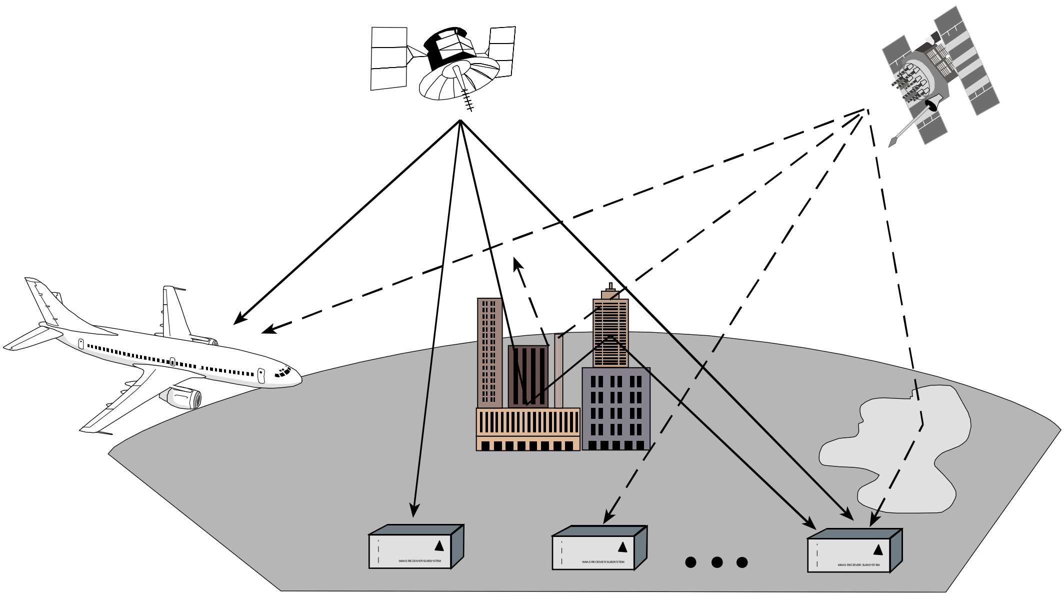
Multipath Assessment Tool

(MAT) User Manual



Multipath Assessment Tool User Manual

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Website: http://www.novatel.ca

Write:

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Chapter 1 Introduction

1.1 Congratulations!

Congratulations on purchasing your Multipath Assessment Tool (referred to as MAT in this manual). MAT is a Windows based program that is designed to display multipath parameters along with signal and satellite information in order to monitor undesirable multipath effects. The software works with real-time data from the serial port of a WAAS-type receiver with Multipath Meter firmware within it, or with data previously saved to a file.

MAT uses a multipath meter feature from within the Multipath Estimating Delay Lock Loop (MEDLL) portion of a WAAS-type, or Portable MEDLL, receiver. MEDLL utilizes innovative correlator delay lock loop techniques. The correlator is the heart of the GPS receiver C/A code tracking loop. MEDLL splits the received signals into their direct path and multipath components by determining the amplitude, delay, and phase angle of each of the signals. Further discussion on the correlator and MEDLL technology are provided in *A.2, The Role of the GPS Receiver Correlator* beginning on *Page 38*.

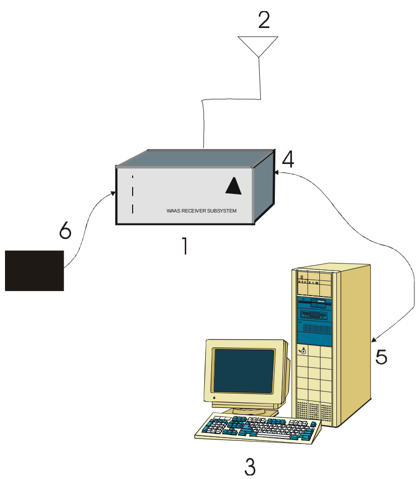
The MPMB, SATB, DOPB, POSB, TM1B and ETSB logs are used by MAT. For a description of these logs, please see *Appendix B* beginning on *Page 42*.

1.2 Scope

The *Multipath Assessment Tool User Manual* is a complete installation, reference and instructional manual for the MAT software.

This manual describes the graphical user interface on your PC that is used to collect, view and manage logged information, as it is output by the Multipath Meter feature from a MEDLL-capable receiver, see *Figure 1*. It can also be used to post-process previously collected MEDLL data, from the correct logs, in order to study the multipath environment.

Figure 1: Real Time Data Collection



Reference	**Description**
1	WAAS, EGNOS, MSAS, or a Portable MEDLL receiver with MPM firmware
2	Antenna
3	PC
4	Connection to L1-C/A or WAAS MEDLL
5	Connection to COM1 or COM2
6	22-30 V DC power supply

1.3 Prerequisites

The recommended minimum system requirements to run MAT are:

- A Pentium-class PC with 32MB
- 6MB of hard disk space for program files
- Microsoft Windows NT / 2000 / 98 / 95
- Microsoft Mouse or compatible pointing device

1.4 What's New?

Here is a list of what is new in this manual since revision 1:

- A new statistics window accessed by the σ button, see *Section 5.8, Statistics on Page 34*.
- Details of the NovAtel logs used in the MAT software, see *Appendix B, NovAtel Format Data Logs on Page 42*.
- The scope of the manual has changed from a WAAS receiver to any WAAS-type receiver with MEDLL capability, see back to *Sections 1.1 and 1.2* of this chapter.
- For your convenience, space saving, and standardization, this manual has been reformatted to a new 7" x 9" size

Chapter 2 Installation

The MAT software operates from your PC's hard drive. You will need to install the software from the compact disk (CD) supplied by NovAtel.

2.1 Quick Start

1. Start Microsoft Windows NT/2000/98/95.
2. Execute the MAT auto-install software by clicking on the Start button of your Windows screen and then select Run.
3. In the Run dialog, enter

   ```
   d:\setup.exe
   ```

   where d:\ is your CD drive. SETUP.EXE is the executable file from the CD. Click on the OK button. (Alternatively click on the Browse button, select setup.exe from the files on your CD and click on the OK button.) The installation program will request that you confirm or re-enter the name of the directory where MAT is to be loaded.
4. Once MAT is installed, start MAT by double clicking on its program icon (MAT.EXE).
5. Select your WAAS-type receiver and desired settings or your previously saved logging file by selecting Device | Open Serial or Device | Open File from the main menu.

2.2 MAT Software Files

The MAT program disk contains the following files that have been copied to the correct directories during the set up process. These are shown below.

File Name	File Type
MAT.EXE	Program file
MAT.HLP	Program help file
README.TXT	Late breaking information about the program
MAT.LF	License file
KEYLIB32.DLL	Program file
MACHNML.EXE	Program file

Chapter 3 MAT Menus Overview

3.1 Menu Options

The following table displays the menu options in the MAT program. The following sections in this chapter describe the Window and Help menu options while the Device and View menu options are described in the chapters that follow.

Table 1: Menu Options

Device	View	Window	License	Help
Open Serial	Console	Tile	Transfer License…	Contents
Open File	ASCII Messages	Cascade	Enable Retail…	Search for Help On…
Active Config	Logging Control	Arrange Icons		How to Use Help
Status	Satellite Position			About…
Close	Multipath Info			
Close All	Histogram			
Print Active Screen	D/U Polar Plot			
Print MAT Screen	Capture Control			
Print Preview MAT Screen	Statistics			
Print Setup …				
1 COM2 115200 [a]				
2 MP july 6.gps				
3 dervila_data.gps				
4 MP June 9.gps				
5 COM1 115200				
Exit				

a. The devices in *Table 1* represents either the name of a previously opened file or a connection to a WAAS-type receiver in MAT. The last five device configuration names are displayed.

3.2 Window Menu

The MAT Window menu allows automatic arrangement of all open windows inside MAT for easier viewing. Tile arranges the open windows in smaller sizes to fit next to each other within the MAT window. Cascade causes any open windows to overlap so that the title bars are visible. The Arrange Icons menu item arranges all the windows that have been minimized.

3.3 License Menu

The MAT License menu enables you to transfer a license to your computer or set up a retail version of the software.

3.3.1 Transfer License From This Computer

MAT will allow you to transfer a license from one computer to another. To transfer a license you need one computer to have a valid retail license. Insert a blank floppy disk into the non-licensed computer and select Transfer License To This Computer from the License menu.

The computer will create a license file on the floppy disk. Leave MAT running.

Go to the computer with the valid license, insert the floppy disk and select Transfer License From This Computer. The computer will transfer information to the floppy disk and the MAT program will quit automatically.

The final step is to transfer the license file from the floppy disk to the non-licensed computer by following the instructions on the screen.

3.3.2 Enable Retail Version Of Software

Select Enable Retail Version Of Software from the License menu. The Enable Full Version of MAT dialog appears with three fields:

Computer ID	Copy the Computer ID number down and send it to NovAtel's Customer Service department by phone, facsimile or e-mail. See *Page 7* for contact information.
NovAtel Key 1	The first NovAtel key supplied by our Customer Service personnel.
NovAtel Key 2	The second NovAtel key supplied by our Customer Service personnel.

Enter the two NovAtel key numbers into the Enable Full Version of MAT dialog and press the OK button. The retail version will then be ready to use.

3.4 Help Menu

The MAT program has been enhanced by the inclusion of a Help system that can be accessed from any dialog. If a screen does not include a Help button, press the F1 key on your keyboard to bring up the help for that screen.

You can also click on the Help option in the main menu to bring up the help files. The Help contains excerpts from this manual to clarify the contents and function of each screen.

If you are unfamiliar with using a Windows Help file, assistance can be obtained by looking through the How to Use Help option topics.

The About window reveals the MAT version number, the issue date of the MAT software and NovAtel's contact information.

Chapter 4 Device Menu

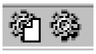
This menu allows you to open and close a file or serial port that supplies MAT with NovAtel logs. Both are referred to as a device in this manual. You can also print or exit MAT completely from this menu.

4.1 Open

To open a device, choose either Device | Open Serial or Device | Open File from the main menu.

You can also open a device by selecting a device configuration from the numbered list in the Device menu. This list displays the last five devices that have been opened by MAT.

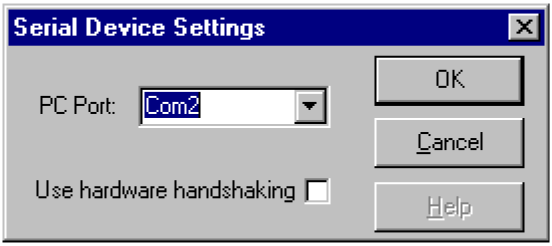
You can look in the far right of the MAT status bar to see what devices are currently open:



The icon on the left shows that a file device is open while the icon on the right shows that a serial device is open. To make an open device an active configuration, right click over its icon and choose Select from the options. You can also select an active configuration by choosing one of the devices that appear when you select Device | Active Config from the main menu.

4.1.1 Open Serial

When you select Device | Open Serial from the menu, the Serial Device Settings dialog appears:



Use the down arrow in the PC Port list to select the COM port on your PC that your device is connected to.

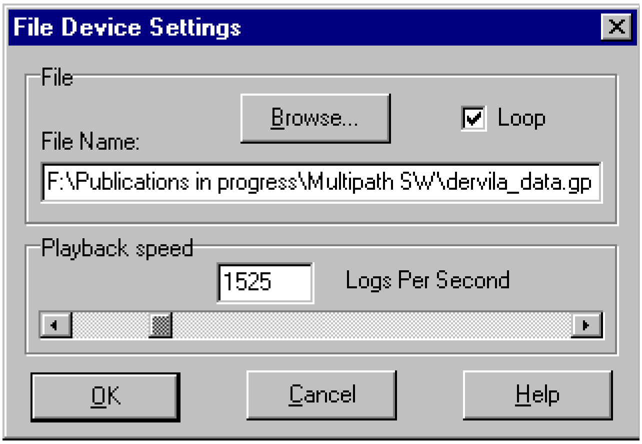
Handshaking is the predetermined hardware or software activity designed to establish or maintain two machines in synchronization. Hardware handshaking uses voltage levels or pulses in wires to carry the handshaking signal. Click in the Use Hardware Handshaking check box to turn hardware handshaking on.

Press the OK button to open the selected serial device on the specified COM port. Once communications with the receiver have been successfully started, the Console window will be automatically opened, see *Page 19*.

If MAT is opened using a serial port device, it will automatically ask the receiver for the logs necessary to run all the MAT functions. You can also request additional logs not needed by MAT, by issuing a command to the receiver through the Logging Control window, see *Page 21*.

4.1.2 Open File

When you select Device | Open File from the menu, the File Device Settings dialog appears:



A file device reads logs from an existing file. This is called file playback. Use the Browse… button in the File Device Settings dialog to select a playback file.

You can choose the play back speed from very slow (slower than real time) to very fast (your processor may be going at maximum speed) with the Playback Speed scale bar. The Logs Per Second field is for displaying the chosen speed and is not editable. The most important factors affecting this rate are the performance of your PC’s hardware and the number of plot windows that are open, see *Plots* on *Page 25*. For example, a Pentium 133 MHz computer’s fastest rate of file playback, with several Time Series windows open, is approximately real-time. However, a Pentium II 400 MHz computer’s rate of playback, with several Time Series windows open, is about 10 times faster than real-time.

Click in the Loop checkbox if you want MAT to continue to replay your file from the beginning when it comes to the end of the file.

MAT uses 6 binary logs in its playback mode (MPMB, SATB, DOPB, POSB, TM1B and ETSB). If you use the Logging Control window, these logs will be saved automatically. For a description of these logs, please see *Appendix B* starting on *Page 42*.

4.2 Active Config

To view a currently active configuration, select Device | Active Configuration and click on the device to be viewed or right click over its icon in the bottom right of the MAT window and choose Select from the options.

4.3 Status

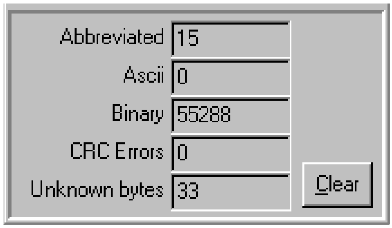
Select Device | Status from the main menu, or right click over the device icon in the far right of the status bar and select Status, for the Status window to appear when MAT is in file playback mode. The name of the device configuration appears in the dialog header.

This window allows you to pause, restart or choose a point in the file to begin the playback. Use the slider or, to be more precise, fill in the Seconds (seconds into the week) and Week fields, and click on the GO button. You can turn on and off the loop feature by clicking on the Loop button (looped arrow symbol). You can also change the rate of playback in the Play Back Speed field using its slider. The field box itself is for display purposes only and is not editable.

☒ When the GO button is pressed, the software will attempt to start at the week and seconds specified in the Week and Seconds fields. During this move, no logs are read and your plot windows will not be updated.

Clicking on the More button shows you information about the type and status of logs that are being used in the playback. There are three different types of log format: Abbreviated ASCII, ASCII and Binary. The number of logs in the playback file, or being received through a serial connection, in each of these formats is shown. A cyclic redundancy check (CRC) verifies ASCII and binary data. The number of errors found by the CRC is shown. The number of bytes that are not recognised as being any of the above formats is also shown. You can use the Clear button at any time to restart producing these numbers from zero.

To show the status of a serial port when you are connected to a WAAS-type receiver, select Device | Status from the main menu or right click over the device icon in the far right of the status bar and select Status from the list. The following dialog appears with the name of the device configuration in the dialog header.



This status dialog shows the status of the connection to the receiver and the current baud rate (bps). The lights turn green when the PC is transmitting or receiving data respectively. The Comm Error light glows red when there is an error in the communication link between the PC and MEDLL receiver.

Clicking on the More button shows you information about the type and status of logs that are being logged. There are three different types of log formats: Abbreviated ASCII, ASCII and Binary. The number of logs being received through the serial connection, in each of these formats is shown. A cyclic redundancy check (CRC) verifies ASCII and binary data. The number of errors found by the CRC is shown. The number of bytes that are not recognised as being any of the above formats is also shown. You can use the Clear button at any time to reset these numbers to zero.

4.4 Close and Close All

Currently open devices can be seen in the far right side of the MAT status bar. To close a current device, right click over the device icon in the MAT status bar and select Close from the list or, select Device | Close from the main menu and the active device is closed. To close all open devices in MAT, select Device | Close All from the main menu.

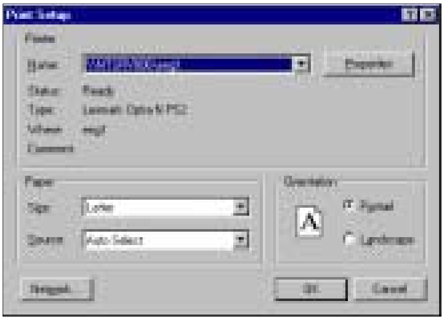
4.5 Print and Print Setup

The contents of any MAT window may be printed. A window must be selected with your cursor, making it the active window, before it can be printed. To print an individual window, select Print Active Window from the Device menu. To print the whole MAT screen, select Device | Print MAT Screen from the main menu. You can see how the MAT screen will appear before printing it by selecting Device | Print Preview MAT Screen from the main menu. Your print request will always go directly to the printer.

Plots are scaled to fill the entire available page area upon which they are to be printed. Printing a graphic never spans multiple pages (it is always performed in fit-to-page mode).

Keep in mind that the printed view may differ from the displayed view because the colours available on your printer may differ from those available on your computer monitor.

The Print Setup dialog allows you to alter your printer settings without actually printing anything. This dialog is accessed by selecting Device | Print Setup… from the main menu. When all your settings are correct, click on the OK button in the Properties dialog and then on the OK button in the Print Setup dialog.



4.6 Exit

To exit the MAT program, select Device | Exit from the main menu.

Chapter 5 View Menu

Once a device is open, windows can be opened through the View menu or with the buttons on the toolbar. Each View menu option is described here along with its window appearance and icon.

5.1 Console

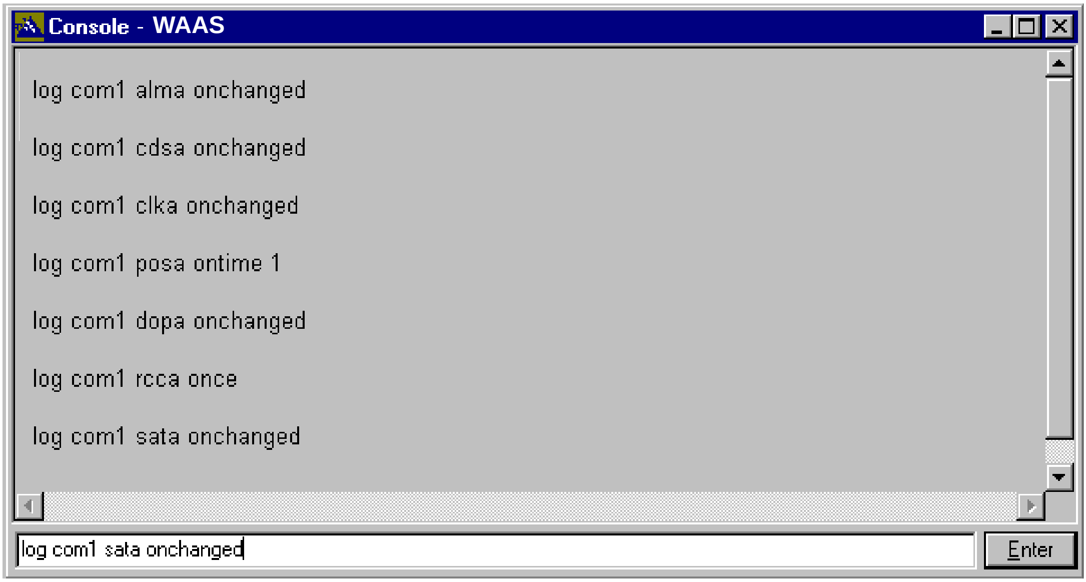
The Console window allows you to communicate directly with the WAAS-type receiver through the serial connection port. If MAT is in file playback mode, you cannot issue commands to the device.

✉ Although it is possible to issue commands and logs from the Console window, it is not recommended. See *Logging Control* on *Page 21* for the recommended method of logging additional logs.

Warning!:	Do not use the UNLOG command to stop logging any of the six logs used by MAT (MPMB, SATB, DOPB, POSB, TM1B and ETSB). If you do, the multipath software may not work properly until the logs have been restored.

You may wish to issue logs that have no bearing on the multipath meter but are of interest to you. With this screen you can send commands to the WAAS-type receiver. Refer to your receiver's operation manual for detailed information about WAAS-type receiver commands and logging protocol. See *Logging Control* on *Page 21* for the recommended method of logging additional logs.

In the Console window, following, the SATA log (satellite specific data) is entered in the command line. The history of logs can be seen in the main area of the window. Also shown are the menu items that appear when you right click anywhere in the window.



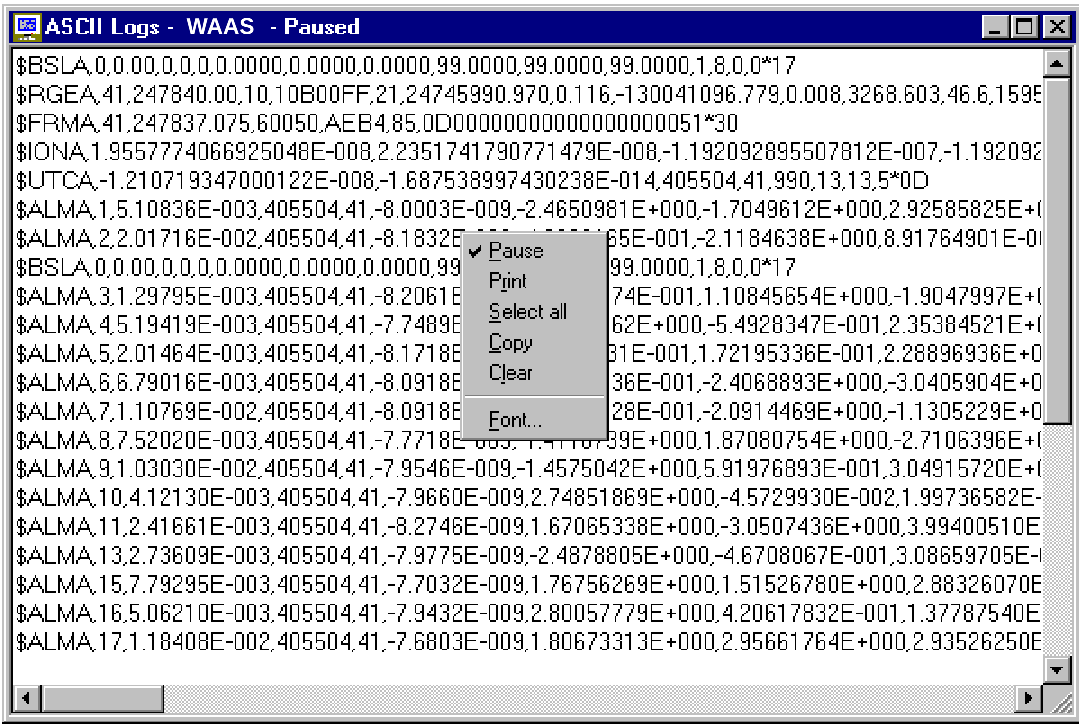
The Console window is where any error messages the WAAS-type receiver sends will be displayed. It is a good idea to monitor this window to be aware of any problems with the operation of the WAAS-type receiver. The console window is always open – it cannot be closed.

Any ASCII logs that are requested from this window and directed to the appropriate COM port may be monitored in the ASCII Messages window.

The last 20 commands entered may be reviewed by using the up and down keys (▲ ▼) in the far right scroll bar of the Console window. Commands are listed from top to bottom in order of least to most recent. The console window cannot be closed, only minimized.

5.2 ASCII Messages

The ASCII Messages window displays all of the ASCII records requested by you in the Console window and logged by the receiver. The last 100 logs are held in a buffer, which may be scrolled horizontally, and vertically using the scrollbars attached to the window or with the cursor keys. The output of the window may be paused by pressing either the space bar or pause key. All logs that arrive while the ASCII window is paused are not shown. Displaying ASCII output resumes when you uncheck the Pause option after right clicking anywhere in the window.



5.3 Logging Control

The Logging Control window allows you to browse for a file and record all logs output by the receiver. The length of time that the file has been recording and the file size are indicated in the Save to File dialog's status bar. The resultant file is the type of file that can be used in playback mode, see *Page 15* for more information on playback mode.

You can decide if the file is generated according to an elapsed amount of time or the amount of disk space used. Do this by clicking in one of the New File Every checkboxes and then enter the time, or disk space, specifics for your application. If both are checked, the condition that is met first is used to decide when to start a new file.

The software will automatically add an extension to the filename in the following form:

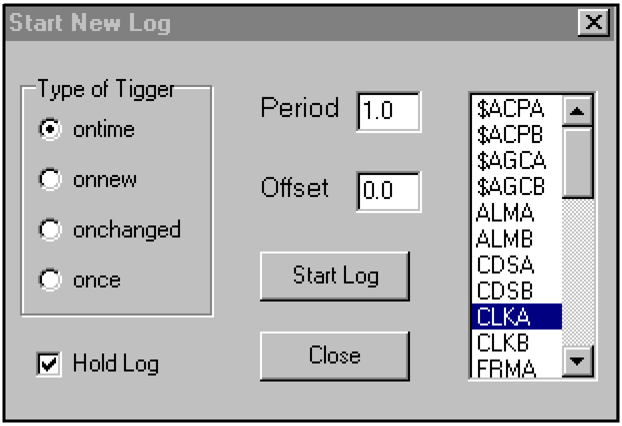
#_gpsweek_gpseconds

where

#	is an automatically incremented number
gpsweek	is the GPS week number
gpseconds	is the number of GPS seconds into the week

This will help you to see when a file was created. The software will be able to decide in what order to play files when in playback file mode.

The MPMB, SATB, DOPB, POSB, TM1B and ETSB logs are logged automatically by MAT but you can add logs in the Logging Control section of the Save to File dialog. To start a new log, click on the Start New Log button:

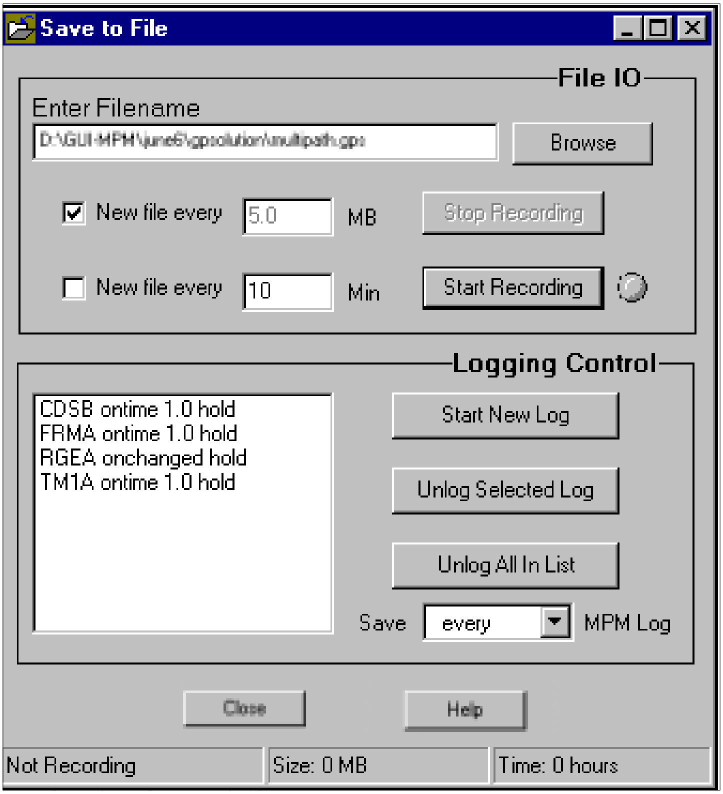


Select a log from the list, choose a trigger and then, if the log trigger is ontime, enter its period and offset. The hold check box is permanently checked for all your log choices. This ensures that the UNLOGALL command does not affect those logs in your Logging Control list. Click on the Start Log button to add it to the list in the Save to File dialog.

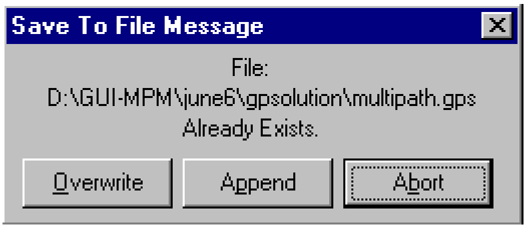
To remove a log from the list, highlight it and press the Unlog Selected Log button. The Unlog All In List button removes all the logs in the Logging Control list. The Save Every MPM Log field allows you to choose how often you save an MPM log (every one to every 10th). MPM logs arrive once every second for every satellite. Tracking 12 satellites means logging 12 MPM logs per second. This option is to help reduce file size.

✉ It is recommended that you set up the logging control window to create a new file at least every 24 hours.

When you have added all the logs you require, press the Start Recording button in the File IO section of the dialog. A green light appears to show you that recording is in progress. You can stop the recording at any time by pressing the Stop Recording button.



If you start recording and the target file already exists, the following message will appear:



✉ MAT uses a strict file naming convention to keep track of multiple files. If you choose an extension other than .GPS, MAT will warn you and change it to .GPS.

Select Overwrite to overwrite the previously recorded file, Append to record new information following the current information in the file, or Abort to abandon this recording name and enter a new target file in the Enter Filename field.

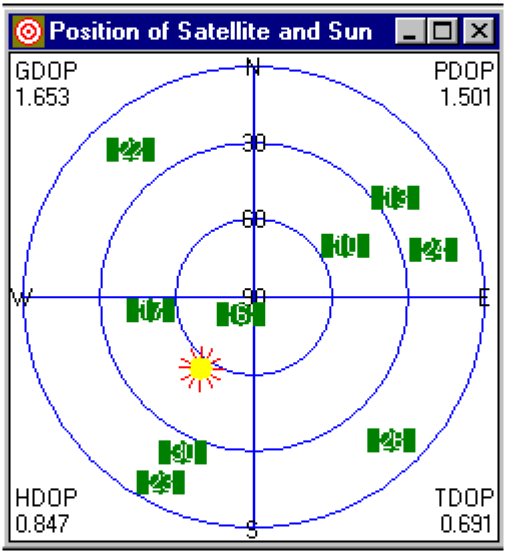
The Logging Control window cannot be opened during file playback.

5.4 Satellite Position

The Satellite Position window graphically displays satellite geometry and the position of the sun. The concentric circles are labelled 0° to 90° to represent elevations from the horizon to directly overhead respectively. The azimuth (direction) to each satellite is mapped on a compass relative to true North. When your cursor is over a satellite or the sun, its azimuth and elevation are displayed on the MAT status bar.

Different DOP (dilution of precision) values of the geometry are displayed in each corner of the window. DOP is defined as a numerical value expressing the confidence factor of the position solution based on current satellite geometry. The lower the value is, the greater the confidence in the solution. DOP can be expressed in the following forms:

GDOP	-	all parameters are uncertain (latitude, longitude, height, clock offset)
PDOP	-	3D parameters are uncertain (latitude, longitude, height)
HDOP	-	2D parameters are uncertain (latitude, longitude)
TDOP	-	clock offset is uncertain

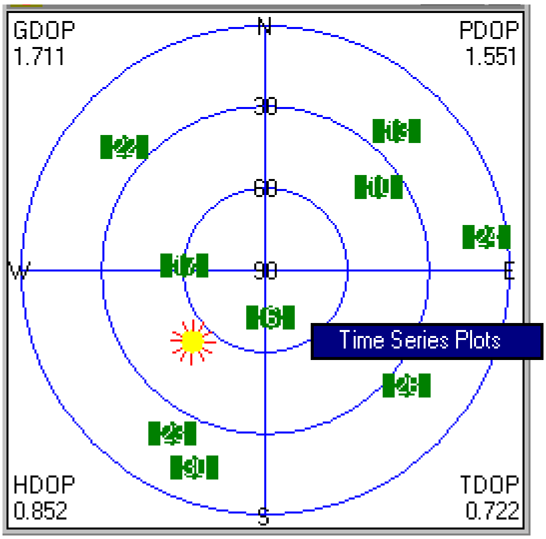


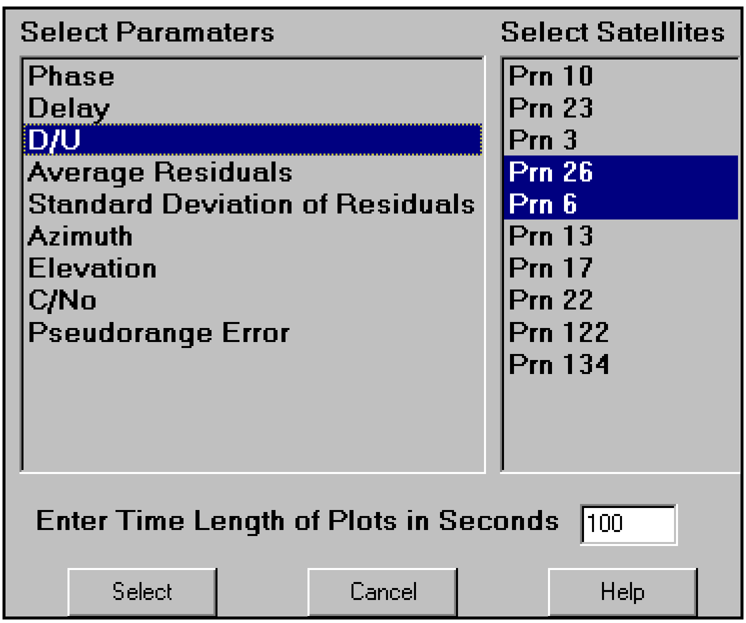
The position of the sun is dependant on your time zone. If you collect data in one time zone and then play back the data in another time zone, the sun will not be correctly placed on the plot.

Each satellite that is being tracked and is in good health is represented on the window with a stylized picture at its position. The satellite PRN is displayed on the body of the satellite. A sun icon represents the position of the sun. Below are examples of the type of information that appears in the status bar when you position your mouse over the sun or any of the satellites.

5.4.1 Plots

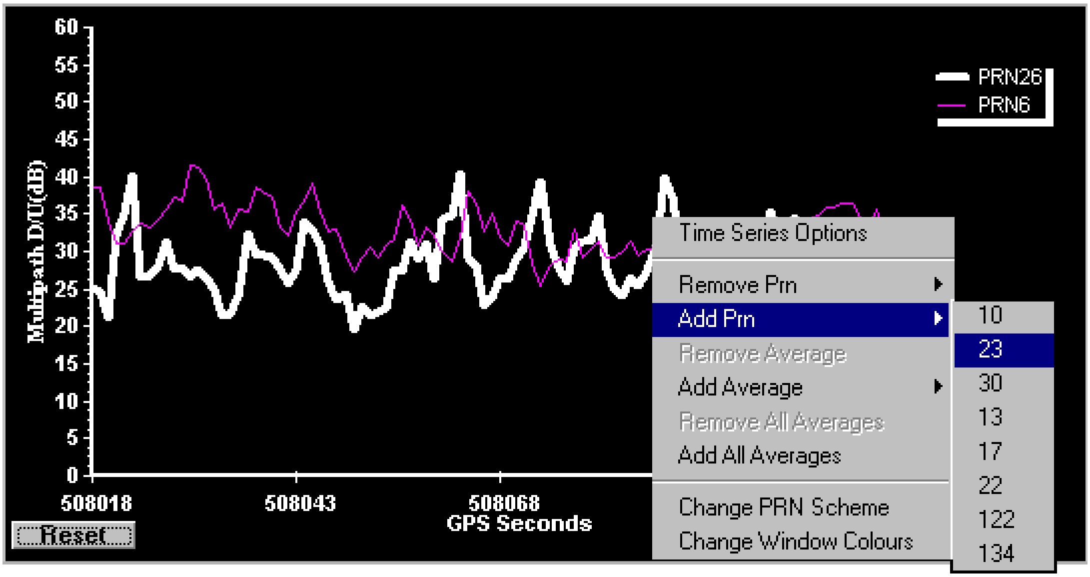
Right clicking on a satellite will display a Time Series Plot speed menu. Click on this speed menu to bring up the Select Multiple Satellites dialog.





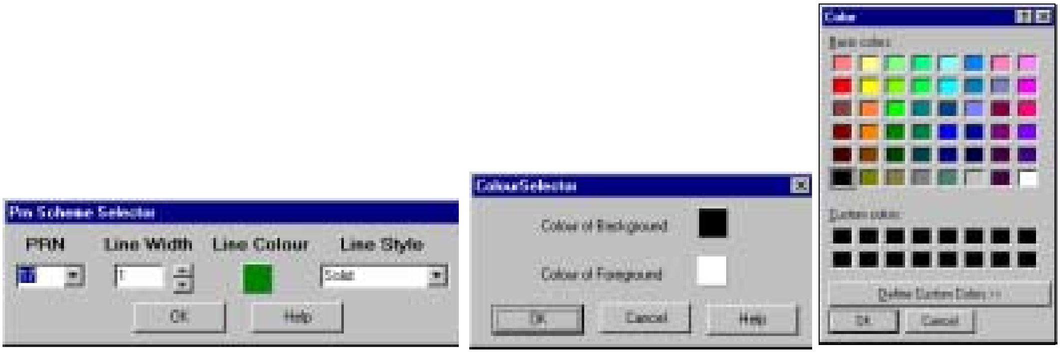
First choose a plot against time from the Select Parameters list. You can choose extra satellites to include in the plot from the Select Satellites list. Hold down the <Ctrl> key, select individual PRNs with your mouse and release the <Ctrl> key. If you want to select all the satellites, or all the satellites you want are together in the list, select your topmost PRN in the list with your mouse, hold down the <Shift> key, select your undermost PRN in the list and release the <Shift> key. All the PRNs you have chosen will appear in your time series plot. You can change the length of the x-axis by inputting a value in the Enter Time Length of Plots in Seconds field.

The plots show parameters from the Multipath Info table, against time. The running average of the parameters are also shown on the plots except on Phase, Azimuth and Elevation. Below is an example of the D/U Vs Time plot showing the speed menu that appears when you right click anywhere in the window.



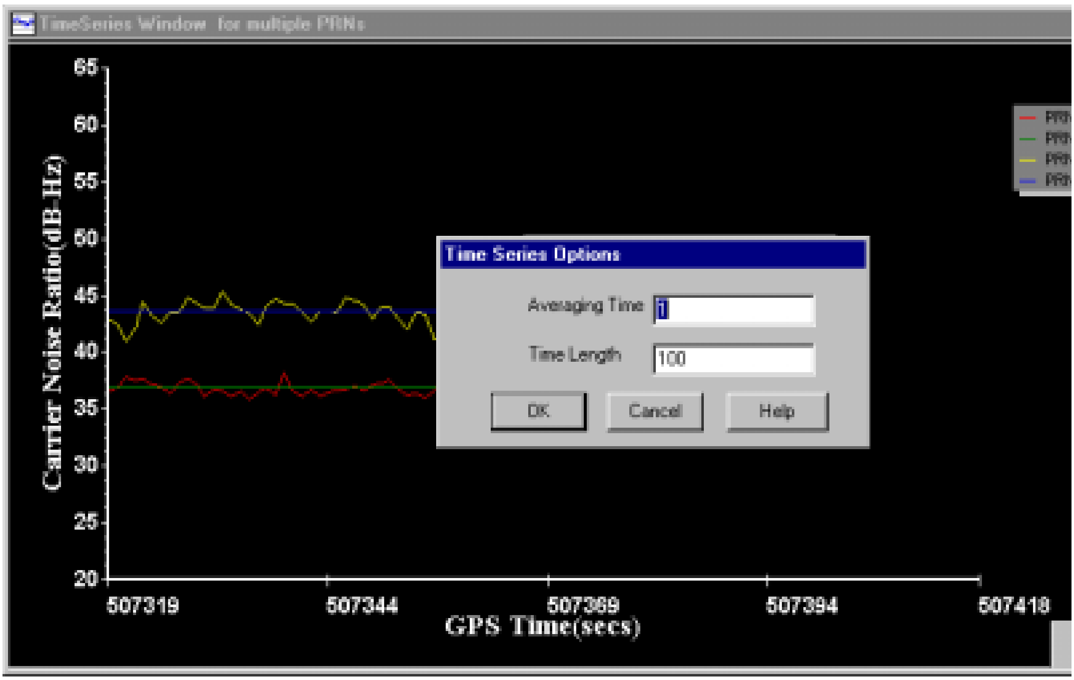
If there is more than one PRN in a plot, each satellite representation will appear in a different colour. The colour for an individual PRN, between time series plots, will stay the same. They will not stay the same between different device configurations. You can customize colour and line conventions for each PRN by selecting Change PRN Scheme from the speed menu. The PRN Scheme Selector dialog will appear. You can also customize the colour of the plot window foreground and background by selecting Change Window Colours from the menu. The Colour Selector dialog will appear. In both colour scheme dialogs, right clicking on a coloured square brings up a typical Windows colour selector dialog. When you are finished your customisations press the OK button in any of these dialogs to save your changes.

Choosing a line width greater than 1 will make a dashed line appear solid.

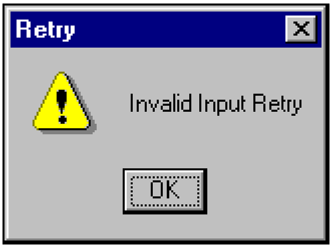


The Reset Plot button in the plot window, allows you to reset the plot.

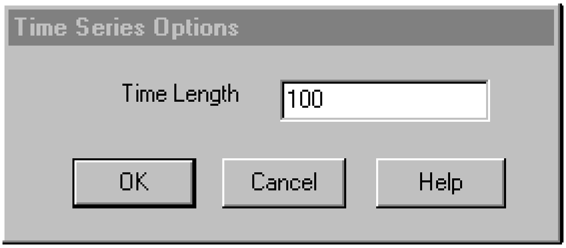
You can change the length of the x-axis and the amount of averaging by selecting Time Series Options from the speed menu. The parameters are either plotted every time the device sends a value or averaged over a period of time (user configurable) in which case this average is displayed.



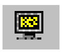
The averaging time, in the Time Series Options dialog, must be more than half the time length. If it is not, the following error message appears:



If the plot does not include averaging, only the Time Length option is shown.



5.5 Multipath Info

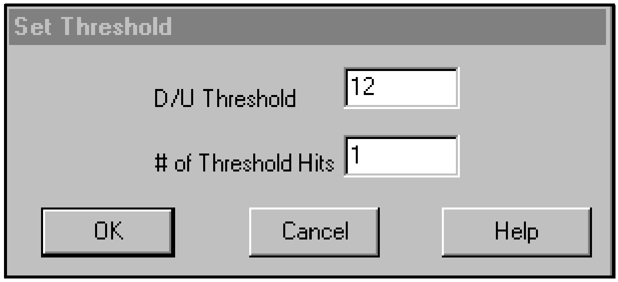


The data in the Multipath Info window is arranged in tabular format with each row representing a different satellite. The window is updated with new data every time it gets a complete set of data for all the satellites being tracked. The Multipath Info table displays a set of parameters related to multipath:

- Chan — SV receiver channel number
- PRN — The Pseudorandom Noise Number that is unique for each satellite
- Lock — Locktime (number of seconds of continuous tracking)
- Dop — Doppler frequency
- C/N_0 — Carrier to Noise density ratio (0 to 99 dB-Hz; 0 when not tracking)
- AZ — Azimuth: The horizontal direction of a celestial point from a terrestrial point, expressed as the angular distance from 000° (reference) clockwise through 360°. The reference point is generally True North.

- ELE — Elevation: The angle from the horizon to the observed position of a satellite.
- D/U — Desired/Undesired: MEDLL splits the received signals into their direct path (desired) and multipath (undesired) components. Generally, the higher the D/U ratio is, the more accurate the pseudorange will be. D/U is the relative power of the desired signal compared to the undesired signal.

If you right click anywhere on the Multipath Info window you can make a selection to bring up the Set Threshold dialog. Specify a D/U threshold and initialize a count of the number of threshold instances to allow.



If any satellite consecutively falls below the D/U threshold more than the number of times specified in the # of Threshold Hits field, the row representing that satellite is coloured red. If a satellite is unhealthy or no information is available for that satellite, its row is coloured gray.

Over long time periods you can see which satellites are experiencing a level of multipath that is unacceptable to you by monitoring which are red.

Select Reset DU Threshold Hits on the speed menu to reset the count of successive threshold instances.

Multipath Information

Chan»	PRN	Lock	Dop	C/No	AZ	ELE	D/U	Delay	Phase
15	134	125	5.9	36.0	0.0	0.0	18.3	1.36	-2.47
14	122	1772	-13.0	33.2	0.0	0.0	18.6	1.41	-0.54
13	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
12	22	4603	-4.9	46.7	298.8	24.6	22.5	0.31	-2.30
11	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
10	17	4646	1150.3	50.8	289.2	72.4	31.5	1.30	-1.61
9	13	4639	-2198.6	43.7	34.2	14.4	24.1	1.21	0.88
8	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
7	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
6	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
5	30	4603	-3638.8	38.6	195.0	1.4	17.2	1.09	-2.27
4	6	4669	-1894.7	50.8	164.6	57.9	31.1	0.05	1.31
3	26	4190	2351.8	48.2	119.4	31.8	27.6	0.99	2.46
2	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
1	23	3790	2959.9	45.1	212.4	32.9	26.9	0.40	2.88
0	10	4655	-3242.0	47.0	52.3	26.9	29.4	1.14	0.15

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- DELAY — Delay between multipath and direct signal (Time \ C/A Chips), see the x-axis of the *Multipath Error Envelopes Plot* in *Appendix A, Page 40.*
- PHASE — The phase shift between the multipath and direct signal (in the range $-\pi$ to $+\pi$ where π = 3.1415927 radians).

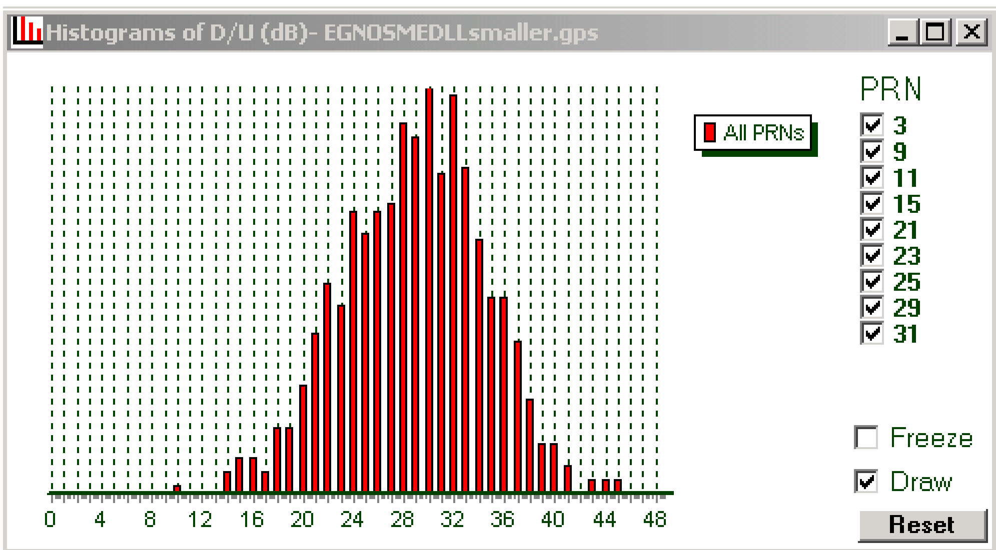
The current GPS week, represented by an integer (0 to 1023), and GPS seconds into the week (from Sunday morning at 00:00 a.m. UTC) are displayed in the status bar of the Multipath Information window.

The rows may be put in ascending or descending order for any column by clicking in the column header. You may remove and add the headers that you see in the Multipath Information window at any time by right clicking anywhere on the Multipath Info window and choosing Select Headers from the speed menu:

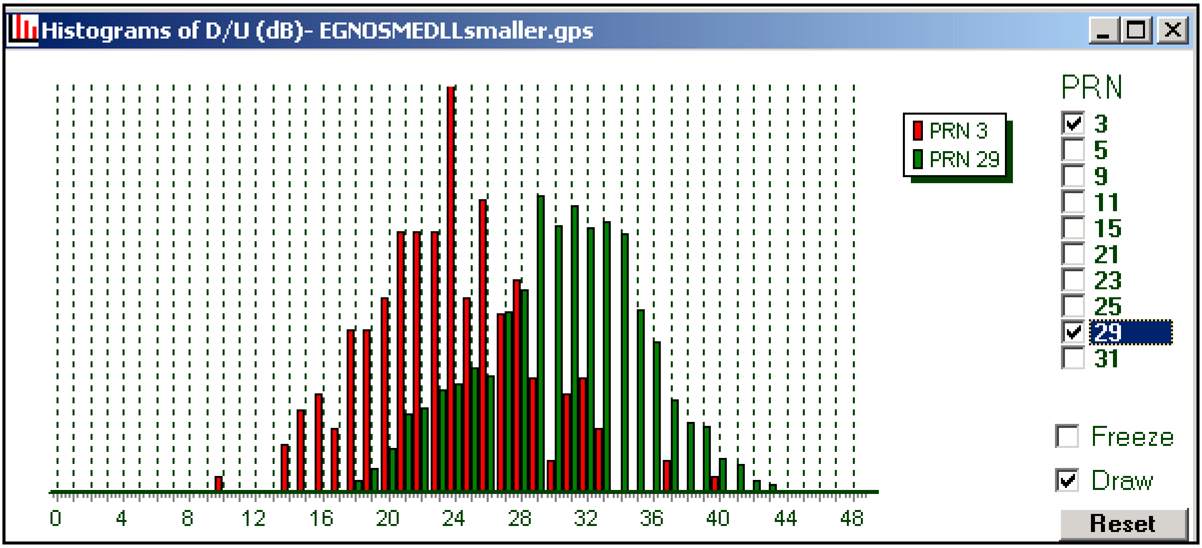
Right clicking anywhere in the window will allow you to open a time series plot of your choice by selecting Time Series Plots from the speed menu. The Select Multiple Satellites dialog appears. See its description in the *Plots* section starting on *Page 25*.

5.6 Histogram

The Histogram window gives you a graphical representation of the D/U and pseudorange error distribution. For an explanation on D/U and pseudorange error, please see *Page 41*. There are three types of histograms available. The histograms shown are “PRNs As One” and “Individual Side by Side” . You can also use the percentage option to show how many D/U or pseudorange error observations from each satellite contribute to the bar height.



The PRN checkboxes along the right side of each histogram allow you to add and remove satellite PRNs from the histogram.



The default for the x-axis is D/U values. You can change this to the pseudorange error in metres by right clicking with your mouse any where in the plot window and selecting Show Pseudorange Error from the speed menu.

Also on the speed menu is the Change Window Colours option. See *Pages 26-27*. If there is more than one PRN in a plot, each satellite representation will appear in a different colour. The colour for an individual PRN, between time series plots, will stay the same. They will not stay the same between different device configurations. You can customize colour and line conventions for each PRN by selecting Change PRN Scheme from the speed menu. The PRN Scheme Selector dialog will appear. You can also customize the colour of the plot window foreground and background by selecting Change Window Colours from the menu. The Colour Selector dialog will appear. In both colour scheme dialogs, right clicking on a coloured square brings up a typical Windows colour selector dialog. When you are finished your customisations press the OK button in any of these dialogs to save your changes. for more information on this dialog.

The Freeze check box, when selected, stops the histogram from using any new data and therefore the histogram stays unchanged. The freeze mode is useful to preserve the information currently in the histogram plot and still be able to fast forward and rewind the playback file to look at time series or other plots. You can still change the type of histogram and remove PRNs in this mode.

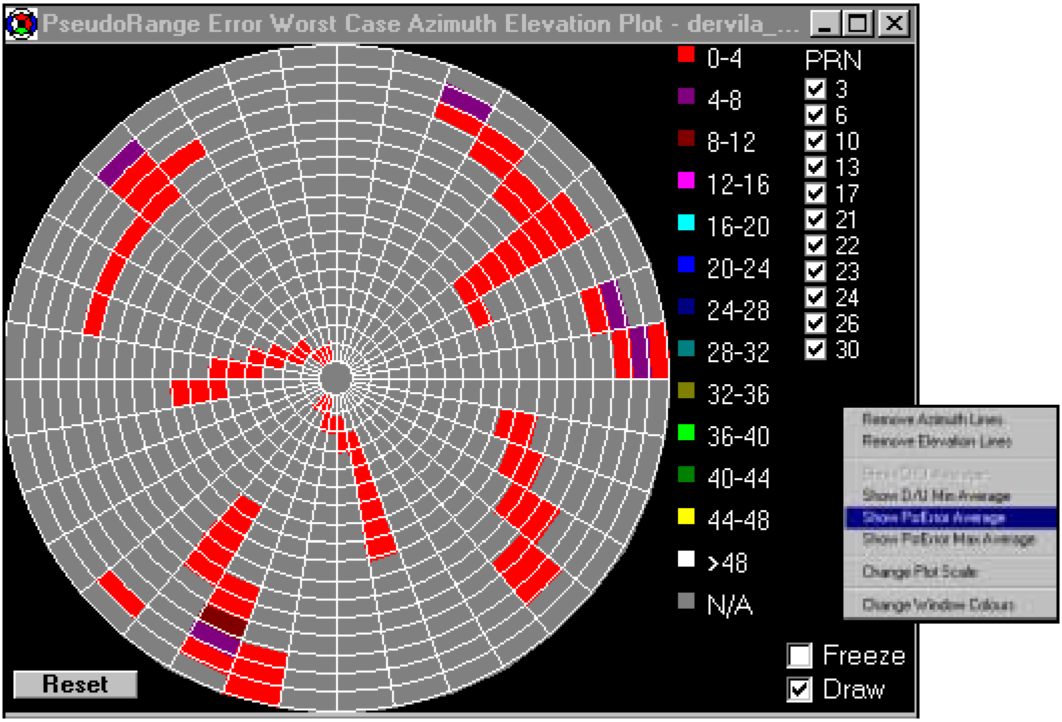
When the Draw check box is selected, it stops the histogram from changing, however, it is still accepting new data. The draw mode helps speed up the playback because your computer will not need to redraw the histogram every time new data is available.

The Reset button in the histogram window, allows you to reset the histogram.

5.7 D/U Azimuth Elevation Polar Plot

This polar plot represents different values for each satellite being tracked at that elevation and azimuth in the sky. The boxes that are produced in the plot, when the azimuth and elevation lines cross, are referred to as bins in the manual. Each bin represents 10° azimuth and 5° elevation.

The different colours in the plot indicate the different values:



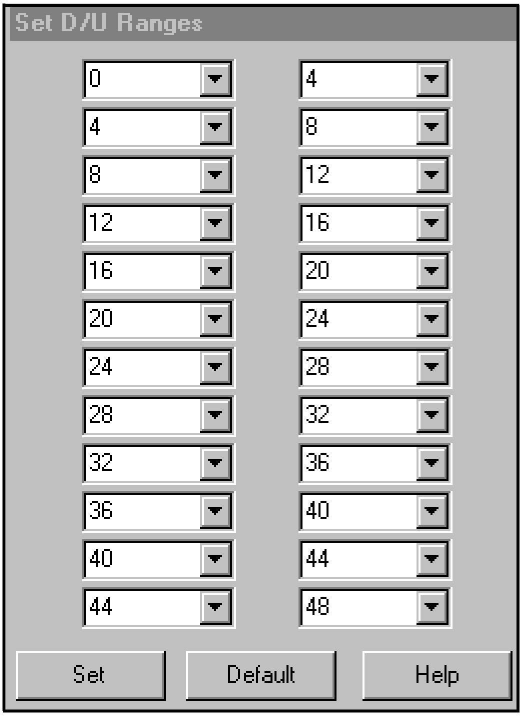
Right click anywhere in the plot's window to add or remove the azimuth or elevation grid lines, to set the window default colours and change what appears in the plot.

The default view is the Show D/U Average option. Below is an example of the type of information that appears in the status bar when you position your mouse over any of the coloured bins in the plot:

When the Show PsError Average option is selected the window displays the average of the pseudorange errors of PRNs in metres. In both cases (pseudorange error and D/U ratio), you can also select to view their minimums rather than their averages from the speed menu. The minimum is an average of the least values and not an absolute minimum. See *Page 41* for an explanation of pseudorange error and D/U ratio.

When the Change Plot Scale option is selected the following Range dialog appears so you can change the range values in the bins. Changing polar plot scales for a particular view, for example D/U Min

Average, will store these scale settings on a per view basis. You must then set your scale for each view in the polar plot.

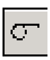


The Freeze check box, when selected, stops the polar plot from using any new data and therefore the plot stays unchanged. When the Draw check box is selected, it stops the polar plot from changing, however, it is still accepting new data.

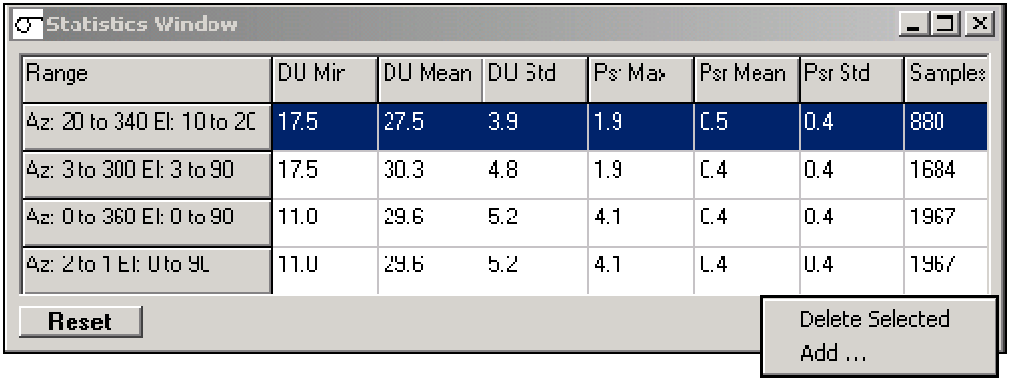
The PRN checkboxes along the right side of each plot allow you to add and remove satellite PRNs from the plot. Click once on the colours representing a range of values to change the colour. A standard Windows colour dialog appears. Select a colour or define a custom colour and press the OK button.

The Reset Plot button in the plot window, allows you to reset the plot.

5.8 Statistics



The Statistics window reports the mean, the standard deviation, and the minimum D/U values. It also reports the mean, standard deviation, and maximum values for the estimated pseudorange error. For an explanation of D/U and pseudorange error, please see *Page 41*.



Each row displays statistics for a user-defined range of azimuth and elevation. Right click anywhere in the Statistics window to delete rows, or add rows and specify the ranges. A maximum of 9 rows can be present in the window.

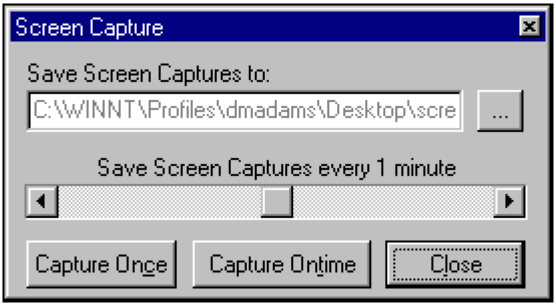
The Samples column displays the number of samples used to calculate the mean and standard deviations. This window is updated every second. The Reset button restarts the statistics.

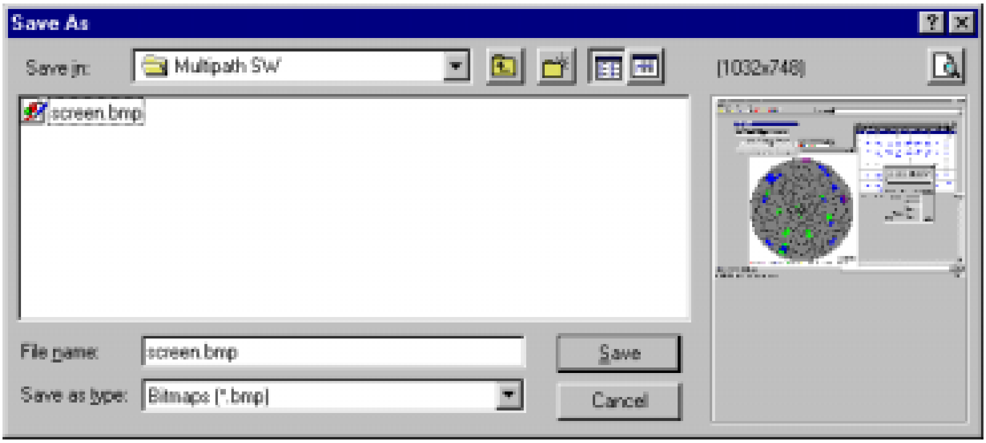
5.9 Capture Control

The capture control feature helps you to copy MAT screen images to a file. Select View | Capture Control from the main menu. The Save Screen Captures To field is not editable directly; you must browse for a file by pressing the ellipses button (…) on the right.

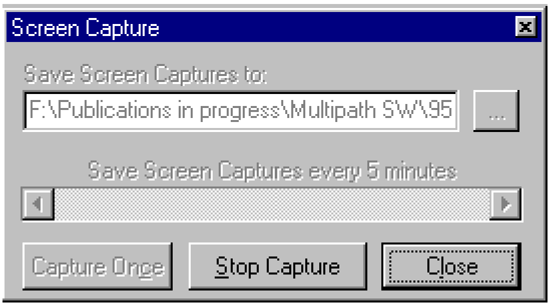
To capture a screen only once, click on the Capture Once button. To capture a screen more than once, decide the length of time between captures with the Save Screen Captures Every slider and press the Capture Ontime button. This is useful for recording information over time especially if you cannot be there to watch the screen.

✉ The capture control will capture the active screen including any screen saver. It is recommended you disable your screen saver program and turn off your monitor to capture the MAT images.





If you select ONTIME, the Capture Once button appears grey and clicking on the Stop Capture Button can stop the ontime trigger. If you select Capture Once, both buttons appear grey until the capture is finished and then the screen capture dialog may be used again. To close the Screen Capture dialog, click on the Close button.



Appendix A Radio Frequency (RF) And Multipath

A.1 Overview

The influence on radio wave propagation depends on the frequency and propagation mediums through which the RF signal travels. UHF signals such as GPS are highly susceptible to reflections because of the short wavelengths at the L1 channel. As GPS is a radio navigation ranging system, the direct path signal is of primary interest. Any propagation delays or multipath reception causes biases to the ranging measurements that cannot be differenced by traditional DGPS single differencing techniques. Multipath is the greatest source of errors to a system operating in single differencing mode, see *Figure 2*. Careful site selection and the GPS model 600 Pinwheel Technology antenna, or good patch antenna design combined with a choke ring ground plane are very effective in reducing multipath reception, see *Figure 3*.

The role of a correlator is discussed to provide some insight into how multipath influences the correlation function required for satellite tracking and ranging. MEDLL is a multi-correlator array technology whereby a multi-card system is used to sample the multipath signals as well as the direct path signals, recognizing the difference between them, then rejecting the multipath signals, leaving only the desired direct path signal. MEDLL is the most effective receiver technology available that reduces the combined effects of GPS L1 C/A code and carrier phase multipath by as much as 90%.

Figure 2: GPS Signal Multipath Scenario

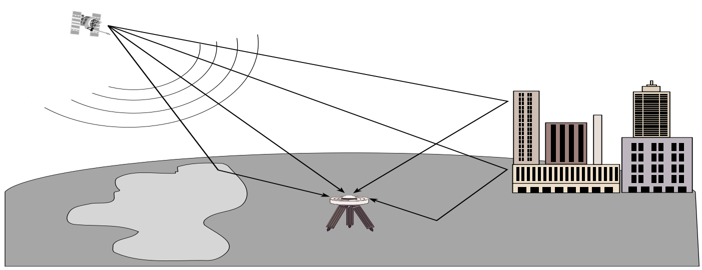
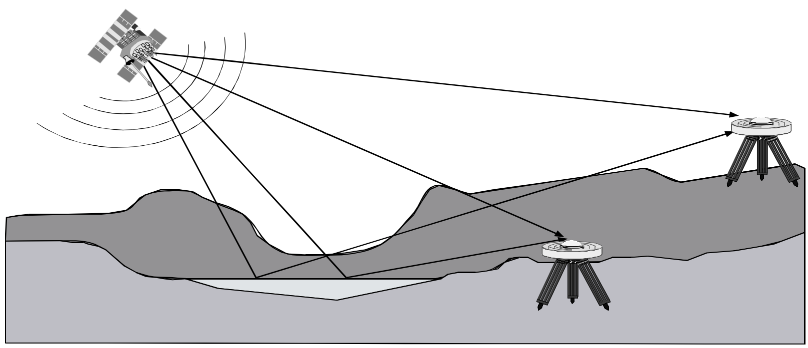


Figure 3: GPS Signal Multipath versus Increased Antenna Height



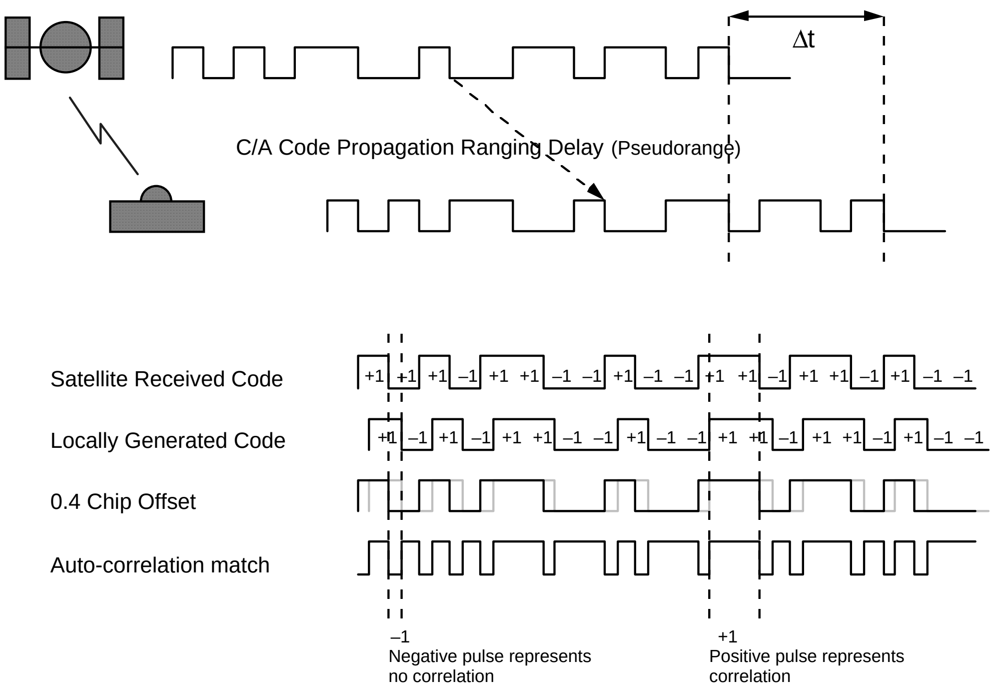
A.2 The Role of the GPS Receiver Correlator

Each GPS satellite transmits a unique pseudorandom noise (PRN) C/A code (coarse/acquisition) and P code (precision). As the P code is generally for military and special authorized use only, this discussion is limited to C/A code.)

The C/A code has a clocking rate (chipping rate) of approximately 1.023 MHz. This chipping rate causes the GPS RF signal to have a main lobe (90% power) spread spectrum of approximately 2.046 MHz. As each satellite transmits on the same L1 carrier frequency, they are differentiated only by their respective PRN codes.

To receive each GPS satellite PRN signal, the earth station receivers have C/A code generators that can match each of the satellite PRN codes. As well, the internal code generator must be clocked at a chipping rate that is as close as practical to that of the satellite's clock. It is in the "matching" of the individual received C/A codes against those generated by the local receiver code generator that the ***correlator*** becomes of crucial importance. As the name "correlator" implies, it must be able to "correlate" a match between two PRN codes. Unless correlation can be achieved, the received signals only appear as random noise.

Figure 4: Example of C/A Code Correlation

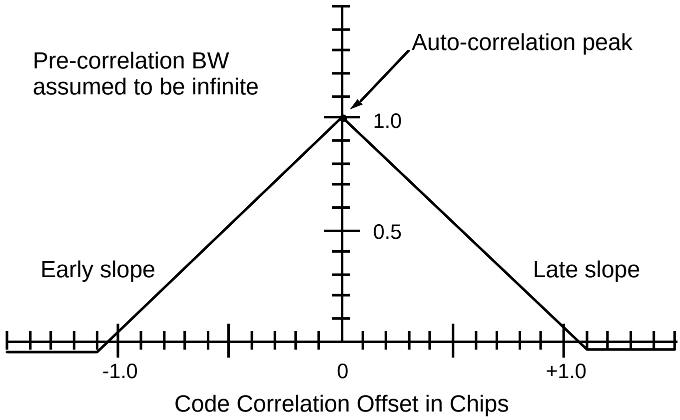


The GPS receiver measures its distance from each satellite by measuring the time it takes the GPS signal to propagate from the satellite to the receiver antenna. The GPS receiver determines its position by means of trilateration of the range measurements of at least four measured satellite ranges. The receiver's ability to accurately correlate and phase lock on each PRN code directly influences the accuracy of the receiver's range measurements accuracy, which in turn affects the accuracy of the computed position. NovAtel's WAAS MEDLL has sixteen parallel channels that can simultaneously correlate and track up to 16 satellites.

A.2.1 The Autocorrelation Function

The ideal GPS receiver would have an infinitely wide receiver bandwidth (BW), which would allow the receiver to capture 100% of the GPS spread spectrum signal. The normalized autocorrelation function for an infinitely wide BW is generally illustrated as shown in *Figure 6* below.

Figure 5: Theoretical Normalized Auto-correlation Function



The auto-correlation peak is maintained by continually adjusting the locally generated code for maximum correlator output. The unlimited BW provides a sharp correlation peak and steep early/late slope that facilitates accurate error correction for the code-lock-loop (also called Delay Lock Loop). As the bandwidth is reduced, the peak of the correlation function becomes more rounded.

In reality, a GPS receiver would need an extremely wide band pass filter, with a BW of at least ten times the C/A code chipping rate, to be capable of capturing > 99% of the GPS spread spectrum signal. For most GPS receivers this is generally not practical to achieve.

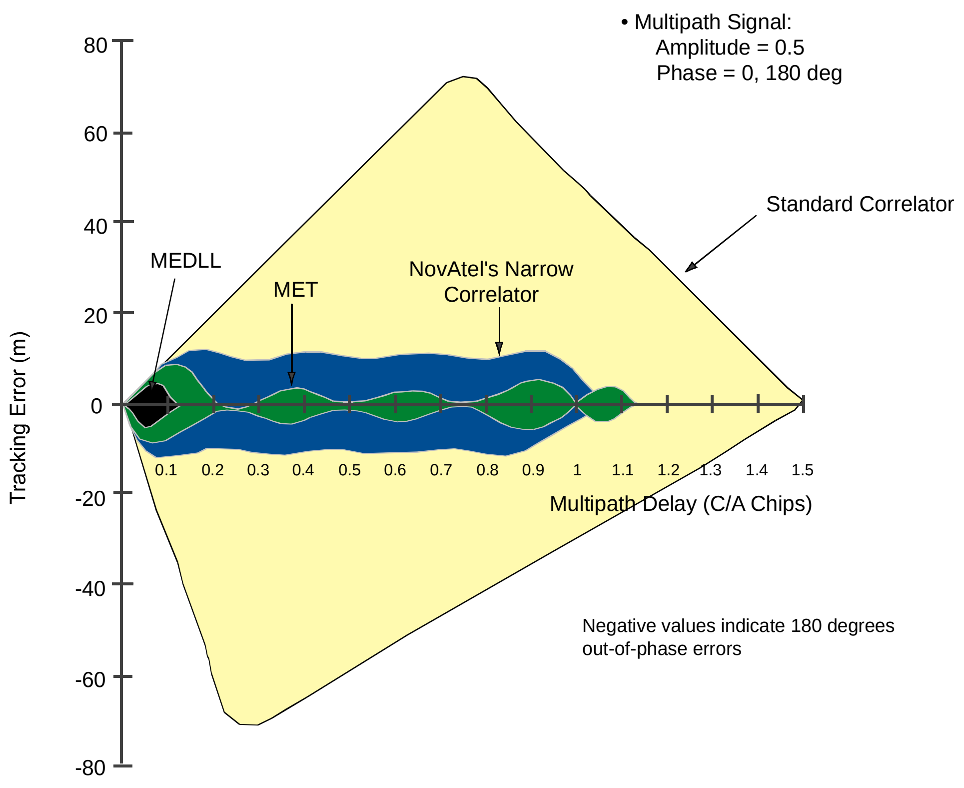
A.2.2 MEDLL

NovAtel's MEDLL multipath reduction technology approaches the theoretical limits of multipath-free GPS signal reception. Multipath Estimating Delay-Lock-Loop (MEDLL) utilizes a combination of hardware and software techniques that are capable of reducing the combined effects of pseudorange multipath errors by as much as 90%. As well, MEDLL does all this without the need to mount the antenna on a choke ring ground plane. (If you are using a GPS model 600 Pinwheel Technology antenna, you will never need to mount it on a choke ring ground plane.)

The MEDLL technology takes further advantage of NovAtel's parallel channel Narrow Correlator tracking technology as seen in *Figure 6 on Page 40*. It is unique in that it utilizes an array of narrowly spaced correlators distributed about the autocorrelation function whereby each satellite-tracking channel is sampled by a dedicated correlator array. Currently, MEDLL is a 16-channel receiver. This array distribution of correlator sampling allows the receiver to measure the shape of the received correlation function. Using a "maximum likelihood estimation" technique, MEDLL splits the received signals into their direct path and multipath components by determining the amplitude, delay, and phase angle of each of the composite signals. Once the composite signal has been broken down into its components, the signal with the least delay is determined to be the direct signal, and all other signals with greater delay are considered to be the multipath components (assuming the direct path signal is available and unobstructed).

MEDLL can effectively remove all multipath signals that have a propagation delay of greater than 0.1 chips relative to the direct path signal. The remaining multipath effect on the C/A code pseudorange measurements is now in the same order of magnitude as a P code GPS receiver.

Figure 6: Multipath Error Envelopes for Narrow Correlator vs. MET vs. MEDLL



A.3 D/U Ratio

Given that MEDLL determines the amplitude of the direct signal and reflected signal, you can create a ratio of the direct signal strength relative to the reflected signal strength. This ratio is called D/U and is correlated with pseudorange error due to multipath.

For information on monitoring the D/U ratio, see *Multipath Info* starting on *Page 28*.

A.4 Pseudorange Error

D/U, delay and phase can be used to generate a plot similar to *Figure 6 on Page 40*. The pseudorange error reported in MAT is an estimate of the pseudorange error for a receiver with NovAtel's Narrow Correlator tracking technology. Pseudorange error is estimated from MEDLL parameters and not from a code minus carrier technique.

Appendix B NovAtel Format Data Logs

WAAS-type receivers are capable of generating many NovAtel-format output logs, in either ASCII or binary format.

The following log descriptions are listed in alphabetical order. Each log first lists the ASCII format, then the binary format description.

B.1 ASCII Log Structure

Log types ending with the letter A are output in ASCII format (e.g., POSA). The structures of all ASCII logs follow the general conventions as noted here:

1. The lead code identifier for each record is '$'.
2. Each log is of variable length depending on amount of data and formats.
3. All data fields are delimited by a comma ',' with the exception of the last data field, which is followed by a '*' to indicate end-of-message data.
4. Each log ends with a hexadecimal number preceded by an asterisk and followed by a line termination using the carriage return and line feed characters, e.g., *xx[CR][LF]. This 8-bit value is an exclusive OR (XOR) of all bytes in the log, excluding the '$' identifier and the asterisk preceding the two checksum digits.

Structure:

$xxxx,	data field...,	data field...,	data field...	*xx	[CR][LF]

B.2 Binary Log Structure

Log types ending with the letter B are output in binary format (e.g., POSB). The structures of the binary logs follow the general conventions as noted here:

1. Basic format of:

Sync	3 bytes
Checksum	1 byte
Message ID	4 bytes unsigned integer
Message byte count	4 bytes unsigned integer
Data	x bytes

2. The Sync bytes will always be:

Byte	Hex	Decimal
First	AA	170
Second	44	68
Third	11	17

3. The Checksum is an XOR of all the bytes, including the 12 header bytes with CRC = 00.
4. The Message ID identifies the type of log to follow.
5. The Message byte count equals the total length of the data block including the header.

The following describes the format types used in the description of binary logs:

Type	Size (bytes)	Size (bits)	Description
char	1	8	The **char** type is used to store the integer value of a member of the representable character set. That integer value is the ASCII code corresponding to the specified character.
int	4	32	The size of a signed or unsigned **int** item is the standard size of an integer on a particular machine. On a 32-bit processor (such as the NovAtel GPSCard), the **int** type is 32 bits, or 4 bytes. The **int** types all represent signed values unless specified otherwise. Signed integers are represented in two's-complement form. The most-significant bit holds the sign: 1 for negative, 0 for positive and zero.
double	8	64	The **double** type contains 64 bits: 1 for sign, 11 for the exponent, and 52 for the mantissa. Its range is ±1.7E308 with at least 15 digits of precision.
float	4	32	The **float** type contains 32 bits: 1 for the sign, 8 for the exponent, and 23 for the mantissa. Its range is ±3.4E38 with at least 7 digits of precision.
long	4	32	The **long** type is a 32-bit integer in the range –2147483647 to +2147483648

Each byte within an **int** has its own address, and the smallest of the addresses is the address of the int. The byte at this lowest address contains the eight least significant bits of the double word, while the byte at the highest address contains the eight most significant bits. Similarly the bits of a "double" type are stored least significant byte first. This is the same data format used by personal computers.

B.3 Time Conventions

All logs report GPS time expressed in GPS weeks and seconds into the week. The time reported is not corrected for the local receiver's clock error.

GPS time is based on an atomic time scale. Universal Time Coordinated (UTC) time is also based on an atomic time scale, with an offset of seconds applied to coordinate Universal Time to GPS time. GPS time is designated as being coincident with UTC at the start date of January 6, 1980 (00 hours) GMT. GPS time does not count leap seconds, and therefore an offset exists between UTC and GPS time. The GPS week consists of 604800 seconds, where 000000 seconds is at Saturday midnight. Each week at this time, the week number increments by one, and the seconds into the week resets to 0.

B.4 Log Descriptions

The log references that follow are in alphabetical order.

For the binary logs, the 32-bit CRC is calculated with all fields in the log filled except for the checksum field, which is zero. For the ASCII logs, the 32-bit CRC is calculated from all fields of the log after the ‘$’ symbol. Once the CRC has been calculated, the log checksum is calculated in the normal fashion, in order to preserve the standard NovAtel log format.

The GPS seconds into the week value is stored in a number of different ways within the receiver. Depending on which log is being output, the time may be derived from a different source. However, all sources of time are interconnected. Generally, the seconds into the week field is stored as either an integer (in milliseconds) or a floating-point value before being output in the log.

B.4.1 DOPA/B Dilution of Precision

The dilution of precision data is calculated using the geometry of only those satellites that are currently being tracked and used in the position solution by the GPSCard and updated once every 60. Therefore, the total number of data fields output by the log is variable, depending on the number of satellites being tracked. Twelve is the maximum number of satellite PRNs contained in the list.

✉ If insufficient satellites are being tracked to calculate DOP values, the last calculated DOP values are output.

DOPA

Structure:

$DOPA week sec gdop pdop htdop hdop tdop #sats

prns *xx [CR][LF]

Field #	Field type	Data Description	Example
1	$DOPA	Log header	$DOPA
2	week	GPS week number	637
3	sec	GPS seconds into the week	512473.00
4	gdop	Geometric dilution of precision - assumes 3-D position and receiver clock offset (all 4 parameters) are unknown	2.9644
5	pdop	Position dilution of precision - assumes 3-D position is unknown and receiver clock offset is known	2.5639
6	htdop	Horizontal position and time dilution of precision	2.0200
7	hdop	Horizontal dilution of precision	1.3662
8	tdop	Time dilution of precision - assumes 3-D position is known and only receiver clock offset is unknown	1.4880
9	#sats	Number of satellites used in position solution (0-12). See the notes above.	6
10...	prns	PRN list of SV PRNs tracking (1-32), null field until first position solution available	18,6,11,2,16, 19
variable	*xx	Checksum	*29
variable	[CR][LF]	Sentence terminator	[CR][LF]

Example:

$DOPA,637,512473.00,2.9644,2.5639,2.0200,1.3662,1.4880,6,18,6,11,2,16,19
*29[CR][LF]

DOPB

Format: Message ID = 07
Message byte count = 68+(#sats*4)

Field #	Data	Bytes	Format	Units	Offset
1 (header)	Sync	3	char		0
	Checksum	1	char		3
	Message ID	4	integer		4
	Message byte count	4	integer	bytes	8
2	Week number	4	integer	weeks	12
3	Seconds of week	8	double	seconds	16
4	gdop	8	double		24
5	pdop	8	double		32
6	htdop	8	double		40
7	hdop	8	double		48
8	tdop	8	double		56
9	Number of satellites used	4	integer		64
10	1st PRN	4	integer		68
11...	Next satellite PRN Offset = 68 + (sats x 4) where sats = 0 to (number of sats-1)				

B.4.2 ETSA/B Extended Channel Tracking Status

These logs provide channel tracking status information for each of the GPSCard parallel channels.

🖂 This log is intended for status display only; since some of the data elements are not synchronized together, they are not to be used for measurement data. Please use the RGEA / B / C, SATA / B, and SVDA / B logs to obtain synchronized data for post processing analysis.

If both the L1 and L2 signals are being tracked for a given PRN, two entries with the same PRN will appear in the range logs. As shown in *Table 2* (Channel Tracking Status word) on *Page 51*, these entries can be differentiated by bit 19, which is set if there are multiple observables for a given PRN, and bit 20, which denotes whether the observation is for L1 or L2. This is to aid in parsing the data.

ETSA

Structure:

$ETSA week seconds sol status # obs

prn ch tr-status dopp C/No residual locktime psr reject code

:

prn ch tr-status dopp C/No residual locktime psr reject code

*xx [CR][LF]

Field #	Field type	Data Description	Example
1	$ETSA	Log header	$ETSA
2	week	GPS week number	850
3	seconds	GPS seconds into the week (receiver time, not corrected for clock error, CLOCKADJUST enabled)	332087.00
4	sol status	Solution status (see *Page 52*)	0
5	# obs	Number of observations to follow	24
6	prn	Satellite PRN number (1-32) (channel 0) [a]	7

7	ch tr-status	Hexadecimal number indicating channel tracking status (see *Page 51*)	00082E04
8	dopp	Instantaneous carrier Doppler frequency (Hz)	-613.5
9	C/No	Carrier to noise density ratio (dB-Hz)	54.682
10	residual	Residual from position filter (m)	27.617
11	locktime	Number of seconds of continuous tracking (no cycle slips)	12301.4
12	psr	Pseudorange measurement (m)	20257359.5 7
13	reject code	Indicates whether the range is valid (code = 0) or not (see *Page 53*)	0
14-21 .. 94-101	.. .. ..	next observation .. last observation	
102	*xx	Checksum	*19
103	[CR][LF]	Sentence terminator	[CR][LF]

a. Satellite PRN = 0 if the channel is idle.

Example (carriage returns have been added between observations for clarity):

```
$ETSA,850,332087.00,0,24,
7,00082E04,-613.5,54.682,27.617,12301.4,20257359.57,0,
7,00582E0B,-478.1,46.388,0.000,11892.0,20257351.96,13,
5,00082E14,3311.2,35.915,1.037,1224.4,24412632.47,0,
5,00582E1B,2580.4,39.563,0.000,1186.7,24412629.40,13,
9,00082E24,1183.1,53.294,-29.857,7283.8,21498303.67,0,
9,00582E2B,921.9,44.422,0.000,7250.2,21498297.13,13,
2,00082E34,-2405.2,50.824,-20.985,19223.6,22047005.47,0,
2,00582E3B,-1874.1,41.918,0.000,19186.7,22046999.44,13,
4,00082E44,3302.8,47.287,7.522,3648.1,22696783.36,0,
4,00582E4B,2573.6,37.341,0.000,3191.2,22696778.15,13,
14,00082E54,2132.7,41.786,-22.388,541.3,25117182.07,0,
14,00582E5B,1661.7,33.903,0.000,500.7,25117179.63,13,
26,00082E64,-3004.3,43.223,2.928,14536.2,25074382.19,0,
26,00582E6B,-2340.9,33.019,0.000,14491.7,25074378.01,13,
15,00082E74,-3037.7,43.669,0.508,12011.5,24104788.88,0,
15,00582E7B,-2367.0,34.765,0.000,11842.4,24104781.53,13,
24,00082E84,3814.0,37.081,7.511,95.7,25360032.49,0,
24,00582E8B,2972.0,24.148,0.000,5.2,25360030.13,13,
28,00082A90,-9800.9,0.000,0.000,0.0,0.00,9,
28,00382A90,-7637.0,0.000,0.000,0.0,0.00,9,
3,000822A0,-3328.3,0.000,0.000,0.0,0.00,9,
3,005828A0,-2593.5,0.000,0.000,0.0,0.00,9,
27,000822B0,-3851.7,0.000,0.000,0.0,0.00,9,
27,005828B0,-3001.7,0.000,0.000,0.0,0.00,9
*41[CR][LF]
```

ETSB

Format: Message ID = 48
Message byte count = 32 + (n*52) where n is number of channels in receiver

Field #	Data	Bytes	Format	Units	Offset
1	Sync	3	char		0
(header)	Checksum	1	char		3
	Message ID	4	integer		4
	Message byte count	4	integer	bytes	8
2	Week number	4	integer	weeks	12
3	Time of week	8	double	seconds	16

4	Solution status	4	integer	(See *Page 52*)	24
5	No. of channels	4	integer	number of channels in receiver	28
6	PRN number (chan 0)	4	integer		32
7	Channel tracking status	4	integer	(See *Page 51*)	36
8	Doppler	8	double	Hz	40
9	C/N_0 (db-Hz)	8	double	db Hz	48
10	Residual	8	double	metres	56
11	Locktime	8	double	seconds	64
12	Pseudorange	8	double	metres	72
13	Rejection code	4	integer	(See *Page 53*)	80
14 ...	Offset = 32 + (chan x 52) where chan varies from 0 - highest channel number				

Table 2: Channel Tracking Status Bits

N 7 | N 6 | N 5 | N 4 | N 3 | N 2 | N 1 | N 0 <-<- Nibble Number

Bit	Description	Range Values	Hex.
lsb=0	Tracking state	0-11 See below	1
1			2
2			4
3			8
4	Channel number	0-n (0=first, n=last)	10
5		(n depends on GPS Card model)	20
6			40
7			80
8			100
9	Phase lock flag[4]	1=Lock, 0=Not locked	200
10	Parity known flag[4]	1=Known, 0=Not known	400
11	Code locked flag[4]	1=Lock, 0=Not locked	800
12	Correlator spacing type	0-7 See the Correlator Spacing Table[5]	1000
13			2000
14			4000
15	Satellite system	0=GPS 3=Reserved	8000
16		1=Reserved 4-7 Reserved	10000
17		2=GEO[1]	20000
18	Antenna	1=Secondary, 0=Primary[2]	40000
19	Grouping	1=Grouped, 0=Not grouped	80000
20	Frequency	1=L2, 0=L1	100000
21	Code type	0=C/A 2=P-codeless	200000
22		1=P 3=Reserved	400000
23	Forward error correction	1=FEC enabled, 0=no FEC[3]	800000
24 : 29	Reserved. Set to 0.		
30	External range	1=Ext. range, 0=Int. range	
31	Channel assignment	1=Forced, 0=Automatic	

1 GEO will never be set for MEDLL channels 0-11.
2 Antenna will always be primary.
3 MEDLL channels 12-15 will be 1 and MEDLL channels 0-11 will be 0.
4 When phase, parity, and code lock have been established, the channel has reached steady state tracking in state 4.
5 See *Table 3, Bits 12-14: Correlator Spacing, on Page 52*.

Table 3: Bits 12-14: Correlator Spacing

State	Description
0	Unknown: this only appears in versions of software previous to x.4x, which didn't use this field
1	Standard correlator: spacing = 1 chip
2	Narrow Correlator
3	MET: uses Early-Late Slope Technique to improve Narrow Correlator performance in reducing errors due to multipath
4	Reserved.
5	MEDLL: decomposes the incoming signal into direct-path and reflected-path components to reduce errors due to multipath

Higher numbers are reserved for future use

Table 4: GPSCard Solution Status

Value	Description
0	Solution computed
1	Insufficient observations
2	No convergence
3	Singular AtPA Matrix
4	Covariance trace exceeds maximum (trace > 1000 m)
5	Test distance exceeded (maximum of 3 rej if distance > 10 Km)
6	Not yet converged from cold start

Higher numbers are reserved for future use

Table 5: Range Reject Codes

Value	Description
0	Observations are good
1	Bad satellite health is indicated by ephemeris data
2	Old ephemeris due to data not being updated during last 3 hours
3	Eccentric anomaly error during computation of the satellite's position
4	True anomaly error during computation of the satellite's position
5	Satellite coordinate error during computation of the satellite's position
6	Elevation error due to the satellite being below the cut-off angle
7	Misclosure too large due to excessive gap between estimated and actual positions
8	No differential correction is available for this particular satellite
9	Ephemeris data for this satellite has not yet been received
10	Invalid IODE due to mismatch between differential stations
11	Locked out of the position solution by the user
12	Low Power: satellite rejected due to low signal/noise ratio
13	L2 measurements are not currently used in the filter
14	Reserved.
15	
16	
17	GEO satellite not used in the position filter for RIMS-C

B.4.3 MPMA/B Multipath Meter Log

This log is only available for MEDLL. It outputs information that estimates the amount of multipath the antenna is experiencing and how well MEDLL has modelled the multipath signals.

It is recommended that this log be output only with the 'onnew' trigger option. There will be one log for every tracked satellite per epoch. For example, if eleven satellites are being tracked, there will be eleven instances of this log every epoch. MEDLL runs every second, so one epoch is equivalent to one second.

MPMA

$MPMA week seconds prn chtrstat medllstat delay amplitude phase

1st in phase ··· 12th in phase

1st quad. phase ··· 12th quad. phase

xx [CR][LF]

Field #	Field Type	Data Description	Example
1	$MPMA	Log header	$MPMA
2	Week Number	GPS week number	0
3	Seconds of Week	GPS seconds into the week	27.77
4	PRN	Satellite identifier	29
5	Channel Tracking Status	Channel tracking status bits, see *Page 51*	6A84
6	MEDLL Status	MEDLL status bits, see *Page 57*	103
7	Delay	Delay of multipath signal	1.08154941
8	Amplitude	Amplitude of multipath signal	0.01731431
9	Phase	Phase of multipath signal	- 0.00645047
10	1st in phase residual	In phase residual value from correlator 1	0.00160142
	…	Repeated for each correlator	…
22	12th in phase residual	In phase residual value from correlator 12	- 0.00196318
23	1st Quadrature phase residual	Quadrature phase residual value from correlator 1	- 0.00418267

	…	Repeated for each correlator	…
45	12th Quadrature phase residual	Quadrature phase residual value from correlator 12	- 0.00730140
46	*xx	Checksum	*71
47	[CR][LF]	Sentence terminator	[CR][LF]

Example:

$MPMA,0,27.77,29,6A84,103,1.08154941,0.01731431,-0.00645047,0.00160142,
0.00164832,0.00078163,0.00001205,0.00083644,0.00240084,0.00214321,0.
00079274,-0.00032872,-0.00084985,0.00000891,-0.00196318,-0.00418267,
-0.00443155,-0.00665589,-0.00580890,-0.00078493,-0.00101275,
0.00468876,0.00449791,-0.00126932,-0.00140528,0.00004035,
-0.00730140*71[CR][LF]

MPMB

Format: Message ID = 95
Message byte count = 144

Field #	Data	Bytes	Format	Units	Offset
1 (header)	Sync	3	Char		0
	Checksum	1	Char		3
	Message ID	4	Integer		4
	Message Byte Count	4	Integer	bytes	8
2	Week Number	4	Integer	weeks	12
3	Seconds of Week	8	Double	seconds	16
4	PRN	4	Integer		24
5	Channel Status	4	Integer		28
6	MEDLL Status	4	Integer		32
7	Delay	4	Float	C/A chips	36
8	Amplitude	4	Float		40
9	Phase	4	Float		44
10	1st in phase residual	4	Float		48
	…				
22	12th in phase residual	4	Float		92
23	1st Quadrature phase residual	4	Float		96
	…				
45	12th Quadrature phase residual	4	Float		140

The multipath amplitude and residuals are normalized with respect to the reference correlation function. D/U (desired signal power relative to undesired signal power), in units of decibels (dB), can be calculated from the amplitude of the multipath signal (-20 * log [amplitude of multipath signal]).

Table 6: MEDLL Status Bits

Position	Field Description
0x00000001	Sync bit: 1 if MEDLL channels in sync, 0 if not in sync. Sync bit is set to 1 if the different hardware channels use to track the same PRN are aligned.
0x00000002	Phase processing. When phase processing is on, the bit is 1; MEDLL will determine the phase of the multipath signal. If phase processing is set to 0, MEDLL will not process the phase of the multipath signal.
0x000007C	Type of MEDLL will always be 0 for MAT.
0x00000380	Number of signals will always be 1 for MAT.
Other bits	Reserved. Set to 0.

B.4.4 POSA/B Computed Position

This log will contain the last valid position and time calculated referenced to the antenna phase centre. The position is in geographic coordinates in degrees based on your specified datum (default is WGS84). The height is referenced to mean sea level. The receiver time is in GPS weeks and seconds into the week. The estimated standard deviations of the solution and current filter status are also included.

POSA

Structure:

$POSA week seconds lat lon hgt undulation

datum ID lat std lon std hgt std sol status *xx [CR][LF]

Field #	Field type	Data Description	Example
1	$POSA	Log header	$POSA
2	week	GPS week number	637
3	seconds	GPS seconds into the week	511251.00
4	lat	Latitude of position in current datum, in degrees (DD.dddddddd). A negative sign implies South latitude	51.11161847
5	lon	Longitude of position in current datum, in degrees (DDD.dddddddd). A negative sign implies West longitude	-114.03922149
6	hgt	Height of position in current datum, in metres above mean sea level (MSL)	1072.436
7	undulation	Geoidal separation, in metres, where positive is above spheroid and negative is below spheroid	-16.198
8	datum ID	Current datum ID #, see *Table 7, Reference Ellipsoid Constants, on Page 61* and *Table 8, Transformation Parameters (Local Geodetic to WGS84), on Page 62.*	61
9	lat std	Standard deviation of latitude solution element, in metres	26.636
10	lon std	Standard deviation of longitude solution element, in metres	6.758
11	hgt std	Standard deviation of height solution element, in metres	78.459

12	sol status	Solution status as listed in *Table 4, GPSCard Solution Status, on Page 52.*	0
13	*xx	Checksum	*12
14	[CR][LF]	Sentence terminator	[CR][LF]

Example:

$POSA,637,511251.00,51.11161847,-114.03922149,1072.436,-16.198,61,26.636,
6.758,78.459,0*12[CR][LF]

POSB

Format: Message ID = 01
Message byte count = 88

Field #	Data	Bytes	Format	Units	Offset
1 (header)	Sync	3	char		0
	Checksum	1	char		3
	Message ID	4	integer		4
	Message byte count	4	integer	bytes	8
2	Week number	4	integer	weeks	12
3	Seconds of week	8	double	seconds	16
4	Latitude	8	double	degrees (+ is North, - is South)	24
5	Longitude	8	double	degrees (+ is East, - is West)	32
6	Height	8	double	metres with respect to MSL	40
7	Undulation	8	double	metres	48
8	Datum ID	4	integer		56
9	StdDev of latitude	8	double	metres	60
10	StdDev of longitude	8	double	metres	68

11	StdDev of height	8	double	metres	76
12	Solution status	4	integer		84

The following tables contain the internal ellipsoid parameters and transformation parameters used in the GPSCard. The values contained in these tables were derived from the following DMA technical reports:

1. TR 8350.2 Department of Defence World Geodetic System 1984 – Its Definition and Relationships with Local Geodetic Systems - Revised March 1, 1988.
2. TR 8350.2B Supplement to Department of Defence World Geodetic System 1984 Technical Report - Part II - Parameters, Formulas, and Graphics for the Practical Application of WGS84 - December 1, 1987.

Table 7: Reference Ellipsoid Constants

ELLIPSOID	ID CODE	a (metres)	1/f	f
Airy 1830	AW	6377563.396	299.3249647	0.00334085064038
Modified Airy	AM	6377340.189	299.3249647	0.00334085064038
Australian National	AN	6378160.0	298.25	0.00335289186924
Bessel 1841	BR	6377397.155	299.1528128	0.00334277318217
Clarke 1866	CC	6378206.4	294.9786982	0.00339007530409
Clarke 1880	CD	6378249.145	293.465	0.00340756137870
Everest (India 1830)	EA	6377276.345	300.8017	0.00332444929666
Everest (Brunei & E.Malaysia)	EB	6377298.556	300.8017	0.00332444929666
Everest (W.Malaysia & Singapore)	ED	6377304.063	300.8017	0.00332444929666
Geodetic Reference System 1980	RF	6378137.0	298.257222101	0.00335281068118
Helmert 1906	HE	6378200.0	298.30	0.00335232986926
Hough 1960	HO	6378270.0	297.00	0.00336700336700
International 1924	IN	6378388.0	297.00	0.00336700336700
South American 1969	SA	6378160.0	298.25	0.00335289186924
World Geodetic System 1972	WD	6378135.0	298.26	0.00335277945417
World Geodetic System 1984	WE	6378137.0	298.257223563	0.00335281066475

Table 8: Transformation Parameters (Local Geodetic to WGS84)

GPSCard Datum ID Number	NAME	DX	DY	DZ	DATUM DESCRIPTION	ELLIPSOID
1	ADIND	-162	-12	206	Adindan (Ethiopia, Mali, Senegal & Sudan)	Clarke 1880
2	ARC50	-143	-90	-294	ARC 1950 (SW & SE Africa)	Clarke 1880
3	ARC60	-160	-8	-300	ARC 1960 (Kenya, Tanzania)	Clarke 1880
4	AGD66	-133	-48	148	Australian Geodetic Datum 1966	Australian National
5	AGD84	-134	-48	149	Australian Geodetic Datum 1984	Australian National
6	BUKIT	-384	664	-48	Bukit Rimpah (Indonesia)	Bessel 1841
7	ASTRO	-104	-129	239	Camp Area Astro (Antarctica)	International 1924
8	CHATM	175	-38	113	Chatum 1971 (New Zealand)	International 1924
9	CARTH	-263	6	431	Carthage (Tunisia)	Clarke 1880
10	CAPE	-136	-108	-292	CAPE (South Africa)	Clarke 1880
11	DJAKA	-377	681	-50	Djakarta (Indonesia)	Bessel 1841
12	EGYPT	-130	110	-13	Old Egyptian	Helmert 1906
13	ED50	-87	-98	-121	European 1950	International 1924
14	ED79	-86	-98	-119	European 1979	International 1924
15	GUNSG	-403	684	41	G. Segara (Kalimantan - Indonesia)	Bessel 1841
16	GEO49	84	-22	209	Geodetic Datum 1949 (New Zealand)	International 1924
17	GRB36	375	-111	431	Great Britain 1936 (Ordinance Survey)	Airy 1830
18	GUAM	-100	-248	259	Guam 1963 (Guam Island)	Clarke 1866

GPSCard Datum ID Number	NAME	DX	DY	DZ	DATUM DESCRIPTION	ELLIPSOID
19	HAWAII	89	-279	-183	Hawaiian Hawaii (Old)	International 1924
20	KAUAI	45	-290	-172	Hawaiian Kauai (Old)	International 1924
21	MAUI	65	-290	-190	Hawaiian Maui (Old)	International 1924
22	OAHU	56	-284	-181	Hawaiian Oahu (Old)	International 1924
23	HERAT	-333	-222	114	Herat North (Afghanistan)	International 1924
24	HJORS	-73	46	-86	Hjorsey 1955 (Iceland)	International 1924
25	HONGK	-156	-271	-189	Hong Kong 1963	International 1924
26	HUTZU	-634	-549	-201	Hu-Tzu-Shan (Taiwan)	International 1924
27	INDIA	289	734	257	Indian (India, Nepal, Bangladesh)	Everest (EA)
28	IRE65	506	-122	611	Ireland 1965	Modified Airy
29	KERTA	-11	851	5	Kertau 1948 (West Malaysia and Singapore)	Everest (ED)
30	KANDA	-97	787	86	Kandawala (Sri Lanka)	Everest (EA)
31	LIBER	-90	40	88	Liberia 1964	Clarke 1880
32	LUZON	-133	-771	-51	Luzon (Philippines excluding Mindanoa Is.)	Clarke 1866
33	MINDA	-133	-70	-72	Mindanoa Island	Clarke 1866
34	MERCH	31	146	47	Merchich (Morocco)	Clarke 1880
35	NAHR	-231	-196	482	Nahrwan (Saudi Arabia)	Clarke 1880
36	NAD83	0	0	0	N. American 1983 (Includes Areas 37-42)	GRS-80

GPSCard Datum ID Number	NAME	DX	DY	DZ	DATUM DESCRIPTION	ELLIPSOID
37	CANADA	-10	158	187	N. American Canada 1927	Clarke 1866
38	ALASKA	-5	135	172	N. American Alaska 1927	Clarke 1866
39	NAD27	-8	160	176	N. American Conus 1927	Clarke 1866
40	CARIBB	-7	152	178	N. American Caribbean	Clarke 1866
41	MEXICO	-12	130	190	N. American Mexico	Clarke 1866
42	CAMER	0	125	194	N. American Central America	Clarke 1866
43	MINNA	-92	-93	122	Nigeria (Minna)	Clarke 1880
44	OMAN	-346	-1	224	Oman	Clarke 1880
45	PUERTO	11	72	-101	Puerto Rica and Virgin Islands	Clarke 1866
46	QORNO	164	138	-189	Qornoq (South Greenland)	International 1924
47	ROME	-255	-65	9	Rome 1940 Sardinia Island	International 1924
48	CHUA	-134	229	-29	South American Chua Astro (Paraguay)	International 1924
49	SAM56	-288	175	-376	South American (Provisional 1956)	International 1924
50	SAM69	-57	1	-41	South American 1969	S. American 1969
51	CAMPO	-148	136	90	S. American Campo Inchauspe (Argentina)	International 1924
52	SACOR	-206	172	-6	South American Corrego Alegre (Brazil)	International 1924
53	YACAR	-155	171	37	South American Yacare (Uruguay)	International 1924
54	TANAN	-189	-242	-91	Tananarive Observatory 1925 (Madagascar)	International 1924

GPSCard Datum ID Number	NAME	DX	DY	DZ	DATUM DESCRIPTION	ELLIPSOID
55	TIMBA	-689	691	-46	Timbalai (Brunei and East Malaysia) 1948	Everest (EB)
56	TOKYO	-128	481	664	Tokyo (Japan, Korea and Okinawa)	Bessel 1841
57	TRIST	-632	438	-609	Tristan Astro 1968 (Tristan du Cunha)	International 1924
58	VITI	51	391	-36	Viti Levu 1916 (Fiji Islands)	Clarke 1880
59	WAK60	101	52	-39	Wake-Eniwetok (Marshall Islands)	Hough 1960
60	WGS72	0	0	4.5	World Geodetic System - 72	WGS-72
61	WGS84	0	0	0	World Geodetic System - 84	WGS-84
62	ZANDE	-265	120	-358	Zanderidj (Surinam)	International 1924
63	USER	0	0	0	User Defined Datum Defaults	User *

* Default user datum is WGS84.
* The POSA/B log reports the Datum used according to the “GPSCard Datum ID” column.

B.4.5 SATA/B Satellite Specific Data

This log provides satellite specific data for satellites actually being tracked. The record length is variable and depends on the number of satellites.

Each satellite being tracked has a reject code indicating whether it is used in the solution, or the reason for its rejection from the solution. The reject value of 0 indicates the observation is being used in the position solution. Values of 1 through 13 indicate the observation has been rejected for the reasons specified in *GPSCard Solution Status on Page 52*.

In normal operation, if the almanac indicates bad health in a satellite, the receiver does not track it. Also, in normal operation, if the almanac indicates good health and the ephemeris indicates bad health, the receiver tracks the satellite, but the receiver does not output the SAT log (elevation and azimuth).

However, on start-up, before the almanac is acquired, the receiver fills in the stored ’almanac’ with ephemeris data from tracked satellites. When the Core Computer requests the almanac, the receiver provides this stored ’almanac’. Once the almanac is received, the receiver overwrites its stored ’almanac’ with the real almanac. This almanac does not contain data associated with satellites that are already being tracked that have a good ephemeris health and a bad almanac health (this is because the ephemeris is generally more up-to-date).

SATA

Structure:

$SATA week Seconds sol status # obs

prn azimuth elevation residual reject code

:

prn azimuth elevation residual reject code *xx [CR][LF]

Field #	Field type	Data Description	Example
1	$SATA	Log header	$SATA
2	week	GPS week number	637
3	seconds	GPS seconds into the week	513902.00
4	sol status	Solution status as listed on *Page 52*	0
5	# obs	Number of satellite observations with information to follow	7
6	prn	Satellite PRN number (1-32)	**18**
7	azimuth	Satellite azimuth from user position with respect to True North, in degrees	168.92

8	elevation	Satellite elevation from user position with respect to the horizon, in degrees	5.52
9	residual	Satellite range residual from position solution for each satellite, in metres	9.582
10	reject code	Indicates that the range is being used in the solution (code 0) or that it was rejected (code 1-13), as shown on *Page 53*	0
11...	..	Next PRN	
variable	*xx	Checksum	*1F
variable	[CR][LF]	Sentence terminator	[CR][LF]

Example:

$SATA,637,513902.00,0,7,18,168.92,5.52,9.582,0,6,308.12,55.48,0.737,0,
15,110.36,5.87,16.010,0,11,49.63,40.29,-0.391,0,
2,250.05,58.89,-12.153,0,16,258.55,8.19,-20.237,0,
19,118.10,49.46,-14.803,0*1F[CR][LF]

SATB

Format: Message ID = 12
Message byte count = 32 + (obs*32)

Field #	Data	Bytes	Format	Units	Offset
1	Sync	3	char		0
(header)	Checksum	1	char		3
	Message ID	4	integer		4
	Message byte count	4	integer	bytes	8
2	Week number	4	integer	weeks	12
3	Seconds of week	8	double	seconds	16
4	Solution status	4	integer		24
5	Number of observations (obs)	4	integer		28
6	PRN	4	integer		32
7	Azimuth	8	double	degrees	36
8	Elevation	8	double	degrees	44
9	Residual	8	double	metres	52
10	Reject code	4	integer		60
11...	Next PRN offset = 32 + (obs# x 32) where obs# varies from 0 to (obs-1)				

B.4.6 TM1A/B Time of 1PPS

This log provides the time of the GPSCard 1PPS in GPS week number and seconds into the week. It also includes the receiver clock offset, the standard deviation of the receiver clock offset and clock model status. This log will output at a maximum rate of 1 Hz.

TM1A

Structure:

$TM1A week seconds offset offset std utc offset cm status

*xx [CR][LF]

Field #	Field type	Data Description	Example
1	$TM1A	Log header	$TM1A
2	week	GPS week number	794
3	seconds	GPS seconds into the week at the epoch coincident with the 1PPS output strobe (receiver time)	414634.999999966
4	offset	Receiver clock offset, in seconds. A positive offset implies that the receiver clock is ahead of GPS Time. To derive GPS time, use the following formula: GPS time = receiver time – (offset)	-0.000000078
5	offset std	Standard deviation of receiver clock offset, in seconds	0.000000021
6	utc offset	This field represents the offset of GPS time from UTC time, computed using almanac parameters. To reconstruct UTC time, algebraically subtract this correction from field 3 above (GPS seconds): UTC time = GPS time – (utc offset)	-9.999999998
7	cm status	Receiver Clock Model Status where 0 is valid and values from -20 to -1 imply that the model is in the process of stabilization	0
8	*xx	Checksum	*57
9	[CR][LF]	Sentence terminator	[CR][LF]

Example:

$TM1A,794,414634.999999966,-0.000000078,0.000000021,-9.999999998,0*57[CR][LF]

TM1B

Format: Message ID = 03
Message byte count = 52

Field #	Data	Bytes	Format	Units	Offset
1 (header)	Sync	3	char		0
	Checksum	1	char		3
	Message ID	4	integer		4
	Message byte count	4	integer	bytes	8
2	Week number	4	integer	weeks	12
3	Seconds of week	8	double	seconds	16
4	Clock offset	8	double	seconds	24
5	StdDev clock offset	8	double	seconds	32
6	UTC offset	8	double	seconds	40
7	Clock model status	4	integer	0 = good, -1 to -20 = bad	48

Appendix C Some Common Unit Conversions

Distance

1 metre (m) = 100 centimetres (cm) = 1000 millimetres (mm)

1 kilometre (km) = 1000 metres (m)

1 nautical mile = 1852 metres

1 international foot = 0.3048 metre
1 statute mile = 1609 metres
1 US survey foot = 0.3048006096 metre

Frequency

L1 frequency = 1575.42 MHz

L2 frequency = 1227.60 MHz

Temperature

degrees Celsius = (5/9) x [(degrees Fahrenheit) - 32]

degrees Fahrenheit = [(9/5) x (degrees Celsius)] + 32

Hexadecimal And Binary Equivalents

Hexadecimal	Binary	Hexadecimal	Binary
0	0000	8	1000
1	0001	9	1001
2	0010	A	1010
3	0011	B	1011
4	0100	C	1100
5	0101	D	1101
6	0110	E	1110
7	0111	F	1111

GPS Time of Week To Week and Time of Day (example)

511200 seconds	Day	511200 /86400 seconds per day	**5**.916666667 **days**
	Hour	0.916666667 x 86400 / 3600 seconds per hour	**22**.0000 **hours**
	Minute	0.000 x 3600 / 60 seconds per minute	**0**.000 minutes
	Second	0.000 x 60	**0**.000 seconds

Day 5 (Thursday) + 22 hours, 0 minutes, 0 seconds into Friday.

Calendar Date to GPS Time (e.g. 13:30 hours, January 28, 2005)

Days from January 6, 1980 to January 28, 2005 = 6 years x 365 days /year =	9125 days
Add one day for each leap year (a year which is divisible by 4 but not by 100 unless it is divisible by 400; every 100 years a leap year is skipped)	7 days
Days into 2005 (28th is not finished)	27 days
Total days	9159 days
Deduct 5 days: (Jan. 1 - 5, 1980)	9154 days
GPS Week: 9154 x 86400 seconds per day = 790905600 seconds/ 604800 sec per week =	**1307** weeks
Seconds into week: 6th day = 13.5 hrs x 3600 sec/hr =	**48600** seconds

GPS time of week: **Week 1307, 48600 second**

Appendix D Acronyms

ASCII	American Standard Code for Information Interchange
bps	Bits per Second
BW	Bandwidth
C/A Code	Coarse/Acquisition Code
C/N_0	Post Correlation Carrier to Noise Ratio in dB-Hz
dB	Decibel
DGPS	Differential Global Positioning System
DOP	Dilution Of Precision
D/U	Desired/Undesired
GDOP	Geometric Dilution Of Precision
GPS	Global Positioning System
GUS	Ground Uplink Station
HDOP	Horizontal Dilution Of Precision
hex	Hexadecimal
Hz	Hertz
MAT	Multipath Assessment Tool
MEDLL	Multipath Estimating Delay Lock Loop
MET	Multipath Elimination Technology
MHz	Mega Hertz
MPM	Multipath Meter
OEM	Original Equipment Manufacturer
PC	Personal Computer
P Code	Precise Code
PDOP	Position Dilution Of Precision
PRN	Pseudo Random Noise number
RAM	Random Access Memory
RF	Radio Frequency
TDOP	Time Dilution Of Precision
UTC	Coordinated Universal Time
UHF	Ultra High Frequency
VDOP	Vertical Dilution of Precision
WAAS	Wide Area Augmentation System

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