weighs less than 200 grams and includes a four hole mounting system for secure installation. The GPS-532-C includes an FAA airworthiness certificate.

GPS-600-LB

The GPS-600-LB provides access to the OmniSTAR L-band and GPS L1 and L2 frequencies for decimeter level accuracy when combined with the ProPak®-LBplus. With a rugged, compact housing suitable for extreme environments and high vibration applications, the GPS-600-LB is ideal for precision agriculture, marine, and mobile applications.

Features	Benefits
Choice of specialized antennas	Offers performance and a form factor optimized to meet the needs of your application
Wide input voltage range	Ensures compatibility with virtually all GPS receivers
Rugged, environmentally sealed housings	Provide reliability in a wide range of severe environments and applications

L1/L2 Antennas

Receiver Compatibility

All antennas listed on this page are designed for use with NovAtel's OEM4-based receivers or other equivalent high-precision GPS receivers.

GPS-702

For more specifications on the GPS-702, see the GPS-700 Series product sheet.

3 dB Pass Band	
L1	1575 -15/+30 MHz (typical)
L2	1228 -15/+30 MHz (typical)
Out-of-Band Rejection (f_c = L1, L2)	
f_c -30/+50 MHz	30 dBc (typical)
f_c -40/+80 MHz	50 dBc (typical)
LNA Gain	**27 dB (typical)**
Gain at Zenith (90°)	
L1	+5 dBic (minimum)
L2	+2 dBic (minimum)
Noise Figure	**≤ 2.0 dB (typical)**

GPS-600-LB

For more specifications on the GPS-600-LB, see the GPS-600-LB product sheet.

3 dB Pass Band	
L1	1575 ± 10 MHz (typical)
L2	1228 ± 10 MHz (typical)
L-band	1520 - 1565 MHz (typical)
Out-of-Band Rejection	
L1, L-band	
1420 MHz	40 dBc (typical)
1675 MHz	45 dBc (typical)
L2	
f_c -100 MHz	50 dBc (typical)
f_c -50/+100 MHz	30 dBc (typical)
f_c +50 MHz	20 dBc (typical)
LNA Gain	
L1, L2	26 ± 3 dB (typical)
L-band	29 ± 3 dB (typical)
Gain at Zenith (90°)	
L1	+6 dBic (minimum)
L2	+6 dBic (minimum)
L-band	+5 dBic (minimum)
Noise Figure	**≤ 2.6 dB (typical)**

GPS-533

Performance

3 dB Pass Band	
L1	1575 ± 13 MHz (typical)
L2	1227 ± 13 MHz (typical)
Out-of-Band Rejection (f_c = L1, L2)	
f_c ± 50 MHz	40 dBc (typical)
LNA Gain	
L1	31 ± 2 dB (typical)
L2	33 ± 2 dB (typical)
Gain at Zenith (90°)	
L1	+7.7 dBic (minimum)
L2	+4.7 dBic (minimum)
Gain Roll-Off (from Zenith to Horizon)	
L1	15 dB
L2	18 dB
Noise Figure	**≤ 3.0 dB (typical)**
VSWR	**≤ 1.5 : 1**

Physical & Electrical

Size	
Diameter	308 mm
Height	223 mm
Weight	**4.1 kg**
Power	
Input Voltage	+2.5 to +24 VDC
Power Consumption	1 W (typical)
Operating Temperature	**-55°C to +85°C**
Regulatory	**FCC Class B, CE**

GPS-532 / GPS-532-C

Performance

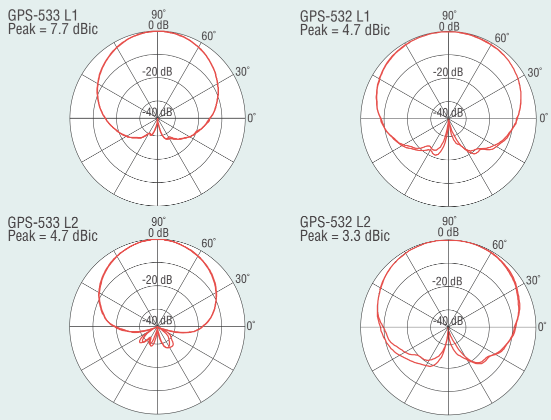
3 dB Pass Band	
L1	1575 ± 12 MHz (typical)
L2	1227 ± 12 MHz (typical)
Out-of-Band Rejection (f_c = L1, L2)	
f_c ± 50 MHz	40 dBc (typical)
LNA Gain	
L1	31 ± 2 dB (typical)
L2	33 ± 2 dB (typical)
Gain at Zenith (90°)	
L1	+4.7 dBic (minimum)
L2	+3.3 dBic (minimum)
Gain Roll-Off (from Zenith to Horizon)	
L1	6.5 dB
L2	7.1 dB
Noise Figure	**≤ 3.0 dB (typical)**
VSWR	**≤ 1.5 : 1**

Physical & Electrical

Size	**19 x 76 x 119 mm (Conforms to ARINC 743A)**
Weight	**198 g**
Power	
Input Voltage	+2.5 to +24 VDC
Power Consumption	1 W (typical)
Operating Temperature	**-55°C to +85°C**
Regulatory	**FCC Class B, CE**

GPS-533 and GPS-532 Elevation Gain Patterns

The plots to the right represent the typical right-hand polarized normalized radiation pattern for the L1 and L2 frequencies. The plots on the left are for the GPS-533 antenna and the plots on the right are for the GPS-532 antenna.



For more information, visit our website.

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Email	sales@novatel.ca
Web	www.novatel.com

NovAtel

APPENDIX B – EXAMPLE SLOG SCRIPT FOR RECORDING HIGH-RATE (50 Hz) LOGS

```
;
; Script to log raw scintillation data if the threshold parameters are
; exceeded.
;
; Go to the end of the script to see the different ways the script executed
; may be called from the DOS prompt.
;


; Parameter definition subroutine
sub ParameterDefinition              \
   int      iHighScintDuration&      \
   double   dElevation&              \
   double   dCno&                    \
   double   dS4Lock&                 \
   double   TotalS4&                 \
   double   d60SecPhaseSigmaLock&    \
   double   d60SecPhaseSigma&        \
   string   sRawDataLog&
;
; Modify threshold parameters here
;
   iHighScintDuration   =  2         ; Length of time to log raw data after a
                                     ; high scintillation moment in minutes,
                                     ; must be 1 or greater
   dElevation           =   5.0      ; Elevation angle Threshold
   dCno                 =  35.0      ; C/No Threshold
   dS4Lock              =  60.0      ; S4 Lock Time Threshold
   TotalS4              =   0.3      ; Total S4 Threshold
   d60SecPhaseSigmaLock = 240.0      ; 60-Sec Phase Sigma Lock Time Threshold
   d60SecPhaseSigma     =   0.2      ; 60-Sec Phase Sigma
   sRawDataLog          = "detrsinb" ; Type of raw data to be logged
                                     ; "rawsinb" or "detrsinb"
return



; Main logging subroutine
sub log int iPort  double dFilePeriod string sSite
```

APPENDIX B – EXAMPLE SLOG SCRIPT FOR PERIODIC FILES FOR RECORDING 60-SECOND LOGS

```
; Main logging subroutine
sub log int iPort  double dLogPeriod   string sSite

; Convert minutes into seconds
dLogPeriod = dLogPeriod*60

;--------------------------------------------------------------

testname "Scintillation Monitor Data Logging"

;Initiate communication with Novatel via COMx on PC

find com%iPort% 57600 receiver none

pause 60    ; Give the enough time for the find to do its job

define string sSerialNumber
sSerialNumber = serialnumber("receiver", 0)

send * "ecutoff 5\r"                     ; minimum elevation angle
send * "SinBandWidth 0.1 0.0\r"          ; sets phase and amplitude detrending cutoffs
send * "SinTECCalibration 0\r"           ; removes bias in TEC measurements
send * "assign 11 122 0 500\r"           ; assigns an SBAS GEO to channel 11
send * "clockadjust disable\r"           ; disables receiver clock adjustments

; enter PRN C/A-to-P offsets
send * "CPOFFSET -0.0321 -0.3186 0.0447 0.4605 -0.267 0.1788 -0.1854 -0.1539 0.096 -0.4974 0.2265 0 0.4677
0.1281 -0.2841 -0.0855 -0.2574 0.0255 0 -0.3057 -0.0801 -0.4266 -0.2235 0.1035 0.1833 0.3966 0.0015 -0.0288
0.2868 0.6195 -0.0732 0\r"

pause 5


; Wait for time to be set
send * "log rangeb ontime 5.0\r"
label WaitForTime
  jump TimeIsSet gpsset() == TRUE
  pause 1.0
  jump WaitForTime
```

```
label TimeIsSet
; Make sure the script doesn't start near the rollover so that the GPS
; week number and weekseconds are from the same week
jump WaitForTime GPSWEEKSECS() > 604800.0-10.0

;----------------------------------------------------------------------

; Start logging (hourly) data files

define double  dGpsWeek      ;  GPS week number
define double  dGpsWeekSecs  ;  Seconds into the week
define double  dHourOfWeek   ;  Hour into the week
define double  dDayOfWeek    ;  Day into the week
define double  dHourOfDay    ;  Hour into the day

define string  gpsfile       ;  Name of the file

define double  dStopWeekSecs ;  Seconds into the week at end of file

let dGpsWeek = GPSWEEK()
; GpsWeekSecs aligned with interval
let dGpsWeekSecs = (floor(GPSWEEKSECS()/dLogPeriod))*dLogPeriod

; Loop Forever

label again

   ; GPS file name

   let dHourOfWeek = FLOOR(dGpsWeekSecs/3600.0)      ; Hour of week
   let dDayOfWeek = FLOOR(dHourOfWeek/24.0)          ; Day of week
   let dHourOfDay = dHourOfWeek - dDayOfWeek*24.0    ; Hour of day

   print "dHourOfWeek = %dHourOfWeek%"
   print "dDayOfWeek = %dDayOfWeek%"
   print "dHourOfDay = %dHourOfDay%"

   let gpsfile = "%4.0dGpsWeek%\%sSite%%4.0dGpsWeek%_%1.0dDayOfWeek%_%02.0dHourOfDay%"

   ; Start the logging until the next hour

   connect com%iPort% 57600 %gpsfile%_%sSerialNumber% noappend        ; start a new file

   send * "log versiona once\r"
   send * "log rxconfiga once\r"
   send * "log rxstatuseventa onchanged\r"
```

```
   ; Following commands set up logs -- last two are for collecting WAAS
   ; Ionospheric Correction Data to use for TEC Calibration

   send * "log bestposa ontime 60.0\r"
   send * "log ismrb onnew\r"
   send * "log rangeb ontime 60.0\r"
   send * "log waas18B onchanged\r"
   send * "log waas26B onchanged\r"


   let dStopWeekSecs = dGpsWeekSecs+dLogPeriod

   ; Log until the end of the logging interval

   gpstime %.0dGpsWeek% %6.0dStopWeekSecs%

   ; Increase GPS week seconds

   let dGpsWeekSecs = dGpsWeekSecs + dLogPeriod
   if dGpsWeekSecs >= 604800.0
     let dGpsWeek = dGpsWeek + 1
     let dGpsWeekSecs = dGpsWeekSecs - 604800.0
   endif

jump again                                             ; Do this until operator hits "Q"

; Unreachable
return


; Default main of port 1, new file every hour, no site name
main
gosub log 1  60.0 ""
end

; When the user defines a port number, default to a new file every hour, no site name
main int iPort
gosub log iPort 60.0 ""
end

; When the user defines a port number and the number of minutes per file, no site name
main int iPort double dPeriod
gosub log iPort dPeriod ""
end
```

```
; When the user defines a port number and the number of minutes per file and a site name
main int iPort double dPeriod string sSite
string sSitename = sSite+"_"
gosub log iPort dPeriod sSitename
end

End
```

APPENDIX C – EXAMPLE SLOG SCRIPT FOR RECORDING HIGH-RATE (50 Hz) LOGS

```
;
; Script to log raw scintillation data if the threshold parameters are
; exceeded.
;
; Go to the end of the script to see the different ways the script executed
; may be called from the DOS prompt.
;


; Parameter definition subroutine
sub ParameterDefinition              \
   int      iHighScintDuration&      \
   double   dElevation&              \
   double   dCno&                    \
   double   dS4Lock&                 \
   double   TotalS4&                 \
   double   d60SecPhaseSigmaLock&    \
   double   d60SecPhaseSigma&        \
   string   sRawDataLog&
;
; Modify threshold parameters here
;
   iHighScintDuration   =  2        ; Length of time to log raw data after a
                                    ; high scintillation moment in minutes,
                                    ; must be 1 or greater
   dElevation           =   5.0     ; Elevation angle Threshold
   dCno                 =  35.0     ; C/No Threshold
   dS4Lock              =  60.0     ; S4 Lock Time Threshold
   TotalS4              =   0.3     ; Total S4 Threshold
   d60SecPhaseSigmaLock = 240.0     ; 60-Sec Phase Sigma Lock Time Threshold
   d60SecPhaseSigma     =   0.2     ; 60-Sec Phase Sigma
   sRawDataLog          = "detrsinb" ; Type of raw data to be logged
                                    ; "rawsinb" or "detrsinb"
return


; Main logging subroutine
sub log int iPort  double dFilePeriod string sSite
```

```
; Keep the screen clean
printscript false

; Threshold parameters
int      iHighScintDuration   ; Log counter
double   dElevation           ; Elevation angle
double   dCno                 ; C/No
double   dS4Lock              ; S4 L1 Lock Time
double   TotalS4              ; Total S4
double   d60SecPhaseSigmaLock ; 60-Sec Phase Sigma L1 Lock Time
double   d60SecPhaseSigma     ; 60-Sec Phase Sigma
string   sRawDataLog          ; Type of raw data to be logged

int      iReturnCode          ; Returned by RUN


gosub ParameterDefinition     \  ; Get the user defined parameters
      iHighScintDuration&     \  ; Log counter
      dElevation&             \  ; Elevation angle
      dCno&                   \  ; C/No
      dS4Lock&                \  ; S4 L1 Lock Time
      TotalS4&                \  ; Total S4
      d60SecPhaseSigmaLock&   \  ; 60-Sec Phase Sigma L1 Lock Time
      d60SecPhaseSigma&       \  ; 60-Sec Phase Sigma
      sRawDataLog&               ; Type of raw data to be logged

if dFilePeriod < 60
   print "Files cannot be less than 60 minutes in time\n"
   exit -1
endif

; Convert minutes into seconds
dFilePeriod = dFilePeriod*60

; Open the port to start the logging and to get the time
find com%iPort% 230400 rcvr none
pause 1

; Standard setup
send rcvr "clockadjust disable\r"            ; No more adjusting the clock
send rcvr "assign 11 122 0 500\r"            ; Assign SBAS SV to Channel 11
send rcvr "ecutoff 5\r"                      ; Set elevation mask to 5 deg.
send rcvr "SinBandWidth 0.1 0.0\r"           ; Set detrending bandwidths
send rcvr "SinTECCalibration 0.0\r"          ; Set Receiver Calibration value
```

```
send rcvr "CPOFFSET -0.0321 -0.3186 0.0447 0.4605 -0.267 0.1788 -0.1854 -0.1539 0.096 -0.4974 0.2265 0
0.4677 0.1281 -0.2841 -0.0855 -0.2574 0.0255 0 -0.3057 -0.0801 -0.4266 -0.2235 0.1035 0.1833 0.3966 0.0015 -
0.0288 0.2868 0.6195 -0.0732 0\r"

; Start the logging of the ranges first to get the time
send rcvr "log rangecmpb ontime 60.0\r"      ; Get compressed ranges


; Wait for time to be set
label WaitForTime
   pause 1.0
jump WaitForTime gpsset() == FALSE

; For building the file name
double dHourOfWeek, dDayOfWeek, dHourOfDay

double dGpsWeek      = gpsweek()
double dGpsWeekSecs  = gpsweeksecs()

dHourOfWeek = floor(dGpsWeekSecs/3600.0)

dDayOfWeek  = floor(dHourOfWeek/24.0)
dHourOfDay  = dHourOfWeek - dDayOfWeek*24.0

; When to stop logging to the file in week seconds, aligned with the file period
double dStopWeekSecs = floor(dGpsWeekSecs/dFilePeriod)*dFilePeriod+dFilePeriod
double dStopWeek     = dGpsWeek

; Is the stop week seconds pass the end of the week?
if dStopWeekSecs >= 7*24*3600
   ; Move into the next week
   dStopWeekSecs = dStopWeekSecs-7*24*3600
   dStopWeek = dStopWeek+1
endif


; Files are grouped week long directories
string sFilename = "%sSite%%4.0dGpsWeek%_%1.0dDayOfWeek%_%02.0dHourOfDay%.gps"

; So that the directory exists
run "md %4.0dGpsWeek%" iReturnCode

; Open two copyfiles, one with the raw data and one without
int   iRawData, iNoRawData
; Start with copyfile 1
int iCurrentFile = 1, iLastFile
```

```
opencopyfile  rcvr "%4.0dGpsWeek%\RawData%iCurrentFile%.gps"   noappend  iRawData  \
                   "%4.0dGpsWeek%\NoRawData%iCurrentFile%.gps" noappend iNoRawData
copyfile rcvr iRawData iNoRawData versiona  0.0
copyfile rcvr iRawData iNoRawData rxconfiga 0.0
copyfile rcvr iRawData iNoRawData gpsephemb 0.0
copyfile rcvr iRawData iNoRawData waas18B   0.0
copyfile rcvr iRawData iNoRawData waas26B   0.0
copyfile rcvr iRawData iNoRawData oem4ismrb 0.0
copyfile rcvr iRawData iNoRawData rxstatuseventa 0.0
; Only the raw data file gets the raw data
copyfile rcvr iRawData            %sRawDataLog%   0.0
; So that we have a file to append to, open the file and write nothing
int iHandle
openfile "%4.0dGpsWeek%\%sFilename%" write iHandle
writefile iHandle ""
closefile iHandle

bool     bHighScint           ; True if a high scintillation moment

int      iHighScintTimer = 0  ; Count down in minutes after a high scintillation moment

send rcvr "log ismrb onnew\r"               ; Get data every 60 secs
send rcvr "log %sRawDataLog% ontime 1.0\r"   ; Get raw data
send rcvr "log waas18B onchanged\r"          ; Get sbas iono grid
send rcvr "log waas26B onchanged\r"          ; Get sbas iono delays
send rcvr "log rxstatuseventa onchanged\r"   ; Get receiver status events

; Get the current number of ISMRB logs
int iNumberOfIsmrbLogs = %numberoflogs(rcvr, OEM4ISMRB)
int iPreviousNumberOfIsmrbLogs = iNumberOfIsmrbLogs

label nextPeriod
   send rcvr "log versiona once\r"           ; Get a version log
   send rcvr "log rxconfiga once\r"          ; Log the receiver configuration
   send rcvr "log gpsephemb onchanged\r"     ; Get new ephemeris and when it changes here on

   ; Wait for the ISMRB log
   label WaitForIsmrLog
   pause 10
   iNumberOfIsmrbLogs = %numberoflogs(rcvr, OEM4ISMRB)
   jump WaitForIsmrLog iPreviousNumberOfIsmrbLogs == iNumberOfIsmrbLogs
   iPreviousNumberOfIsmrbLogs = iNumberOfIsmrbLogs

   ; Alternate the current copy file
   if iCurrentFile == 1
      iCurrentFile = 2
```

```
      iLastFile    = 1
   else
      iCurrentFile = 1
      iLastFile    = 2
   endif

   ; Close the current copyfiles and open new copyfiles
   newcopyfile rcvr iRawData   "%4.0dGpsWeek%\RawData%iCurrentFile%.gps"   \
                    iNoRawData "%4.0dGpsWeek%\NoRawData%iCurrentFile%.gps"


   ; Returns TRUE if all parameters are exceeded by at least one SV
   ; for one or more SV on this receiver
   bHighScint = HighScint(    "rcvr",                \ ; Port name of receiver
                              dElevation,            \ ; Elevation angle
                              dCno,                  \ ; C/No
                              dS4Lock,               \ ; S4 L1 Lock Time
                              TotalS4,               \ ; Total S4
                              d60SecPhaseSigmaLock,  \ ; 60-Sec Phase Sigma
                                                     \ ; Lock Time
                              d60SecPhaseSigma       \ ; 60-Sec Phase Sigma
                              )

   ; Did a high scintillation moment happen?
   if bHighScint
      ; Start the timer
      iHighScintTimer = iHighScintDuration
   endif

   print "HighScint: %bHighScint%   Time Left in minutes: %iHighScintTimer%\n"

   cd "%4.0dGpsWeek%"
   ; If the timer is going, record the raw data
   if iHighScintTimer != 0
      run "copy /B /Y %sFilename%+RawData%iLastFile%.gps"
   else
      run "copy /B /Y %sFilename%+NoRawData%iLastFile%.gps"
   endif
   run "del    RawData%iLastFile%.gps"
   run "del    NoRawData%iLastFile%.gps"
   cd ".."

   ; If the timer is engaged subtract a minute
   if iHighScintTimer != 0
      iHighScintTimer = iHighScintTimer-1
   endif
```

```
   ; Log until the end of the time period
   jump WaitForIsmrLog %dStopWeekSecs% > gpsweeksecs() || %dStopWeek% != gpsweek()

   ; Build the new file name
   dGpsWeek      = gpsweek()
   dGpsWeekSecs  = gpsweeksecs()
   dHourOfWeek   = floor(dGpsWeekSecs/3600.0)
   dDayOfWeek    = floor(dHourOfWeek/24.0)

   dHourOfDay    = dHourOfWeek - dDayOfWeek*24.0
   sFilename = "%sSite%%4.0dGpsWeek%_%1.0dDayOfWeek%_%02.0dHourOfDay%.gps"

   ; So that the directory exists
   run "md %4.0dGpsWeek%" iReturnCode
   ; Create a null file so that there is a file to append to
   openfile "%4.0dGpsWeek%\%sFilename%" write iHandle
   writefile iHandle ""
   closefile iHandle

   ; Calculate the next stop time
   dStopWeekSecs = dStopWeekSecs+dFilePeriod

   ; Is the stop week seconds pass the end of the week?
   if %dStopWeekSecs% >= 7*24*3600
      ; Move into the next week
      dStopWeekSecs = dStopWeekSecs-7*24*3600
      dStopWeek = dStopWeek+1
   endif

jump nextPeriod

; Unreachable
return


; Default main of port 1, new file every hour, no site name
main
gosub log 1  60.0 ""
end

; When the user defines a port number, default to a new file every hour, no site name
main int iPort
gosub log iPort 60.0 ""
end
```

```
; When the user defines a port number and the number of minutes per file, no site name
main int iPort double dPeriod
gosub log iPort dPeriod ""
end

; When the user defines a port number and the number of minutes per file and a site name
main int iPort double dPeriod string sSite
string sSitename = sSite+"_"
gosub log iPort dPeriod sSitename
end
```

APPENDIX D -- ISMVIEW4 OFF-LINE UTILITY PROGRAM

The ISMVIEW4 program must be run in the folder that contains the ISMView4 files, and the file names must meet MSDOS requirements (8 characters or less). To invoke ISMVIEW4, at the MSDOS prompt, enter:

Ismview4

The first ISMVIEW4 screen displays the ISMVIEW4 version number. When any key is pressed (except the Esc key), the ISMVIEW main menu will be displayed (see Figure D.1):

GPS Silicon Valley - ISMVIEW	
Screen Parameter Selection Display ISMRB File Extract SV ISMRB Records Monitor Color Quit	Select Parameters for Display

Figure D.1. ISMVIEW4 Main Menu

ISMVIEW4 is a menu-driven program. The Main Menu is the starting point of the session; it directs the user to one of its submenus. A sub-menu may be selected in one of two ways. The first way is the common point-and-shoot technique: use the Up and Down Arrow keys to move the highlight bar to the selected sub-menu, and then press Enter. The other way to select a sub-menu is to press the first letter on the sub-menu name (which is normally shown in a different color).

SCREEN PARAMETER SELECTION

The Screen Parameter Selection Menu allows you to select which parameters to be displayed since the PC screen cannot accommodate all data.

DISPLAY ISMRB FILE

The Display ISMRB File Menu allows you to view the ISMR data logs from a selected file. The user will be prompted to enter the file name. The file name is restricted to 8 characters or less.

Next, the ISMVIEW4 will extract only the ISMR data logs from the selected file (except for a BESTPOSA/B data log to obtain position). Since the data logs are expected to be collected every minute, ISMVIEW4 will check if there is any gap(s) in the data file. If there are no data gaps, it will display **"There are no missing records.**

Press any key to continue.” If it found any data gaps, it will inform the user accordingly and ask if the user wants to review the data gap(s) before reviewing the ISM data logs. Either way, the result is stored in the text file $ISMVIEW.TXT.

The next display will show the ISM data logs, one at a time. The display is shown in Figure D.2. The Location is obtained from the very first BESTPOSA/B data log in the selected file, so at least one BESTPOSA/B record should be logged to provide the Location values, but it is not necessary to do so.

GSV4004.GPS **ISMRB DISPLAY - MANUAL MODE**

CH	PRN	ELV	AZM	C/No	S4	1-S-SIG	30-S-SIG	DIV-SIG	GPS Time	
		deg	deg	dB-Hz		rad	rad	meters	**Week:**	1103
1	6	27	150	45.7	-57.0967	-6.2085	5.5169	5.1079	**TOW:**	270420
2	28	29	315	43.7	-54.0952	0.8298	2.2040	-9.8684	**Date:**	28 FEB 01
3	17	61	45	47.8	-61.0268	-1.0212	4.8812	-5.8700	**Time:**	03:07:00
4	21	44	243	46.0	-55.9720	0.0097	9.0566	-14. 1724		
5	23	82	311	46.3	-59.3002	-1.6241	0.0681	3.6946	**Location**	
6	26	28	54	43.9	-54.0815	-5.4782	13.3967	-11.3888	Lat:	37.440212
7	1	5	189	41.4	-50.0821	-3.7413	-1.8424	5.1154	Lon:	-121.896290
8	22	22	257	40.1	-50.2573	0.4925	0.1024	-0.8619	Alt”	5.408
									FileSize:	**81**
									Missing:	0
									Rec:	7

Figure D.2. ISMVIEW4 Display

The user may view the data in **Manual** mode or in **Movie** mode. Once the user is in one mode, he (she) may switch to the other mode by pressing the M key (for Manual or Movie).

In the Manual mode, the user could go to the next data record by pressing the Down Arrow key, or to the previous data record by pressing the Up Arrow key. The user could jump forward or backward to any data record by pressing the J key (for Jump); prompted to enter the record wanted to jump to. Pressing the M key (for Movie) will switch the display to the Movie mode.

In the Movie mode, ISMVIEW will automatically update the display. The user may change the update rate by pressing the F key (for Faster) or the S key (for Slower). The fastest update rate is one screen per second. The user may want to pause (by pressing the P key) to review the data; the display will show <PAUSE>. Pressing the R key (for Resume) will resume the data update. The user may also jump forward or backward by pressing the J key and supplying the record number. The Table D.1 summarizes the key-stroke commands.

Table D.1. Key-Stroke Commands

Pressing Key	Action
M	Switch between Manual and Movie modes
Down Arrow	Advance one data log (Manual mode only)
Up Arrow	Reverse one data log (Manual mode only)
J	Jump to any data log
F	Speed up the movie display
S	Slow down the movie display
P	Pause the movie display
R	Resume the movie display (from pause)
Esc	Exit to the Main Menu

EXTRACTING SV ISMRB RECORDS

The user may also use the ISMVIEW program to extract ISMR data logs belonging to a particular SV PRN (see Figure D.3). The result will be a text file containing the time history of ISMR data fields (S4, 1-sec sigma, etc.) for the selected SV. A utility program (**parseismr5**) is also provided for extraction as well. It is described later and is the recommended program.

SV ISMRB RECORD EXTRACTION	
Input File:	$GSV4004.GPS
PRN:	1
Output File:	OUTFILE.S01
Delimiter:	Comma

Figure D.3. ISMVIEW SV ISMR Data Extraction

The user can use the DOS Edit function to specify the name Input File, the PRN of the SV wanted, the name of the text Output File to store the results, and the data field Delimiter (Space, Comma or Tab). When done, the user can use the Run function to extract the data into the output file.

The output file contains a number of data lines, one for each ISMR data record that contains data for the specified SV. The format of the data line is shown in Table D.2. The data fields are separated with the specified delimiter character (space, comma or tab).

Table D.2. Extracted Data Fields

Input Field #	Data	Units
1	#ISMRB	N/A
1	Week Number (WN)	N/A
1	Time of Week (TOW)	seconds
3	PRN	N/A
4	SV Azimuth angle	degrees
5	SV Elevation angle	degrees
6	C/No	dB-Hz
24	L1 Lock time	seconds
7	Total S4	dimensionless
9	1-second phase sigma	radians
10	3-second phase sigma	radians
11	10-second phase sigma	radians
12	30-second phase sigma	radians
13	60-second phase sigma	radians
14	Average of Code/Carrier divergence	meters
15	Sigma of Code/Carrier Divergence	meters
16	TEC at TOW - 45	TECU
17	∆TEC from TOW - 60 to TOW - 45	TECU
18	TEC at TOW - 30	TECU
19	∆TEC from TOW - 45 to TOW - 30	TECU
20	TEC at TOW - 15	TECU
21	∆TEC from TOW - 30 to TOW - 15	TECU
22	TEC at TOW	TECU
23	∆TEC from TOW - 15 to TOW	TECU

QUIT

From the Main Menu, selecting Quit will return to DOS. Pressing the Esc key will do the same.

USING SPECIAL KEYS

ISMVIEW's use of the keys is generally similar to "common" practice. The Enter key is used to signal the end of data entry. The Esc key is used to abort the current operation; it is also used to return to the previous screen.

APPENDIX E – SBAS-GEO PRN ASSIGNMENTS

C/A PRN CODE ASSIGNMENTS

For additional information, please refer to IS-GPS-200 at http://gps.losangeles.af.mil/engineering/icwg

PRN Signal Number	G2 Delay (Chips)	Initial G2 Setting (Octal)[1]	First 10 Chips (Octal)[1]	PRN Allocations	Orbital Slot
1 – 37	-	-	-	Reserved (GPS)	N/A
38 - 119	-	-	-	Under Review	N/A
120 – 158	-	-	-	Reserved (SBAS)	See Below
159 – 210	-	-	-	Under Review	N/A
Satellite Based Augmentation System (SBAS)					
120	145	1106	0671	INMARSAT 3F2, AOR-E	15.5 W
121	175	1241	0536	INMARSAT 4F2	53 W
122	52	0267	1510	INMARSAT 3F4, AOR-W	54 W
123	21	0232	1545	LM RPS-1, RPS-2[4]	133 W, 107.3 W
124	237	1617	0160	ARTEMIS	21.5 E
125	235	1076	0701	LM RPS-1, RPS-2[4]	133 W, 107.3 W
126	886	1764	0013	INMARSAT 3F5, IND-W	25 E
127	657	0717	1060	INSATNAV	TBD
128	634	1532	0245	INSATNAV	TBD
129	762	1250	0527	MTSAT-1R (or MTSAT-2)[2]	TBD
130	355	0341	1436	INMARSAT 4F1	63 E
131	1012	0551	1226	INMARSAT 3F1, IOR	64 E
132	176	0520	1257	Unallocated	-
133	603	1731	0046	INMARSAT 4F3	N/A
134	130	0706	1071	INMARSAT 3F3, POR	178 E
135	359	1216	0561	LM RPS-1[3]	133 W
136	595	0740	1037	INMARSAT Reserved	8 E
137	68	1007	0770	MTSAT-2 (or MTSAT-1R)[2]	TBD
138	386	0450	1327	LM RPS-2[3]	107.3
139	797	0305	1472	Unallocated	-
140	456	1653	0124	Unallocated	-
141	499	1411	0366	Unallocated	-
142	883	1644	0133	Unallocated	-

143	307	1312	0465	Unallocated	-
144	127	1060	0717	Unallocated	-
145	211	1560	0217	Unallocated	-
146	121	0035	1742	Unallocated	-
147	118	0355	1422	Unallocated	-
148	163	0335	1442	Unallocated	-
149	628	1254	0523	Unallocated	-
150	853	1041	0736	Unallocated	-
151	484	0142	1635	Unallocated	-
152	289	1641	0136	Unallocated	-
153	811	1504	0273	Unallocated	-
154	202	0751	1026	Unallocated	-
155	1021	1774	0003	Unallocated	-
156	463	0107	1670	Unallocated	-
157	568	1153	0624	Unallocated	-
158	904	1542	0235	Unallocated	-

1) In the octal notation for the first 10 bits as shown in this column, the first digit (1/0) represents the first bit and the last three digits are the conventional octal representation of the remaining 9 bits.
2) When MTSAT-2 is unavailable, MTSAT-1R will broadcast two PRN signals-each of which is received from an independent uplink station-in order to maintain continuity in case of uplink signal attenuation or equipment failure at either uplink station. Similarly, MTSAT-2 will broadcast two PRN signals when MTSAT-1R is unavailable. When MTSAT-1R and MTSAT-2 are available, MTSAT-1R will broadcast PRN 129 signal only and MTSAT-2 will broadcast PRN 137 signal only.
3) This code is assigned on a temporary basis.
4) This code is assigned for on-orbit testing only.