

ADU2

Operation and Reference Manual



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Introduction

The Ashtech ADU2 is the most precise GPS-based three-dimensional position and attitude determination system available, providing real-time heading pitch, and roll measurements with accurate position and velocity perfect for static and dynamic platforms. The ADU2 offers unparalleled accuracy as a real-time attitude sensor in high-precision GPS applications such as gyrocompass calibration, open-pit mining, seismic exploration, and oceanographic research.

GPS-based attitude determination technology is based on differential carrier phase measurements between four antennas connected to the receiver. The ADU2 employs a 4 antenna/12 channel configuration with the ability to select the best eight of twelve channels to use in PDOP (Position Dilution of Precision)- based satellite searching and tracking. This improves solution integrity, allowing close to 100% attitude availability, providing two meter position accuracy and attitude angles can be as accurate as one milliradian (0.057°) or better in real-time at a 2 Hz update rate.

The ADU2 capably compensates for a variety of antenna configurations in order to accommodate diverse vehicle mounting requirements and cable lengths. In installations, the unit requires that relative positions need only be determined once per installation. Ashtech provides solutions for calibration in stationary conditions (e.g. an airplane on a runway) and dynamic conditions (e.g. a ship at sea), saving valuable time before beginning navigation computations.

How To Use This Manual

This manual describes the Ashtech ADU2 standard and optional configurations, installation procedures, operation procedures, and requirements for a communications interface with external equipment.

This manual explains how to install the ADU2 and calibrate the antenna array. For environments where the ADU2 default settings are not suitable, instructions are included to change the operating parameters using an external interface device such as a personal computer.

Common GPS acronyms are listed in Appendix C, Reference.

This manual is divided into the following parts:

- **Chapter One: Introduction**— general information on the ADU2 and interfacing cables, including pin assignments.
- **Chapter Two: Quickstart**—quick overview of the ADU2 installation process.

- **Chapter Three: Installation Procedure**— detailed explanation of the antenna and calibration software installation process.
- **Chapter Four: Antenna Calibration**— detailed explanation of the static and dynamic calibration program options.
- **Chapter Five: Command/Response Formats**— command and response formats for the ADU2.
- **Chapter Six: Troubleshooting**— suggestions for troubleshooting the ADU2 receiver.
- **Chapter Seven: ADULOG**— detailed explanation on using ADULOG.
- **Appendix A: Antennas and Cabling**— description about and mounting antennas.
- **Appendix B: Improving Performance**— discussion on attitude accuracy, offset angles, and error sources.
- **Appendix C: Reference**— listing of common GPS acronyms, GPSIG information and reference sources used in this manual.

Description

The ADU2 provides real-time attitude information with accurate position and velocity at a half-second rate.

The ADU2 uses four twelve-channel Sensor II GPS receivers to make carrier phase measurements and perform real-time differential processing. The following measurements are provided up to a half-second rate:

- attitude
- position
- velocity
- time data

The ADU2 is controlled and measurement data are output from two RS-232 ports at baud rates up to 115,200. The ADU2 computes accurate real-time heading, roll, and pitch information as shown in Figure 1.1.

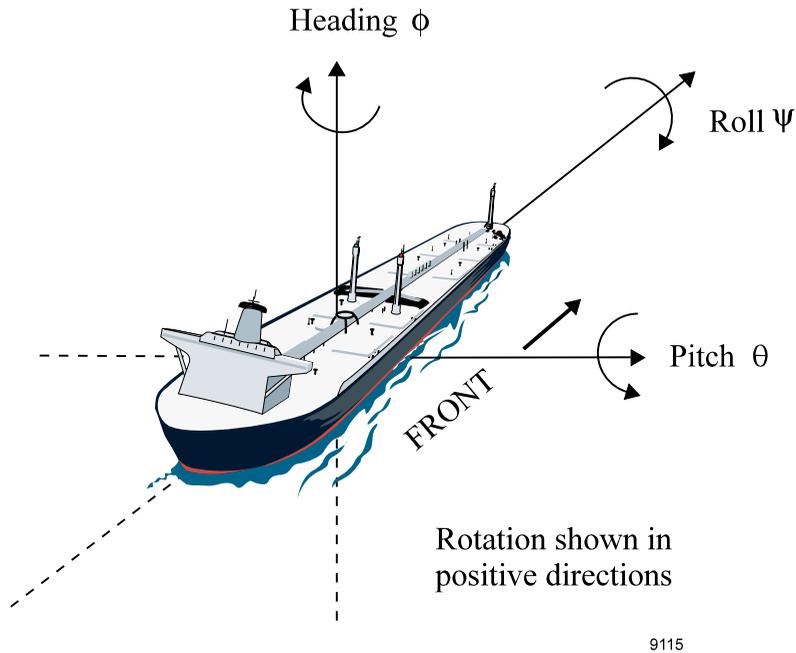


Figure 1.1: Attitude Components

For best performance, four or more satellites should be visible above a 15 degree elevation angle.

Physical Description

The ADU2 is housed in an aluminum case measuring 22 cm wide by 10 cm high by 20 cm deep. Four TNC connectors on the front panel, as shown in Figure 1.2, connect to four GPS antennas. Four LEDs indicate satellite tracking on the associated antenna.

One green flash is associated with each satellite being tracked. Brackets are attached to the bottom of the case for easy mounting.

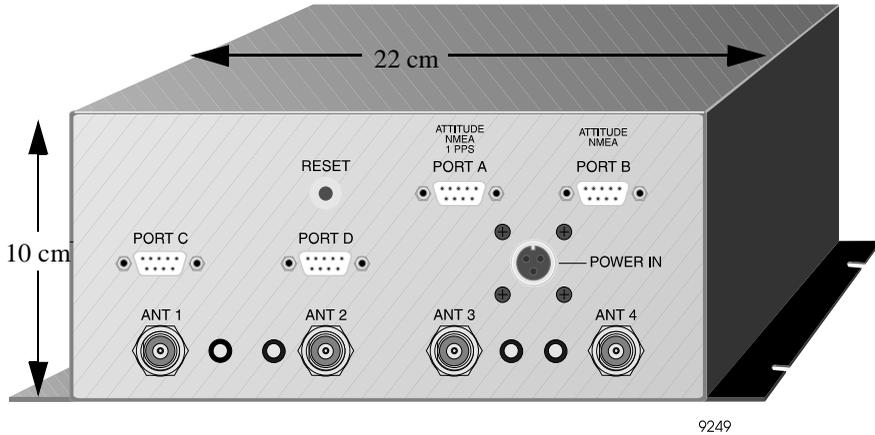


Figure 1.2: ADU2 Front Panel

Table 1.1 describes the components of the ADU2 Front Panel.

Table 1.1: ADU2 Front Panel Components

Component	Description
Reset button	This button reboots the ADU2 unit. If the user defined parameters are not saved, then reset sets the parameters to the factory defaults.
Port A	A complete RS-232 port with full-handshaking. Port A can be used for communications with a hand-held computer, a personal computer, or a radio. Port A is used for transferring data from the receiver to a computer, from a PC to a receiver, and all other communications to and from the receiver.
Port B	A complete RS-232 port with full-handshaking. Port B can be used for communications with a hand-held computer, a personal computer, or a radio. Port B is used for transferring data from the receiver to a computer, from a PC to a receiver, and all other communications to and from the receiver.
Port C	An abbreviated RS-232 port that has flow-control only. Port C is currently inactive and reserved for future use.
Port D	An abbreviated RS-232 port that has flow-control only. Port D is currently inactive and reserved for future use.

Table 1.1: ADU2 Front Panel Components (continued)

Component	Description
Power Input	Three pin power cable input. For description of recommended fuses, see Table 1.3.
Antennas 1 to 4	The RF Antenna connector is a standard TNC-type female receptacle wired for connection via 50-ohm coaxial cabling to a GPS antenna with an integral LNA. The TNC-type connector shell is connected to the Sensor common ground. The TNC-type connector center pin provides + 5 VDC (to power the LNA) and accepts 1575.42 MHz RF input from the antenna; the RF and DC signals share the same path.

Table 1.2 lists the physical and technical specifications of the ADU2.

Table 1.2: Technical Specifications of the ADU2

Parameter	Variable
Attitude accuracy (1x1M antenna array) <ul style="list-style-type: none"> • Heading • Pitch/Roll 	<ul style="list-style-type: none"> • 0.4° static, 0.2° dynamic • 0.8° static, 0.4° dynamic
Positional accuracy <ul style="list-style-type: none"> • Stand-alone • Real-Time Differential (optional) • Post-processed 	<ul style="list-style-type: none"> • 100m (95% with selective availability turned ON) • 2m (2D rms). 3m (3D rms) • 1cm + 2ppm
Velocity accuracy (PDOP<4)	1 cm/second
Time to first fix <ul style="list-style-type: none"> • Warm Start • No Almanac (cold start) 	<ul style="list-style-type: none"> • < 3 minutes • < 6 minutes
Update rate	2 per second
Input Voltage	12 to 32 volts DC
Power requirements	14 Watts
Temperature limits	-40° to +65° C
Speed limit	1000 knots*
Altitude	60,000 feet*

Table 1.2: Technical Specifications of the ADU2 (continued)

Parameter	Variable
Physical Characteristics	
• Weight	• 5.1 lb (2.31 Kg)
• Area	• Aluminum case measures 22 cm x 10 cm x 20 cm.
• Connectors	• Four TNC connectors as shown in figure 2.0 connect to 4 GPS antennas
• Power Input	• 12 to 32 V provided by 3-pin non-waterproof connector
• Port A and B	• DB9 RS232 male connectors for communication with attitude processing unit
• Port C and D	• Optional DB9 RS232 male connectors for future use.
• LEDs	• Four LEDs indicate satellite tracking on the associated antenna.
• Brackets	• Attached to bottom of case for mounting
*Higher limits are available with special authorization.	

Standard Equipment

Each ADU2 includes the following items:

- ADU2 unit
- ADU2 Operation and Reference Manual
- One power cable
- Two serial data cables
- ADU2 calibration software package (PN 600417)
- Real-time differential (remote only)—RTCM 104, Version 2 format
- **EVALUATE** software package and User's Guide

Optional Equipment

The following options are available. Contact you local Ashtech distributor.

- Photogrammetry (event input)
- 12-volt battery (8 amp-hours)
- 10-meter antenna cable
- 30-meter antenna cable
- 60-meter antenna cable
- Antenna line amplifier
- Marine antenna kit
- Aircraft antenna kit

- Fixed portable antenna array
- TNC male to Type N female adapter

Interfaces

Four TNC connectors provide interfaces to four GPS antennas over 10-meter 50-ohm coaxial cables. Two standard RS232 ports are accessible on DB9 connectors A and B. Two optional RS232 ports are accessible on DB9 connectors C and D. Pin 9 of Port B is used for the event trigger input (photogrammetry) and pin 9 of Port A is used for the 1PPS output function.



Use 50-ohm coaxial RG-121 cable or equivalent to wire 1PPS and event input signals.

Figure 1.3 displays the Port A pin assignments.



Figure 1.3: Port A Pin Assignments

Figure 1.4 displays the Port B pin assignments.



Figure 1.4: Port B Pin Assignments

Figure 1.5 displays the Port C pin assignments.

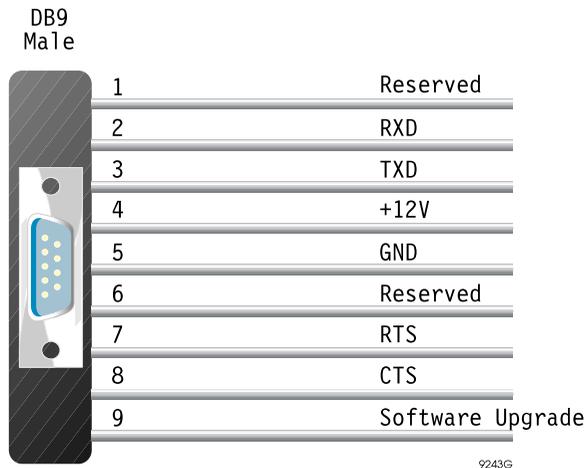


Figure 1.5: Port C Pin Assignments



The signal through pin 9 should be activated only for software upgrades, otherwise damage may occur to the receiver.

Figure 1.6 displays the Port D pin assignments.

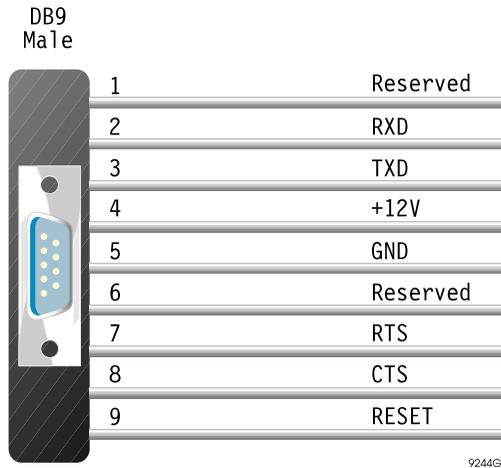


Figure 1.6: Port D Pin Assignments

Figure 1.7 displays the wiring information for the Null Modem data cable.

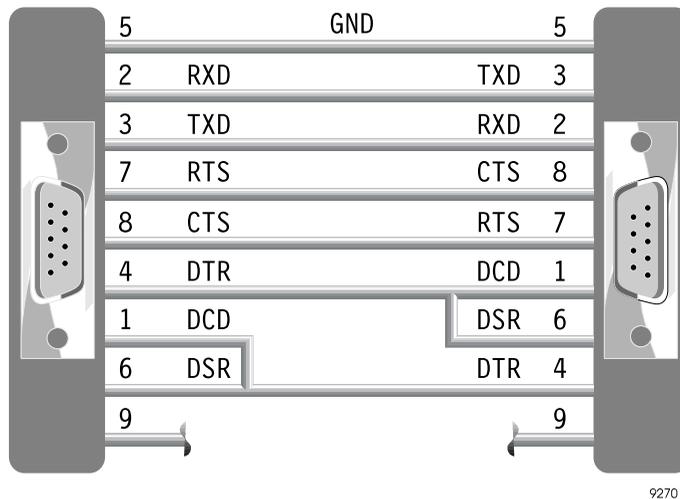


Figure 1.7: Null Modem Data Cable

Figure 1.8 shows the ADU2 power connector with the fuse holder.

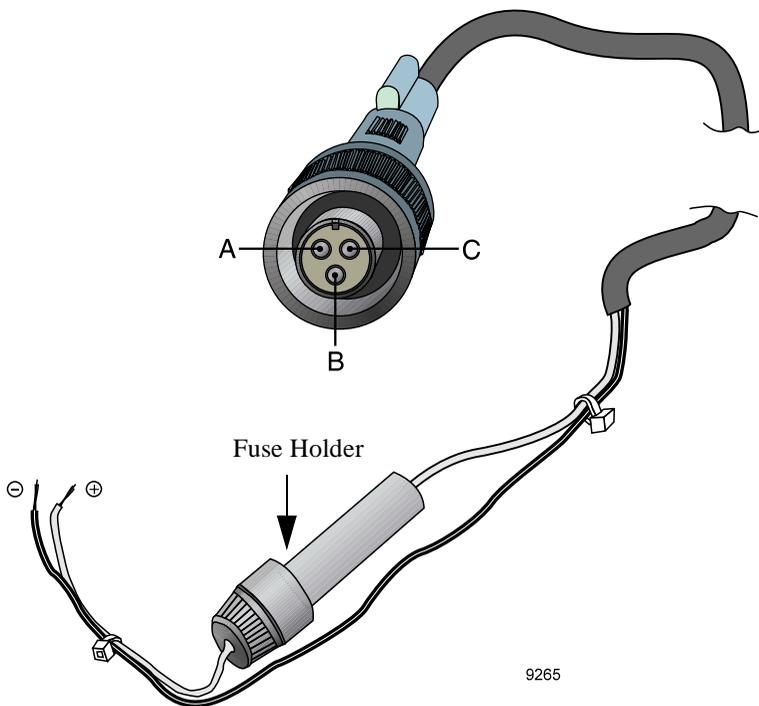


Figure 1.8: ADU2 Power Connector with Fuse Holder

Table 1.3 lists the required fuse type to use according to input voltage.

Table 1.3: Fuse Types

Input Voltage	Fuse Amperage
12V	2A
24V	1A

Quickstart

This chapter provides a brief overview for setting up the ADU2 receiver. Users experienced with the ADU2 receiver may use this chapter to accelerate the installation and operation of the receiver. Refer to the following chapters for more detailed explanations: Chapter 3 for installation procedures, Chapter 4 for antenna calibration procedures, and Chapter 6 for information on troubleshooting problems.

Installation

The following procedure brings the ADU2 on-line.

1. Mount the antennas on any rigid platform as follows:
 - a. If using the Ashtech fixed, portable antenna array, mount it using the 1 inch standard pipe fitting. Refer to Appendix A, Antennas and Cabling, for instructions to build the fixed portable antenna array.
 - b. If using aircraft antennas, mount the antenna on a metallic ground plane with at least a 25 cm diameter.
 - c. If using geodetic or marine antennas, mount them on poles at least one meter away from any metal surface.



The four antennas must be separated by more than 20 cm and less than 200 meters. The vehicle's heading and pitch are determined by the vector from antenna 1 to antenna 2. Therefore, place these antennas along (parallel to) the centerline of the vehicle. Place antennas 3 and 4 to sides of antennas 1 and 2 to provide roll information (Figure 2-1).



One to two meter antenna separation is recommended to minimize attitude determination initialization time (ambiguity search). For one to two meter separation, the time is about one to two seconds. For a 10 meter separation, the time increases to five seconds.



The vehicle's position and velocity are computed using antenna 1. The other three antennas are only used to provide attitude information.

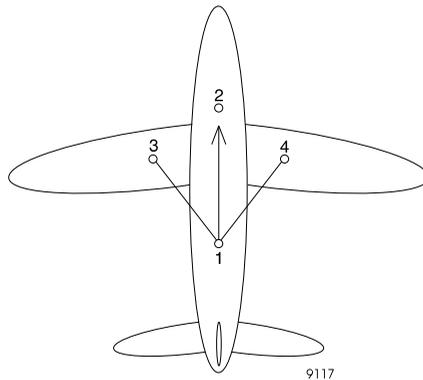


Figure 2.1: Antenna locations on an aircraft

2. Connect the four antenna cables, labeled 1, 2, 3, and 4, to the antennas and the ADU2 Antenna Ports.
3. Connect the interface cable from an RS232 port (A or B) to a PC and the power cable from the ADU2 to a power source. Turn on the power source if necessary.

The ADU2 configuration and operation are controlled through two RS-232 ports (Ports A and B) by ASCII commands sent from the PC. You can use **EVALUATE**, **REMOTE** or any other commercial communications package, such as **PROCOMM**, to issue all serial Command/Response functions.

4. Insert the ADU software diskette into the appropriate drive. Type **a:install** (or **b:install**). Follow the installation program instructions.
5. If using the Ashtech fixed portable antenna array, proceed to step 7.

Antenna Calibration

Determine the relative antenna position vectors by conducting either a static or dynamic survey as follows:

Static Survey

- a. Verify that each antenna tracks at least four satellites (**\$PASHQ,STA**).
- b. Make sure position is computed (**\$PASHQ,POS**).
- c. Collect data for at least one hour, at a five second recording interval, using **ADULOG** in calibration mode (at 38,400 baud or greater).

- d. Split the B-file and E-file into four files (one for each antenna) using **SPLIT3DF**.
- e. Process the data using **GPPS** for a static survey. Process the data radially to obtain output files (O- files) for antennas 1 to 2, 1 to 3, and 1 to 4.
- f. Generate the relative antenna position vectors (1-2, 1-3, and 1-4) by running **ADJENU**.
- g. Make a printout of these vectors, or write the vectors in Table 2.1, and proceed to step 6.

Table 2.1: Relative Antenna Position Vectors for Static Survey

Vectors	X(R)	Y(F)	Z(U)
1-2 vector			
1-3 vector			
1-4 vector			

Dynamic Survey

- a. Verify that each antenna tracks at least five satellites (**\$PASHQ,STA**).
- b. Make sure position is computed (**\$PASHQ,POS**).
- c. Collect data for at least one hour at a one second rate using **ADULOG** in calibration mode (at 38,400 baud or greater).
- d. Run steps A through D of the program **CAL3DF** to determine the relative antenna position vectors.
- e. Make a printout of these vectors, or write the vectors in Table 2.2, and proceed to step 6.

Table 2.2: Relative Antenna Position Vectors for Dynamic Survey

Vectors	X(R)	Y(F)	Z(U)
1-2 vector			
1-3 vector			
1-4 vector			

Enter Offset Vector Information

6. Enter the position vectors into the receiver with the following commands:

```
$PASHS,3DF,V12,Sddd.ddd,Sddd.ddd,Sddd.ddd  
$PASHS,3DF,V13,Sddd.ddd,Sddd.ddd,Sddd.ddd  
$PASHS,3DF,V14,Sddd.ddd,Sddd.ddd,Sddd.ddd
```

where ddd.ddd is a vector component and S is the sign of the vector component. Be sure to include the sign (+/-) of the vector value.

7. If you conducted a static survey, use the vectors in Table 2.1. If you conducted a dynamic survey, use the vectors in Table 2.2. If using the Ashtech fixed portable antenna array, refer to Table 3 for vector information.

Table 2.3: Relative Antenna Position Vectors for the Ashtech Fixed Portable Antenna Array

Vectors	X(R)	Y(F)	Z(U)
1-2 vector	0.000	+1.000	0.000
1-3 vector	-0.500	+0.500	0.000
1-4 vector	+0.500	+0.500	0.000

8. Set the data recording interval to 0.5 second (**\$PASHS,RCI,0**).
9. Turn on the position and attitude output messages on Port A (**\$PASHS,OUT,A,PBN,ATT**).

Instead of having two separate output messages for position and attitude, you may want only one message which provides both. This message is the NMEA **\$GPPAT** message. Turn this message on with the following command:

\$PASHS,NME,PAT,A,ON

Once the ADU2 has been calibrated and the offset vectors uploaded to the ADU2 receiver, the ADU2 is ready to output position velocity and attitude data.

10. Set the data recording interval to 0.5 second (**\$PASHS,RCI,0**).
11. Turn on the position and attitude output messages on Port A (**\$PASHS,OUT,A,PBN,ATT**).

Instead of having two separate output messages for position and attitude, you may want only one message which provides both. This message is the NMEA **\$GPPAT** message. Turn this message on with the following command:

\$PASHS,NME,PAT,A,ON

Inspect the NMEA and Raw Data, found in Chapter 5, **Command Response Formats**, output formats closely to determine which output messages are most applicable for your application.



\$GPPAT is not a standard NMEA message. If only heading information is required, the NMEA standard message \$GPHDT should be used.

Graphical displays of heading, pitch, roll, position, course over ground, and speed over ground are available in the **ADULOG** program (DOS) and in the **EVALUATE** program (Windows).

Installation

The ADU2 installation procedure consists of the following parts:

- Antennas
- Equipment
- Software

Antenna Installation

Several different types of antennas and configurations are available to meet a variety of mounting requirements. Mount the four antennas on the vehicle using the hardware furnished or locally fabricated hardware. Refer to Appendix A, **Antennas and Cabling**, for a detailed description on the various types of GPS antennas and how to install them properly on a vehicle to avoid high multipath and skyward obstruction.



All four antennas must be connected in order for the attitude computations to take place.

For best results the antenna array or platform must be completely rigid.

Table 3.1 provides information to keep in mind when choosing antenna locations.

Table 3.1: Antenna Placement Suggestions

Antenna Consideration	Suggestion
Antenna location and spacing	<ul style="list-style-type: none"> • Avoid placing antennas on wing tips of aircraft. Due to excessive wing-flex of the antenna baseline, the attitude computation algorithm becomes unreliable. • The software in the ADU2 requires that the antennas be separated from each other by at least 20 centimeters. The further the antennas are spaced from each other, the greater the potential attitude measurement accuracy provided by the ADU2. Refer to Appendix B, Performance Improvement, for more information.

Table 3.1: Antenna Placement Suggestions (continued)

Antenna Consideration	Suggestion
Accuracy	Accuracy is directly proportional to the antenna separation. Typical attitude accuracies versus antenna separation are described in Appendix C. Also refer to the references [2,3] in Appendix D. Pitch and roll accuracies are typically a factor of two worse than the heading accuracy when a square antenna array is used.
Multipath Migration	The reliability of the phase ambiguity resolution and the attitude accuracy is degraded by multipath signals. The antennas should be located on top of the vehicle (or platform) to minimize the possibility of satellite signals reflecting off metal objects near the antenna.
Stability	The ADU2 behavior depends upon the stability of the four-antenna system. This means that the selected antenna mounting locations should not move in any direction (up/down, left/right) relative to the other antennas. If the vehicle (or platform) moves, the entire antenna system should move in the same manner. Use care in mounting antennas on flexible structures such as the mast of a ship or the wing tips of an airplane.
Maximum Length	The supplied cables have a maximum length for the particular type of cable. Do not extend the cables beyond 30 meters without an in-line amplifier, provided as an option, since the radio frequency (RF) signal presented to the ADU2 will be degraded.
Geometrical Configuration	<ul style="list-style-type: none">• Almost any geometric shape is acceptable provided that none of the resultant vectors are co-linear (i.e. if three antennas are arranged in a line, Antenna 1 may not be one of those antennas (Figure 3.1).• Antennas do not need to be co-planar, however, for best results, at least two antennas should be at the same height.

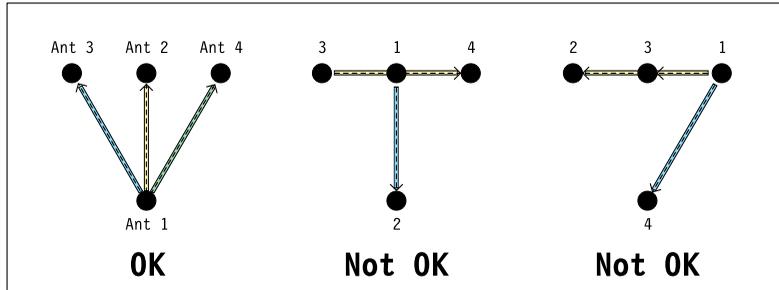


Figure 3.1: Configurations of Antennas (Top View)

1. The position computed by the ADU2 is referenced only to the primary antenna (Antenna 1).
The other three antennas (Antennas 2, 3 and 4) are used only to provide attitude information, no positions are computed for these antennas.
2. If you are using a fixed antenna array, then secure the array such that the line formed between Antenna 1 and Antenna 2 is along, or parallel to, the centerline of the vehicle.
If Antennas 1 and 2 cannot be mounted along, or parallel to, the centerline of the vehicle, the heading offset angle induced may be computed by independent means. Refer to Appendix B, **Performance Improvement**.
3. If you are mounting each antenna individually, then secure Antennas 1 and 2 such that the line formed between Antenna 1 and Antenna 2 is along, or parallel to, the centerline of the vehicle. (Figure 3.2).

If Antennas 1 and 2 cannot be mounted along, or parallel to, the centerline of the vehicle, the heading offset angle induced may be computed by independent means. Refer to Appendix B, **Performance Improvement**.

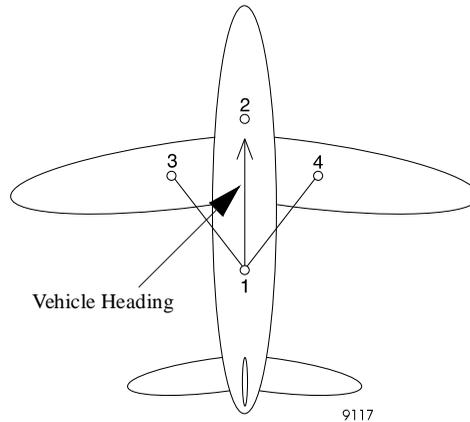


Figure 3.2: Suggested Locations for Antennas on Aircraft

4. Secure the remaining two antennas, Antennas 3 and 4, to rigid structures of the vehicle as suggested in Figure 3.1.



Mark each end of the co-axial cables with antenna numbers before installation.

5. Connect each antenna cable to the corresponding Antenna input connector on the ADU2 unit.



Verify that each antenna cable is connected to its respective antenna and input connector.

For best performance, four or more satellites should be visible above a 15 degree elevation angle.

Software Installation

The ADU2 package contains software diskettes for the initial antenna calibration. The software is installed on a personal computer. The minimum requirements for the PC are:

- 486 processor
- Math co-processor
- EGA video display
- Three megabytes of hard disk space
- Microsoft Windows if using the **EVALUATE** software

To install the software programs:

1. Insert ADU software diskette 1 into the appropriate drive. If drive A, type **a:install** or if drive B, type **b:install**. Then press **<ENTER>**.

After a few moments the following message appears:

```
This program installs Ashtech's ADU2 Software Version X.X.XX on
your computer system and verifies the integrity of the
distribution files.
```

```
Press the [Esc] key at any time to abort the installation.
```

```
Press [Esc] to quit, any other key to continue...
```

2. Press any key. A prompt similar to the following appears:

```
Detected Computer Configuration
DOS Version 6.22
CPU type is an 80486
Math coprocessor detected
VGA Video Adapter Card
Press [Esc] to quit, any other key to continue...
```

3. Press any key. The program prompts:

```
On which disk drive to you wish to install ADU:
```

```
Drive C:
```

```
Drive D:
```

4. Make a selection based upon your computer configuration. The default is Drive C. Select a drive letter and press **<ENTER>**.

5. The program prompts for the name of a subdirectory where the software will be installed. The default designation ADU, but you can specify another subdirectory. To accept the default, press **<ENTER>**. To specify another name, type \ followed by the subdirectory name, and press **<ENTER>**.

6. The program displays "Installing ADU2—Please wait." A list of files appears on the screen. After a few minutes, the program prompts:

```
May I create/modify your AUTOEXEC.BAT file if needed?
```

7. Unless you have a specific reason not to modify **autoexec.bat**, type **Y**. The program prompts:

The node "C:\ADU" has been added to the existing PATH command.



The GPPS program and its associated files must be in the DOS path statement.

8. Press any key. The program prompts:
May I modify your **CONFIG.SYS** file if needed (Y/N)?
9. Unless you have a specific reason not to modify your **config.sys** file, type **Y**. Install modifies the **config.sys** file if necessary, then displays the following prompt:
Press any key.
10. Press any key. The screen goes blank for a moment, then the program prompts:
The ADU software installation has concluded successfully.
Press any key to continue...
11. Press any key. The program displays the DOS prompt: \ADU>
12. Type **dir** and press <ENTER>. Table 3.2 list the files in the \ADU directory.

Table 3.2: Software Files in the ADU Directory

File	Description
ACD.EXE	Changes directories in the GPPS program.
ADJENU.EXE	Defines a three-vector reference frame using the four antenna positions given by the GPPS program. It reads the GPPS output files (O-files) and provides a file called BRVVEC.XYZ which contains the three vectors required for the ADU2 unit.
ADULOG.EXE	Collects measurement data from the 3DF into a B-file, containing raw measurement and position data, the E-file, containing satellite ephemeris data, and an A-file, containing attitude data. All files are in binary format and can be viewed using FILETOOL and BIN2ASC.
BASELINE.INP	GPPS Setup file
BIN2ASC.EXE	Conversion utility program that converts a binary attitude file (an A-file) to an ASCII attitude file (S-file). The binary attitude file is created by ADULOG.
CALI3DF.EXE	Determines the relative antenna position vectors for a moving vehicle. It is referred to as the Dynamic Calibration program and is described in Dynamic Calibration section of Chapter 4.
COMNAV.EXE	Reads each of the satellite ephemeris data files (E-files) in the current directory, and produces one common navigation file, COMMON.NAV.

Table 3.2: Software Files in the ADU Directory (continued)

File	Description
FILETOOL.EXE	Set of utilities that allows the viewing and editing of raw measurement data files (B-files). These files are in binary format.
GPPS.EXE	Primary program for static survey processing. GPPS provides several menus with options for different types of surveys. Most options have been disabled, except for the ones that pertain to static survey processing for the ADU2 installation.
LINECOMP.EXE	Uses the BASELINE.INP file, which contains variables which control the data analysis, and the U-files (generated by MAKEUFIL) Output files from this program are the O-files, which contain detailed vector solution results; BASELINE.OUT, which contains a summary of the processing results; and P-files, which are plot files of the computed residuals.
MAKEINP.EXE	Change the variables in theBASELINE.INP file.
MAKEUFIL.EXE	Generates expanded data files (U-files) from the input measurement data files (B-files).
PHONENUM.LST	REMOTE: Stores modem parameters
PLOT.EXE	Displays the designated plot file, in Ashtech plot file format.
PLOT.EXE	Application to view more than one plot file.
PROCESS.EXE	Primary program that performs the baseline processing for the static survey.
REMOTE.EXE	Serial port communications
REMOTE.CNF	REMOTE: stores default parameters
SPLIT3DF.EXE	Separates the measurement data file (B-file) into four separate files (one for each antenna).

13. Start Microsoft Windows.
14. Insert the **EVALUATE** software diskette into the appropriate drive.
15. Select **Run** from the **File** Menu.
16. Enter the following command in the **Command Line** of the **Run** dialog box:
a:\setup (or **b:\setup** if the diskette is in drive B).
17. Click the OK button to start the **EVALUATE** setup program.
18. Follow the setup program instructions.
19. Refer to the **EVALUATE** User's Guide for additional information on **EVALUATE**.

Equipment Installation

1. Mount the ADU2 unit using mounting brackets (Figure 3).

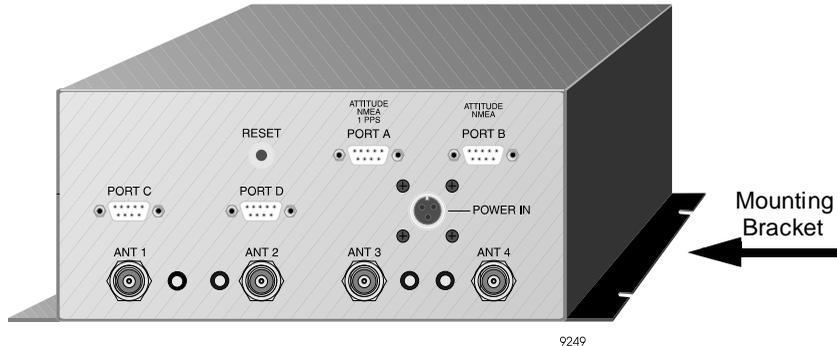


Figure 3.3: ADU2 Unit with Mounting Brackets

2. Connect serial Port A to a PC or other serial port communications device using the supplied serial data cable.



There is no power switch on the ADU2. It is best if the power supply is off while connections are made. If you are using a battery or power supply with no on/off switch, then connect the power cable to the ADU2 first, then the leads to the power supply.

3. Connect power supply cable to the power input on the ADU2.



Use a 12 to 32 Volt regulated DC power supply.

4. Connect the black power cable lead to the Ground terminal and the red power cable lead to the positive (+) terminal of the power supply.
5. Turn on the power supply.

When the ADU2 unit is powered up, it beeps once, the LEDs flash orange and red several times, and then 10-15 seconds later, the ADU2 beeps a second time indicating that it has successfully booted. Communication through Port A or B can only be established after the ADU2 successfully booted.

Verify Antennas are Tracking Satellites

After installing the ADU2 and antennas or antenna array, Ashtech recommends verifying that the antennas are connected to the ADU2, receiving information from satellites, and computing a position.

1. Verify all four antennas are connected to their respective port on the ADU2 unit as described in “Antenna Installation” on page 17.
2. Verify that the antennas are tracking satellites.
 - a. On the attached PC computer, type **remote** **<ENTER>** at the DOS prompt. The **REMOTE** main screen opens.
 - b. Verify the COM Port listed at the bottom of the screen is correct. To change the COM Port:
 - i. Press **<ALT>C**, then use the arrow keys to select COM2, and press **<ENTER>**.
 - ii. Press **F10** to return to the main screen and press **<ALT>W** to save the configuration.
 - c. Type **\$PASHQ,STA** to query each antenna for satellite tracking.

An example response is:

```

TIME: 15:46:36 UTA
-- ANTENNA 1 --
PRN: 26 07 15 19 31 02.  .. .. 27 16 ..
SNR: 34 71 15 72 28 68          55 19
-- ANTENNA 2 --
PRN: 07 18 31 19 26 15 16 02 .. .. 27 ..
SNR: 62 08 24 56 35 22 21 62      37
-- ANTENNA 3 --
PRN: 26 15 19 16 07 31 02 27 .. .. ..
SNR: 44 26 68 26 69 2 64 52
-- ANTENNA 4 --
PRN: 02 07 15 19 16 26 31 .. 27 .. ..
SNR: 70 63 32 71 29 33 20      57
  
```

The PRN line indicates the satellite tracked on each of the 16 channels for each antenna. Verify each antenna is tracking at least five satellites. You may need to wait several minutes after turning on the power to track all available satellites.

3. Type **\$PASH,POS** to verify the ADU2 is computing a position. **REMOTE** responds with a computed position for the ADU2.
4. Exit **REMOTE** by typing **<ALT>x**. At prompt message, type **y**.

Antenna Calibration

This chapter describes the antenna calibration process for a static calibration and a dynamic calibration. An antenna calibration must be performed and the resultant vectors entered before the ADU2 can calculate attitudes.

A static calibration can be used for the following circumstances:

- stationary vehicle
- vessel moored to a pier or in dry dock. A static calibration tolerates small antenna motions such as rising and falling tides if the tide range is less than 6 feet.
- aircraft parked on tarmac

A dynamic calibration should be used for a vessel, aircraft, or other vehicle which moves during the antenna calibration.

Static Calibration Procedure

Conduct the static calibration procedure when the vehicle does not physically move during calibration. You only need to calibrate the antennas once. However, you must recalibrate the antenna array if the relative positions of the antennas change (i.e. replacing an antenna, lowering and /or raising of antennas, etc.).



Every attempt should be made to set the antenna platform level during calibration.

The static calibration procedure has the following steps:

1. Collect the data (**ADULOG**)
2. Split the data (**SPLIT3DF**)
3. Process and view the data (**GPPS**)
4. Adjust relative antenna positions (**ADJENU**)
5. Enter offset vector information (**REMOTE**).

Collect the Data

After the antennas are tracking satellites, the calibration data can be collected. Use **ADULOG** to collect measurement data. Additional, detailed information about **ADULOG** and the measurement data is available in Chapter 7, ADULOG. Table 4.1

provides guidelines for recording intervals, duration of collection, and number of data sets.

Table 4.1: Static Calibration Times

Calibration Quality	Number of Data Sets	Duration of Collection	Recording Interval
Good	1	1 hour	5 seconds
Better	3	1 hour	5 seconds
Best	3	3 hours at 3 hour intervals between data sets	20 seconds

1. Start **ADULOG** by typing **adulog <ENTER>** at the DOS prompt. The main screen opens.
2. Verify the PC Port listed at the bottom of the screen is correct. To change the PC Port, press **1, 2, 3, or 4** corresponding to the PC Port.
3. Tab to the Baud field. If the baud rate is not set to 38400, then use **Page Up** and **Page Down** to set the baud rate to 38400.
4. Tab to the Recording Interval field. Type in the recording interval (in seconds) as specified in Table 4.1.
5. Tab to the Elevation Mask field. There is no need to change the elevation mask from 10°.
6. Tab to the Target Disk Drive field. If you wish your collection data saved to files located on a drive other than the C drive, enter the drive letter.
7. Tab to the Directory field. Type in the name of the directory where you want your data files saved.
8. Tab to the Template field. Type **cali** and press **<ENTER>**. The template creates the B and E-file names.
9. Press **F10** to start collecting the data. A dialog box asks
Auto SV selection for best PDOP?
10. Type **n**. ADULOG starts collecting the data.
11. Continue collecting the data for the time indicated in Table 4.1.
12. After collecting the data, press **<Esc>** to stop collecting the data.
13. Press **<Esc>** a second time to exit **ADULOG**. At prompt message, type **y**.
14. Verify the B- E- and A- files exist in the working directory by typing **dir**. Only B- and E-files are needed for calibration. The first letter of each file name designates the file type.

Split the Data

ADULOG collects the data from all four antenna into one data file. The data must be split into a file for each antenna using **SPLIT3DF** so it can be processed.

1. Start **SPLIT3DF** by typing **split3df <ENTER>** at the DOS prompt. The main screen of **SPLIT3DF** opens (Figure 4.1).

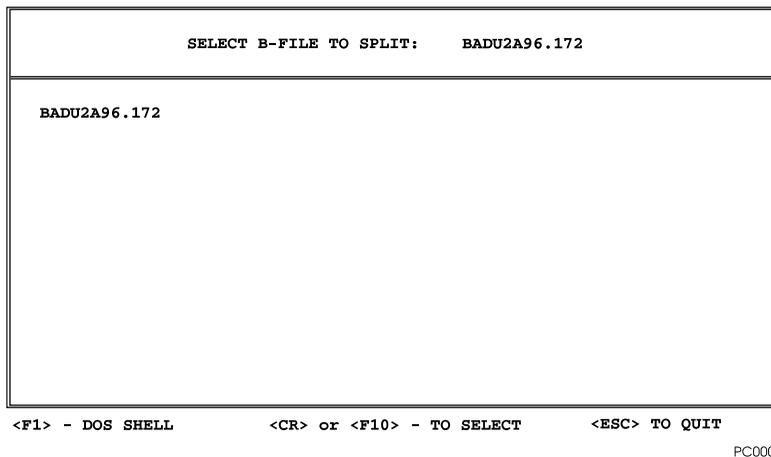


Figure 4.1: ADU2 B-File Selection

2. Use the arrow keys to highlight the B-file for splitting. If there is only one B-file listed it is automatically selected.
3. Press **F10** or **<ENTER>** to split the file.

SPLIT3DF splits the file into four data files, copies the E-file four times, and renames the original B-file to an X-file (e.g. BADU_B91.247 to XADU_B91.247).



B- and **E-** files are in binary format and can be viewed using **FILETOOL**.

4. Upon completion, **SPLIT3DF** flashes a message indicating that the process is complete.
5. If **SPLIT3DF** reads only one file that needs splitting, **SPLIT3DF** terminates upon completion. If you have other B-files in the directory, press **<Esc>** to exit **SPLIT3DF**.

Process the Data

The individual data files must be processed to compute a baseline summary using GPPS.

1. Start **GPPS** by typing **gpps <ENTER>** at the DOS prompt. The main menu opens.
2. Select **auto process** and press **<ENTER>**. The Processing Options menu opens.
3. Select **static survey** and press **<ENTER>**. Several warning messages may appear briefly indicating that no site information files (S-files) exist in the current directory. S-files are not needed when processing data for calibration.
4. The Editing Options menu opens. Select **Process Project**, and press **<ENTER>**.
5. The Processing Options menu opens. Select **Process Radially** and press **<ENTER>**. The baseline processing starts and may take several minutes to complete.
6. Upon completion, GPPS displays the message:
Baseline Processing Complete
7. Press any key to return to the Processing Options menu.
8. Select **View Baseline Summary**, and press **<ENTER>**. The processing summary displays on the screen. The results are contained in the file `summary.out`.
9. Page Down to LINECOMP Results.
10. Verify
 - the lengths are reasonable to the antenna setup
 - the rms error values are less than 1 cm
 - the ratios are greater than 95%
 - SOL for each is FIXED

If the results differ from these, then repeat the calibration procedure or view the plotfile using PLOT, and determine if the calibration procedure can be rerun eliminating any noisy satellites. Noisy satellites can be omitted by editing the Runtime Parameters.

11. Press **<Esc>** to return to the Processing Options menu, and press **F5** to return to the main menu.
12. A prompt message asks
Save profile on Disk?
13. Press **y** to save, and press **<Esc>** to exit GPPS.

Adjust relative antenna positions

After processing and viewing the baseline results, the relative antenna positions need to be calculated using **ADJENU** (**ADJENU** stands for adjust east north up).

ADJENU reads the output files (O-files) generated by GPPS and computes the relative antenna position vectors.

1. Start **ADJENU** by typing **adjenu <ENTER>** at the DOS prompt. The Relative Antenna Position Rotation Methods screen opens (Figure 4.2).

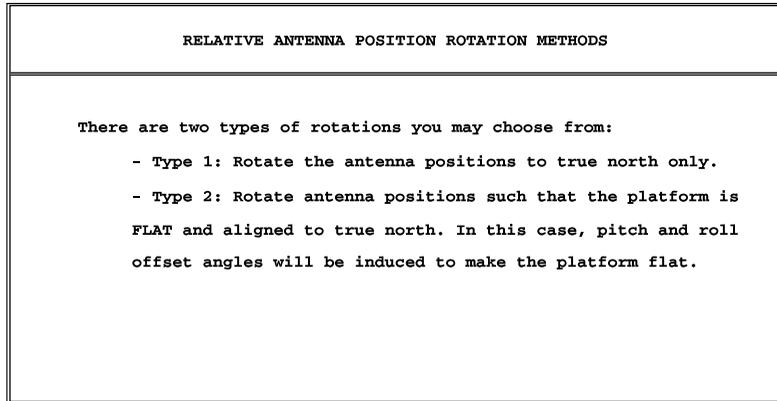


Figure 4.2: Relative Antenna Position Rotation Methods

2. Select Type 1 and press <ENTER>. The Defining a Heading Direction Using one of the Baselines screen opens (Figure 4.3).

Type 1 rotation rotates the relative antenna positions to true north only. This type is used if you performed the survey with pitch and roll equal to 0, or you obtained the vehicle's pitch and roll angles by some other means.

Type 2 rotation rotates the relative antenna positions to true north along with the necessary rotations of pitch and roll to "level" three antennas to the same height. This type should only be entered if the vehicle was tilted during the survey. See Appendix B for a further explanation of these rotations.

3. The Defining a Heading Direction Using one of the Baselines screen is used to tell the system which antenna vector defines the heading direction. If you antennas are set up as described in this manual, then the Antenna 1/ Antenna 2 vector defines the heading direction. Type **2** and press **<ENTER>**.

If you selected Type 2 rotation, you will need to select the heading vector and the vector that defines zero pitch and zero roll.



Every attempt should be made to set the antenna platform level during calibration. Type 1 is the recommended rotation method.

DEFINING A HEADING DIRECTION USING ONE OF THE BASELINES	
Choose one of the three baselines as the heading direction:	
BASELINE	CHOICE
1-2	2
1-3	3
1-4	4

Figure 4.3: Relative Antenna Position Rotation Methods

4. ADJENU asks if you wish to add a heading offset angle from heading baseline. If there is no induced offset heading, type **n**. If there is a heading offset angle, type **y**, and enter the angle. For more information on heading offset angles, see Appendix B.
5. ADJENU computes and displays the computed relative antenna position vectors, and terminates.
6. Table 4.2 is provided for your convenience to write down the relative antenna position vectors. ADJENU saves the vectors to the file `brfvec.xyz`.



Remember to include positive and negative signs for relative antenna position vectors.

Table 4.2: Relative Antenna Position Vectors

Vectors	X(R)	Y(F)	Z(U)
1-2 vector			
1-3 vector			
1-4 vector			

Enter Relative Antenna Position Vectors Information

The final step in the static calibration procedure is to enter the relative antenna position vectors using REMOTE.

1. Start REMOTE by typing **remote <ENTER>** at the DOS prompt.
2. Enter the relative antenna position vector for the vector between Antennas 1 and 2 by typing the following command. Be sure to enter + or - signs before each number.
\$PASHS,3DF,V12,+/-x.xx,+/-y.yy,+/-z.zz <ENTER>
3. Enter the relative antenna position vector for the vector between Antennas 1 and 3 by typing the following command. Be sure to enter + or - signs before each number.
\$PASHS,3DF,V13,+/-x.xx,+/-y.yy,+/-z.zz <ENTER>
4. Enter the relative antenna position vector for the vector between Antennas 1 and 4 by typing the following command. Be sure to enter + or - signs before each number.
\$PASHS,3DF,V14,+/-x.xx,+/-y.yy,+/-z.zz <ENTER>
5. Verify you entered the correct information including + and - signs by typing **\$PASHQ,3DF**
6. The system lists the relative antenna position vectors entered into the system. Check these to verify you entered each vector into the system correctly. If you made a mistake, you can reenter any of the three vectors.
7. After verifying you entered the vectors correctly, type **\$PASHS,SAV,Y** to save the relative antenna position vector configuration in the receiver memory.
8. Press **<ALT>x** to exit Remote.

The static calibration procedure is now complete. There is no need to recalibrate the ADU2 system unless you replace an antenna or if there has been any other changes made to the relative positions of the antennas.

Dynamic Calibration Procedure

The Dynamic Calibration procedure is used when the antenna array is mounted on a vehicle that moves during calibration, such as a ship at sea. This program determines relative antenna positions on moving vehicles using GPS carrier phase measurements. You only need to calibrate the antennas once, however if the relative locations between an antenna changes, you must recalibrate the antenna array.

The Dynamic Calibration procedure has the following steps:

1. Collect the data (**ADULOG**)
2. Determine the relative antenna positions (**CALI3DF**)
3. Enter offset vector information (**REMOTE**)

Collect the Data

After the antennas or antenna array has been tested, the sample data should be collected. ADULOG is the application used to collect measurement data. For Dynamic Calibrations, the software requires at least one half hour of continuous, cycle-slip free measurement for five or more satellites with a PDOP less than six for each antenna. Collect the data for at least one hour at a recording interval of once second when the vehicle is under normal motion to ensure meeting the software data requirements.

1. Start ADULOG by typing **adulog** <ENTER> at the DOS prompt. The main screen opens.
2. Verify the PC Port listed at the bottom of the screen is correct. To change the PC Port, press **1**, **2**, **3**, or **4** corresponding to the PC Port.
3. Tab to the Baud field. If the baud rate is not set to 38400, then use **Page Up** and **Page Down** to set the baud rate to 38400.
4. Tab to the Recording Interval field. Type **1** in the recording interval.
5. Tab to the Elevation Mask field. There is no need to change the elevation mask from 10°.
6. Tab to the Target Disk Drive field. If you wish your collection data saved to files located on a drive other than the C drive, enter the drive letter.
7. Tab to the Directory field. Type in the name of the directory where you want your data files saved.
8. Tab to the Template field. Type **cali** and press <ENTER>. The cali template creates the B and E-file names.
9. Press F10 to start collecting the data. A dialog box asks
Auto SV selection for best PDOP?

10. Type **n** to enter calibration mode, and **ADULOG** starts collecting the data.
11. Continue collecting the data for at least one hour. This ensures the collection of 30 minutes of cycle-slip free measurements.
12. After collecting the data, press **<Esc>** to stop collecting the data.
13. Press **<Esc>** a second time to exit **ADULOG**. At prompt message, type **y**.
14. Verify the B- E- and A- files exist in the working directory by typing **dir**. Only B- and E-files are needed for calibration. The first letter of each file name designates the file type.

Determine Relative Antenna Positions

After the data has been collected the relative vectors need to be computed. **CALI3DF** computes highly accurate relative position vectors for the four antennas and does not require the vehicle to be stationary. It achieves this by employing double differencing techniques, a Kalman filter, and an ambiguity search method. Refer to references [1,2] listed in Appendix C for an explanation of double differencing and phase ambiguity resolution. Reference [3] provides a theoretical description of the Dynamic Calibration.

1. Start **CALI3DF** by typing **cali3df <ENTER>** at the DOS prompt. The Select B-File for Calibration screen opens (Figure 4.4).



It is not necessary to use **SPLIT3DF** before running the dynamic calibration software. **CALI3DF** completes this operation.

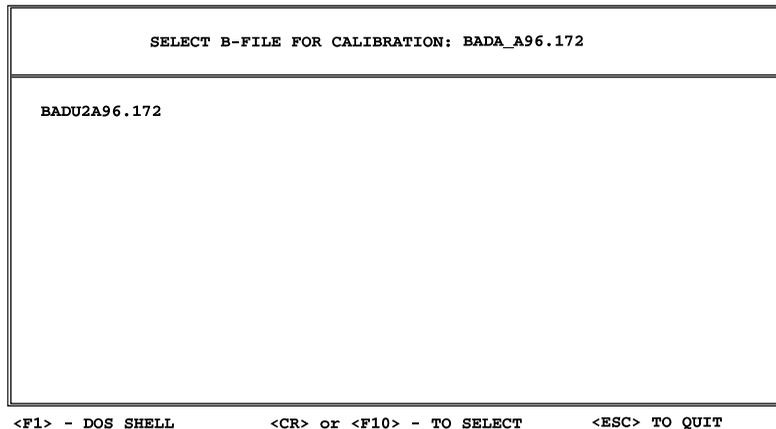


Figure 4.4: Select B-File for Calibration

2. Use the arrow keys to highlight the B-file for calibration. If there is only one B-file listed it is automatically selected.
3. Press **F10** to accept the selection and open the Program Options Menu (Figure 4.5).

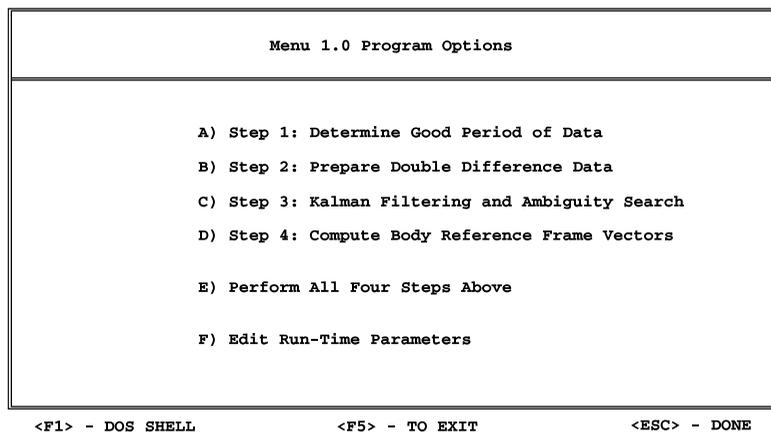


Figure 4.5: Calibration Program Options

4. The calibration program first checks a collected ADU2 B-file for adequate good measurement data to allow the program to provide the correct relative antenna positions. Next, the double difference phase ambiguities are determined, or fixed. After these ambiguities have been fixed, they are used along with the carrier phase measurements to determine the relative position vectors with respect to a defined body-fixed reference frame (BRF). You can complete these steps in a single step by selecting Option E, however running each step manually allows for more user control.
5. Use the arrow keys to select Option A, Determine Good Period of Data, and press **<ENTER>**.

Option A scans the selected ADU2 B-file to determine if a good data period of 1800 seconds exists with no cycle-slips from at least five satellites. At the same time, the satellite with the highest elevation over the whole period is chosen as the reference. The results are displayed on the screen (Figure 4.6) and saved in

the file **REF.SAT**.

```
STEP 1. DETERMINE GOOD PERIOD OF DATA

Skipping to epoch 1...
New start epoch = 711
Total epochs = 712
SVs:  24  3  20  16  100  17

  20          | Reference satellite.
  0           | Satellite to be omitted from processing.
  1           | Data collection sampling rate (sec).
 716         | New start epoch.
 706         | Number of epochs to be processed.

The above results have been saved to file REF.SAT

< Hit Any Key to Continue >
```

Figure 4.6: Determine Good Period of Data

The first line of the file lists the reference channel, that is, the channel on which the reference satellite is tracked. The ADU2 receiver has 12 possible channels, which the software numbers 0 through 11. The second line lists satellites with cycle-slips in the data file and are eliminated. The third line indicates the data collection sampling period was the particular for the particular B-file being scanned. The last two lines list the starting epoch of the good data and the number of epochs of data to process.

An SV of “100” indicates that no satellite is being tracked on that channel. Unhealthy satellites are automatically rejected.

If Step 1 is unsuccessful, the Determine Good Period of Data screen opens (Figure 4.7):

```

STEP 1. DETERMINE GOOD PERIOD OF DATA

Skipping to epoch 1...
New start epoch = 1445
Total epochs = 99
SVs:  21  26  3  22  28  23  17  1

Not enough good SVs to process data.
Look at file SLIP.SVS to determine which SV to omit.

< Hit Any Key to Continue >

```

Figure 4.7: Determine Good Period of Data

An illegal reference satellite and an illegal number of epochs are generated when enough good data is not available. As indicated above, a **SLIP.SVS** file is generated. This file shows which satellites experienced cycle-slips during the data collection period and at what times they happened (in seconds-of-week).

t_begin	t_end	time_span	start_epoch	tot_epochs	good_sv	last_sv	current_sc
149921	150327	405	1	406	5	100	7
149921	150478	556	1	557	5	15	100

At the end of an unsuccessful Step 1, complete one of the following:

- If tracking six or more satellites in the data file, refer to the **SLIP.SVS** file to determine which satellite to omit. In the example above, SV 15 is eliminated in the Run-Time Parameters screen (option F) and Step 1 reruns.
- If the longest period of continuous tracking is close to the “User-defined good period”, shorten the “User-defined good period” appropriately and rerun Step 1. Never shorten the user defined good period to less than 900 seconds.
- If neither of these two things can be performed, collect another set of data and attempt the calibration procedure again.

6. Press any key to return to the Program Options menu.

7. Select Option B, Prepare Double Difference Data, and press **F10**.

A valid REF.SAT file generates the carrier phase and code phase double differences, saved in file **BDDDATA.TMP**. At the end of this step, the Prepare Dou-

ble Difference screen opens (Figure 4.8):

```
STEP 2. PREPARE DOUBLE DIFFERENCE DATA

Skipping to epoch 716...
Reference satellite: 20
Sampling rate (sec): 1
The double difference data file has been saved to file
BDDDATA.TMP
      < Hit Any Key to Continue >
```

Figure 4.8: Prepare Double Difference Data

The double differences are used by a Kalman filter to estimate the phase ambiguities for each baseline in the step 3.

8. Press any key to return to the Program Options menu.
9. Select Option C, Kalman Filtering and Ambiguity Search, and press **F10**.

The Kalman filtering is the most important step of the calibration program. A Kalman filter recursively estimates a set of ambiguities for three baselines using consecutive epochs of double difference measurement data.

10. The Kalman Filtering and Ambiguity Search screen opens and updates every few epochs (Figure 4.9).

STEP 3. KALMAN FILTERING AND AMBIGUITY SEARCH										
TIME:	150350									76.9%
		East	North	Up	Ambiguities					
1-2:	est:-0.377	1.393	0.541	-7.6	-1.4	-2.2	-8.8	0.0		
	rms: 0.400	0.349	0.530	0.530	1.4	2.1	2.1	1.3	100.00	
1-3:	est: 0.753	1.874	-0.030	-7.2	-6.6	3.3	-13.1	0.0		
	rms: 0.400	0.349	0.530	0.530	1.4	2.1	2.1	1.3	100.00	
1-4:	est: 0.697	-0.007	0.366	0.7	-4.1	0.8	-1.7	0.0		
	rms: 0.400	0.349	0.530	0.530	1.4	2.1	2.1	1.3	100.00	

Figure 4.9: Kalman Filtering and Ambiguity Search



The estimated ambiguities are saved to a file `amb.fix`. Do not delete this file.

The last five numbers on the second line for each baseline are the Kalman filter's ambiguity estimation covariances which decrease as time goes on. These numbers must fall below the minimum covariance that you specify.

When this happens, an ambiguity search (\pm the chosen ambiguity search region) is performed around the ambiguity estimates from the Kalman filter, which are given by the last five numbers on the first line for each baseline. 0.0 and 100.0 on the first and second lines indicate that no satellite is being tracked for that column.

The first three numbers in the first line are the estimated relative position vectors and the first three numbers on the second line are the rms values of the estimates. The ambiguity search generates a list of the top ten cases for each baseline (but only the top five are displayed). A case is a residual and a set of ambiguity offsets from the Kalman filter's estimated ambiguities. When the ratio between the residuals of the top two cases for a baseline is greater than the user-specified minimum, the ambiguities are fixed for that particular baseline.

Figure 4.10 is an example. Assume the minimum contrast is 3.0.

Baseline 1-3:						
Minimum residual change = 1.373522, Chi2 Ratio = 2.889211						
1	2.289440	0	2	-1	0	1
2	6.614675	-2	-2	0	0	-2
3	11.577207	3	0	2	0	-2
4	13.716034	1	0	1	0	0
5	18.823117	-3	0	-2	0	-1
Baseline 1-4:						
Minimum residual change = 4.188390, Chi2 Ratio = 4.637013						
1	2.132113	-1	1	-1	0	1
2	9.886634	2	-1	2	0	-2
3	10.813614	-3	-3	0	0	-2
4	14.272999	0	-1	1	0	0
5	16.271142	4	3	1	0	1
Fixing integers for baseline 1-4.						

PC0024

Figure 4.10: Ambiguity Search Example

The ratio for baseline 2 does not exceed the minimum contrast, but the ratio for baseline 1-4 does. Therefore, the integer ambiguities are fixed for baseline 3 and another search for the ambiguities is performed after 60 seconds of more data are processed for baseline 2 only.

If the Kalman filter's covariance numbers do not fall below the minimum covariance after 80% of the double difference data file has been processed, a search for the integers is automatically conducted every 60 seconds for the remaining 20% of the data. This attempts to fix the ambiguities before the end of the file is reached.

If the ambiguities are not fixed properly for all three baselines, they are stored in file AMB.FIX with the word "fixed" at the end of each line. If the ambiguities are not found for any baseline by the end of the data file, they are forced to the best case at that time. When this happens, the word "Forced" is at the end of the line for that particular baseline.

-2	4	3	1	10000	-2	Ratios:	5.03	1.51	1.05	Forced	-1
3	3	0	1	10000	1	Ratios:	3.28	2.04	2.94	Fixed	0
4	-2	0	1	10000	-1	Ratios:	3.27	3.06	1.19	Fixed	1

This file shows that the ambiguities for the first baseline have been forced, while the second and third baselines have been fixed successfully. The number 10000 represents the reference satellite channel and 0 indicates that no satellite was traced on that channel.

At the end of an unsuccessful Step 3, the message in Figure 4.11 is displayed:

```
STEP 3. KALMAN FILTERING AND AMBIGUITY SEARCH

The fixed ambiguities have been saved to file
AMB.FIX.

*** WARNING ***

The integers in Baseline(s) 1 are not fixed properly.
*** DO NOT TRUST THE AMBIGUITIES FOR THESE BASELINES ***
You may want to change the run=time parameters and rerun the
calibration program. You may also look at file AMB.LST to try to
fix the ambiguities by hand.

< Hit Any Key to Continue >
```

Figure 4.11: Ambiguity Search Warning

If Step 3 is unsuccessful, a file, **AMB.LST**, is created. It contains the last list generated for each baseline that was not fixed properly. An example **AMB.LST**

file:

```
Baseline # 1
The estimated integers are :
      2      3      -2      0      -4
The contrast is 1.451724
And the candidate list is
1      3.760010      1      -1      1      0      -1
2      5.458498      3      3      0      0      2
3      25.452416      -1      -5      2      0      -4
4      45.733724      -1      2      -2      0      2
5      59.296720      -3      -2      -1      0      -1
6      66.192181      5      0      3      0      -1
7      72.623103      3      -4      4      0      -4
8      72.649638      0      -4      2      0      -4
9      80.285511      -4      -5      0      0      -4
10     88.297062      -4      2      -4      0      3
```

These files show that the ambiguities for the first baseline have been forced. While the second and third baselines have been fixed successfully. The number 10000 represents the reference satellite channel and 0 indicates that no satellite was traced on that channel.

This file contains residual values and the integer offsets to the estimated integers from the Kalman filter for the top 10 cases (the candidate list). The channel not used has a 0 value.

The candidate list generated above shows that the top two cases are the most promising based on their residuals of 3.7 and 5.4, while the next highest residual is 25.4. Both of these cases may be tested by performing Step 4 on each and checking that the variance of all the vector components generated are less than five millimeters. As an example, choose the top case from the above candidate list. Adding the integer offsets for case 1 to the estimated integers gives:

```
3      2      -1      0      -5
```

These numbers are entered into file **AMB.LST** and Step 4 is executed. If all three

baselines have been fixed properly, the message in Figure 4.12 appears:

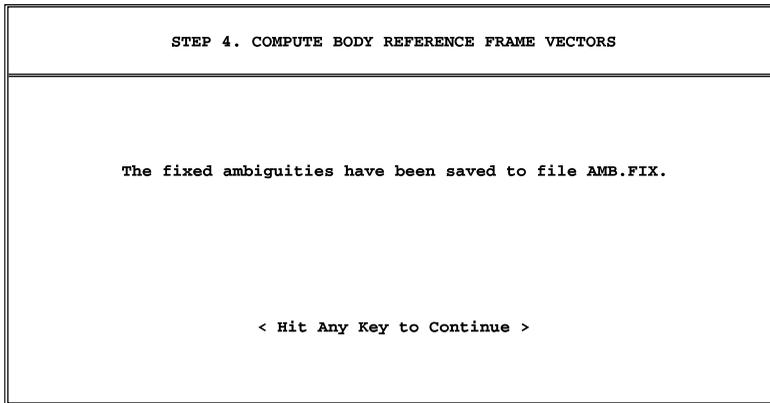


Figure 4.12: Compute Body Reference Frame Vectors

11. Press any key to return to the Program Options menu.
12. Select Option D, Compute Body Reference Frame Vectors, and press **F10**. This step uses the integers from **AMB.FIX** and computes the relative antenna positions, called the BRF vectors. This uses all the double difference data in file **BDDDATA.TMP**.

The Compute Body Reference Frame Vectors screen opens (Figure 4.13).

```
STEP 4. COMPUTE BODY REFERENCE FRAME VECTORS

X(R)      Y(F)      Z(U)      100%
1-2 Vector: 0.000    1.671    0.000
1-3 Vector: 1.067    1.674    0.000
1-4 Vector: 1.073   -0.006   -0.006

The BRF vectors have been saved in plotfile PLOTBRF.
The averaged BRF vectors have been saved to file BRFVEC.XYZ.

< Hit Any Key to Continue >
```

Figure 4.13: Computing Body Reference Frame Vectors

The final output is stored in **BRFVEC.XYZ**, and a plotfile called, **PLOTBRF**, is created. An example of the **BRFVEC.XYZ** files is listed as follows:

```
***   Input Relative Antenna Positions (meters)   ***
***   -----   ***
X(R)      Y(F)      Z(U)
1-2 Vector 0.000    1.671    0.000
1-3 Vector 1.067    1.674    0.000
1-4 Vector 1.073   -0.006   -0.004
***   -----   ***
The RMS values of these three baselines are (meters):
Baseline 1-2: 0.002 Good
Baseline 1-3: 0.002 Good
Baseline 1-4: 0.002 Good
***   -----   ***
*** Adjusted Relative Antenna Positions (meters) ***
***   -----   ***
X(R)      Y(F)      Z(U)
1-2 Vector 0.000    1.670    0.056
1-3 Vector 1.066    1.671    0.093
1-4 Vector 1.072   -0.007    0.033
***   -----   ***
NOTE: This adjustment was based on the assumption
      that the average orientation of the vehicle
```

was level during the calibration. The pitch and roll offset angle computed from this adjustment are:

PITCH OFFSET ANGLE: 1.937 (degrees)

ROLL OFFSET ANGLE: -1.970 (degrees)

If the adjusted relative antenna positions are used, no pitch or roll offset angles are needed.

*** ----- ***

The nine numbers listed in Adjusted Relative Antenna Positions (meters) section list the BRF vectors of antennas 1-2, 1-3, and 1-4, respectively. Three of the parameters are exactly 0.0, since only six independent parameters are needed to describe a platform with three vectors.



It is very likely that pitch and roll offset angles will be induced. Refer to Appendix B.

13. Press any key to return to the Program Options menu.
14. Press **<Esc>** several times to exit **CALI3DF**.
15. Start PLOT by typing **pplot <ENTER>** at the DOS prompt. The plotfile is useful to judge whether the ambiguities have been fixed properly.
16. The main menu opens. Select the file **plotbrf** and press **<ENTER>**.
PLOT plots the six non-zero parameters of the BRF vectors given in file PLOTBRF (Figure 4.14). A good solution should have a small variation on all six parameters, that is, the peak-to-peak error should be no more than two centimeter on the screen. The largest variation is usually in the z-components of the BRF vectors.

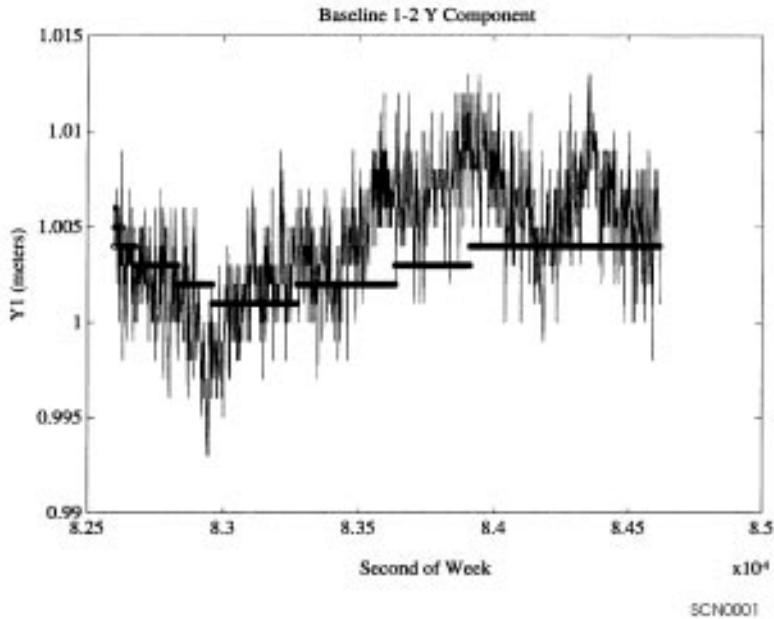


Figure 4.14: BRF Vectors Plot

The dark line on the plot is the running average of the vector computational value. It should become flat or nearly so by the end of the dataset.

If the drift of one of the parameters is more than five millimeters, one or more of the integers in **AMB.FIX** were probably wrong. Try to correct the integers by recollecting a new set of data or try a different set of integers in file **AMB.FIX** and re-running Option D.

17. Table 4.3 is provided for your convenience to write down the relative antenna position vectors. Remember to include positive and negative signs for relative antenna position vectors.

Table 4.3: Input Relative Antenna Position Vectors

Vectors	X(R)	Y(F)	Z(U)
1-2 vector			
1-3 vector			
1-4 vector			

Enter Relative Antenna Position Vectors Information

The final step in the dynamic calibration procedure is to enter the relative antenna position vectors using REMOTE or any other communications software package.

1. Start REMOTE by typing **remote <ENTER>** at the DOS prompt.
2. Enter the relative antenna position vector for the vector between Antennas 1 and 2 by typing the following command. Be sure to enter + or - signs before each number.

\$PASHS,3DF,V12,+/-x.xx,+/-y.yy,+/-z.zz <ENTER>

3. Enter the relative antenna position vector for the vector between Antennas 1 and 3 by typing the following command. Be sure to enter + or - signs before each number.

\$PASHS,3DF,V13,+/-x.xx,+/-y.yy,+/-z.zz <ENTER>

4. Enter the relative antenna position vector for the vector between Antennas 1 and 4 by typing the following command. Be sure to enter + or - signs before each number.

\$PASHS,3DF,V14,+/-x.xx,+/-y.yy,+/-z.zz <ENTER>

5. Verify you entered the correct information including + and - signs by typing

\$PASHQ,3DF

6. The system lists the relative antenna position vectors entered into the system. Check these to verify you entered each vector into the system correctly. If you made a mistake, you can reenter any of the three vectors.
7. After verifying you entered the vectors correctly, type **\$PASHS,SAV,Y** to save the relative antenna position vector configuration in the receiver memory.
8. Press **<ALT>x** to exit Remote.

The dynamic calibration procedure is now complete. There is no need to recalibrate the ADU2 system unless you replace an antenna or if there has been any changes made to the relative positions of the antennas.

Dynamic Calibration-Run-Time Parameters

The Run-Time parameters are the parameters **CALI3DF** uses to process the data in the B-file for calibration. If the calculated body reference frame (BRF) vectors are poor quality, the Run-Time parameters can be changed to process the data slightly differently for better results.

The Run-Time parameters are accessed by selecting Option F in CALI3DF (Figure 4).

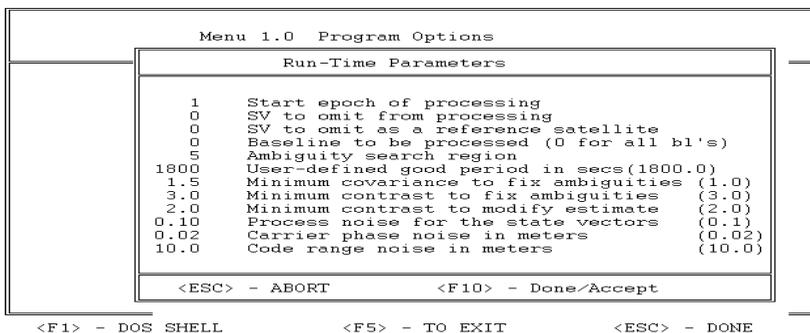


Figure 4.14: Run-Time Parameters

Table 4 describe the Run-Time parameters with suggestions for changes.

Table 4.4: Run-Time Parameters Descriptions

Run-Time Parameter	Description
Start epoch of processing	Indicates which epoch in the B-file to begin processing. Do not confuse epochs with seconds. For example, if the data recording interval is 0.5 seconds, epoch 200 refers to a time 1000 seconds into the B-file. For calibration, the default start epoch is 1.
SV to omit from processing	Option to eliminate a satellite. For example, if you have a data set with six satellites, but one satellite is at a low elevation angle and some cycle-slips occur, that satellite should be eliminated here. Since the dynamic calibration program requires at least five satellites to process successfully and the ADU2 receiver can track a maximum of 8 satellites, you can eliminate only three satellites.
SV to omit as a reference satellite	The reference satellite is a key satellite in the calibration program, by which all double differences are computed. It is chosen as the satellite with the highest elevation. If satellite data exhibits odd behavior, you may want to eliminate that satellite as a reference.

Table 4.4: Run-Time Parameters Descriptions (continued)

Run-Time Parameter	Description
Baseline to be processed (0 for all bl's)	There are three baselines for which the calibration program tries to solve the double difference phase ambiguities, thus providing accurate relative position vectors. Antennas 1 and 2 form baseline 1, 1 and 3 form baseline 2, and 1 and 4 form baseline 3. By default (0), you usually want to process all the baselines to determine all three relative antenna position vectors. In the case where only one baseline needs to be determined, specify the appropriate baseline number.
Ambiguity search region	Range of integer ambiguities (positive and negative) that the search routine searches around an initial ambiguity estimate to find the correct set of ambiguities. This initial ambiguity estimate is provided by a Kalman filter. The program can handle a maximum search range of ± 9 .
User-defined good period in secs	Shortest period required in which five satellites must be tracked continuously. The B-file must have at least this many seconds of uninterrupted satellite measurement data in order to fix the ambiguities successfully, that is, no cycle-slips. Initial testing shows that this number should be an absolute minimum of 900.0 seconds. The default good period is 0.5 hour (1800.0 seconds).
Minimum covariance to fix ambiguities	The minimum covariance is used only in Option C of the calibration program. Altering the covariance from the default value requires some experience with the collected data and the Kalman filter used in the program.
Minimum contrast to fix ambiguities	The minimum contrast is used only in Option C of the calibration program. Altering the contrast from the default value requires some experience with the collected data and the Kalman filter used in the program.
Minimum contrast to modify estimate	Contrast is used only in Option C of the calibration program. Altering the contrast from the default value requires some experience with the collected data and the Kalman filter used in the program.
Process noise for the state vectors	Part of the system noise and measurement noise description for the Kalman filter. The default values for these have been chosen based on experience with the data collected by the ADU2 receiver.

Table 4.4: Run-Time Parameters Descriptions (continued)

Run-Time Parameter	Description
Carrier phase noise in meters	Part of the system noise and measurement noise description for the Kalman filter. The default values for these have been chosen based on experience with the data collected by the ADU2 receiver.
Code range noise in meters	Part of the system noise and measurement noise description for the Kalman filter. The default values for these have been chosen based on experience with the data collected by the ADU2 receiver.

Command Response Formats

Once the ADU2 has been calibrated and the offset vectors uploaded to the ADU2 receiver, the ADU2 is ready to output position velocity and attitude data.

Graphical displays of heading, pitch, roll, position, course over ground, and speed over ground are available in **ADULOG** (DOS) and **EVALUATE** (Windows). Refer to Chapter 7 for more information on **ADULOG** and the **EVALUATE** User's Guide.

The ADU2 configuration and operation are controlled through two RS-232 ports (Ports A and B) by ASCII commands sent from the PC. You can use **EVALUATE**, **REMOTE** or any other commercial communications package, such as **PROCOMM**, to issue serial Commands.

Inspect the NMEA and Raw Data output formats closely to determine which output messages are most applicable for the given application, and turn off the unuseful messages.

This chapter presents an overview of the command set, and a detailed explanation of each command.

Overview

This section discusses the format and structure of the commands to and the responses from the ADU2. As noted previously, an external device such as a personal computer (PC) or a handheld controller must be used to input commands to the sensor, and to monitor responses from the sensor. All commands must be terminated with **<CR><LF>** or **<Enter>**, as appropriate for the external device.

The commands and responses have the following headers:

Set Commands:	\$PASHS
Query Commands:	\$PASHQ
Responses:	\$PASHR

The commands and responses fall into the following functional categories:

- Receiver Control Commands
- Attitude Setup Commands
- Attitude Control Commands
- RTCM Differential Commands
- NMEA Output Commands
- RAW Data Commands

Table 5.1 summarizes the commands and responses. The pages following Table 5.1 list each command/response alphabetically, describing them in detail.

Table 5.1: Command Summary

Command	Description	Page
RECEIVER CONTROL COMMANDS		
\$PASHQ,PAR	Queries for the configuration of the general setup parameters	64
\$PASHQ,PRT	Queries for the port being used and the baud rate	66
\$PASHQ,RID	Queries for the receiver version ID.	68
\$PASHQ,RIO	Queries the product type, receiver version, sensor version, any options included as well as the receiver serial number	68
\$PASHQ,STA	Queries for the current satellite tracking status for each antenna	71
\$PASHQ,TST	Requests the results from the power-up initialization test.	71
\$PASHS,ALT	Set altitude for Fix mode 0 and 1	75
\$PASHS,ELM	Set elevation mask	75
\$PASHS,FIX	Set altitude fixed mode	75
\$PASHS,HDP	Set HDOP mask	75
\$PASHS,INI	Initialize receiver	75
\$PASHS,MSV	Set minimum number of satellites	75
\$PASHS,PDP	Set PDOP mask	94
\$PASHS,PDS	Set satellite selection for best PDOP	94
\$PASHS,POS	Set position of antenna	95
\$PASHS,RST	Reset receiver parameters to defaults	95
\$PASHS,SAV	Save receiver setup parameters	96
\$PASHS,SIT	Assign site ID name	96
\$PASHS,SPD	Set receiver serial port baud rate	96
\$PASHS,SVS	Enable/disable satellites	97
\$PASHS,UNH	Use unhealthy satellite	97
\$PASHS,USE	Use/not use a particular satellite	97
\$PASHS,VDP	Set VDOP mask	97
ATTITUDE SETUP COMMANDS		
\$PASHS,3DF,OFS	Sets the offset angles in degrees	72

Table 5.1: Command Summary (continued)

Command	Description	Page
\$PASHS,3DF,V12	The relative position vector from antenna 1 to antenna 2	75
\$PASHS,3DF,V13	The relative position vector from antenna 1 to antenna 3	75
\$PASHS,3DF,V14	The relative position vector from antenna 1 to antenna 4	75
ATTITUDE CONTROL COMMANDS		
\$PASHQ,3DF	Queries for the configuration of the attitude parameters	57
\$PASHS,3DF,ANG	The maximum angle above the horizon that the vehicle (or platform) is expected to tilt (pitch or roll) in degrees.	71
\$PASHS,3DF,CYC	The phase error in cycles.	72
\$PASHS,3DF,FLT	Smoothing filter	72
\$PASHS,3DF,HKF	Identifies the heading Kalman filter parameters	72
\$PASHS,3DF,MXB	The maximum baseline rms error (BRMS) in meters	72
\$PASHS,3DF,MXM	Sets the maximum phase measurement rms error (MRMS) in meters	72
\$PASHS,3DF,PKF	Identifies the pitch Kalman filter parameters	73
\$PASHS,3DF,RAT	Sets the ambiguity search ratio	74
\$PASHS,3DF,RKF	Sets the roll Kalman filter parameters	74
\$PASHS,3DF,RST	Restarts the Kalman filters	74
RTCM DIFFERENTIAL SETUP COMMANDS		
\$PASHQ,RTC	Queries current RTCM (differential mode) parameters	68
\$PASHS,RTC,AUT	Sets the receiver to automatically compute a stand-alone position when RTCM corrections are unavailable.	95
\$PASHS,RTC,MAX	Sets the maximum age for messages when handling RTCM format	95
\$PASHS,RTC,QAF	Sets the communication quality when handling RTCM format	95
\$PASHS,RTC,REM	Sets a receiver to handle RTCM input	96
\$PASHS,RTC,STI	Sets the station ID when handling RTCM format	96
NMEA OUTPUT MESSAGE COMMANDS AND RESPONSES		
\$PASHS,NME,ALL,OFF	Disable all NMEA outputs	76
\$PASHS,NME,ALM	Enable/disable NMEA NMEA almanac message	76
\$PASHS,NME,DAL	Enable/disable NMEA decimal almanac message	77
\$PASHS,NME,GGA	Enable/disable NMEA GPS position response message	78

Table 5.1: Command Summary (continued)

Command	Description	Page
\$PASHS,NME,GLL	Enable/disable NMEA latitude/longitude message	79
\$PASHS,NME,GRS	Enable/disable NMEA GRS (satellite range residual) message	80
\$PASHS,NME,GSA	Enable/disable NMEA DOP and active satellite message	80
\$PASHS,NME,GSN	Enable/disable NMEA GSN signal strength/satellite number	81
\$PASHS,NME,GSS	Enable/disable NMEA GSS (satellite tracked and DOP messages)	82
\$PASHS,NME,GSV	Enable/disable NMEA GSV (satellites in view) message	82
\$PASHS,NME,GXP	Enable/disable NMEA GXP (horizontal position) message	83
\$PASHS,NME,HDT	Enable/disable NMEA true heading message	84
\$PASHS,NME,MSG	Enable/disable NMEA MSG (RTCM) message	84
\$PASHS,NME,PAT	Enable/disable Ashtech proprietary position and altitude message	86
\$PASHS,NME,PER	Set NMEA send interval	87
\$PASHS,NME,POS	Enable/disable position message	87
\$PASHS,NME,RRE	Enable/disable NMEA RRE (satellite residual and position error) message	88
\$PASHS,NME,SA4	Enable/disable NMEA satellite tracking message	90
\$PASHS,NME,SAT	Enable/disable NMEA SAT (satellite tracking) message	90
\$PASHS,NME,TTT	Enable/disable output of time trigger message	92
\$PASHS,NME,VTG	Enable/disable NMEA VTG (velocity/course) message	93
RAW DATA COMMANDS		
\$PASHQ,AT2	Attitude, flags, PDOP data	57
\$PASHQ,ATT	Attitude data	58
\$PASHQ,DSO	Attitude and position data	59
\$PASHQ,MBN	Satellite measurement data	60
\$PASHQ,PBN	Position, velocity, DOP data	64
\$PASHQ,PSA	Position and attitude data	66
\$PASHS,RCI	Set raw data output message rate	95
\$PASHQ,SNV	Ephemeris data	69
\$PASHS,OUT,x,	Turns on the specified raw data output type.	93

Commands Detailed Descriptions

\$PASHQ,3DF

Queries for the configuration of the attitude parameters.

An example response is:

```
V12: +009.987 -004.554 +000.444
V13: +010.000 +010.000 +000.000
V14: +000.000 +014.000 +004.300
OFFSET ANG: +000.00 +00.00 +00.00
MAX CYCL: 0.150 SMOOTHING: N
MAX BRMS: 0.040 MAX ANGLE: 05
MAX MRMS: 0.005 SRCH RAT : 0.5
HKF: 999 000 1.0E-2 1.0E+0
PKF: 020 000 4.0E-2 1.0E+0
RKF: 020 000 4.0E-2 1.0E+0
STATIC: N
```

\$PASHQ,AT2

Queries the AT2 structure.

Table 5.2 lists the structure of the AT2 message in ASCII:

Table 5.2: AT2 Data in ASCII Format

Variable	Description
Header	\$PASHR,AT2
GPS Receive Time	Seconds of Week
Heading	Degrees
Pitch	Degrees
Roll	Degrees
Baseline rms error (BRMS)	Meters
Measurement rms error (MRMS)	Meters
Reset	Attitude Reset Flag
Last State	0—no search in progress >0—start from last completed state
Double Differences (each vector)	Each digit is the number of double differences for V12, V13, V14

Table 5.2: AT2 Data in ASCII Format (continued)

Variable	Description
PDOP	Position Dilution of Precision

Table 5.3 lists the structure of the AT2 message in Binary:

Table 5.3: AT2 Data in Binary Format

Variable	Bytes	Description
\$PASHR,AT2	11	Header
double head	8	Heading in degrees
double pitch	8	Pitch in degrees
double roll	8	Roll in degrees
double brms	8	BRMS in meters
double mrms	8	MRMS in meters
long tow	4	Seconds of Week in milliseconds
char reset	1	Attitude reset flag
char spare	1	Spare byte which is not used

\$PASHQ,ATT

Queries for the ATT structure. An example of real-time ASCII attitude output is:

**\$PASHR,ATT,153663.5,092.09,-
000.48,+000.04,0.0027,0.0103,0,000.48,+000.04,0.0027,0.0103,0**

Table 5.4 lists the format for Attitude Data in ASCII is:

Table 5.4: Attitude Data in ASCII Format

Variable	Description
Header String	\$PASHR,ATT
GPS Receive Time	seconds of week
Heading	Degrees
Pitch	Degrees
Roll	Degrees

Table 5.4: Attitude Data in ASCII Format (continued)

Variable	Description
MRMS (measurement RMS error)	Meters
BRMS (baseline RMS error)	Meters
Attitude Reset Flag	—

Table 5.5 lists the structure of the attitude output when it is transmitted in binary format.

Table 5.5: Attitude Data in Binary Format

Variable	Type (Bytes)	Description
\$PASHR,ATT,	11	Header
Head	Double (8)	Heading in degrees
Pitch	Double (8)	Pitch in degrees
Roll	Double (8)	Roll in degrees
BRMS	Double (8)	BRMS in meters
MRMS	Double (8)	MRMS in meters
Tow	Long (4)	Seconds-of-Week in milliseconds
Reset	Char (1)	Attitude reset flag
Spare	Char (1)	Spare byte which is not used
Unsigned int chksum	Short (2)	Checksum (sum of words from head to spare)
	Char (1)	Carriage return
	Char (1)	Line Feed
Total bytes	61	

\$PASHQ,DSO

Queries the DSO structure.

Table 5.6 lists the structure of the DSO message in ASCII.

Table 5.6: DSO Data in ASCII Format

Variable	Description
Header	\$PASHR,DSO

Table 5.6: DSO Data in ASCII Format (continued)

Variable	Description
GPS Receive Time	Seconds of Week
Heading	Degrees
Pitch	Degrees
Roll	Degrees
Baseline (rms error)	Meters
Reset	Attitude reset flag
Latitude	Degrees
Longitude	Degrees
Altitude	Meters

Table 5.7 lists the structure of the DSO message in Binary format:

Table 5.7: DSO Data in Binary Format

Variable	Bytes	Description
\$PASHR,DSO	11	Header
long tow	4	Seconds of Week in milliseconds
double head	8	Heading in degrees
double pitch	8	Pitch in degrees
double roll	8	Roll in degrees
double brms	8	BRMS in meters
char reset	1	Attitude reset flag
double lat	8	Latitude in degrees
double lon	8	Longitude in degrees
double alt	1	Altitude in meters
char spare	2	Spare byte which is not used

\$PASHQ,MBN

Queries the MBEN structure for all four antennas, in order: 1, 2, 3, 4.

Table 5.8 lists the format for MBEN in ASCII:

Table 5.8: MBEN Data in ASCII

Variable	Description
Header	indicates the type of data sent and allows a resynchronization with the data stream in case some bits were lost in transmission. It reports in the receiver configuration. (\$PASHR,MCA)
Structure identification	
Sequence tag	the time tag used to associate all structures with one epoch. It is in units of 50 ms and modulo 30 minutes (one count equals 50 ms and is reset every 30 minutes).
Number of remaining MBEN structures	structures remaining to be sent for that epoch.
Satellite data	
Satellite PRN number	PRN number for satellite in this message
Elevation	Satellite elevation angle in degrees. Values range from 0 to 90 degrees.
Azimuth	Satellite azimuth angle in degrees. Values range from 0 to 360 degrees.
Channel index	Internal ADU2 channel assignment (1 to 32)
Measurement data	
Warning flag	<p>Flag displaying status of receiver clock, carrier phase signal, and loss of lock.</p> <p>0 = everything OK</p> <p>bit 1 set (1) = satellite range approaching 1 ms offset</p> <p>bit 2 set (2) = clock offset is close to 1 ms</p> <p>bit 3 set (4) = polarity known flag less than 5</p> <p>bit 7 set (64)= receiver sometimes detects a false loss of lock. This bit is used to flag this condition, but it is not set in the B-file.</p> <p>bit 8 set (128) = loss of lock in previous epoch</p> <p>More than one bit may be set at the same time. For example, if bits 1,2, and 3 are set at the same time, the warning flag will be 7 (1 + 2 + 4).</p>

Table 5.8: MBEN Data in ASCII (continued)

Variable	Description
Measurement quality (Good/bad flag)	<p>indicates the quality in the measurement of position.</p> <p>0 = measurement not available and no additional data will be sent</p> <p>22 = code and/or carrier phase measured</p> <p>23 = code and/or carrier phase measured, and navigation message was obtained but measurement was not used to compute position.</p> <p>24 = code and/or carrier phase measured, navigation message was obtained, and measurement was used to compute position.</p>
Polarity known flag	<p>shows synchronization stage of receiver with NAV message</p> <p>0 = looking for data bit transition</p> <p>1 = looking for valid data bit</p> <p>2 = looking for subframe preamble</p> <p>3 = reading subframe ID</p> <p>4 = waiting for first subframe ID</p> <p>5 = receiver completely synchronized to NAV message</p>
Signal to noise ratio (signal/noise)	<p>high signal level with low noise level indicates good quality signal. Typical range 15 to 130.</p>
Phase quality indicator (%)	<p>to obtain this value, an equation using carrier phase and integrated doppler is computed. The result should be a value close to an integer. Values from 0 to 5 or 95 to 100 indicate good quality.</p>
Full carrier phase (in cycles)	<p>total number of cycles plus fraction of the range between the antenna and the satellite.</p>
Code transmit time (ms)	<p>length of time of code transmission (t or pseudorange). The satellite clock offset correction from GPS time is not included.</p>
Doppler (10^{-4} Hz)	<p>doppler measurement. To get doppler in units of Hz, divide this number by 10,000. Doppler is positive when the satellite is moving away from the antenna, negative if it is moving toward.</p>
Range smoothing correction (in meters)	<p>raw range minus smoothed range. The smoothed range is obtained by filtering the raw range with the integrated doppler.</p>
Range smoothing quality	<p>indicates how long the raw range has been smoothed.</p>
Footer	
Checksum (displayed in decimal)	<p>a bitwise exclusive OR (xor) on all bytes from the sequence tag to the checksum.</p>

Table 5.9 lists the format of the MBEN file in binary:

Table 5.9: MBEN Data in Binary

Field	Type (Bytes)	Contents
header	11	Indicates the type of data sent and allows a resynchronization with the data stream in case some bits were lost in transmission. Header reports the receiver configuration. C/A-only is: \$PASHR,MCA,
Block identification, 3 bytes		
sequence_tag	Unsigned short (2)	Sequence id number in units of 50 ms, Module 30 minutes
left	Unsigned Char (1)	Number of remaining MBEN structures to be sent for current epoch.
Satellite data, 4 bytes		
svprn	Unsigned Char (1)	Satellite PRN number.
elev	Unsigned Char (1)	Satellite elevation angle (degree).
az	Unsigned Char (1)	Satellite azimuth angle (degrees).
chnind	Unsigned Char (1)	Channel ID (1 to 12).
C/A code data block, 29 bytes		
warn	Unsigned char (1)	Warning flag
goodbad	Unsigned char (1)	Indicates quality of the position measurement.
polarity_know	Unsigned Char (1)	Indicates synchronization of receiver with NAV message.
ireg	Unsigned Char (1)	Signal to noise of satellite observation.
qa_phase 1	Unsigned Char (1)	Phase quality indicator: 0 to 5 and 95 to 100 are normal
full_phase	Double (8)	Full carrier phase measurements in cycles.
raw_range	Double (8)	Raw range to SV (in seconds), that is, receive_time - raw_range = transmit time
doppler	Long (4)	Doppler (10-4 Hz).
smoothing	Long (4)	32 bits where 31-24 are the smooth_count, unsigned and normalized, representing the amount of smoothing where: 1 is least smoothed 200 is most smoothed 0 is unsmoothed. Bits 23-0 are smooete_corr, where bit 23 (MSB) is the sign and the LSBs (22-0) are the magnitude of correction (centimeters)

Table 5.9: MBEN Data in Binary (continued)

Field	Type (Bytes)	Contents
Footer, 3 bytes:		
checksum	Unsigned Char (1)	Checksum, a bitwise exclusive OR (XOR) on all bytes from sequence_tag (just after header) to the byte before checksum.
	Char (1)	Carriage return.
	Char (1)	Line feed.

For a given channel expecting more than one block of data, when one of them is not yet available, its warning flag is set to 7 and the rest of the block is zeroed out.

\$PASHQ,PAR

Queries for the configuration of the general setup parameters.

An example response is:

```
SVS:YYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYY
POS:0 FIX:0 UNH:N PDP:40 HDP:04 VDP:04
ELM:10 RCI:000 MSV:3 SIT:???? SAV:N PDS:ON
ONE SECOND UPDATE: N   ALT: +00000.00
OUT: MBN PBN ATT SNV BIN   NMEA  RTCM
PRTA: -  -  -  -  -      -  -
PRTB: -  -  -  -  -      -  -
NMEA:GLL GXP GGA VTG GSN ALM MSG PAT HDT
PRTA: -  -  -  -  -      -  -
PRTB: -  -  -  -  -      -  -
NMEA:GSA GSV GRS GSS POS SAT RRE TTT SA4
PRTA: -  -  -  -  -      -  -
PRTB: -  -  -  -  -      -  -
PER:000
```

\$PASHQ,PBN

Queries for the PBEN data for one epoch.

Table 5.10 lists format for PBEN in ASCII:

Table 5.10: PBEN Data in ASCII Format

Variable	Description
Header	\$PASHR,PBN
Receive time	seconds of week when code was received
Station position	ECEF-X (meters)
Station position	ECEF-Y (meters)
Station position	ECEF-Z (meters)
Latitude	degrees, minutes ("-" before latitude indicates south)
Longitude	degrees, minutes ("-" before longitude indicates west)
Altitude	meters
Velocity in ECEF-X	m/sec
Velocity in ECEF-Y	m/sec
Velocity in ECEF-Z	m/sec
	Number of satellites used for position computation
Site name	4 characters (operator entered.)
PDOP	Position Dilution of Precision
HDOP	Horizontal Dilution of Precision
VDOP	Vertical Dilution of Precision
TDOP	Time Dilution of Precision

Example of an ASCII PBEN message:

**\$PASHR,PBN,101940.00,6345291.4,2166399.6,0547982.1,037:395
115,-122:24.6627,00025.6,010.36,015.92,002.19,6,30F1,3,2,2,1**

Table 5.10 lists format for PBEN in Binary format:

Table 5.11: PBEN Data in Binary Format

Field	Type (Bytes)	Contents
\$PASHR,PBN,	11	Header.
pbentime	Long (4)	GPS time in 10^{-3} seconds of the week when data was received.
sitename	Char (4)	4-character site name (operator entered)

Table 5.11: PBEN Data in Binary Format (continued)

Field	Type (Bytes)	Contents
navx	Double(8)	Station position: ECEF-X
navy	Double(8)	Station position: ECEF-Y
navz	Double(8)	Station position: ECEF-Z
navt	Float (4)	Clock offset (meters).
navxdot	Float (4)	Velocity in ECEF-X (m/sec)
navydot	Float (4)	Velocity in ECEF-Y (m/sec)
navzdot	Float (4)	Velocity in ECEF-Z (m/sec)
navtdot	Float (4)	Clock drift.
pdop	Unsigned short (2)	Position Dilution of Precision
checksum	Unsigned short (2)	Checksum word (sum of words from pbentime to PDOP)
<CR>	Char (1)	Carriage return.
<LF>	Char (1)	Linefeed.
Total bytes	69	

\$PASHQ,PRT

Queries for the port being used and the baud rate.

Example response is:

\$PASHR,PRT,A,5

This response indicates that the port is A and the baud rate is 9600 based on the baud rate code of 5. Refer to Table 5.40 for baud rate codes.

\$PASHQ,PSA

Requests a PSAT structure. Table 5.12 lists format for PSAT in ASCII:

Table 5.12: PSAT Data in ASCII Format

Variable	Description
Header	\$PASHR,PSA
Receive Time	GPS seconds of week
X-position	Earth-centered, Earth-fixed,m
Y-position	ECEF, m
Z-position	ECEF, m
X-Velocity	ECEF, m/sec
Y-velocity	ECEF, m/sec

Table 5.12: PSAT Data in ASCII Format (continued)

Variable	Description
Z-velocity	ECEF, m/sec
PDOP	Position Dilution of Precision
SVs	Number of Satellites used
Position Mode	1: Standalone 2: Differential
Yaw angle	(Heading-COG), degrees
heading	Degrees
Pitch	Degrees
Roll	Degrees
Attitude State	0: Ambiguities fixed, 1: Ambiguities not fixed
Position State	0: Normal 1: No position computed

Table 5.13 lists the structure of the PSAT message in Binary:

Table 5.13: PSAT Data in Binary Format

Variable	Bytes	Description
\$PASH,PSA	11	Header
long tow	4	Seconds of Week in milliseconds
double navx	8	ECEF-X in meters
double navy	8	ECEF-Y in meters
double navz	8	ECEF-Z in meters
float navxdot	4	ECEF-X vel in m/s
float navydot	4	ECEF-Y vel in m/s
float navzdot	4	ECEF-Z vel in m/s
float navt	4	Clock offset in meters
float navtdot	4	Frequency off in m/s
short pdop	2	Position Dilution of Precision
char nsvs	1	Number of satellites used
char posmode	1	Position Mode
float yaw	4	Yaw angle in degrees
float head	4	Heading in degrees
float pitch	4	Pitch in degrees
float roll	4	Roll in degrees

Table 5.13: PSAT Data in Binary Format (continued)

Variable	Bytes	Description
char attitude state	1	Attitude state
char position state	1	Position state
unsigned int checksum	2	Checksum (sum of words from head to spare)
char	1	Carriage return
char	1	Line Feed
Total Bytes	72	

\$PASHQ,RID

Queries for the receiver version ID.

Example:

\$PASHR,RID,38,00,AB00

This response indicates that the receiver type is 38 for ADU, the firmware version is AB00.

\$PASHQ,RIO

Queries for the product type, receiver version, sensor version, any options included as well as the receiver serial number.

Example:

\$PASHR,RIO,ADUII-1,AB00,1E8, -----,101_-----

This response indicates that the product type is ADUII-1, the firmware version is AA00, the sensor version is 1E8, there are no options, and the receiver serial number is 101.

\$PASHQ,RTC

Queries the differential mode parameters, and is only available if one of the differential options are installed.

Example Response:

```

SYNC: *      QA:000%   AGE:+000
STH:0      QAF:999   MAX AGE:0120
REM STI:0000 BASE STI:0123
AUTODIFF: OFF
    
```

“SYNC” indicates whether synchronization has taken place to the differential corrections sent from the base station. “*” indicates synchronization. “*?” indicates corrections are received but have not yet been synchronized. A blank indicates no

synchronization. “QA” is the data quality indicator percentage. “AGE” is the current age of the differential corrections being used for the position solution.

Table 5.14 describes each item of the message.

Table 5.14: RTC Message Structure

Item	Description
STATUS	Asterisk (*) denotes sync to last received RTCM message between base and remote stations (remote only).
STID	Station identification received from the base station. 4 characters, 0 through 1023
AGE	In base mode, displays the elapsed time between the beginning of transmission of message types 1, 9, 18/19. In remote mode, displays the age of the received messages in seconds.
QA	Displays the communication quality factor between base and remote. Defined as 100 x number of good measurements, divided by total number of messages. Remote only.
MAX	Specifies the maximum age, in seconds, required for a message to be used (remote only). Range is 0 through 999, 60 is default.
QAF	Sets the criteria to be applied when evaluating the quality of communication between base and remote. Remote only. Range is 0 through 999, default is 100.

\$PASHQ,SNV,x

Requests a SNAV ephemeris data response message on port x.

Example: Display SNV on port A

\$PASHQ,SNV,a

The SNAV data (ephemeris data) is output only in binary. Its record definitions and the units for orbit data conform to the GPS-ICD-200 standard. Table 5.15 lists the structure.

Table 5.15: SNAV Data

Field	Type (Bytes)	Contents
\$PASHR,SNV,	11	Header.
wn;	Short (2)	GPS week number.
tow;	Long (4)	Seconds of GPS week.
tgd;	Float (4)	Group delay (sec).
aodc;	Long (4)	Clock data issue.
toc;	Long (4)	(sec).

Table 5.15: SNAV Data (continued)

Field	Type (Bytes)	Contents
float	af2	Clock: (sec/sec ²)
float	af1	Clock (sec/sec)
float	af0	Clock (sec)
aode;	Long (4)	Orbit data issue.
deltan;	Float (4)	Mean anomaly correction (semi-circle/sec).
m0;	Double (8)	Mean anomaly at reference time (semi-circle).
e;	Double (8)	Eccentricity.
roota;	Double (8)	Square root of semi-major axis (meters p)
toe;	Long (4)	Reference time for orbit (sec).
cic;	Float (4)	Harmonic correction term (radians).
cr;	Float (4)	Harmonic correction term (meters).
cis;	Float (4)	Harmonic correction term (radians).
crs;	Float (4)	Harmonic correction term (meters).
cuc;	Float (4)	Harmonic correction term (radians).
cus;	Float (4)	Harmonic correction term (radians).
omega0;	Double (8)	Lon of Asc. node (semi-circles).
omega;	Double (8)	Arg. of Perigee (semi-circles).
i0;	Double (8)	Inclination angle at reference time (semi-circles).
omegadot;	Float (4)	Rate of right Asc. (semi-circles per sec).
idot;	Float (4)	Rate of inclination (semi-circles per sec).
accuracy;	Short (2)	(coded).
health;	Short (2)	(coded).
fit;	Short (2)	Curve fit interval (coded).
prnnum;	Char (1)	(SV PRN number -1)
res;	Char (1)	Reserved byte.
checksum;	Unsigned short (2)	Checksum word (sum of words from wn to res).
	Char (1)	Carriage return.
	Char (1)	Linefeed.
Total bytes	145	

\$PASHQ,STA

Queries for the current satellite tracking status for each antenna.

Example response is:

```
TIME: 15:46:36 UTC
-- ANTENNA 1 --
PRN:  26 07 15 19 31 02 .. .. . 27 16 ..
SNR:  34 71 15 72 28 68           55 19
-- ANTENNA 2 --
PRN:  07 18 31 19 26 15 16 02 .. .. 27 ..
SNR:  62 08 24 56 35 22 21 62           37
-- ANTENNA 3 --
PRN:  26 15 19 16 07 31 02 27 .. . . . .
SNR:  44 26 68 26 69 2 64 52
-- ANTENNA 4 --
PRN:  02 07 15 19 16 26 31 .. 27 .. . . .
SNR:  70 63 32 71 29 33 20           57
```

This response gives the UTC time (after the UTC-GPS time shift has been received from a satellite, GPS time before) and satellites locked on each of the four antennas.

Also shown are the signal-to-noise ratios of the satellites being tracked. Will give GPS time until GPS/UTC offset is received from satellite(s).

\$PASHQ,TST

Queries the results from the power-up initialization test.

Example response is:

```
$PASHR, TST, 00F.
```

Each field in the response “00F” represents, in order, the EPROM checksum test, the internal RAM test, and the 32-channel initialization. A “0” (for pass) indicates that the test was completed successfully. An “F” indicates that the particular test failed. In the example above, the EPROM checksum test and the internal RAM test passed, but the channel initialization failed.

If one or more of the above tests fail, turn the power off, wait a few seconds, and turn the power on again. If any of the tests still do not complete successfully, issue the command \$PASHS,INI and check for self-test results again. If the problem persists, call the local Ashtech representative for repair.

\$PASHS,3DF,ANG,dd

Sets the maximum angle (ANG) above the horizon that the vehicle (or platform) is expected to tilt (pitch or roll) in degrees. The default is 15. This narrows down the

ambiguity search region when the 3DF ADU first tries to determine the attitude therefore, allowing a quicker time-to-first-fix for the attitude solution.

\$PASHS,3DF,CYC,d.ddd

Sets the phase error (CYC) in cycles (1 cycle = 19 cm). The default is 0.200. The maximum is 0.500.

\$PASHS,3DF,FLT,Y

Sets the first order low-pass smoothing filter that provides acceptable results for vehicles experiencing low dynamics such as a ship. Medium to high dynamics, such as those experienced by aircraft, may introduce too much lag in the output attitude for this filter.

x = Y turns filter on. x = N turns filter off default on.

\$PASHS,3DF,HKF,uuu,vvv,w.w,sx,y.y,sz

Identifies the heading Kalman filter parameters (HKF).

Table 5.16: Kalman Filter Parameters

Field	Description
uuu	is the value of tau (default is 020)
vvv	is the value of To (default is 000)
w.w	is the root decimal value for Q (default is 1.0)
sx	is the signed exponential value for Q (default is -1)
y.y	is the root decimal value for R (default is 1.0)
sz	is the signed exponential value for R (default is +0)

\$PASHS,3DF,MXB,d.ddd

Sets the maximum baseline rms error (BRMS) in meters. The default is 0.035. The maximum is 0.500. If the error for an individual baseline exceeds this setting, the Kalman filter resets and the ambiguity search re-starts.

\$PASHS,3DF,MXM,d.ddd

Sets the maximum phase measurement rms error (MRMS) in meters. The default is 0.005. The maximum is 0.050 and the minimum is 0.001m.

\$PASHS,3DF,OFS,Sddd.dd,Sdd.dd,Sdd.dd

Sets is the offset angle in degrees. Sddd.dd is the signed heading offset angle, Sdd.dd is the signed pitch offset angle, and Sdd.dd is the signed roll offset angle.

The offset rotation angles (in degrees) align the 3DF attitude measurements given to the desired vehicle coordinate system. These rotation angles must be determined by some other accurate measurement device.

OFFSETS: heading(H), pitch(P), roll(R)

The offset rotation angles are normally 0.0. These numbers should not be changed unless you have a case such as the following:

Occasionally mounting restrictions may require the antennas to be located from one another such that the surveyed relative antenna position vectors (from file BRFVEC.XYZ) do not directly provide the vehicle's angular rotations (heading, pitch, roll). In this situation, some other form of accurate measurement capability is required to measure the offset angles (for example, a tape measure or a gyro-theodolite).

For example, suppose that Antenna 1 and Antenna 2 could not be mounted exactly along the heading direction of the vehicle and you chose the vector from Antenna 1 to Antenna 2 to provide heading information. The installation software can determine a 1-2 relative antenna position vector, but the heading offset angle must be determined with another precise measurement technique.

\$PASHS,3DF,PKF,uuu,vvv,w.w,sx,y.y,sz

Sets the pitch Kalman filter parameters.

Three two-state Kalman filters are implemented in the ADU software to help predict an approximate attitude of the vehicle at the current epoch. They are a heading and heading rate filter, a pitch and pitch rate filter, and a roll and roll rate filter. Several Kalman filter variables for heading, pitch, and roll are described below:

- tau: Correlation time (sec) (default values are 999, 20, 20) - Any number greater than 500 or 000 implies that the system model is an integration of a random-walk process (or a constant velocity model).
- To: Oscillation period (seconds) (default values are 0, 0, 0.) A zero implies that no oscillation exists. For ship installations, an oscillation period exists for both pitch and roll. This information aids the Kalman filter.
- Q: Process noise power spectral density [(radian/sec)²*sec] (Defaults are 1.0e-2, 4.0e-2, 4.0e-2). The default values are valid for low to medium vehicle dynamics. High dynamics require higher values, such as 1.0.
- R: Measurement noise scale factor (defaults are 1, 1, 1)
- These variables may need tuning depending on the vehicle dynamics. When set properly, the variables help the Kalman filter give a good estimate of

attitude for the current epoch using both past and present code phase measurements and previous carrier phase measurements.

\$PASHS,3DF,RAT,d.d

Sets the ambiguity search ratio. The default is 0.5. The minimum is 0.1 and the maximum is 5.0.

A search ratio is used in the following equation helps set the boundaries for the initial ambiguity search by defining the accuracy of the relative position estimates.

$$\text{Position Accuracy} = 2.0 * (\text{RAT} * \text{PDOP}) * 3.0$$

where POSITION ACCURACY is a 95% confidence bound that the true relative position will lie within the estimate, RAT is the search ratio, and PDOP is calculated by the geometry of the visible satellites. Since PDOP can climb to high numbers during periods of poor geometry, the POSITION ACCURACY value is limited to a maximum of 20.

\$PASHS,3DF,RKF,uuu,vvv,w.w,sx,y.y,sz

Sets the roll Kalman filter parameters described below:

Table 5.17: Kalman Filter Parameters

Field	Description
uuu	is the value of tau (default is 020)
vvv	is the value of To (default is 000)
w.w	is the root decimal value for Q (default is 1.0)
sx	is the signed exponential value for Q (default is -1)
y.y	is the root decimal value for R (default is 1.0)
sz	is the signed exponential value for R (default is +0)

\$PASHS,3DF,RST

Restarts the Kalman filters from time zero. This means that the Kalman filters do not use any previous information in attitude prediction for the current epoch.

After Kalman reset, ten seconds of relative antenna position estimation are required before the filters have a good attitude prediction and the initial ambiguity search is started.

For antenna separations less than 3.0 meters, there is no delay before the ambiguity search begins.

\$PASHS,3DF,V12,Sddd.ddd,Sddd.ddd,Sddd.ddd

Sets the relative position vector from antenna 1 to antenna 2. S is the sign (+/-), and ddd.ddd are the X, Y, and Z position vector components in meters.

\$PASHS,3DF,V13,Sddd.ddd,Sddd.ddd,Sddd.ddd

Sets the relative position vector from antenna 1 to antenna 3. S is the sign (+/-), and ddd.ddd are the X, Y, and Z position vector components in meters.

\$PASHS,3DF,V14,Sddd.ddd,Sddd.ddd,Sddd.ddd

Sets the relative position vector from antenna 1 to antenna 4. S is the sign (+/-), and ddd.ddd are the X, Y, and Z position vector components in meters. Initially, this vector is +000.000.

\$PASHS,ALT,Sxxxxx.xx

Sets the altitude of antenna 1, where Sxxxxx.xx is the altitude and S is the sign (+ or -). This is used in conjunction with Position Mode 1, 2, and 3.

\$PASHS,ELM,dd

Sets the elevation mask in degrees. The default is 10.

\$PASHS,FIX,d

Sets the altitude-fixed mode for the position computation.

0 (default) - indicates to use the most recent computed altitude which can be the last one computed when VDOP is less than VDOP mask, or the one entered by ALT.

1 - indicates to always use the altitude entered by the ALT input command.

\$PASHS,HDP,dd

Sets the HDOP (horizontal dilution of precision) mask for the position computation. A position is not computed if the HDOP rises above this number. The default is 4.

\$PASHS,INI

Resets the internal memory of the receiver and resets all configuration parameters to their defaults. Wait 20 seconds after issuing this command before sending subsequent commands.

\$PASHS,MSV,dd

Sets the minimum number of satellites to record. The default is 3.

\$PASHS,NME,ALL,x,OFF

Turns off all the NMEA output messages on Port x at once.



The NMEA message output is always enabled. There is no need to send \$PASHS,OUT,A,NMEA. To turn off all NMEA messages at once send \$PASHS,NME,ALL,X,OFF.

\$PASHS,NME,ALM,x,on/off

Turns on/off the almanac output message or specified port.

\$GPALM

NMEA response message in which each sentence contains the almanac for each satellite in the GPS constellation. The output is in HEX format.

Format:

**\$GPALM,aa,bb,cc,ddd,ee,fff,gg,hhhh,iiii,jjjjj,kkkkkk,ddmm.mm
m,mmmmmmmm,nnn,ooo,<CR> <LF>**

where Table 5.18 lists the structure:

Table 5.18: Almanac Message

Field	Description
aa	Total number of messages
bbb	Message number
cc	Satellite PRN number
ddd	GPS week
ee	SV health
fff	Eccentricity
gg	Almanac reference time (seconds)
hhhh	Inclination angle (semicircles)
iiii	Rate of ascension (semicircles/sec)
jjjjj	Root of semimajor axis
kkkkkk	Argument of perigee (semicircle)
ddmm.mmm	Longitude of ascension mode (semicircle)
mmmmmm	Mean anomaly (semicircle)
nnn	Clock parameter (seconds)
ooo	Clock parameter (sec/sec)

Example:

**\$GPALM,20,01,28,674,00,5C1E,1D,09BC,FD30,A 10D27,BBD4EB,
8CB47B,E35E03,FFA,000 <CR><LF>**

\$PASHS,NME,DAL,(x), ON/OFF

This message displays the NMEA almanac message in decimal almanac format.

Format:

**\$PASHS,NME,DAL,ss,hhh,e.eeeeeeeE±99,tttttt,i.iiiiiiE±99,
±a.aaaaaaaE±99,±m.mmmmmmmE±99,±c,ccccccE±99,
c.cccccccE±99, www**

where the fields are defined in Table 5.19.

Table 5.19: NMEA DAL Structure

Field	Description
ss	Satellite PRN number 1 through 32
hhh	Satellite health 0 through 255
e.eeeeeeeE±99	Eccentricity 9.999999E±99
tttttt	Reference time for orbit 0 through 9999999 seconds
i.iiiiiiE±99	Inclination angle 0 through 9.999999E±99 semicircles
±a.aaaaaaaE±99	Omegadot, rate of right ascension ±9.999999E±99 semicircles/sec
r.rrrrrrE±99	Roota, square root of semi-major axis 0 through 9.999999E±99 meters 1/2
±l.llllllE±99	Omega0, longitude of right ascension node ±9.999999±99
±a.aaaaaaaE±99	Omega, argument of perigee ±9.999999±99 semicircles
±m.mmmmmmmE±99	M ₀ mean anomaly at reference time ±9.999999E±99
±c,ccccccE±99	af ₀ clock parameter ±9.999999E±99 seconds
c.cccccccE±99	af ₁ clock parameter 0 through 9.999999E±99 seconds/second
www	GPS week number wn 3 digits

\$GPDAL

NMEA response almanac message in decimal almanac format.

Example:

**\$GPDAL,14,00,5.2795410E-03,032768,3.065721E-01,-2.4811015E-
09,5.1536948E03,5.8827317E-01,8.8243234E-01,-8.8568139E-
01,8.201599E-05,7.2759576E-12,571**

In decimal almanac (DAL) format, the + sign is suppressed for a positive value in the power of E. The spaces are for readability. Note that if this message is enabled at the same time ALM is, ALM takes precedence and DAL is not output.

\$PASHS,NME,GGA,x, ON/OFF

Enable/disable NMEA GPS position response message on port x, where x is either port A or B, and y is ON or OFF. This message does not output unless position is computed.

Example: Enable GGA on port A

\$PASHS,NME,GGA,A,ON<Enter>

\$GPGGA

NMEA response message for GGA (GPS position):

Format:

**\$GPGGA,hhmmss.ss,ddmm.mmmmm,s,dddmm.mmmmm,s,n,q
q,pp.p,saaaa.aa,M,±xxxx.xx,M,sss,aaaa *cc<CR><LF>**

where Table 5.20 lists the structure:

Table 5.20: \$GPGGA Response Messages

Field	Description
hhmmss.ss	Current UTC time, hhmmss, of position fix in hours, minutes and seconds.
ddmm.mmmmm	Latitude component of position, ddmm.mmmmm, in degrees, minutes and fraction of minutes.
s	Latitude sector, s = N - North, s = S - South.
dddmm.mmmmm	Longitude component of position, dddmm.mmmmm, in degrees, minutes and fraction of minutes.
s	Longitude sector, s = E - East, s = W - West.
n	Raw/differential position, n n = 1 - Raw; position is not differential corrected n = 2 - position is deferentially corrected. n = 9 - position computed using almanac information
qq	qq = number of SVs used in position computation.
pp.p	HDOP - horizontal dilution of precision, pp.p = 00.0 to 99.9.
saaaa.aa	GPS Sensor-computed altitude, saaaa s = "+" or "-" aaaaa = Altitude 00000 to 30000 meters above WGS-84 reference ellipsoid. For 2-D position computation this item contains the altitude used to compute the position computation.

Table 5.20: \$GPGGA Response Messages (continued)

Field	Description
M	Altitude units, M = meters.
±xxxx.xx	Geoidal separation (value output only if Geoidal Height option (G) is installed in the receiver).
M	Geoidal separation units, M = meters.
sss	Age of the differential corrections, sss, in seconds.
aaaa	Base STID, aaaa.



If position is not being computed, NMEA messages are still output using the information of the last good computed position. Also, if the number of SVs is less than MSV, no message is output.

Example:

```
$GPGGA,015454.00,3723.2851,N,12202.2385,W,1,4,03.8,+00012,
M,+0000.0,M,002,0123 <CR><LF>
```

\$PASHS,NME,GLL,x, ON/OFF

Enable/disable the NMEA message for latitude and longitude of present vessel position, time of position fix and status.

\$GPGLL

NMEA response message for latitude and longitude.

Format:

```
$GPGLL,xxxx.xxxx,N,xxxxx.xxxx,W,hhmmss.ss,A <CR> <LF>
```

where Table 5.21 lists the structure:

Table 5.21: Latitude/Longitude for Position

Fields	Description
ddmm.mmmm	Latitude in degrees, minutes
N/S	N = north, S = south
dddmm.mmmm	Longitude in degrees, minutes -
E/W	W = west, E = east
h,m,s,h,s	UTC of position (hours, minutes, seconds, hundredths of seconds)
	Status, A = valid, V = invalid

Example:

\$GPGLL,3723.2810,N,12202.2410,W,180236.14,A <CR> <LF>

\$PASHS,NME,GRS,x, ON/OFF

Enables/disables the NMEA satellite range residual response message to port x, where x is A, B, or C, and y is ON or OFF. This message is not output unless a position is computed.

Example: Enable GRS message on port C

\$PASHS,NME,GRS,C,ON followed by output command

\$PASHS,OUT,x,NMEA where x is the output port.

\$GPGRS

NMEA response message for GRS (satellite range residual).

Format:

\$GPGRS,hhmmss.ss,a,sxx.x,syy.y.....<CR><LF>

where Table 5.22 lists the structure:

Table 5.22: Satellite Range Residuals

Field	Description
hhmmss.ss	UTC of position (hours, minutes, seconds, hundredths of a second)
a	Mode used to compute range residuals 0: Residuals were used to compute the position given in the matching GGA line 1: Residuals were recomputed after the GGA position was computed
sxx.x	Satellite 1 range residual in meters
syy.y	Satellite 2 range residual in meters

Example:

**\$GPGRS,184958.5,1,+00.4,+02.1,+03.0,-01.8,+02.2,-05.9
<CR><LF>**

\$PASHS,NME,GSA,x, ON/OFF

Enable/disable DOP and active satellite message to be sent out to the serial port, where x is port A or B, and y is ON or OFF. This message is output even if a position is not computed.

Example: Enable GSA message on port B

\$PASHS,NME,GSA,B,ON<Enter>

\$GPGSA

NMEA response message for DOP and active satellite.

Format:

\$GPGSA,a,b,cc,dd,ee,ff,gg,hh,i.i,j,j,k.k <CR><LF>

where Table 5.23 lists the structure:

Table 5.23: DOP and Satellites Being Tracked

Field	Description
a	Mode: M=manual, A=automatic
b	Mode: 1=fix not available, 2=2D, 3=3D
cc,dd,ee,ff,gg	Satellites used in solution (null for unused fields)
i.i	PDOP
j.j	HDOP
k.k	VDOP

Example:

\$GPGSA,M,3,27,19,26,02,15,07,2.1,1.3,1.6 <CR><LF>

\$PASHS,NME,GSN,x, ON/OFF

Enable/disable the signal strength/satellite number response message on port x, where x is either port A or B, and y is ON or OFF. This message is output even if a position is not computed.

Example: Enable GSN message on port B

\$PASHS,NME,GSN,B,ON<Enter>

\$GPGSN

NMEA response message for GSN signal strength/satellite number.

Format:

\$GPGSN,aa,bb,ccc,xx,xxx,xx,xxx... <CR> <LF>

where Table 5.24 lists the structure:

Table 5.24: SNR of GPS Satellites Being Tracked

Fields	Description
aa	Number of svcs currently being tracked. When 0, message terminates after this field. For a nonzero count, the subsequent fields give each satellite number and its SNR.
bb	Satellite number

Table 5.24: SNR of GPS Satellites Being Tracked (continued)

Fields	Description
cc	Signal-to-noise ratio for satellite
...	Next Satellite. Number and Signal to Noise ratio.
dd	RTCM age

Example:

\$GPGSN,04,19,038,14,136,18,117,15,036,999 <CR> <LF>

\$PASHS,NME,GSS,x, ON/OFF

Enable/disable NMEA satellite tracked and DOP messages.

\$GPGSS

NMEA response message for satellite used.

Format:

\$GPGSS,0,a,b,cc,dd.d <CR><LF>

where Table 5.25 lists the structure:

Table 5.25: Satellites Tracked and PDOP Message

Field	Description
0	Always "0"
a	Flag to indicate whether an altitude fixed (2) or 3-dimensional (3) position was computed
b	Number of satellites used in the position computation
cc	Satellite PRN number
ddd	PDOP

Example:

\$GPGSS,0,3,6,20,13,24,07,09,12,02.6 <CR><LF>

\$PASHS,NME,GSV,x, ON/OFF

Number of SVs in view, PRN numbers, elevation, azimuth and SNR value. Four satellites maximum per transmission, additional satellite data sent in second or third message. Total number of messages being transmitted and the number of the message being transmitted is indicated in the first two fields.

\$GPGSV

NMEA response message for GSV (satellites in view).

Format:

**\$GPGSV,a,b,cc,dd,ee,fff,gg,hh,ii,jjj,kk,ll,mm,nnn,oo,pp,qq,rrr,ss
<CR><LF>**

where Table 5.26 lists the structure:

Table 5.26: Satellites Tracked

Field	Description
a	Total number of messages (1 to 3)
b	Message number (1 to 3)
cc	Total number of satellites in view
dd	Satellite PRN number
ee	Elevation (degrees)
fff	Azimuth (degrees)
gg	SNR (0 to 99 dB), null when not tracking
hh	Same as 4,5,6,7 but for second satellite
ii	Same as 4,5,6,7 but for third satellite
jjj	Same as 4,5,6,7 but for fourth satellite

Example:

**\$GPGSV,2,1,06,23,53,041,99,28,55,273,99,11,24,326,55,17,36,10
1,68 <CR><LF>**

\$PASHS,NME,GXP,x, ON/OFF

Enable/disable position horizontal message on port x, where x is either port A or B, and y is ON or OFF. This message is not output unless position is computed.

Example: Output GXP message on port B

\$PASHS,NME,GXP,B,ON<Enter>

\$GPGXP

NMEA response message for GXP (position horizontal).

Format:

\$GPGXP,hhmmss.ss,aaa.aaa,N/S,bbbb.bbbb,E/W <CR> <LF>

where Table 5.27 lists the structure:

Table 5.27: Present Position Fix with Time of Fix

Fields	Description
hhmmss.ss	UTC of position (hours, minutes, seconds, hundredths of second)
aaaa.aaaa	Latitude (in degrees, with decimal minutes) - ddmm.mmmm
N/S	North or South of fix
bbbb.bbbb	Longitude (in degrees, decimal minutes) - dddmm.mmmm
E/W	East or West of fix



If position is not computed, NMEA messages are output using the information of the last good computed position. Also, if the number of SVs is less than MSV, no message is output.

Example:

\$GPGXP,015324.00,3723.2833,N,12202.2430,W<CR> <LF>

\$PASHS,NME,HDT,x, ON/OFF

Enable/disable true vessel heading in degrees true produced by any device or system producing true heading.

\$GPHDT

NMEA response message for true heading.

Example:

\$GPHDT,xxx.xxx,T <CR><LF>

where Table 5.28 lists the structure:

Table 5.28: HDT: Heading

Field	Description
xxx.xxx	Vehicle heading in degrees
T	“T” for true north reference

\$PASHS,NME,MSG,x, ON/OFF

Enable/disable NMEA message containing RTCM reference (base) station message types 01, 03, 09, and 16 on port x, where x is port A or B, and y is ON or OFF.



Unless the ADU2 is sending or receiving differential corrections, this command is ignored.

Example: Enable MSG on port A

\$PASHS,NME,MSG,A,ON<Enter>

\$GPMSG

NMEA response message for MSG (RTCM) message

Message type 1 format: (output at a rate equal to PER)

**\$GPMSG,aa,bbbb,cccc.c,d,e,fff,gggggg,h,ii,±jjjj.jj,±k.kkk,III,.....<CR>
<LF>**

Message type 3 format: (Only output when new message received from the RTCM base. The PER setting does not affect the output rate.)

**\$GPMSG,aa,bbbb,cccc.c,d,e,fff,hmmss,±gggggg.gg,±iiii.ii,±jjjjj.jj
<CR><LF>**

Message type 16 format:

\$GPMSG,aa,bbbb,cccc.c,d,e,fff,hmmss,gggggg.... <CR><LF>

where Table 5.29 lists the structure:

Table 5.29: RTCM Message

Fields	Description
a	RTCM message type
bbbb	Station Identifier
cccc.c	Z count in seconds and tenths
d	Sequence number
e	Station health
fff	Total number of characters after the time field, including checksum, CR/LF
hmmss	UTC time of position fix (hours, minutes, seconds)
ggggggg	For type 1 only: user differential range error 9 (UDRE)
ggggg.g	For type 3 only: station X component
ggggg.g	For type 16 only: text
ii	For type 1 only: satellite PRN number
ii	For type 3 only: station Y component
j	For type 1 only: pseudo range correction (PRC) in meters
j	For type 3 only: station Z component
k	For type 1 only: range rate correction (RRC) in meters/sec
l	For type 1 only: issue of data (IODE)

Table 5.29: RTCM Message (continued)

Fields	Description
m	For type 1 only: same as 8,9,10,11,12 but for next SVs

Examples:

**\$GPMMSG,01,0000,2220.0,1,0,127,003702,2,12,-0081.30,
+0.026,235,2,13,+0022.86,+0.006,106,2,26,-0053.42,-0.070,155,
2,02,+0003.56,+0.040,120,2,27,+0047.42,-0.004,145 <CR> <LF>**

**\$GPMMSG,03,0000,1200.0,7,0,038,231958,-2691561.37,
4301271.02,+3851650.89 <CR> <LF>**

**\$GPMMSG,16,0000,1209.6,5,0,038,232008,THIS IS A MESSAGE
SENT FROM BASE <CR> <LF>**

\$PASHS,NME,PAT,x, ON/OFF

Enable/disable Ashtech proprietary position and altitude message.

\$GPPAT

Response message for Ashtech proprietary position and altitude message.

Format:

**\$GPPAT,hhmmss.s,ddmm.mmmm,N,dddmm.mmmm,W,+/-
aaaaa.aa,bbb.bbb,+/-eee.ee,+/-fff.fff.fff,g.gggg,h<CR> <LF>**

where Table 5.30 lists the structure:

Table 5.30: Position and Attitude Message

Field	Description
hhmmss.s	UTC of position (hours, minutes, seconds, tenths of second)
ddmm.mmmm	GPS latitude in degrees (d) and minutes (m): ddmm.mmmm
N	Latitude north (N) or south (S)
dddmm.mmmm	GPS longitude in degrees (d) and minutes (m) dddmm.mmmm
W	Longitude east (E) or west (W)
aaaaa.aa	Altitude in meters
bbb.bbb	Heading in degrees
eee.ee	Pitch in degrees
fff.fff.fff	Roll in degrees
h	Attitude phase measurement rms error, MRMS (meters)

Table 5.30: Position and Attitude Message (continued)

Field	Description
11	Attitude baseline length rms error, BRMS (meters)
12	Attitude reset flag (0:good attitude, 1:rough estimate or bad attitude)

Example:

**\$GPPAT,223924.0,3922.2871,N,12159.4503,W,+/-00253.2,121.673,
+/-002.59,+/-004.61,0.0031,0.0205,0<CR> <LF**

\$PASHS,NME,PER,ddd

Sets the send interval time in NMEA messages. The send interval for NMEA messages is unaffected by the RCI or ONE settings. Default is 000, corresponding to a half-second rate.

\$PASHS,NME,POS

Enable/disable time, position, speed, and DOP message.

\$PASHR,POS

Response message indicating the time, position, speed, and DOP values.

Format:

**\$PASHR,POS,a,bb,hhmmss.ss,cccc.cccc,N,dddd.dddd,W,+ffff,
g,iii,jjj,kk,ll,mm,oo,pp,qqqq <CR><LF>**

where Table 5.31 lists the structure:

Table 5.31: Position Messages

Field	Description
a	Raw/differential pos 0=raw position 2=differentially connected
bb	# of SVs used to compute position
hhmmss.ss	UTC of position (hours, minutes, seconds, hundredths of a second)
cccc.cccc	GPS latitude
N	Latitude north (N) or south (S)
dddd.dddd	GPS longitude
W	Longitude east (E) or west (W)
ffff	Altitude in meters

Table 5.31: Position Messages (continued)

Field	Description
g	Altitude of external encoder (Null)
iii	Course over ground (COG) in degrees
jjj	Speed over ground (SOG) in knots
kk	Vertical velocity in meters/sec
ll	PDOP
mm	HDOP
oo	VDOP
pp	TDOP
qqqq	Receiver version ID (ASCII characters)

Example:

```
$PASHR,POS,0,6,185006.50,3722.3866,N,12159.8386,W,-00006,,  
164,000,000,02,01,02,01,1A11 <CR><LF>
```

\$PASHS,NME,RRE,x, ON/OFF

Enables/disables the satellite residual and position error message to port x, where x is A, B, or C and y is ON or OFF. This message is not output unless a position is computed.

Example: Enable RRE message on port A

```
$PASHS,NME,RRE,A,ON followed by output command  
$PASHS,OUT,x,NMEA where x is the output port.
```

\$GPRRE

NMEA response message for RRE (satellite residual and position error).

Format:

```
$GPRRE,qq,ss,sxxx.x,...hhhh.h,vvvv.v*c
```

A range residual (xxx.x) is computed for each satellite (ss) used in position computation. Residuals and position errors not computed unless at least 5 satellites

are used in position computation. The fields in the RRE message are defined in Table 5.32.

Table 5.32: RRE Structure

Field	Description
qq	Number of satellites used to compute position
ss	PRN number for each of the satellites used in position computation
s,xxx.x.....	+ or - and xxx.x = range residuals magnitude in meters for each satellite used in position computation
hhhh.h vvvv.v	Last 2 fields: hhhh.h = horizontal RMS position error in meters vvvv.v = vertical RMS position error in meters

Example:

**\$GPRRE,05,18,+000.2,29,+000.2,22,-000.1,19,-000.1,28,
+000.5,0002.0,0001.3*76**

where Table 5.33 lists the structure:

Table 5.33: Typical RRE Response

Item	Description
\$GPRRE	Header
05	Number of SVs used to compute position
18	PRN of first SV
+000.2	Range residual for first SV in meters
29	PRN of second SV
+000.2	Range residual for second SV in meters
22	PRN of third SV
-000.1	Range residual for third SV in meters
19	PRN of fourth SV
-000.1	Range residual for fourth SV in meters
28	PRN of fifth SV
+000.5	Range residual for fifth SV in meters
0002.0	Horizontal position error in meters
0001.3	Vertical position error in meters
76	Message checksum in hexadecimal

\$PASHS,NME,SA4,x, ON/OFF

Enables/disables the NMEA SA4 (satellite status message).

Format:

\$PASHS,NME,SA4,x,y

where x is the output port A, B, or C, and y is ON or OFF.

Example: Enable SA4 message on port A

\$PASHS,NME,SA4,A,ON followed by output command

\$PASHS,OUT,x,NMEA where x is the output port.

\$PASHR,SA4

NMEA response message for SA4 (satellite status) being tracked.

Format:

\$PASHR,SA4,a,bb,cc,dd,eee,ff,U,.....<CR><LF>

where Table 5.34 lists the structure:

Table 5.34: Satellite Information Messages Structure

Field	Description
a	Antenna number
bb	Total number of satellites in the message
cc	Satellite PRN number
dd	Azimuth (degrees)
eee	Elevation (degrees)
ff	Signal to noise ratio (SNR) (0 to 99)
U	Flag whether usable (U) or not (-)
...	Same as 2,3,4,5,6 but for second satellite
...	Same as 2,3,4,5,6 but for third satellite

Example:

\$PASHR,SA4,1,08,22,51,14,44,25,15,16,54,19,24,04,24,18,48,29,51*69

\$PASHR,SA4,2,08,18,35,25,10,14,36,04,17,22,50,19,20,29,47,16,43*64

\$PASHR,SA4,3,08,04,15,14,41,19,25,16,49,18,33,22,55,25,21,29,56*69

\$PASHR,SA4,4,08,25,18,16,59,14,47,04,20,18,46,22,60,29,51,19,30*62

\$PASHS,NME,SAT,x, ON/OFF

Enables/disables the NMEA SAT (satellite status message).

Format:

\$PASHS,NME,SAT,x,y

where x is the output port A, B, or C, and y is ON or OFF.

Example: Enable SAT message on port B

\$PASHS,NME,SAT,B,ON followed by output command

\$PASHS,OUT,x,NMEA where x is the output port.

\$PASHR,SAT

NMEA response message for SAT (satellite status) being tracked.

Format:

\$PASHR,SAT,a,bb,cc,dd,eee,ff,U,.....<CR><LF>

where Table 5.35 lists the structure:

Table 5.35: Satellite Information Messages Structure

Field	Description
a	Antenna number
bb	Total number of satellites in the message
cc	Satellite PRN number
dd	Azimuth (degrees)
eee	Elevation (degrees)
ff	Signal to noise ratio (SNR) (0 to 99)
U	Flag whether usable (U) or not (-)
...	Same as 2,3,4,5,6 but for second satellite
...	Same as 2,3,4,5,6 but for third satellite

Example:

**\$PASHR,SAT,6,20,23,310,58,U,13,37,034,61,U,24,75,144,99,U,07,12,06
8,32,U,09,49,227,99,U,12,72,249,99,U <CR><LF>**

\$PASHS,NME,STR,x,switch

Sets individual NMEA messages where str is GLL, GXP, GGA, VTG, GSN, ALM, MSG, DAL, GSA, GSV, HDT, TTT, RRE, PAT, GRS, GSS, POS, SAT. x is port A or B; and switch is ON or OFF. Refer to the section NMEA Message Formats for an explanation of the various message types.

\$PASHS,NME,TTT,x, ON/OFF

The trigger signal is generated through the event input line, pin 9 of Port B of the ADU2. The following message outputs on the selected port on each trigger epoch being generated. If your are planning on using the trigger time tag or one pulse per second, then you must make a cable. Use the pin diagram in Figure 1-4 to build the necessary cable.

Format:

\$PASHS,NME,TTT,a,hh:mm:ss.sssssss <CR><LF>

where Table 5.36 lists the structure:

Table 5.36: Trigger Time Tag Serial Output Message

Field	Description
a	Day of the week, with 1 being Sunday and 7 being Saturday
hh:mm:ss.sssssss	GPS time tag in hours, minutes, seconds

Example:

\$PASHS,NME,TTT,3,18:01:33.1200417 <CR><LF>

\$PASHR,TTT

Response message for the time trigger (event marker). The trigger signal is generated through the event input line, pin 9 of Port B of the ADU2. The following message outputs on the selected port on each trigger epoch being generated. If your are planning on using the trigger time tag or one pulse per second, then you must make a cable. Use the pin diagram in Figure 1-4 to build the necessary cable.

Format:

\$PASHR,TTT,a,hh:mm:ss.sssssss <CR><LF>

where Table 5.37 lists the structure:

Table 5.37: Trigger Time Tag Serial Output Message

Field	Description
a	Day of the week, with 1 being Sunday and 7 being Saturday
hh:mm:ss.sssssss	GPS time tag in hours, minutes, seconds

Example:

\$PASHR,TTT,3,18:01:33.1200417 <CR><LF>

\$PASHS,NME,VTG,x, ON/OFF

Enable/disable the actual track made good and speed relative to the ground message.

\$GPVTG

NMEA response message for VTG (velocity/course).

Format:

\$GPVTG,ddd.dd,T,x,x,aaa.aa,N,bbb.b,K <CR> <LF>

where Table 5.38 lists the structure:

Table 5.38: \$GPVTG Structure

Fields	Description
ddd.dd	COG (Course Over Ground) in degrees
T	T for COG with respect to true north
x,x	COG, magnetic (not included)
aaa.aa	SOG (Speed Over Ground)
N	N for Knots
bbb.b	SOG (Speed Over Ground);
k	K for km/hr



If position is not computed, NMEA messages are output using the information of the last good computed position. Also, if the number of SVs is less than MSV, no message is output.

Example:

\$GPVTG,061.00,T,,,000.07,N,000.13,K<CR> <LF>

\$PASHS,OUT,x

Turns off previously specified types of output (refer to the next command), where x, the port, is set to A or B.

\$PASHS,OUT,x,str1,str2,str3,...

Turns on the specified raw data output type, where x, is Port A or B.

Str can be: MBN, PBN, SNV,ATT, AT2, or BIN.

For binary outputs, the BIN string must be combined with the output type.

Example: to send MBEN and PBEN in binary format:

\$PASHS,OUT,A,MBN,PBN,BIN

To turn off an output, repeat the command excluding the str associated with that output type. \$PASHS,OUT,x to turn off all raw data outputs on Port x.



You must set all the output on in one single command.

Example: Sets both ATT and AT2.

\$PASHS,OUT,B,ATT,ATT2

Example: Turns ATT on, and ATT off, AT2 on.

\$PASHS,OUT,B,ATT

\$PASHS,OUT,B,AT2

\$PASHS,PDP,dd

Sets the PDOP (position dilution of precision) mask for the position computation. A position is not computed if the PDOP rises above this number. The default is 40.

\$PASHS,PDS

Sets the satellite tracking routine to maximize for best PDOP. Default is ON. ADULOG sets PDS ON for the purpose of antenna calibration, but resets PDS OFF when exiting ADULOG.

- PDS ON (default):

If more than eight satellites are tracked the set of eight satellites that leads to the best PDOP value are used for the attitude determination. The determination will be made each time a satellite movement is detected (satellite becomes available or is being masked) or every minute if no movement has been encountered. If fewer than eight, all satellites tracked are used in the attitude determination calculation.

- PDS OFF:

Satellites do not move from the allocated channel until they set at the elevation mask. This receiver setting should be used only for the purpose of dynamic calibration. If used otherwise it will degrade the operation of the attitude determination algorithm greatly.

\$PASHS,POS,d

Sets the mode for the position computation:

Table 5.39: Position Computation Codes

Value of D	Position Computation
0 (default)	indicates that only 3-dimensional positions will be computed. This happens when four or more satellites are locked on antenna 1.
1	indicates that either a 2-D or 3-D position will be computed based on the number of satellites locked on antenna 1. If three satellites are locked, a 2-D position is computed (altitude is fixed). If four or more satellites are locked, a 3-D position is computed.
2	indicates that a 2-D, altitude-fixed position will be computed when three or more satellites are locked to antenna 1. A 3-D position will not be computed.
3	indicates that a 2-D, altitude-fixed position will be computed with three SVs locked. If more than three SVs are locked and HDOP is less than HDOP mask, the receiver computes altitude.

\$PASHS,RCI,ddd

Sets the raw data message output rate to the specified value in seconds. The default is 0, which indicates a 0.5-second update rate when **\$PASHS,ONE** is set to N, and a 1-second update rate when **\$PASHS,ONE** is set to Y.

\$PASHS,RST

Resets all configuration parameters to their defaults, except the relative antenna positions and offsets.

\$PASHS,RTC,AUT,sw

Sets the receiver to automatically compute a stand-alone position when RTCM corrections are unavailable. Default is OFF.

\$PASHS,RTC,MAX,d

Sets the maximum age for messages when handling RTCM format where d ranges from 0 to 1199 seconds. If the age of corrections exceeds this limit, the age will be set to 999. Default is 120 seconds.

\$PASHS,RTC,QAF,d

Sets the communication quality when handling RTCM format where d ranges from 0 to 999. The default is 100.

\$PASHS,RTC,REM,x,sw

Sets a receiver to handle RTCM input where x is Port, A or B and switch is ON or OFF.

\$PASHS,RTC,STI,d

Sets the station ID when handling RTCM format where d ranges from 0 to 1023. Default is 0, which accepts corrections from any base station ID.

\$PASHS,SAV,x

Saves the current receiver configuration, that is, all the setup parameters through a power cycle where x is Y(save) or N (don't save). The default is N. If any parameter is modified afterwards, it will return to its saved value after a power cycle.

\$PASHS,SIT,xxxx

Provides a four-character site name.

\$PASHS,SPD,x,d

Sets a baud rate of specified port (x) to value (d) per Table 5.40.

The default baud rate is 9600 (code 5).



Table 5.40: Serial Port Baud Rate Codes

Code	Baud Rate
0	300
1	600
2	1200
3	2400
4	4800
5	9600
6	19200
7	38400
8	57600
9	115200

\$PASHS,SVS,xxxxxxxxxx

Enables or disables all 32 satellite PRN numbers at once by typing Y to enable or N to disable a particular satellite (any character other than Y is interpreted as N). If this command is issued and is incomplete, all remaining satellites are disabled. The default is all satellites enabled. For example, the command \$PASHS,SVS,YYNYYYY enables SV's 1,2,3,5,6,7 and disables all the remaining SV's (that is, 4,8,9,10,...32).

\$PASHS,UNH,x

Uses unhealthy satellites in position computation when Y. Unhealthy satellites are always used for attitude determination. The default is N.

\$PASHS,USE,dd,x

Enables or disables satellite tracking where dd is the satellite PRN number and x is uppercase Y (enable) or N (disable). For example, to disable satellite 8, enter \$PASHS,USE,08,N.

\$PASHS,VDP,dd

Sets VDOP (vertical dilution of precision) mask for the position computation. A position is not computed if the VDOP rises above this number. The default is 4.

Troubleshooting

This chapter contains information for troubleshooting problems with the operation of the ADU2. It is divided into two sections depending on the type of problem:

- Installation and initialization problems.
- Position and attitude measurement problems.

For each section, there is a list of potential problems and suggestions on how to resolve them. Refer to Chapter 6 for an explanation of any of the commands that are suggested below.

Installation and Initialization Problems

No power at the receiver

- The DC power supply should provide 12 to 32 V at 2A.
- The battery should be fully charged.
- Check the results from the initialization self-test with the **\$PASHQ,TST** command.

No communication response from the receiver

- Connect the interface cable to a different port (A or B).
- The baud rate of the PC communications program should match the ADU2. The ADU2 default rate 9600 baud, 8 data bits, 1 stop bit, no parity.
- The commands being issued from the PC should be terminated with a carriage-return and linefeed.
- Turn the power to the receiver off and then on again.
- If RTCM is enabled on a port, no other communication with that port is possible until RTCM is disabled.
- Make sure the interface cable is securely fastened to the ADU2 and the PC.
- If the interface cable was not supplied by Ashtech, check the J1 connector's pin-out diagram of the RS-232 ports with the cable you manufactured. (Refer to the Overview.)
- Clear internal memory with the **\$PASHS,INI** command. (You may need to toggle the power to the receiver after this command is issued.) An example session using the PCPLUS communications program is as follows:

Run PCPLUS and press **<ALT-P>** to configure the port properly to 9600 baud. Next, press **<ALT-O>** to enter the command mode. Type **\$PASHQ,PRT <Enter>** to ask the receiver for its serial port configuration.

All letters must be capital and **<Enter>** is the enter key. **<ENTER>** should provide both a carriage-return **<CR>** and linefeed **<LF>**. These must be at the end of any command given to the ADU2. For the PCPLUS program, **<CTRL-J>** and **<CTRL-M>** may be used instead of the enter key to represent a carriage-return/linefeed. The ADU2 should respond to this command with **\$PASHR,PRT,A,5** indicating the use serial port A at 9600 baud (code 5).

Position and Attitude Measurement Problems

Receiver does not compute position

- Antenna 1 is used to compute position. Check the satellite tracking status for Antenna 1 with the command **\$PASHQ,STA**. At least four satellites should be locked on Antenna 1.
- Check for satellites below the elevation mask angle (default is 10) with the **\$PASHQ,GSV** or **\$PASHQ,SAT** command.
- Check if PDOP is above the pdop mask (default is 40) with the **\$PASHQ,GSA** command.
- Check for unhealthy satellites with the **\$PASHQ,SAT** command.
- Verify that the receiver is not locked-up and is currently tracking satellites with the **\$PASHQ,STA** command two or three times and see that the signal-to-noise ratios change for a locked satellite on a particular bank.
- Make sure signal-to-noise ratios (SNR) are strong enough. The SNR for a particular satellite should be about twice its elevation angle. Verify this with the **\$PASHQ,SAT** command. SNR values of 20 or greater are generally usable. SNR values for higher elevation satellites range from 60 to 99.

Causes for Bad Antennas or Low SNRs

- Check for damaged coaxial cable, such as broken shielding, salt water intrusion between shielding and the conductor, poor connections at the terminations.
- Make sure antenna coaxial cables cross high voltage lines only at 90 degree angles if possible.
- Check for condensation or saltwater (spray) intrusion inside the antenna housing.
- Check for bad LNA (preamp) in the antenna. In this case there is no signal at all.

- Monitor SNRs from antenna to antenna to make sure that none are significantly lower than the others with the **\$PASHQ,STA** command.

Receiver computes position but not attitude

- Verify cables are labeled properly and that:
 - Cable 1 is connected to antenna 1 and the Ant 1 port of the ADU2 receiver;
 - Cable 2 is connected to antenna 2 and the Ant 2 port of the ADU2 receiver;
 - Cable 3 is connected to antenna 3 and the Ant 3 port of the ADU2 receiver;
 - Cable 4 is connected to antenna 4 and the Ant 4 port of the ADU2 receiver.
- Check that the relative antenna position vectors from the initial survey are entered into the receiver properly and have the correct sign with the **\$PASHQ,3DF** command.
- The initial relative antenna position survey is very important. Determine that the survey provided valid results. (Refer to Chapter 4 for static or dynamic survey.) Perform the survey more than once to validate the results. The static survey should provide nearly the same results every time. Conversely, a dynamic survey does not provide exactly the same relative antenna position vectors each time (if the vehicle was indeed moving), but a good check is to make sure that the baseline lengths for each vector agree for each survey.
- Verify that the antennas have not moved since the initial survey. The antennas should be mounted on a rigid platform. Very little relative movement between the antennas (less than 2 cm) can be tolerated.
- At least four satellites must be locked on all four antennas before attitude information can be computed. Verify this condition with the **\$PASHQ,STA** command.
- For proper receiver performance, determine if all four antennas are locked evenly to the satellites with the **\$PASHQ,STA** command. Verify that each satellite locked on all four antenna banks has about the same signal-to-noise (SNR) ratio (max difference of ten counts).
- The vehicle may be tilted (pitch or roll) more than five degrees, which is the default maximum angle around the horizon (+ and -) that the search for the initial ambiguities takes place. If the vehicle tilts more than five degrees, increase this maximum search angle with the **\$PASHS,3DF,ANG,dd** comand where dd can be a maximum of 90 degrees. The larger this number,

the longer it takes to determine the initial ambiguities for the attitude solution.

- The limits for the attitude measurement noise errors (BRMS, MRMS, CYC) may have been exceeded. This happens when the antennas are installed in high-multipath environments (that is, antennas are located near metallic, signal-reflecting objects, see Appendix A). Check this as follows:
 - The default maximum BRMS (baseline rms) error is 3.5 cm. Try to increase this by small steps (1 cm) with the **\$PASHS,3DF,MXB,0.060** command. Do not exceed 8 cm.
 - The default maximum MRMS (measurement rms) error is 5 mm. Generally, a good attitude solution should always have an error less than this. It may be necessary for very noisy environments to set this value slightly higher with the **\$PASHS,3DF,MXM,0.006** command.
 - The default maximum phase cycle error is 15% of a cycle (1 L1 carrier cycle = 19 cm). Try to increase this to 20% with the **\$PASHS,3DF,CYC,0.20** command.



Increase the BRMS and MRMS in small increments only.

- Before precise attitude information is given, the double-difference carrier phase ambiguities must be resolved. (Refer to References [1], [2], and [3] in Appendix C). The search for the initial ambiguities may be unsuccessful. The receiver keeps trying to determine these ambiguities until a solution is found. When the antenna separation is greater than three meters, Kalman filters help with the ambiguity search. If noisy, or bad, satellite measurement data was received by the ADU2, the Kalman filters may get “lost”. Reset the attitude’s Kalman filters with the **\$PASHS,3DF,RST** command.

Noisy attitude data

- Check the attitude reset flag with the **\$PASHQ,ATT** command. It should be “0” for precise attitude (carrier phase ambiguities are resolved). A “1” indicates that the attitude is a code phase estimate (the ambiguities have not yet been resolved).
- Check the attitude’s BRMS (baseline rms error), which should be less than 4 cm when an attitude solution is found with the **\$PASHQ,ATT** command.
- Check the attitude’s MRMS (measurement rms error), which should be less than 5 mm when an attitude solution is found with the **\$PASHQ,ATT** command.
- Check the mask angle. Ashtech recommends that you keep the default satellite elevation mask angle of 10 degrees (or even increase it to 15

degrees) since satellites at lower elevations have a high level of multipath on their signals due to reflections from the ground and nearby metal objects. Multipath is a major error source affecting attitude accuracy and reliability (See Appendix A).

- Check the PDOP computed by the receiver. It should be less than 6 for “clean” attitude data. The attitude data becomes very noisy and the solution may even be lost when PDOP rises above 6. A high PDOP causes the BRMS error go above 4 cm. Increase the maximum allowable value of BRMS with the **\$PASHS,3DF,MXB,d.ddd** command.

Notes on Attitude Data

Antenna Separations

For antenna separations less than three meters, “999” appears for heading in the attitude output message (**\$PASHR,ATT,...**) when the receiver is searching for the ambiguities, or when a valid solution has not been found. When the baselines are greater than three meters, a code phase estimate of heading appears and pitch and roll are exactly “0.00”. When either of these situations exist, the attitude reset flag is set to “1” in the attitude output message (a “0” indicates a good attitude solution).

If the antenna separations are less than three meters, it should require only a few seconds resolve the initial ambiguities and provide attitude information. When the antenna separations are greater than three meters and the Kalman filters are reset (**\$PASHS,3DF,RST**), the receiver first smooths the satellite measurement data for ten seconds before beginning the ambiguity search, which takes a few more seconds.

Attitude Quality Indicators

To assure a good attitude solution has been computed, the MRMS and BRMS errors are used as quality indicators and are checked against maximums at every epoch.

An incorrect attitude solution causes both the MRMS and BRMS errors to continually grow larger. The rate at which these errors grow depends on the relative motion between the vehicle and satellites. The higher the vehicle dynamics, the faster the error growth rate of a false solution.

Also, as Position Dilution of Precision (PDOP) becomes higher, the BRMS error grows as well. Typically, GPS provides good attitude information as long as PDOP is below 6, which is approximately 95% of the time with the full 24-satellite constellation, worldwide.

Multipath significantly affects the computed BRMS error, causing it to rise and fall as the antennas receive “constructive” and “destructive” interference. The period and

amplitude of the multipath oscillations varies significantly depending on vehicle dynamics and environment. Static vehicles are the most affected by multipath while dynamic vehicles' multipath errors tend to average out.

The maximum limit for the BRMS error is set to 3.5 centimeters. This limit may be increased for vehicles in high multipath environments that is, 6-8 centimeter limit). The maximum limit for the MRMS error is 5 millimeters and may be increased for high dynamic vehicles (that is, 6-7 millimeter limit).

ADULOG

ADULOG, provided with the ADU2 receiver software, logs data from the receiver in real-time and saves the data in three files: b-file, e-file and a-file. The B-file contains raw measurements. The E-file contains ephemerides from all tracked satellites. The A-file contains computed attitude values. These files are used to calibrate the antennas and can be used for post-processing.

Operating ADULOG

ADULOG operates in the DOS environment and is part of the software package included with the ADU2. The receiver must be connected to the computer for data transfer. See “Installation” on page 17, for more information.

Sometimes disk caching programs introduce block errors in the received data. To preclude bytes loss, **ADULOG** switches off **SMARTDRV.EXE** during the data collection. At the end of the session, **ADULOG** restores the previous status of SMARTDRV.EXE. However, there is an option `Do_Not_Disable_Smartdrv` to change the default behavior. If `Do_Not_Disable_Smartdrv` is set to **Yes**, then **ADULOG** does not switch off SMARTDRV.EXE.

The main screen opens after starting **ADULOG** (Figure 7.1):

PC Port: 2	Baud: 38400	Rec Intvl: 1.0 s	Elev Mask: 10
Target Disk Drive: C	Free Disk Space:	131	Kbytes
Target Directory: \ANDRE\WORK\ADU_BC	Template: _A96.242	B-File: ---closed---	E-File: ---closed---
<Esc> - To Exit <1> - DOS Shell <F10> - Start Receiving			

Figure 7.1: ADULOG Main Screen

The main screen has three sections:

- Communication
- Target system
- Status information

The Communication section sets the recording interval, elevation mask, communication port from 1 to 4 (for COM1-COM4 respectively), and communication speed. The recording interval is the update rate of the information coming from the receiver. Default value is 1 second. Communication parameters can be specified using corresponding command line options (see **ADULOG** options section), or by using the **<PgUp>** or **<PgDn>** keys.

The target system section selects the target disk drive, target directory path, and the target file names. The template prompt is used to enter the base name which generates the target B-file, E-file and A-file names according to the recommended file naming convention. When **ADULOG** starts, **ADULOG** uses the target computer to generate the session year and day fields of the template (i.e., only the 4-character site name is not supplied). A template name can be entered using corresponding command line option. (See **ADULOG** options section).

The status information section provides information on the status of data logging communications with the receiver. Figure 7.1 has no information in the status information section.

Logging Data

1. Start **ADULOG** by typing **adulog <ENTER>** at the DOS prompt. The main screen opens.
2. Verify the PC Port listed at the bottom of the screen is correct. To change the PC Port, press **1**, **2**, **3**, or **4** corresponding to the PC Port.
3. Tab to the Baud field. If the baud rate is not set to 38400, then use **Page Up** and **Page Down** to set the baud rate to 38400.
4. Tab to the Recording Interval field. Type in the recording interval (in seconds).
5. Tab to the Elevation Mask field. There is no need to change the elevation mask from 10°.
6. Tab to the Target Disk Drive field. If you wish your collection data saved to files located on a drive other than the C drive, enter the drive letter.
7. Tab to the Directory field. Type in the name of the directory where you want your data files saved.
8. Tab to the Template field. Type **cali** and press **<ENTER>**. The template creates the B and E-file names.

9. Press **F10** to start collecting the data.

If target file names or template name are not properly specified, **ADULOG** issues a flashing warning “Invalid file names”.

If the target drive or path does not exist, **ADULOG** issues the flashing warning: Invalid drive and/or path specified.

If the files exist, **ADULOG** asks permission to overwrite them:

```
File B0001a96.301 already exists on disk.  
Do you wish to [A]ppend, [O]verwrite, or a[B]ort  
By hitting highlighted keys user can choose any of  
offered ways.
```

After opening the target files, **ADULOG** tries to establish the data link. If the data link is not properly established, the following message appears in the status section:

```
ERROR: While attempting to initialize the  
communications port, an RS-232 line status check  
indicates one of the following conditions:  
1) Cables not connected properly (e.g., wrong receiver  
port)  
2) Cables not fastened securely; and/or  
3) Receiver power not "ON" Ensure cables are connected  
(with full NULL MODEM) and receiver power is on.  
Press any key when ready to try again...
```

After five unsuccessful attempts to establish the data link **ADULOG** terminates with the message Too many attempts.

Once the data link is established, the message Installing RS-232 driver on COM2 appears in the status section.

10. A dialog box asks

```
Auto SV selection for best PDOP?
```

The answer affects the algorithm of selection satellites depending on whether this recording is used for antenna calibration or not.

11. Type **n** if recording for antenna calibration, otherwise type **y**.

ADULOG starts collecting the data. Figure 7.2 appears in the status information section indicating the logging process has started.

Record Number	Nav Msg	Total Block Errors	Attitude Messages
65	34	2	67

ATTITUDE INFORMATION					
Sec of Week	Heading	Pitch	Roll	BRMS	MRMS
458204.00	999.00	000.00	000.00	5.7770	1.4615

Figure 7.2: ADULOG Logging Table

The upper table indicates the number of received messages and block errors. Record Number lists the number of records written to the b-file. Nav Msg is lists number of ephemerid messages collected in the e-file. Attitude Messages lists the number of correctly received attitude messages written to the a-file.

The lower table displays the contents of the latest attitude message.

If either the Record Number or the Attitude Messages do not increase, one of the following conditions exists:

- i. The receiver is not tracking enough satellites
- ii. An epoch interval has not transpired since the time the connection established
- iii. The communication cable is not properly connected

If **ADULOG** does not receive any data for a long period of time, the following message appears:

```
Did not receive data from COMM PORT within time-out
interval. Possibly you have the cable connected
incorrectly, you have selected incorrect data type,
and/or there are not enough satellites above elevation
mask. Continuing anyway --
Press <Esc> if you wish to quit.
```

The user can switch on/off an optional audible beep at receiving each record. This ensures that the logging process is ongoing without looking at the screen. Press **<Alt>B** to switch the audible beep on and off.

ADULOG periodically closes and opens the output data files to protect the data against unexpected error or power supply failure.

As logging continues, **ADULOG** indicates the free space left on the target disk.

12. Hitting **<Esc>** key interrupts the logging. The output files close and the data link terminated.
13. Press **<Esc>** a second time to exit **ADULOG**. At prompt message, type **y**. **ADULOG** restores the previous receiver communication speed before exiting to the operating system.

Graphical Representation

ADULOG displays the current attitude data graphically by pressing **<Alt>G**. Three three gauges can be displayed: compass, artificial horizon, and ascend/descend rate gauge. The set of gauges can be changed depending on the vehicle preferred: ship, airplane, or automobile. Press **<Alt>W** to change the gauge set.

<Alt>C toggles between color and black/white modes. The following parameters are displayed in the bottom part of the screen:

- latitude
- longitude
- altitude
- GPS time
- heading
- pitch
- roll
- course over ground (only if speed exceeds 5 km/h)
- speed over ground (only if speed exceeds 5 km/h)

Pressing **<Esc>** returns to the main screen.

The compass indicates the current heading (Figure 7.3)

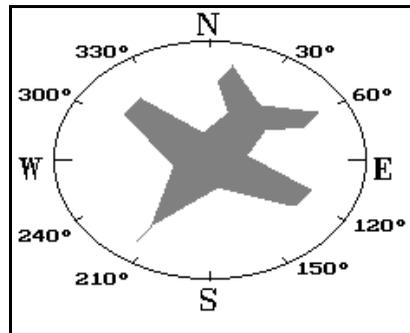


Figure 7.3: ADULOG Compass

The artificial horizon indicates the current roll and pitch (Figure 7.4).

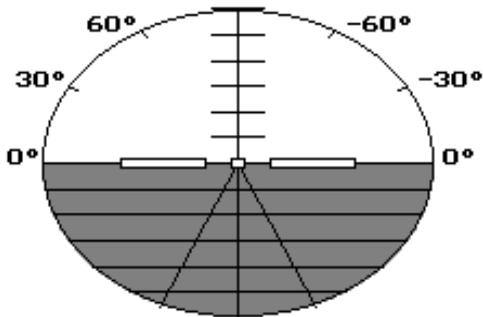


Figure 7.4: ADULOG Horizon Representation

ADULOG Options

Table 7.1 describes the command line options available for **ADULOG**.

Table 7.1: ADULOG Options

Option	Parameters	Description
-a	<none>	Read almanac.
-b	number	Set baud rate (default 9600)
-c	number 1-4	Set PC comm port (default COM1)
-e	<none>	Called by upper level
-f	number	Set save interval (default 1 sec)
GMT_Offset	number	Set GMT offset
-i	<none>	Ignore DTR-DSR auto satisfaction
-n	Letter A-D	Set receiver port
-p	<none>	Position only
-r	file name	Specify RID file name in simulation mode
-s	<none>	No setup
Statistic	Yes No	Switch on/off statistic mode
-t	<none>	Attitude only
-u	<none>	Audible beep when a new epoch is logged
-y	template name	Specify template
-z	file name	Simulation mode. Read data from the specified file.
@	file name	Specified parameter file name. All options can be listed in that file.

Almanac downloading

ADULOG can optionally download almanac information from the receiver. The user has to specify the corresponding option and the almanac file name in order to have almanac downloaded. Almanac file constitutes 32 binary structures. Each structure contains almanac data for a satellite. Satellite numbers can be determined by the location of the structure within a file. Almanac for satellite 1 is the first, almanac for satellite 2 is the second, etc. If there is no almanac for a satellite, the corresponding structure will be filled with zeros.

The bytes order is “LSB is the first”. Table 7.2 describes the almanac structure. Total length is 70 bytes. File length is 2240 bytes.

Table 7.2: Almanac File Structure

Name	Type	Length	Description
e	float	4	Eccentricity
toe	long	4	Reference time for orbit (sec)
i0	float	4	Inclination angle (semi-circles)
omegadot	float	4	Rate of right ascension (semi-circles/sec)
health	short	2	Satellite health
roota	double	8	Square root of semi-major axis (meters $1/2$)
omega0	double	8	Longitude of ascending node (semi-circles)
omega	double	8	Argument of perigee (semi-circles)
m0	double	8	Mean anomaly at reference time (semi-circles)
af0	float	4	Clock correction (sec)
af1	float	4	Clock correction (sec/sec)
bulhealth	short	2	
wna	short	2	Almanac week number
wn	short	2	Week number
tow	long	4	Seconds of GPS week
config	short	2	

Statistics

ADULOG can display additional attitude statistic information by setting STATISTIC to YES with the command line or in the .INI file. Additional statistics include the number of attitude message with the reset flag set and reset, maximal and minimal heading, roll, and pitch values. If ordered, the additional statistics are displayed on the main screen below the transfer status window.

When STATISTIC is set to YES, **ADULOG** creates the summary file that contains the logging session parameters and additional statistics. The name of the summary file is SUMMARY.XXX, where XXX is the next available number.

Autonomous Mode

ADULOG can be programmed and work in autonomous mode, arranging up to 10 sessions of data logging. Each session can have its own settings. Table 7.3 lists the parameters which can modify **ADULOG** behavior during logging. Some parameters are mandatory, the others are optional.

Table 7.3: ADULOG Logging Parameters

Option name	Mandatory/Optional
Start_Time	Mandatory
End_Time	Mandatory
Template	Mandatory
Calibration	Optional
Interval	Optional
Elevation_Mask	Optional
Min_SV	Optional
Ref_Day	Optional
Day_Offset	Optional
Second_B_File	Optional

To specify a session add the following line to the options file:

```
[Session X]
```

where X is the session number from 1 to 10. All options below this line pertain only to the specified session.

All parameters from any of the previous sessions can be inherited in the following sessions with the following syntax:

```
[Session X : Session Y]
```

where session X inherits all parameters from session Y, and session Y must be defined. Any parameters listed in session X override the inherited values of session Y.

If any files derived from the specified template exists, **ADULOG** asks permission to overwrite them:

```
File B0001a96.301 already exists on disk.
```

```
Do you wish to [A]ppend, [O]verwrite, or a[B]ort
```

Table 7.4 lists possible error messages while parsing sessions section of the parameters file:

Table 7.4: ADULOG Error Messages

Error Number	Error Message
8	Session number is out of range
16	Duplicate session
17	Wrong 'hour' in time definition
18	Wrong 'minutes' in time definition
19	Wrong 'seconds' in time definition
20	Parameter is specified outside of any session
21	Value is out of range
22	Wrong 'day' in date definition
23	Wrong 'month' in date definition
24	Can not inherit from the unknown session
-	Start Time is not defined in session X
-	End Time is not defined in session X
-	Template is not defined in session X
-	Duplicate templates in sessions X and Y

Logging parameters

Start_Time

Specifies the session start time in hours, minutes, and seconds. If an erroneous value is used, error message 17, 18, or 19 is issued.

Format: Start_Time=hh:mm:ss

Example: Start_Time = 17:25:00

End_Time

Specifies the session end time in hours, minutes, and seconds. If an erroneous value is used, error message 17, 18, or 19 is issued.

Format: End_Time=hh:mm:ss

Example: End_Time = 18:05:00

Template

Specifies the template for the naming files, used to generate B-file, E-file, and A-file names.

Format: Template = <template_name>

Example: Template="0001"

Calibration

Selects if the recording session will be held in the antenna calibration mode. This mode affects satellite selection algorithm during logging. By default the calibration mode is OFF.

Format: Calibration=<Yes/No>

Example: Calibration = Yes

Interval

Sets the data update interval expressed in seconds. Default interval is 1 second.

Format: Interval = <Number>

Example: Interval = 5

Elevation_Mask

Sets the satellite elevation mask in degrees. Default value is 10 degrees.

Format: Elevation_Mask=<Number>

Example: Elevation_Mask = 5

Min_SV

Specifies the minimum number of satellites that must be visible before the session begins to log data.

Format: Min_SV=<Number>

Example: Min_SV = 3

Ref_Day

Sets the reference day for the start and end logging times. If set to a date later than the current date, logging does not start until specified date. If set to a date previous or equal to the current date, logging starts, and ends at the time specified with the Day_Offset parameter.

Format: Ref_Day=MM/DD/YY

Example: Ref_Day = 9/06/96

Day_Offset

Sets the displacement in minutes and seconds from the reference day. For a day subsequent to the Ref_Day, the start and end times are incremental by the minutes and seconds specified in Day_Offset, multiplied by the day number. (For example, if the offset is 04:00, day 1 is offset 4 minutes, day 2 is offset 8 minutes.)

Format: Day_Offset = mm:ss

Example: Day_Offset = 04:00

Second_B_File

Concurrently logs a second b-file which can be logged with a different update rate. The template suboption sets the template. The interval suboption sets the update rate of the second b-file.

Format: Second_B_File = {Template = <template_name>, Interval = <Number>}

Example: Second_B_File = {Template = "0011", Interval = 20}

Working in autonomous mode

While waiting for the start time, **ADULOG** is in sleeping mode. The following message displays:

```
ADULOG is now in sleeping mode,
current GPS time is XX:XX:XX.
Session X will start at YY:YY:YY
Press <F10> to start recording now,
<Esc> to skip the session.
```

While in sleeping mode, pressing **<F10>** starts logging before the start time, and **<Esc>** skips a session. An **ADULOG** session can be terminated by pressing **<ALT>E**.

Upon starting the session the following message displays:

```
Session X has been started.
```

If a second b-file was ordered, the displayed message is augmented:

Session X has been started.(The second b-file is being written)

File Formats

B-file Format

Each B-file starts with a *rawheader* structure (Table 7.5). Total length is 90 bytes.

Table 7.5: B-file Rawheader Structure

Type	Name	Length
char	version[10]	10
unsigned char	raw_version	1
char	rcvr_type[10]	10
char	chan_ver[10]	10
char	nav_ver[10]	10
int	capability	2
long	wn_start	4
char	num_obs_types	1
char	spare[42]	42

Each epoch starts with a *rawnav* structure (Table 7.6). Total length is 67 bytes.

Table 7.6: B-file Epoch Rawnav structure

Type	Name	Length	Description
char	sitename[4]	4	4-character site name (operator entered)
double	rcv_time	8	signal reception time at the receiver (sec)
double	navx	8	station position: ECEF-X (m)
double	navy	8	station position: ECEF-Y (m)
double	navz	8	station position: ECEF-Z (m)
float	navxdot	4	velocity in ECEF-X (m/sec)
float	navydot	4	velocity in ECEF-Y (m/sec)
float	navzdot	4	velocity in ECEF-Z (m/sec)

Table 7.6: B-file Epoch Rawnav structure (continued)

Type	Name	Length	Description
double	navt	8	clock offset (meters)
double	navtdot	8	clock offset rate (m/s)
unsigned int	pdop	2	PDOP
char	num_sats	1	Number of satellites

The *rawdata* structures follow. *Rawdata* contains *chan_obs* within its structure (Table 7.7). Total length is 31 bytes.

Table 7.7: B-file Rawdata structure

Type	Name	Length	Description
double	raw_range	8	raw range to SV (in seconds)
float	smth_corr	4	magnitude of correction (centimeters)
unsigned int	smth_count	2	unsigned and normalized, representing the amount of smoothing where: 1 is least smoothed, 200 is most smoothed, 0 is unsmoothed,
char	polarity_known	1	indicates synchronization of receiver with NAV message (0 - phase measurements it is impossible to use, 5 - phase measurements it is possible to use)
unsigned char	warning	1	warning flag
unsigned char	goodbad	1	indicates quality of the position measurement
unsigned char	ireg	1	signal to noise of satellite observation
char	qa_phase	1	phase quality indicator: 0 - always
long	doppler	4	doppler (Hz)
double	carphase	8	full carrier phase measurements in cycles

Each epoch has a *rawdata* structure per satellite (Table 7.8).

Table 7.8: B-file Epoch Rawdata structure

Type	Name	Length	Description
unsigned char	svprn	1	satellite PRN number (for "GPS" - 1+32, for "GLONASS" - 33+56)
unsigned char	elevation	1	satellite elevation angle (degree)
unsigned char	azimuth	1	satellite azimuth angle (degrees)

Table 7.8: B-file Epoch Rawdata structure (continued)

Type	Name	Length	Description
unsigned char	chnind	1	channel ID (1 to 24)
struct chan_obs	obs[3]	31 * rawheader.num_ obs_types	See above

E-file Format

E-file constitutes a sequence of unlimited binary structures. Each structure contains ephemerids for a satellite (Table 7.9). Total length is 129 bytes.

Table 7.9: E-file Structure

Name	Type	Length	Description
svprn	char	1	Satellite PRN number
wn	short	2	GPS week number
tow	long	4	Seconds of GPS week
tgd	float	4	Croup delay (sec)
aodc	long	4	Clock data issue
toc	long	4	Reference time for clock (sec)
af2	float	4	Clock correction (sec/sec2)
af1	float	4	Clock correction (sec/sec)
af0	float	4	Clock correction (sec)
aode	long	4	Orbit data issue
deltan	float	4	Mean anomaly correction (semi-circles/sec)
m0	double	8	Mean anomaly at reference time (semi-circles)
e	double	8	Eccentricity
roota	double	8	Square root of semi-major axis (meters 1/2)
toe	long	4	Reference time for orbit (sec)
cic	float	4	Harmonic correction term (radians)
crc	float	4	Harmonic correction term (meters)
cis	float	4	Harmonic correction term (radians)
crs	float	4	Harmonic correction term (meters)
cuc	float	4	Harmonic correction term (radians)

Table 7.9: E-file Structure (continued)

Name	Type	Length	Description
cus	float	4	Harmonic correction term (radians)
omega0	double	8	Longitude of ascending node (semi-circles)
omega	double	8	Argument of perigee (semi-circles)
i0	double	8	Inclination angle (semi-circles)
omegadot	float	4	Rate of right ascension (semi-circles/sec)
idot	float	4	Rate of inclination (semi-circles/sec)
accuracy	short	4	User range accuracy
health	short	2	Satellite health
fit	short	2	Curve fit interval

A-file Format

A-file constitutes a sequence of binary structures containing attitude data (Table 7.10). Total length is 46 bytes.

Table 7.10: A-file Structure

Name	Type	Length	Description
head	double	8	Heading in degrees
roll	double	8	Roll in degrees
pitch	double	8	Pitch in degrees
BRMS	double	8	Baseline RMS error
MRMS	double	8	Measurement RMS error
tow	long	4	GPS week time in milliseconds
reset	char	1	Reset flag
spare	char	1	Not used

Antennas and Cabling

Three different types of antennas and a fixed portable antenna array are available for the ADU2 system:

- geodetic
- aircraft
- marine

A fixed portable antenna array is also available. The advantage of the portable array is that no calibration procedure is required.

Be careful not to mount the antennas near any metallic surfaces. All GPS antennas are susceptible to multipath signals from metallic objects situated underneath them. For example, GPS signals received from a geodetic antenna mounted less than 20 cm from a metal roof are corrupted extensively with multipath reflection. High multipath effects can corrupt the ADU2 system so severely that an attitude solution is not possible.

Antenna Cables

Antenna cables used with the ADU2 may be up to 30 meters long. A line amplifier is available for greater distances. Other technical specifications are listed in Table A.1. Available cables include:

- 10-meter Belden 8219 (RG-58/U-type, but with better loss specifications)
- 30-meter Belden 8214 (RG-8/U-type, but with better loss specifications)

The cables use type-N male connectors at both ends which are center captured. A cable provided from a source other than Ashtech must be the same type with the same connectors as listed above. Not all RG-58/U and RG-8/U cables meet these specifications. Make sure any substitute cables satisfy these electrical requirements or the GPS receiver will not perform properly.

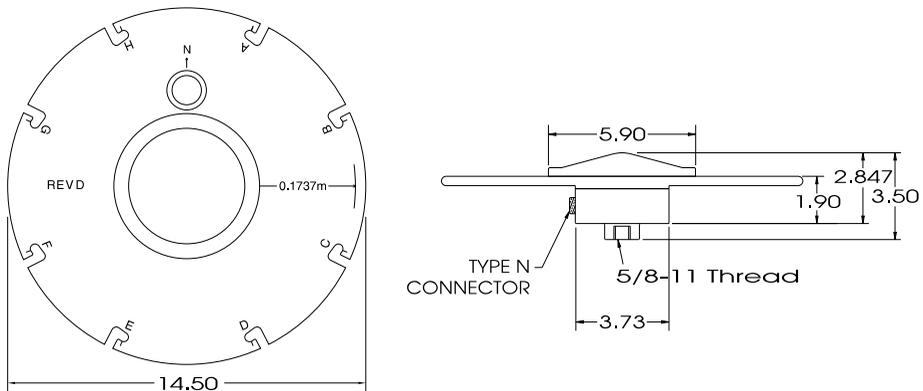
Table A.1: Antenna Cable Electrical Specifications

Category	Value
Insertion loss	17 db max. (at 1.5 GHz)
Characteristic impedance	50 ohm (nominal)
/VSWR (Input/output)	1.1:1 max (at 1.5 GHz)
DC resistance	0.5 ohm ground braid and center conductor

Geodetic Antenna

The geodetic antenna is designed to provide precise carrier phase measurements for survey purposes. Since carrier phase measurements are critical for any attitude determination system using GPS, this antenna is also provided with the ADU2 system.

The geodetic antenna consists of a metallic ground plane about a foot in diameter with a square micro-patch antenna mounted on top (Figure A.1). The patch antenna is covered by a plastic radome for protection from the environment. A low-noise amplifier (LNA) is mounted underneath the antenna. This LNA provides the necessary RF signal gain (35 dB) for the ADU2 to work properly. The ADU2 sends 5 volts through the cable to power the LNA. The bottom of the geodetic antenna has an internal 5/8" thread allowing easy mounting on poles or tripods.



NOTE: All dimensions are in inches.

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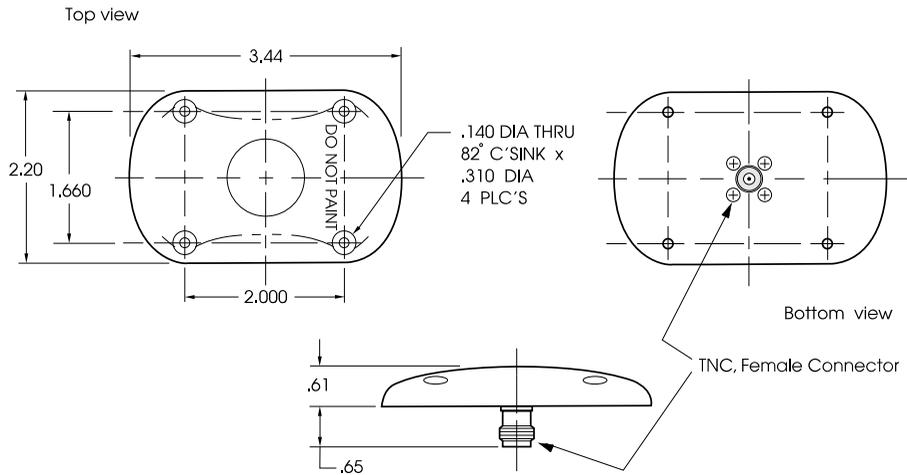
Figure A.1: Geodetic Antenna

Aircraft Antenna

The aircraft antenna is a patch antenna 3” to 4” in diameter (Figure A.2). This antenna requires both an LNA, provided by Ashtech, and a metallic ground plane. These antennas provide precise carrier phase measurements when mounted on a smooth, metallic surface such as the roof of a van.



Unless installed on the skin of an aircraft or on the roof of a van, the aircraft antennas do not work properly without a proper ground plane, with a minimum diameter of ten inches. This is because multipath effects from nearby metallic objects corrupt the signal received by the antenna. A metal ground plane is used to shield the antenna from multipath signals.

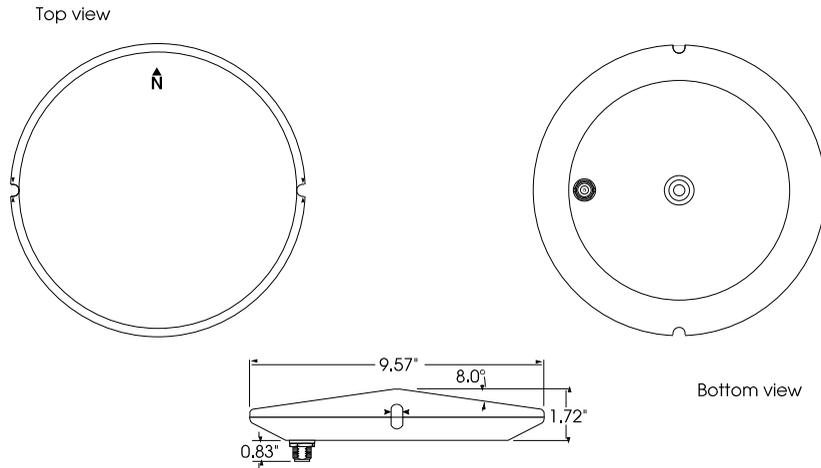


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Figure A.2: Aircraft Antenna

Marine Antenna

The marine antenna contains both a microstrip antenna and a low-noise amplifier (LNA) inside a sealed plastic housing preventing corrosion from highly corrosive environments such as a marine environment (Figure A.3).



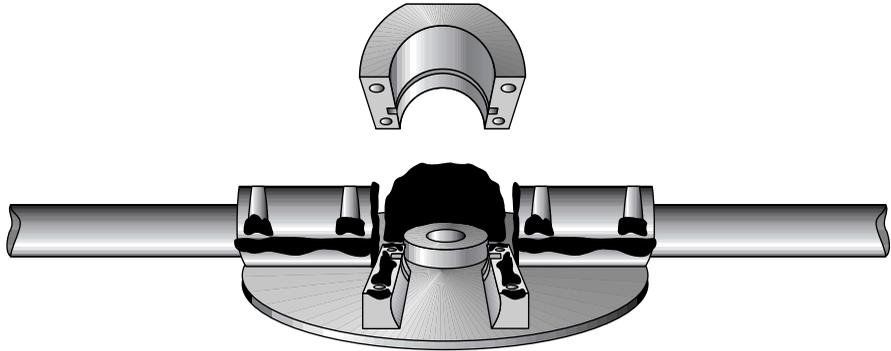
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Figure A.3: Marine Antenna

Fixed Portable Antenna Array

The fixed portable antenna array available from Ashtech provides the unique feature that it is pre-calibrated. The fiber glass cross arms and aluminum base plate of this antenna can be dismantled and packed into a small suitcase. It can be mounted to deck railing, lashed to the top of any deck gear by various methods, or mounted via the 1in standard pipe thread fitting in the center of the base plate.

Ashtech does not recommend the long-term use of the fixed antenna portable array in extreme weather conditions or at sea, unless precautions are taken to weatherize the aluminum fittings. If using the fixed antenna portable array at sea for extended periods of time, use a flexible, rubberized sealing compound, such as RTV or Silicone Sealer, to create a gasket between the cross arm fittings, seal each of the hex screws and the back of the cross arm fittings (Figure A.4) to extend the life of the array.



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Figure A.4: Recommended Placement of Sealing Compound on Cross Arm Fittings

Fixed Portable Antenna Array Installation

The fixed portable antenna array is shipped with the following parts:

- 4 Marine IV antenna kits with cables
- 4 connecting cross arms
- 1 aluminum base with standard 1 inch pipe thread
- 1 3/16 inch allen wrench

Each cross arm and base fitting is engraved with a number and description (Figure A.5). The number represents the recommended antenna number for the cross arm, and the description represents the recommended arrangement for the cross arm in the

array. Table A.2 lists the descriptions and recommended location. Cross arms 1 and 2 should be along, or parallel to, the centerline of the vehicle.

Table A.2: Cross Arm Descriptions

Description on Cross Arm	Recommended Antenna	Recommended Arrangement
1-AFT	1	Aft
2-FORE	2	Fore
3-PORT	3	Port
4-STDB	4	Starboard



Figure A.5: Cross Arm Fitting with Engraved Number and Description

1. Place the cross arm marked 1-AFT in the corresponding base fitting with the flat spot of the cross arm ridge seated flat in base fitting (Figure A.6) to ensure that the cross arm does not revolve and remains rigid.



If you are using the Ashtech cables provided with the antenna kits, RC58 cable with TNC connectors, you can run the cables through the cross arms. RG8 cable is too thick to run through. Be sure to mark the antenna cables on both ends before installing the cable. Run the cable through each antenna arm before securing the arm to the base plate. Do not run the cable through the 1in standard pipe fitting in the center of the plate.

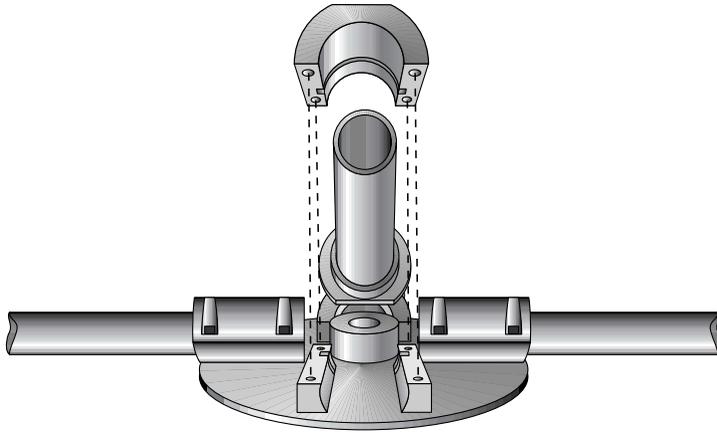


Figure A.6: Placing the Cross Arm in the Base Fitting

2. Place the clamp on top of the cross arm making sure the cross arm ridge seats in the clamp groove.
3. If using the fixed antenna portable array at sea for extended periods of time, use a flexible, rubberized sealing compound, such as RTV or Silicone Sealer, to create a gasket between the cross arm fittings.
4. Use the 3/16 inch allen wrench to tighten the hex screws. Tighten one hex screw partially, then tighten the diagonal hex screw partially, followed by the remaining two hex screws. Once each hex screw is partially tightened, then fully tighten all four hex screws. This method ensures that the clamp and cross arm seat properly.
5. Repeat steps 1 through 3 for the remaining three cross arms (and antenna cable if you are running the cable through the cross arms).
6. Screw each antenna onto a cross arm. Make sure the cable port on the outside of the array, aligned with the cross arm and antenna bolt (Figure A.7). This ensures that antennas are always mounted in the same relative

positions. A change from this routine may necessitate a recalibration of the array.

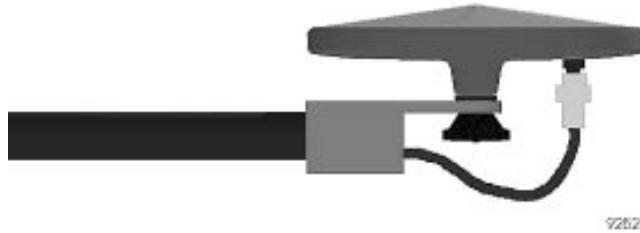


Figure A.7: Alignment of Cable Port, Cross Arm, and Antenna Bolt

7. Screw the antenna cable to the antenna port on each antenna.



Be sure to mark the antenna cables on both ends before installing the cable.

8. Use a permanent marker to write the antenna number on the bottom of the antenna for future reference. This ensures that antennas are always mounted in the same relative positions. A change from this routine may necessitate a recalibration of the array.

9. The completed antenna array (Figure A.8) can now be mounted. Ashtech recommends using the 1 inch standard pipe fitting.



Figure A.8: Completed Fixed Portable Antenna Array

10. Connect the antenna cables to the respective ports on the ADU2 unit using the marked antenna cables as a guide. Connect the ADU2 unit to the power source (refer to Chapter 3, **Installation**).
11. The antenna array is ready for operation. No calibration is required, however you need to input the relative antenna position vectors using **REMOTE** or some other communications software (PROCOMM, CROSSTALK,

EVALUATE). Table A.3 lists the relative antenna position vectors for the Ashtech fixed portable antenna array.

Table A.3: Input Relative Antenna Position Vectors for the Ashtech Fixed Portable Antenna Array

Vectors	X(R)	Y(F)	Z(U)
1-2 vector	0.000	+1.000	0.000
1-3 vector	-0.500	+0.500	0.000
1-4 vector	+0.500	+0.500	0.000

- a. Start REMOTE by typing **remote <ENTER>** at the DOS prompt.
- b. Enter the relative antenna position vector for the vector between Antennas 1 and 2 by typing the following command. Be sure to enter + or - signs before each number.
\$PASHS,3DF,V12,0.000,+1.000,+0.000 <ENTER>
- c. Enter the relative antenna position vector for the vector between Antennas 1 and 3 by typing the following command. Be sure to enter + or - signs before each number.
\$PASHS,3DF,V13,-0.500,+0.500,+0.000 <ENTER>
- d. Enter the relative antenna position vector for the vector between Antennas 1 and 4 by typing the following command. Be sure to enter + or - signs before each number.
\$PASHS,3DF,V14,+0.500,+0.500,+0.000 <ENTER>
- e. Verify you entered the correct information including + and - signs by typing **\$PASHQ,3DF**
- f. The system lists the relative antenna position vectors entered into the system. Check these to verify you entered each vector into the system correctly. If you made a mistake, you can reenter any of the three vectors.
- g. After verifying you entered the vectors correctly, type **\$PASHS,SAV,Y** to save the relative antenna position vector configuration.
- h. Press **<ALT>x** to exit Remote.

Performance Improvement

Attitude Accuracy

The accuracy of the 3DF system depends on two key factors:

- Antenna separation
- Multipath effects

Heading, pitch, and roll accuracies as a function of antenna separation are shown in Figure B.1.

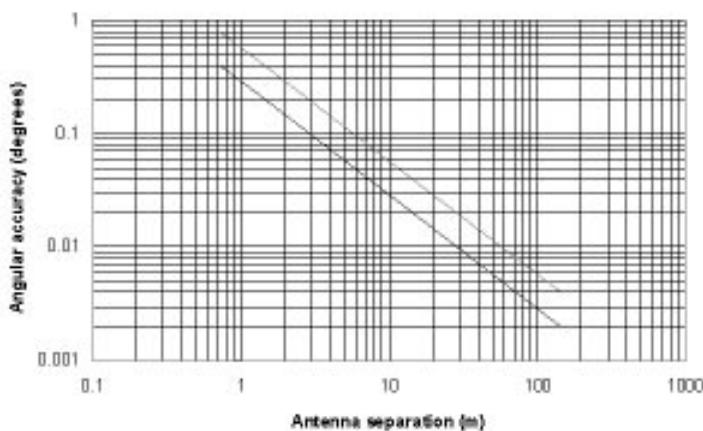


Figure B.1: Angle Accuracy vs. Antenna Separation

This figure is based on several different stationary attitude data sets collected for antenna separations ranging from 30 centimeters to 144 meters.

When analyzing these figures, note that:

- Heading accuracy is about a factor of two better than pitch or roll accuracy.
- Pitch and roll accuracies are the same.
- Attitude accuracy has a linear relationship to antenna separation.
- Accuracies are 1-sigma values, or rms, which means that 67% of the attitude measurements are at or below the accuracy numbers given.
- In each figure, the lower line (dashed) represents accuracy achievable if no multipath errors were present. In a normal environment, this is not possible.

Multipath effects from typical environments are depicted by the upper line (solid). For a given antenna separation, the performance of the 3DF system should lie somewhere near the upper line.

- A moving vehicle does not experience as many multipath effects as when it is stationary. This is because multipath is a correlated error. Correlated errors become more noise-like under vehicle dynamics and therefore can be filtered out. Therefore, accuracy results improve toward the lower line when the vehicle is moving.
- Heading accuracy is directly proportional to the separation between the two antennas which define the heading baseline, however too much separation can result in differential multipath between antennas and introduction of vessel or vehicle flexing into the attitude solution. These two factors are detrimental to heading accuracy. Antenna separations less than one meter are not advised, and antennas should not be located so that any of the three vectors are co-linear. Antenna separations of three to five meters are recommended.



Antenna location is the single most important aspect of successful attitude computation.

Attitude Offset Angles

Attitude offset angles are the angle differences (positive clockwise) in heading, pitch, and roll that exist between the ADU2 antenna system and the vehicle (“truth”). These offset angles are essentially constant bias errors from truth. Since the attitude given by a ADU2 system is so accurate (one milliradian or better), take care when mounting antennas on a vehicle to prevent unnecessary offset angles.

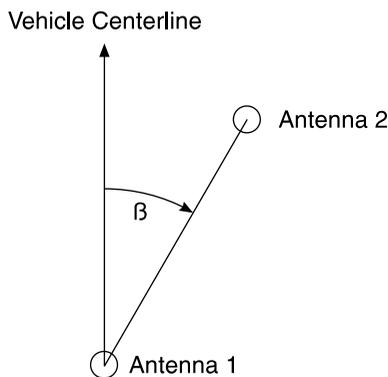
For example, mount two of the four ADU2 antennas on the centerline of a vehicle, separated by 2 meters. Both of these antennas must be placed within 2 millimeters of the centerline to obtain subdegree accuracy with no heading offset angle being induced. Separating the two antennas by 30 meters allows you to place them within 30 millimeters of the vehicle centerline to obtain the same accuracy.

The phase center of an antenna (both geodetic and aircraft types, described in Appendix B) is not in the exact physical center of the antenna. Therefore, when trying to mount two antennas along the vehicle centerline, make sure that both are placed in the same orientation.

If three of the four antennas cannot be mounted in the exact plane parallel to the vehicle body, pitch and roll offset angles are induced. These angles can be measured by taking into account the different heights of the antennas. Also, if the vehicle is stationary and has been oriented in space such that it has zero pitch and zero roll when performing the initial relative antenna position survey, the program ADJENU.EXE

can provide the relative antenna position vectors without any pitch and roll offset angles by choosing a Type 1 rotation. Refer to Step 3 of the Installation Procedure. Attitude offset angles exist for the 3DF system only for the two cases described below:

- A heading offset angle is induced when it is not possible to mount two of the antennas parallel to the vehicle centerline. As shown in Figure B.2, the line from Antenna 1 to Antenna 2 points toward the front of the vehicle. If Antennas 1 and 2 cannot be mounted along the centerline (or parallel to the centerline) of the vehicle, measure the offset angle B to the vehicle's centerline, using some type of measurement device or the vehicle drawings:



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Figure B.2: Antenna Offset Angle

- Pitch and roll offset angles are induced when it is not possible to mount three of the antennas in the same plane, parallel to the vehicle, and the vehicle's orientation is not at zero pitch and zero roll.

Heading, pitch and roll offset angles can be measured by other precise angular measurement devices which tell the orientation of the vehicle in space, such as a gyro-theodolite or an Inertial Measurement Unit (IMU).

Attitude Error Sources

The error sources affecting the accuracy of any GPS attitude system are described in this section.

Multipath is the single largest error source which limits the accuracy of attitude determination systems. It is a slowly varying error which occurs from reflecting

objects (such as metal or water) in the vehicle's environment. As a vehicle becomes more dynamic, the multipath error becomes less. This is because reflecting objects for a dynamic vehicle change (in location and orientation), causing the multipath error to average out.

Antenna separation plays a key role in determining the accuracy of the attitude solution. Since the relative antenna positioning accuracy can be considered constant, translating position accuracy to angular accuracy only depends upon the antenna separation. The further apart the antennas, the better the angular accuracy. Since heading accuracy is a function of antenna separation, multipath can affect the heading accuracy. Pitch and roll accuracy's are usually a factor of 1.5 to 3 times worse than the heading accuracy.

Phase measurement error (with no multipath) accounts for the noise of the attitude solution. This type of error is small and is insignificant when compared to the other error sources.

A bias-type heading error can occur when trying to mount Antennas 1 and 2 (which provide the heading direction) along or parallel to, the centerline of a vehicle. To prevent this, determine the heading offset angle before installation.

For example, most ship mounting restrictions do not allow the installation of two GPS antennas along, or exactly parallel to its centerline. The heading offset angle can be precisely determined while the ship is moored to the pier using a theodolite and EDM, or a total station. First establish an azimuth from a dockside instrument point (IP). Using the assumed coordinates at the IP, observe sideshots (angle and distance measurements) to the prism targets which have been placed both at the ADU2 antennas and at points known to be on the centerline of the vessel. For heading offset, only antennas 1 and 2 need to be targeted. Then use the sideshot observations to calculate the coordinates for all targets. The inverses between relevant target coordinates then provide the offset angle between the Antenna 1-2 vector and the vessel centerline. To negate the effect of any slight vessel movements during the observations, measure several rounds to each target and mean the results. It is helpful to locate the IP at a distance from the vessel sufficient to ensure rapid pointings of the theodolite, since the time delay between sideshots is a critical factor in minimizing the errors caused by vessel movement. An experienced instrument person using good techniques should be able to determine relative position of the targeted objects within a centimeter under good conditions.

Another possible method of determining any alignment between the ADU2 heading vector and the vessel centerline is to perform a simple comparison of ADU2 heading data (make sure no heading offset has been entered in the receiver setup) with readings from the ship's gyrocompass if the ship is so equipped. It is advisable to perform this comparison continuously for a period of at least 84 minutes to allow for the Schuler oscillation of the gyrocompass. If possible, the ship should be swung and re-moored with its opposite side to the pier, and the comparison performed again.

This cancels the bias which could be induced by any physical misalignment of the gyrocompass mounting.

Similar methods can be used to determine pitch and roll offset angles.

Microstrip antennas should be used for GPS attitude determination systems because they have a stable phase center (it does not fluctuate depending on where the GPS satellites are in the sky). Also, the manufacturing process of a microstrip antenna is such that the location of its phase center does not vary from one antenna to the next. But the phase center is usually not the physical center of a microstrip antenna. Therefore, orienting the antennas in the same direction is important so as not to incur bias errors in the heading solution.

When comparing the attitude solution of the ADU2 with any type of gyro, another error source should be considered. The ADU2's solution is raw, no filtering is performed and is provided at a 2Hz rate. On the other hand, a gyro's output is almost always smoothed in some way and give at a much higher rate (5 to 40 Hz). Therefore, you must interpolate the attitude data from the ADU2 and somehow *defilter* the gyro's output data for a time comparison.

Attitude Quality Indicators

To assure a good attitude solution has been computed, the MRMS and BRMS errors are used as quality indicators and are checked against maximums at every epoch.

A wrong attitude solution would cause both the MRMS and BRMS errors to continually grow larger. The rate at which these errors grow depends on the relative motion between the vehicle and satellites. The higher the vehicle dynamics, the faster the error growth rate of a false solution.

Also, as Position Dilution of Precision (PDOP) becomes higher, the BRMS error grows as well. Typically, GPS can provide good attitude information as long as PDOP is below 6, which is approximately 95% of the time with the full 24-satellite constellation, worldwide. (Note that with GPS the high latitudes will generally experience higher PDOPs than the equatorial latitudes.)

Multipath significantly affects the computed BRMS error, causing it to rise and fall as the antennas receive "constructive" and "destructive" interference. The period and amplitude of the multipath oscillations varies significantly depending on vehicle dynamics and environment. Static vehicles are the most affected by multipath while dynamic vehicles' multipath errors tend to average out.

The maximum limit for the BRMS error is set to 4 centimeters. This limit may be increased for vehicles in high multipath environments (that is, 6-8 centimeter limit). The maximum limit for the MRMS error is 5 millimeters and may be increased for high dynamic vehicles (that is, 6-7 millimeter limit).

The root mean square of the post-fit carrier phase measurement residual (MRMS):

$$MRMS = \sqrt{\frac{\sum_{i=1}^n \delta y^2}{n}}$$

where:

n is the number of residuals.

Once the carrier phase integer ambiguities have been found, each baseline vector can be computed through least squares with the equation.

$$\nabla\Delta\Phi + N = [D_r] r_{xyz}$$

where:

r_{xyz} = the baseline vectors in ECEF frame.

The BRMS value is computed based on the difference between the baseline vector lengths $|r_{XYZ}|$ and $|r_{BRF}|$.

$$BRMS = \sqrt{\frac{\sum_{ij=12,13,14} (|r_{xyz}| - |r_{brf}|)_{ij}^2}{3}}$$

where:

$ij = 12$ is the baseline vector formed by Antennas 1 and 2.

$ij = 13$ is the baseline vector formed by Antennas 1 and 3.

$ij = 14$ is the baseline vector formed by Antennas 1 and 4.

Reference

This appendix contains the following reference materials:

- Common GPS Acronyms
- Information about the US Coast Guard Information Center (GPSIG)
- Reference Documents

Common GPS Acronyms

Table C.1: Common GPS Acronyms

Term	Definition
ALT	Altitude
ALM	Almanac
AFT	After
AGE	Age of Data
ANT	Antenna
ASCII	American Standard Code for Information Interchange
AZM	Azimuth
BEF	Before
BIN	Binary Index (file)
BM	Bench Mark
BP	Barometric Pressure
C/A	Coarse/Acquisition or Clear/Access
DGPS	Differential
GPS DIFF	Differential
DMS	Degrees, Minutes, Seconds
DOP	Dilution Of Precision
DOS	Disk Operating System
EDOP	Elevation Dilution Of Precision
ELEV	Elevation

Table C.1: Common GPS Acronyms (continued)

Term	Definition
ELIP	Ellipsoid
ELV	Elevation
ENU	East, North, Up
EPHM	Ephemeris
FCC	Federal Communications
FREQ	Frequency
GLL	Latitude/Longitude for Position
GMST	Greenwich Mean Sidereal Time
GMT	Greenwich Mean Time
GPPS	GPS Post-Processing Software
GPS	Global Positioning System
GPSIC	GPS Information Center
HDOP	Horizontal Dilution Of Position
HEL	Health
HI	Height of Instrument
HTDOP	Horizontal/Time Dilution Of Precision
ID	Identification, Integrated Doppler
LAT	Latitude
LNA	Low-Noise Amplifier
LNG	Longitude
LON	Longitude
MMDD	Date format - Month, Date
MSG	RTCM Message
MSL	Mean Sea Level
NMEA	National Marine Electronics Assoc.
PDOP	Position Dilution of Precision
PE	Precise Ephemeris
POS	Position
RAM	Random-Access Memory

Table C.1: Common GPS Acronyms (continued)

Term	Definition
RF	Radio Frequency
RFI	Radio Frequency Interference
RH	Relative Humidity
RMS	Root Mean Square
RTCM	Radio Technical Commission for Maritime Services
SE	Site Editor or Standard Error
SESS	Session
SOG	Speed Over Ground
SS	Static Survey
SV	Space Vehicle
T-DRY	Temperature - Dry (Celsius)
T-WET	Temperature - Wet (Celsius)
TDOP	Time Dilution Of Precision
UT	Universal Time
UTC	Universal Time Coordinated
VDC	Volts Direct Current
VDOP	Vertical Dilution of Precision
WGS	World Geodetic System
WGS-84	Reference Ellipsoid

GPSIG Information

Since February 1989, the US Coast Guard has developed the requirements and plans for the Civil GPS Service (CGS) and has begun to implement these services. The four CGS functions recognized by the Coast Guard are listed below:

- Provide a GPS Operational Advisory Broadcast (OAB)
- Process applications for the civil use of GPS PPS (Precise Positioning Service)
- Provide precise GPS satellite ephemeris data
- Provide a government interface for civil GPS users

Two agencies perform these functions:

- The GPS Information Center - provides the OAB and precise ephemerides
- The PPS Program Office - processes civil applications to PPS access

The primary source of information for the OAB is the GPS control center at Falcon Air Force Base in Colorado Springs, Colorado. The OAB originates at GPSIC in Alexandria VA and is broadcast during normal working hours, 8AM to 4PM EST, Monday through Friday, except Federal holidays. An answering machine records messages after hours, and calls are returned the next working day. OAB information is updated only during normal working hours, but advisory services are accessible 24 hours, 7 days. OAB presents the following information:

- Status - Current constellation health and availability
- Outages - Recent and future satellite down time
- Almanac - Current projected orbit data for GPS coverage and visibility predictions
- Other - General GPS information and some user documentation



Satellite visibility and coverage predictions are not offered by GPSIC. These services are available from commercial sources or commercially available software.

GPSIC Voice Recording

This tape message contains current satellite status and outage information. The recording is available 24 hours 7 days and can be heard by dialing 703-313-5907. The recording is updated at least daily during normal GPSIC working hours.

WWV/WWVH Voice Broadcasts

These short-wave voice broadcasts contain current GPS status and outage information in a 45-second message. The message is broadcast at minutes 14 and 15 past each hour on WWV and at minutes 43 and 44 past the hour on WWVH. The information

is updated at least daily during normal GPSIC working hours. WWV and WWVH operate at 5.0, 10.0, and 15.0 MHz.

US Coast Guard Broadcast to Mariners

GPS status, future outages, and safety advisories are transmitted on the VHF marine radio band. The information is updated weekly and whenever satellite outages occur.

GPSIC Computer Bulletin Board Service (BBS)

GPSIC operates BBS that lists status, outage, almanac, and other GPS information. The BBS is available to any user free of charge, except for normal telephone fees. To access the BBS, the user will need a computer, a modem, and communication software. Users obtain a User ID password on line during the first session. The following information will be found useful in connecting to the GPSIC BBS.

Call 703-866-3890¹ for connections at 300 bps/Bell103, 1200 bps/Bell 212A, 2400 bps/CCITT V.22bis, no MNP capability (common US specs, Supramodem 2400).

Call 703-866-3893² for connections at 1200 bps/CCITT V.22bis, 1200 bps/CCITT V.22, 1200 bps/Bell 212A, 2400 bps/CCITT V.22bis, 4800 bps/CCITT V.32, 9600 bps/CCITT V.32 and MNP capabilities level 2,3,4,5, none (DigiCom Systems 9624).

Communications parameters at both numbers: Asynchronous, no parity, 8 data bits, full duplex, 1 stop bit (10-bit word).

The BBS ignores the 8th bit of data, restricting the character set to the lower 128 ASCII values. The BBS also checks for ANSI graphics capability, and employs some ANSI graphics if the user's equipment can display them. All users get the same information, but non-ANSI users will not see color images.

Defense Mapping Agency (ANMS)

The Defense Mapping Agency's Navigation Information Network, Automated Notice to Mariners System is a computer database that contains GPS status, outage, almanac, and other information. GPSIC updates the information at least daily. The information is contained in query number 85.

Users must register with DMA. To obtain a user ID and information booklet, contact:

DMA Hydrographic/Topographic Center

Attention: MCN/NAVINFONET

Washington DC 20315-0030 301-227-3296

-
1. FTS subscribers: 398-3890/3894 Autovon access is not available.
 2. Autovon access is not available.

DMA Broadcast Warnings

GPSIC provides GPS status, future outages, and safety advisories through the DMA HYDROLANT, HYDROPAC, and NAVAREA warning systems. These warnings are updated weekly and whenever satellite outages occur.

DMA Weekly Notice to Mariners

DMA publishes weekly navigation warnings and notices to mariners in a weekly publication “Notices to Mariners.” This publication automatically includes active GPS status and outage information generated by both broadcast and NAVAREA warnings. Distributed by:

Director, DMA
Combat Support Center
Attention: PMSS
Washington DC 20315-0010

NAVTEX Text Broadcast

The Coast Guard Local Notice to Mariners and DMA Broadcast Warnings also include text broadcast that contains the same information as the voice broadcasts. NAVTEX data is broadcast in English at 518 KHz from 16 transmitters worldwide. GPS status and outage information is available on NAVTEX.

For further information, contact:

US Coast Guard
7323 Telegraph Road, Alexandria VA 22310-3998
Tel 703-313-5900 Fax 703-313-5920

Sources

National Geodetic Information Center, NOAA

11400 Rockville Pike
Rockville MD 20852 Tel 301-443-8631

Institute of Navigation

1626 16th St. NW
Washington DC 20036

Scripps Orbit and Permanent Array Center (SOPAC)

High-Precision GPS BBS Service

Subscription \$7500/year and \$3000/year

Shelley Marquez, SOPAC Coordinator

IGPP-UCSD 9500 Gilman Drive La Jolla CA 92093-0225

Tel 619-534-0229 Fax 619-534-8090

International GPS Service for Geodynamics (IGS)

Jet Propulsion Laboratory MS 238-540

Pasadena CA 91109

Tel 818-393-6686

Fax 818-354-8330 or -5072

Internet ren@logos.jpl.nasa.gov.

Reference Books on GPS Theory

Wells: *Guide to GPS Positioning* ISBN 0-920-114-73-3 Available from Canadian GPS Associates Box 5378, Postal Station F Ottawa, Ontario Canada K2C 3J1

King, Masters, Rizos, Stolz, Collins: *Surveying with GPS* ISBN 0-85839-042-6 Available from School of Surveying, University of New South Wales P.O. Box 1 Kensington, NSW, 2033, Australia

Mathematical Treatment

Leick: *GPS Satellite Surveying* ISBN 0-471-81990-5 Wiley Interscience 605 3rd Avenue New York NY 10158-0012

Overview of Geodesy

Smith: *Basic Geodesy - An Introduction to the History and Concepts of Modern Geodesy without Mathematics* ISBN 0-910845-33-6

Landmark Enterprises, 10324 Newton Way, Rancho Cordova CA 95670

White Papers

The following papers are used throughout this manual:

- [1] **Ferguson, Kendall, et. al**, “*Three-Dimensional Attitude Determination with the Ashtech 3DF 24-Channel GPS Measurement System*,” ION National Technical Meeting, Phoenix, AZ, January 22-25, 1991.
- [2] **Kuhl, Mark**, et. al, “*Attitude Determination with the Ashtech Three-Dimensional Direction Finding System*,” Fifteenth Biennial Guidance Test Symposium, Holloman Air Force Base, NM, September 24-26, 1991.
- [3] **Qin, Xinhua, et. al**, “*Dynamic Short Baseline Calibration and Attitude Determination Using Ashtech 3DF System*,” Sixth International Geodetic Symposium On Satellite Positioning, Columbus, OH, March 17-20, 1992.
- [4] **Kuhl, Mark**, et al. “*Design Considerations and Operational Results*“

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