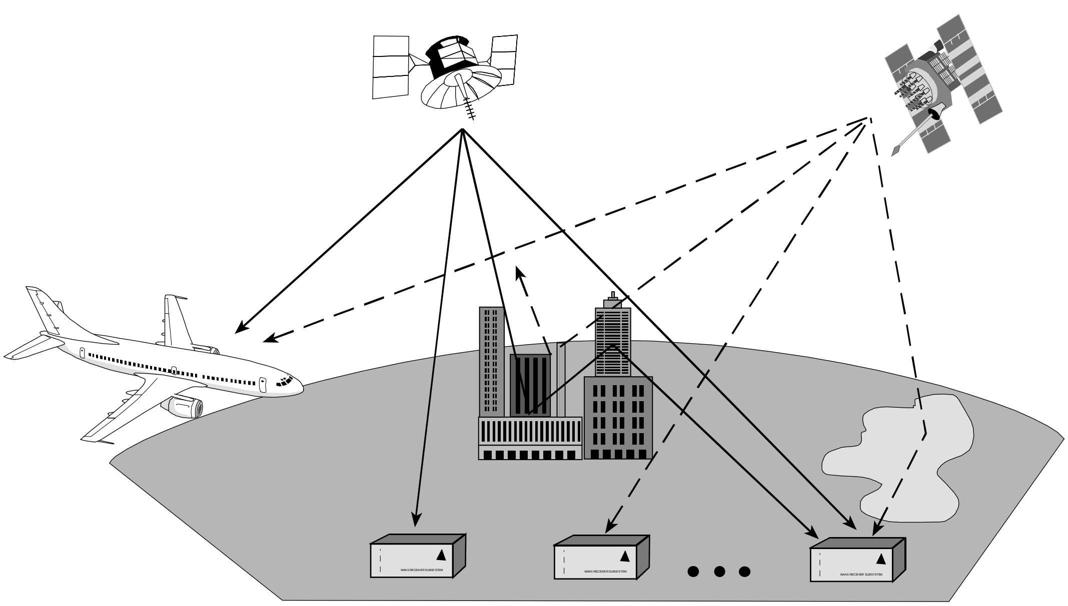
Multipath Assessment Tool™

User Manual



Multipath Assessment Tool

User Manual

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This manual is a companion to the *WAAS/GUS Receiver Subsystem User Manual*.

Proprietary Notice

TABLE OF CONTENTS

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T2E 8S5

1 INTRODUCTION

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 receiver with Multipath Meter firmware within it or with data previously saved to a file.

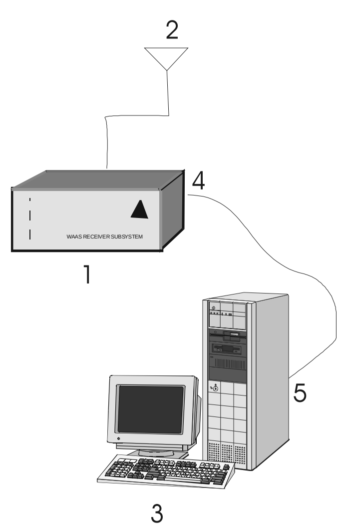
MAT uses a multipath meter feature from within the Multipath Estimation Delay Lock Loop (MEDLL) portion of the WAAS receiver. MEDLL utilises innovative correlator delay lock loop techniques. The correlator is the heart of the GPS receiver C/A code tracking loop. MEDLL splits the received signals into 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 *Appendix A Radio Frequency (RF) And Multipath* beginning on *Page 27*.

SCOPE

The *Multipath Assessment Tool User Manual* is a complete installation, reference and instructional manual for the MAT software. A companion to this manual is the *WAAS/GUS Receiver Subsystem Installation and Operation Manual*.

This manual describes the graphical user interface on your PC that is used to collect, view and manage logged information, as it is output from the Multipath Meter feature within the WAAS receiver, see *Figure 1*. It is also useful to you if you wish to post-process previously collected WAAS MEDLL data, from the correct logs, and are interested in the multipath environment.

Figure 1. Real Time Data Collection



Reference	Description
1	WAAS receiver with MPM feature
2	Antenna
3	PC
4	Connection to L1-C/A or WAAS MEDLL
5	Connection to COM1 or COM2

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/98/95
· Microsoft Mouse or compatible pointing device

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.

Quick Start

1. Start Microsoft Windows NT/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 receiver and desired settings or your previously saved logging file by selecting Device | Open Serial or Device | Open File from the main menu.

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

3 MAT MENUS OVERVIEW

MENU OPTIONS

The following figure 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.

Figure 2. 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				
Print Setup …				
1 COM2 115200 [1]				
2 MP july 6.gps				
3 dervila_data.gps				
4 MP June 9.gps				
5 COM1 115200				
Exit				

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.

LICENSE MENU

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

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.

---

1 The devices in *Figure 2* represents either the name of a previously opened file or a connection to a WAAS receiver in MAT. The last five device configuration names are displayed.

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.

ENABE 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 5* for contact information.
NovAtel Key 1	The first NovAtel key supplied by customer service.
NovAtel Key 2	The second NovAtel key supplied by customer service.

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.

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.

4 DEVICE MENU

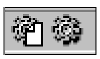
This menu allows you to open and close a file or serial port that supplies MAT with NovAtel logs. Both are referred to as a device in this manual. You can also print or exit MAT completely from this menu.

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.

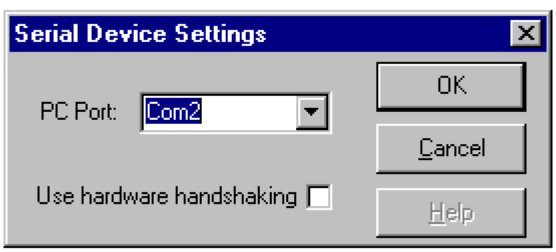
You can look in the far right of the MAT status bar to see what devices are currently open:



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.

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.

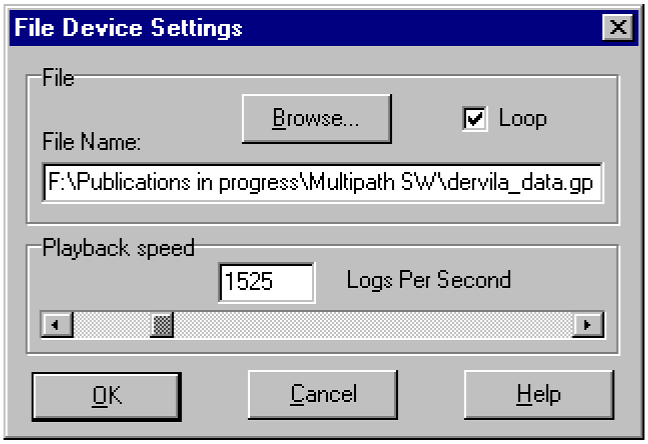
Handshaking is the predetermined hardware or software activity designed to establish or maintain two machines in synchronization. Hardware handshaking uses voltage levels or pulses in wires to carry the handshaking signal. Click in the Use Hardware Handshaking check box to turn hardware handshaking on.

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 14*.

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 15.*

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 18*. 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.

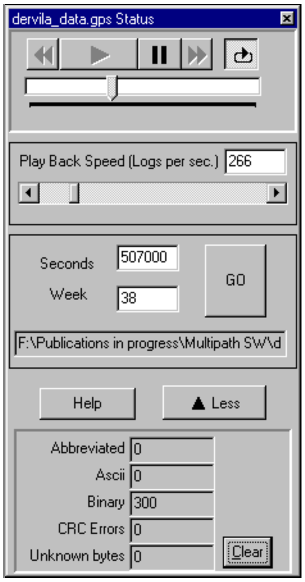
MAT uses 6 binary logs in its playback mode (MPMB, SATB, DOPB, POSB, TM1B and ETSB). If you use the Logging Control window, these logs will be saved automatically. For a description of the MPM log please see *Appendix B* on *Page 31*. A complete description of the other logs and commands in this manual may be found in your *WAAS/GUS Receiver Subsystem Manual*.

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.

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.

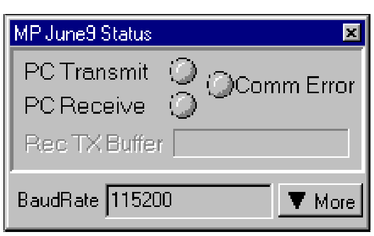


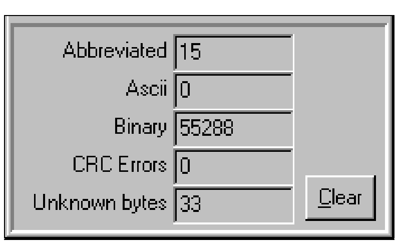
This window allows you to pause, restart or choose a point in the file to begin the playback. Use the slider or, to be more precise, fill in the Seconds (seconds into the week) and Week fields, and click on the GO button. You can turn on and off the loop feature by clicking on the Loop button (looped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

Note: 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 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.

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.

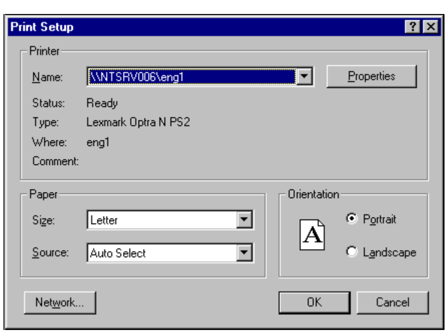
PRINT AND PRINT SETUP

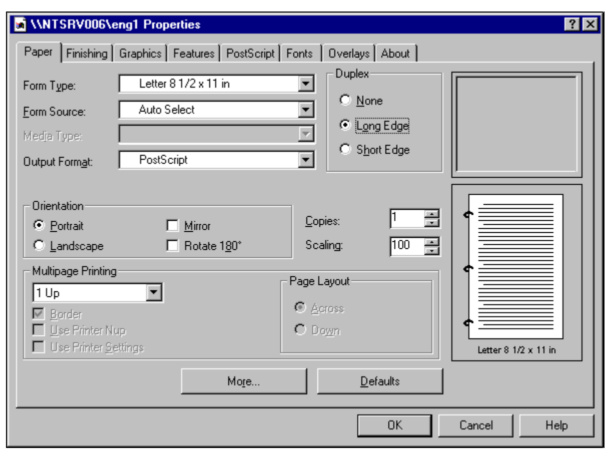
The contents of any MAT window may be printed. A window must be selected with your cursor, making it the active window, before it can be printed. To print an individual window, select Print Active Window from the Device menu. To print the whole MAT screen, select Device | Print MAT Screen from the main 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.





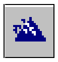
EXIT

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

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.

CONSOLE

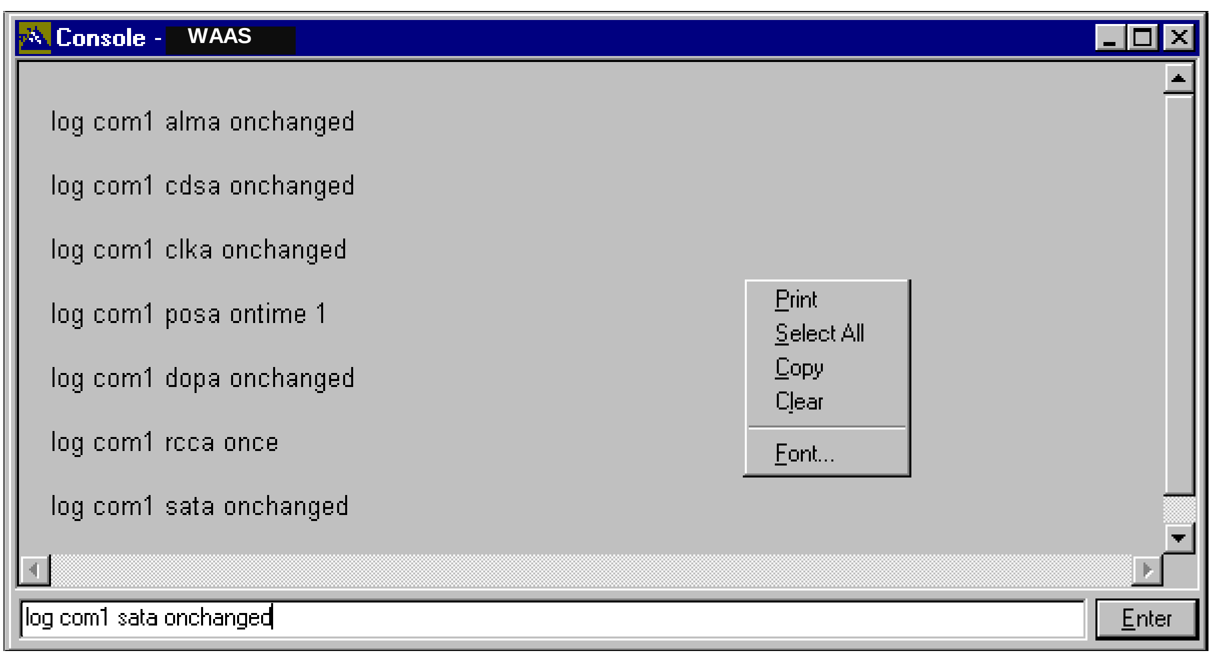


The Console window allows you to communicate directly with the WAAS receiver through the serial connection port. If MAT is in file playback mode, you cannot issue commands to the device. The following logs are used by MAT (MPMB, SATB, DOPB, POSB, TM1B and ETSB). For a description of the MPM log please see *Appendix B* on *Page 31*. A complete description of the other logs and commands in this manual may by found in your *WAAS/GUS Installation and Operation Manual*.

Note:	Although it is possible to issue commands and logs from the Console window, it is not recommended. See *Logging Control* on *Page 15* 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 receiver. Refer to your *WAAS/GUS Installation and Operation Manual* for detailed information about WAAS receiver commands and logging protocol. See *Logging Control* on *Page 15* for the recommended method of logging additional logs.

In the Console window below, 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.



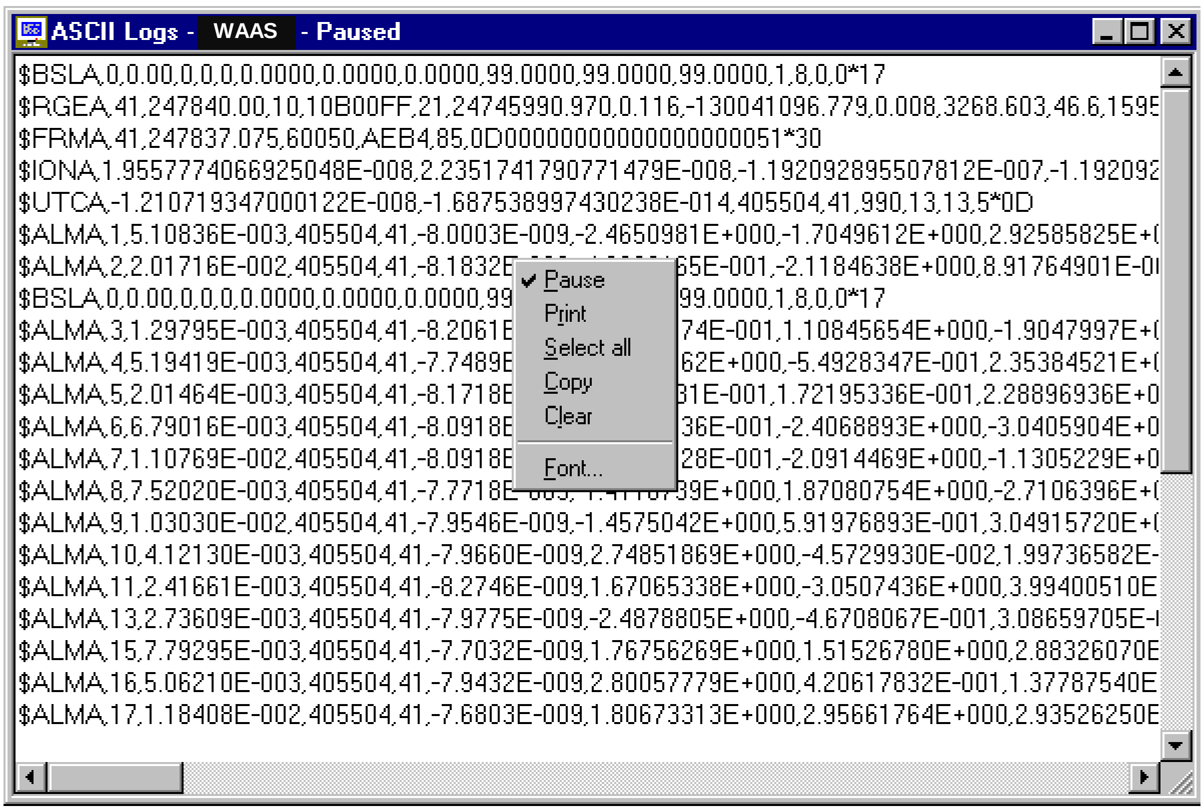
The Console window is where any error messages the WAAS receiver sends will be displayed. It is a good idea to monitor this window to be aware of any problems with the operation of the WAAS receiver. The console window is always open – it cannot be closed.

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.

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.



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 10* 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

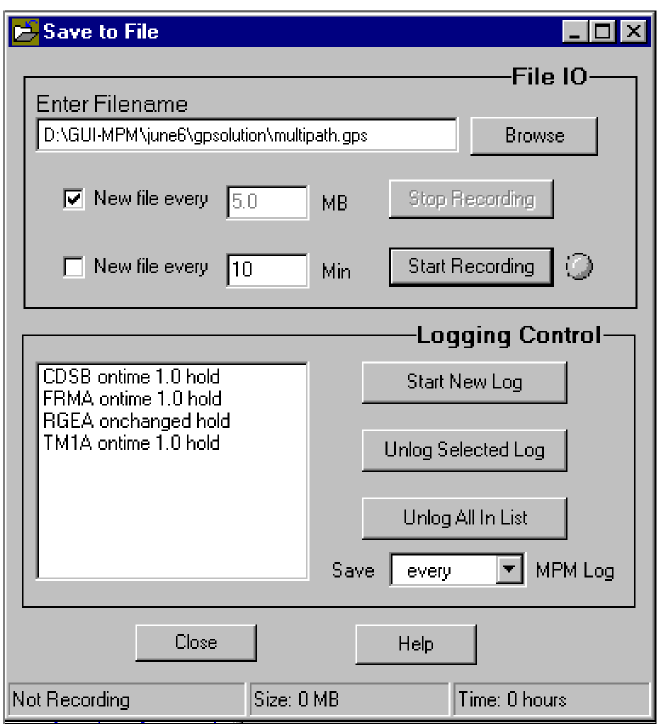
This will help you to see when a file was created. The software will be able to decide in what order to play files when in playback file mode.

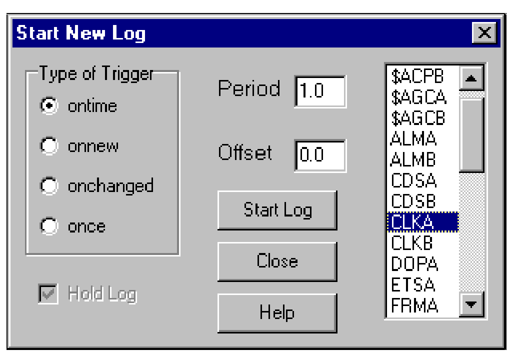
The MPMB, SATB, DOPB, POSB, TM1B and ETSB logs are logged automatically by MAT but you can add logs in the Logging Control section of the Save to File dialog. To start a new log, click on the Start New Log button. Select a log from the list, choose a trigger and then, if the log trigger is ontime, enter 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.

Note: 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:

Note: 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 to follow the current information in the file, or Abort to abandon this recording name and enter a new target file in the Enter Filename field.

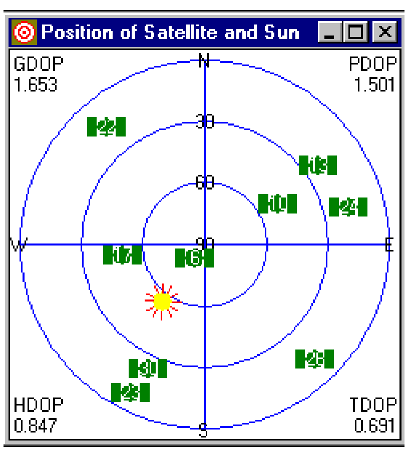
The Logging Control window cannot be opened during file playback.

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.

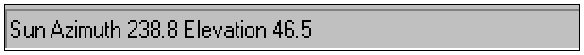
Different DOP (dilution of precision) values of the geometry are displayed in each corner of the window. DOP is defined as a numerical value expressing the confidence factor of the position solution based on current satellite geometry. The lower the value is, the greater the confidence in the solution.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



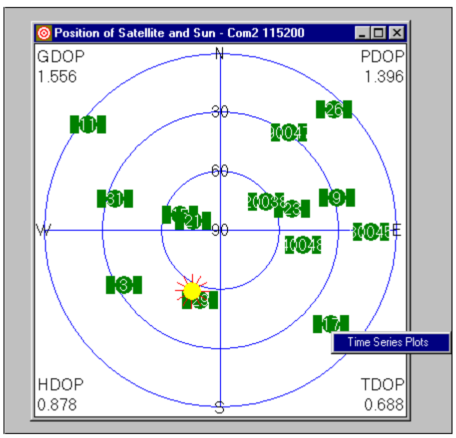
Note: The position of the sun is dependant on your time zone. If you collect data in one time zone and then play back the data in another time zone, the sun will not be correctly placed on the plot.

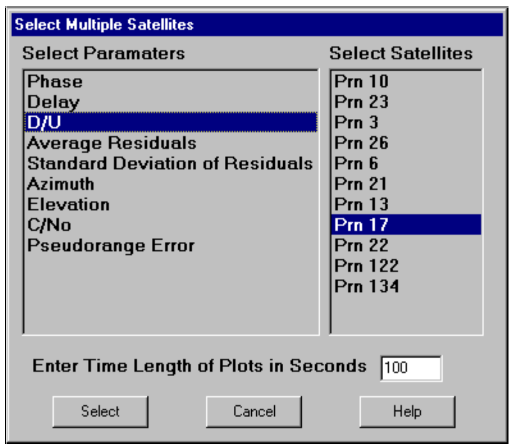
Each satellite that is being tracked and is in good health is represented on the window with a stylised picture at its position. The satellite PRN is displayed on the body of the satellite. A sun icon represents the position of the sun. Below are examples of the type of information that appears in the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



PLOTS

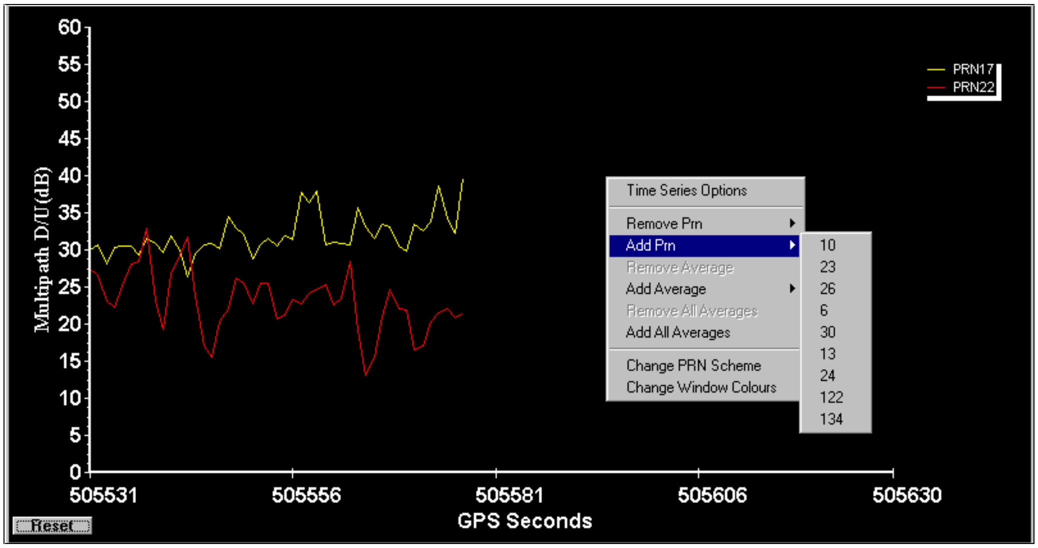
Right clicking on a satellite will display a Time Series Plot speed menu. Click on this speed menu to bring up the Select Multiple Satellites dialog.





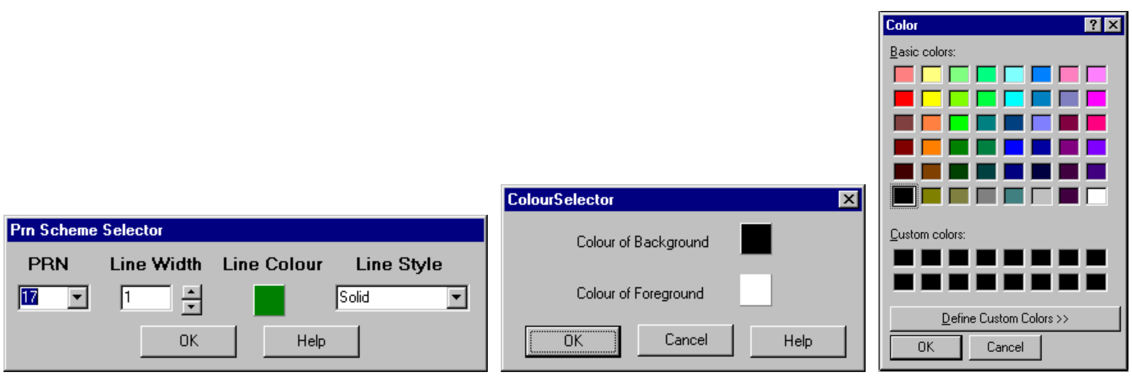
First choose a plot against time from the Select Parameters list. You can choose extra satellites to include in the plot from the Select Satellites list. Hold down the <Ctrl> key, select individual PRNs with your mouse and release the <Ctrl> key. If you want to select all the satellites, or all the satellites 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.



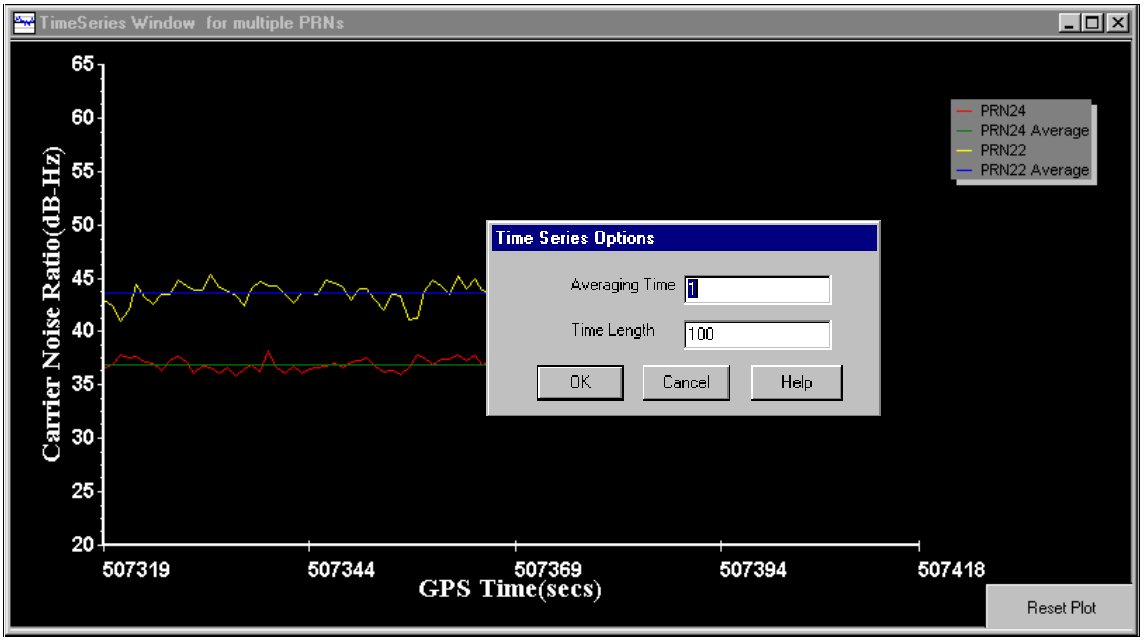
If there is more than one PRN in a plot, each satellite representation will appear in a different colour. The colour for an individual PRN, between time series plots, will stay the same. They will not stay the same between different device configurations. You can customize colour and line conventions 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.

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

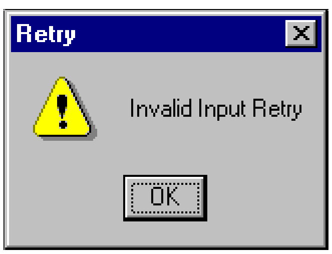


The Reset Plot button in the plot window, allows you to reset the plot.

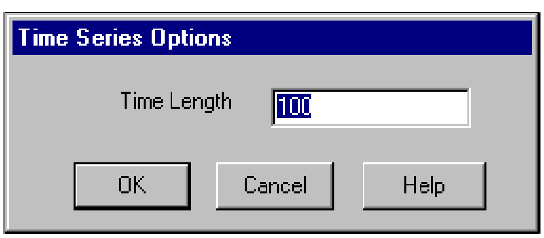
You can change the length of the x-axis and the amount of averaging by selecting Time Series Options from the speed menu. The parameters are either plotted every time the device sends a value or averaged over a period of time (user configurable) in which case this average is displayed.



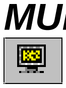
The averaging time, in the Time Series Options dialog, must be more than half the time length. If it is not, the following error message appears:



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



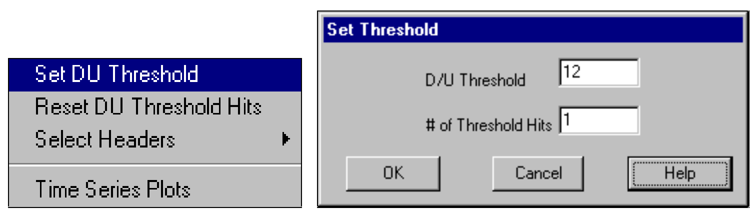
MULTIPATH INFO



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.

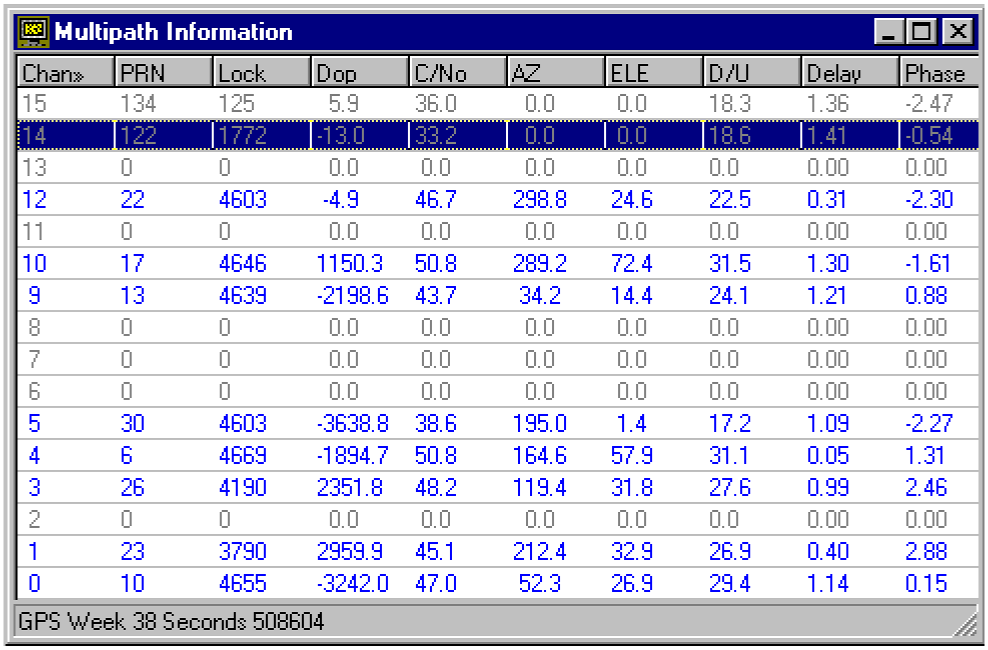
If you right click anywhere on the Multipath Info window you can make a selection to bring up the Set Threshold dialog. Specify a D/U threshold and initialize a count of the number of threshold instances to allow.



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

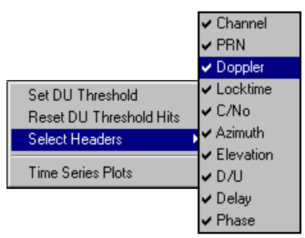
Chan	PRN	Lock	Dop	C/No	AZ	ELE	D/U	Delay	Phase
15	134	125	5.9	36.0	0.0	0.0	18.3	1.36	-2.47
14	122	1772	-13.0	33.2	0.0	0.0	18.6	1.41	-0.54
13	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
12	22	4603	-4.9	46.7	298.8	24.6	22.5	0.31	-2.30
11	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
10	17	4646	1150.3	50.8	289.2	72.4	31.5	1.30	-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

GPS Week 38 Seconds 508604

- 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 30.*
- PHASE — The phase shift between the multipath and direct signal (in the range $-\pi$ to $+\pi$ where $\pi = 3.1415927$ 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 18*.

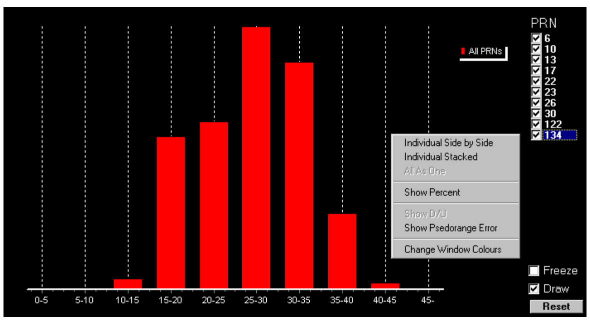
HISTOGRAM

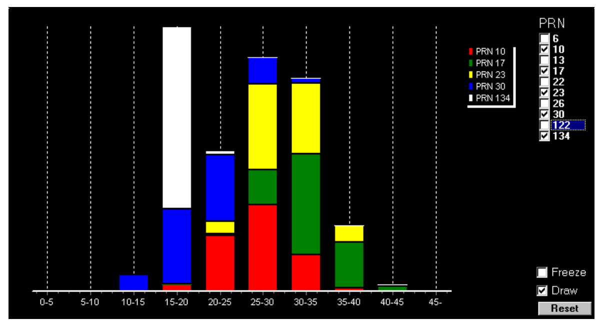
The Histogram window gives you a graphical representation of the D/U and pseudorange error distribution. For an explanation on D/U and pseudorange error, please see *Page 30*. There are three types of histograms available. The histograms shown are “PRNs As One”, “Individual Stacked” and “Individual Side by Side” respectively. The latter also has the Show Percent field checked. The percentage shows how many D/U or pseudorange error observations from each satellite contribute to the bar height.

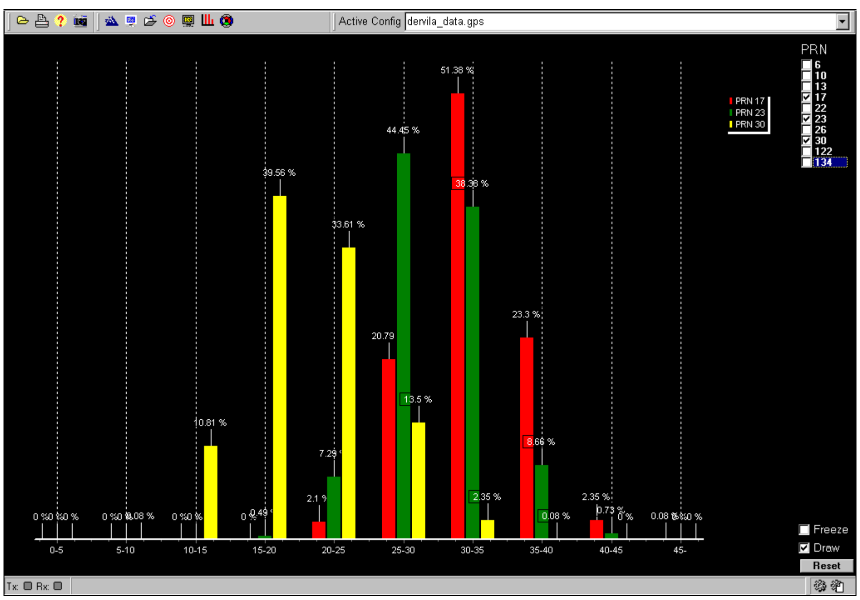
The PRN checkboxes along the right side of each histogram allow you to add and remove satellite PRNs from the histogram.

The default for the x-axis is D/U values. You can change this to the pseudorange error in meters 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 *Page 19* for more information on this dialog.





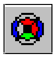


The Freeze check box, when selected, stops the histogram from using any new data and therefore the histogram stays unchanged. The freeze mode is useful to preserve the information currently in the histogram plot and still be able to fast forward and rewind the playback file to look at time series or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

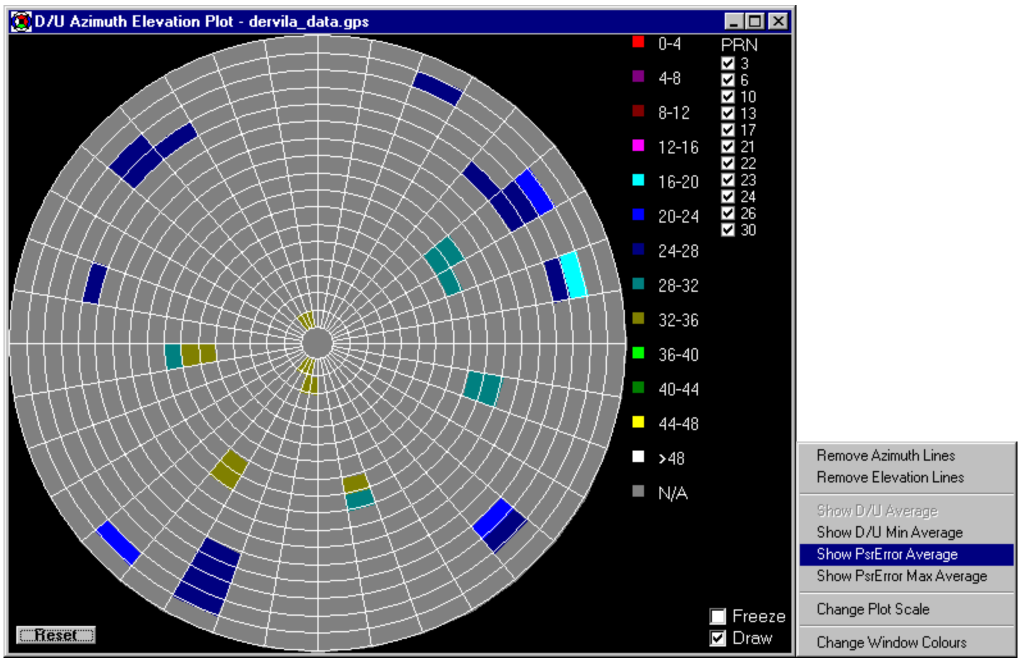
The Reset button in the histogram window, allows you to reset the histogram.

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:

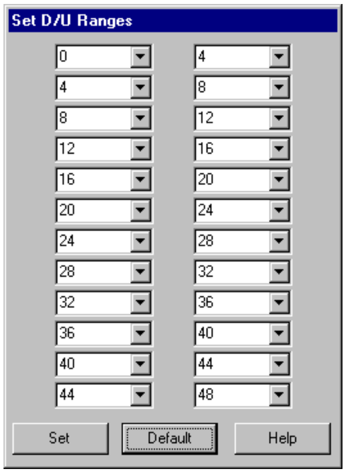


Right click anywhere in the plot's window to add or remove the azimuth or elevation grid lines, to set the window default colours and change what appears in the plot.

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 meters. 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 30* 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 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.

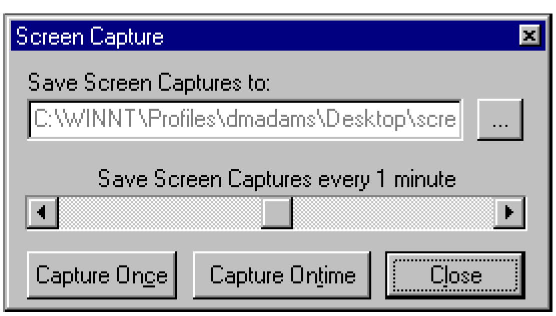
The Reset Plot button in the plot window, allows you to reset the plot.

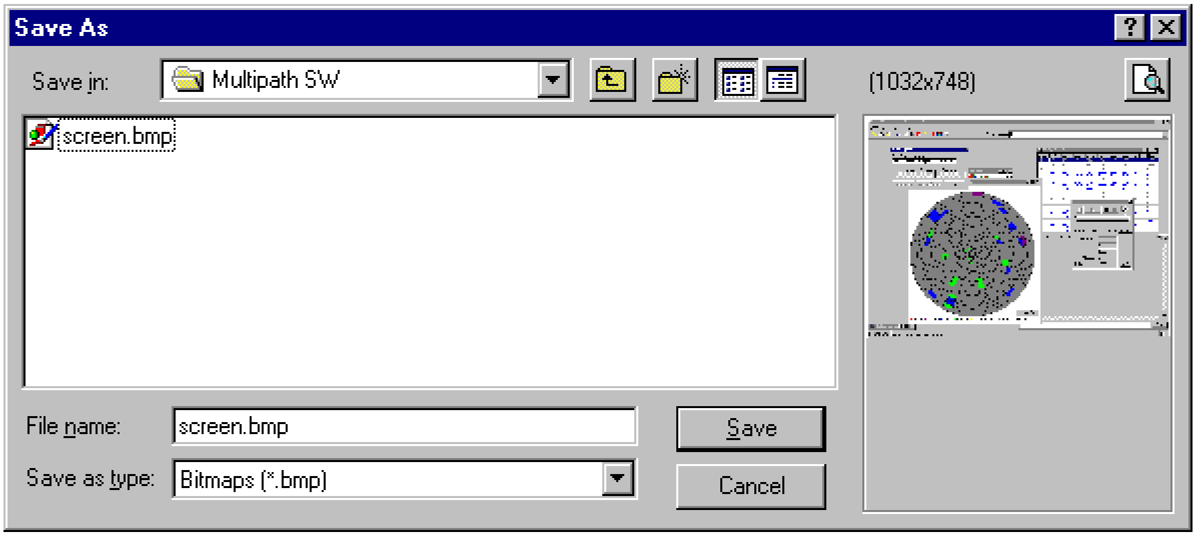
CAPTURE CONTROL

 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.

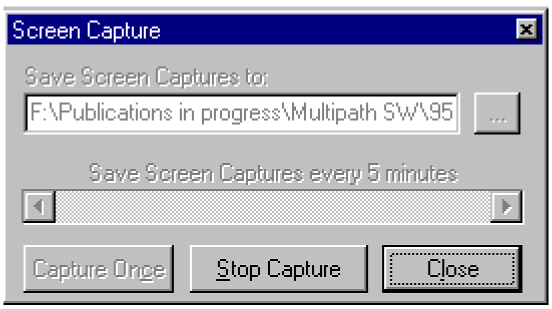
To capture a screen only once, click on the Capture Once button. To capture a screen more than once, decide the length of time between captures with the Save Screen Captures Every slider and press the Capture Ontime button. This is useful for recording information over time especially if you cannot be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

Note: 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.



A Radio Frequency (RF) And Multipath

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 3*. 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 4*.

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 3. GPS Signal Multipath Scenario

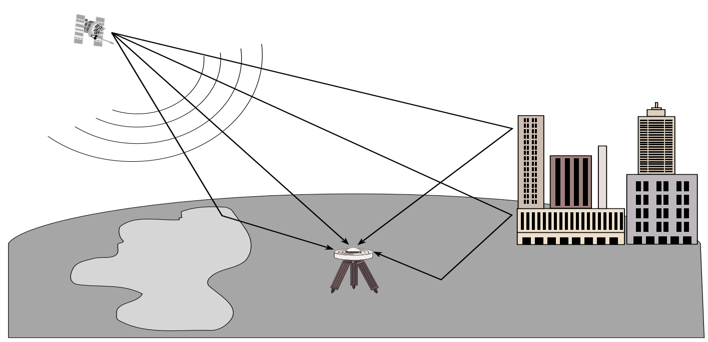
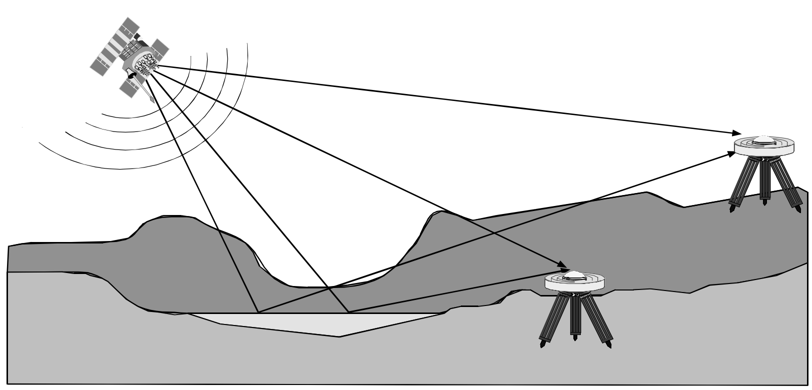


Figure 4. GPS Signal Multipath versus Increased Antenna Height



THE ROLE OF THE GPS RECEIVER CORRELATOR

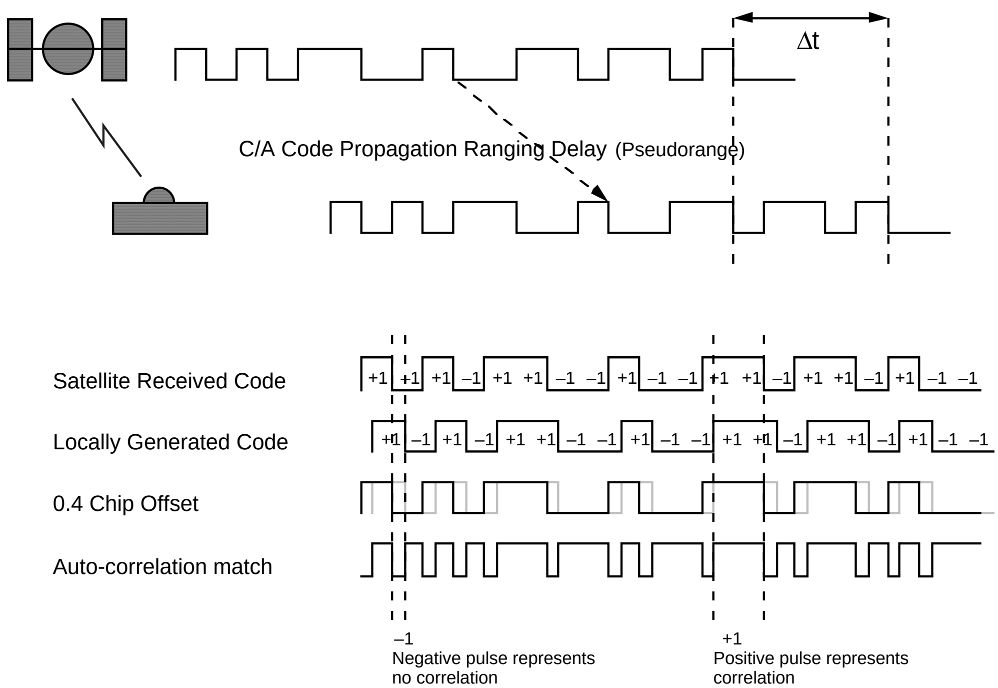
Each GPS satellite transmits a unique pseudorandom noise (PRN) C/A code (coarse/acquisition) and P code (precision). As the P code is generally for military and special authorized use only, it is denied general access by means of Anti-

Spoofing (AS), which is an encryption of the P code and referred to as the Y code. (As commercial GPS users are generally restricted to C/A code use, 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 5. Example of C/A Code Correlation

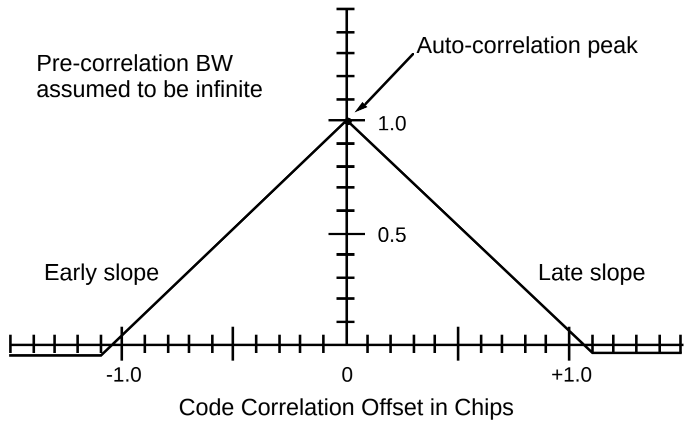


The GPS receiver measures its distance from each satellite by measuring the time it takes the GPS signal to propagate from the satellite to the receiver antenna. The GPS receiver determines its position by means of trilateration of the range measurements of at least four measured satellite ranges. The 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.

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 6. 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.

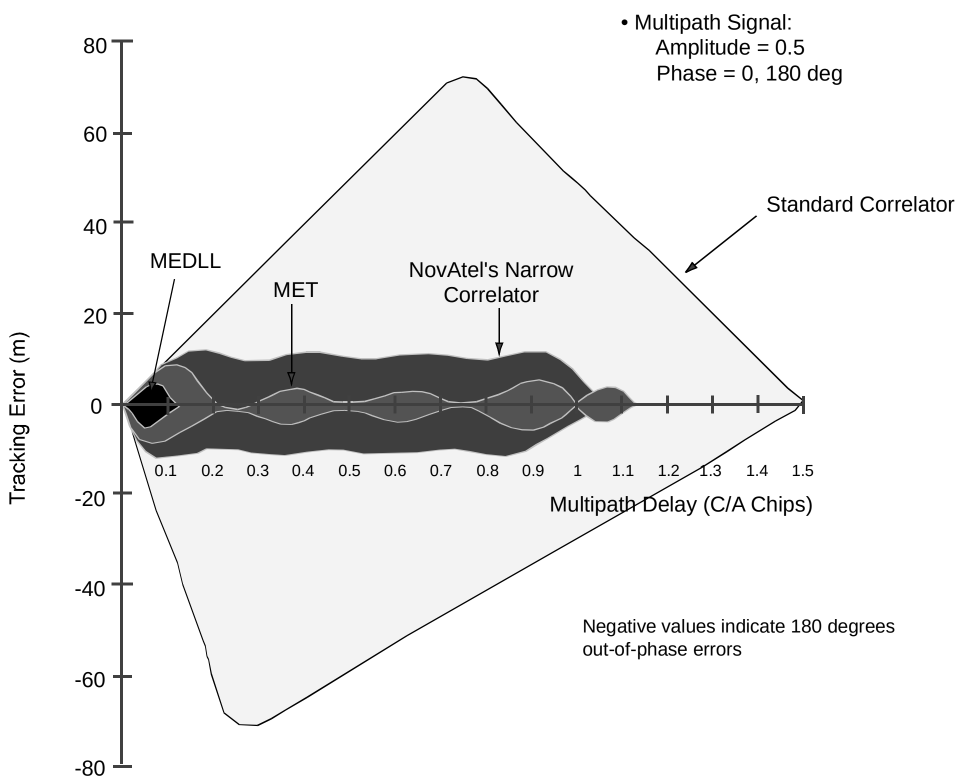
MEDLL

NovAtel’s MEDLL multipath reduction technology approaches the theoretical limits of multipath-free GPS signal reception. Multipath Estimation 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 7*. 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 7. Multipath Error Envelopes for Narrow Correlator vs. MET vs. MEDLL



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 20*.

PSEUDORANGE ERROR

D/U, delay and phase can be used to generate a plot similar to *Figure 7*, above. 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.

B 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.

***Example*:** log com1 mpmb onnew

ASCII

Field #	Field Type	Data Description	Example
1	$MPMA		$MPMA
2	Week Number	GPS week number	2
3	Seconds of Week	GPS seconds into the week	234454.34
4	PRN	Satellite identifier	23
5	Channel Tracking Status [2]	Channel tracking status bits	5E54
6	MEDLL Status	MEDLL status bits, see *Page 32*	2
7	Delay	Delay of multipath signal	0.001
8	Amplitude	Amplitude of multipath signal	0.02
9	Phase	Phase of multipath signal	0.03
10	1st in phase residual	In phase residual value from correlator 1	0.00003563
	…	Repeated for each correlator	
22	12th in phase residual	In phase residual value from correlator 12	0.00034894
23	1st out of phase residual	Out of phase residual value from correlator 1	0.00005924
	…	Repeated for each correlator	
45	12th out of phase residual	Out of phase residual value from correlator 12	0.00061211

[2] A description can be found in the WAAS/GUS Receiver Subsystem manual (*OM-20000015 Rev 2, Page 68, Table8*)

BINARY

Message ID: 95

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		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		96
23	1st out of phase residual	4	Float		100
	…				
45	12th out of phase residual	4	Float		148

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

MEDLL Status Bits Table

Position	Field Description
0x00000001	Sync bit: 1 if MEDLL channels in sync, 0 if not in sync
0x00000002	Reserved (for Phase processing)
Other bits	Reserved

C Some Common Unit Conversions

Distance

1 meter (m) = 100 centimeters (cm) = 1000 millimeters (mm)
1 kilometer (km) = 1000 meters (m)
1 nautical mile = 1852 meters
1 international foot = 0.3048 meter
1 statute mile = 1609 meters
1 US survey foot = 0.3048006096 meter

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**

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 Estimation 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

E INDEX

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