ADU3

Operation and Reference Manual

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Acronyms Used in This Manual

AGE	Age of Data
ALM	Almanac
ALT	Altitude
ANT	Antenna
ASCII	American Standard Code for Information Interchange
AZM	Azimuth
BCD	Binary-coded Decimal
BCN	Beacon
BIN	Binary Index (file)
BIT	Built-in Test
C/A	Coarse/Acquisition
CEP	Circular Error of Probability
DGPS	Differential GPS
DMS	Degrees, Minutes, Seconds
DOP	Dilution Of Precision
DOS	Disk Operating System
ECEF	Earth-Centered, Earth-Fixed
EDOP	Elevation Dilution Of Precision
ELIP	Ellipsoid
FCC	Federal Communications Commission
GMT	Greenwich Mean Time
GPS	Global Positioning System
GPS DIFF	Differential
HDOP	Horizontal Dilution Of Position
HTDOP	Horizontal/Time Dilution Of Precision
ID	Identification, Integrated Doppler
IODA	Issue of Data Almanac
IODE	Issue of Data Ephemeris
LAT	Latitude
LED	Light-emitting Diode
LNA	Low-noise Amplifier
LNG	Longitude
LON	Longitude

MMDD	Date format - Month, Date
MSG	RTCM Message
MSL	Mean Sea Level
NM	Nautical Miles
NMEA	National Marine Electronics Association
NVRAM	Non-volatile Random Access Memory
OEM	Original Equipment Manufacturer
PC	Personal Computer (IBM compatible)
PDOP	Position Dilution of Precision
POS	Position
RAM	Random Access Memory
RF	Radio Frequency
RFI	Radio Frequency Interference
RMS	Root Mean Square
ROM	Read-only Memory
RTCA	Radio Technical Commission for Aeronautics
RTCM	Radio Technical Commission for Maritime Services
SA	Selective Availability
SMA	Type of connector
SNR	Signal-to-noise Ratio
SOG	Speed Over Ground
SV	Space Vehicle (GPS satellite)
TDOP	Time Dilution Of Precision
TNC	Type of connector
TTFF	Time to First Fix
UT	Universal Time
UTC	Universal Time Coordinated
VDOP	Vertical Dilution of Precision
WGS	World Geodetic System
WGS-84	Reference Ellipsoid

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Introduction

The Thales Navigation ADU3, Figure 1.1 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 for static and dynamic platforms. The ADU3 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.

Figure 1.1. ADU3 Attitude Determination Unit

GPS attitude determination technology is based on differential carrier phase measurements between four antennas connected to the receiver. The ADU3 employs a 4-antenna receiver configuration with the ability to select the best eight channels per receiver to use in PDOP (Position Dilution of Precision)-based satellite searching and tracking. This improves solution integrity, allowing nearly 100% attitude availability, providing two-meter position accuracy, and attitude angles as accurate as one milliradian (0.057°) or better in real-time at a 5-Hz update rate.

The ADU3 compensates for a variety of antenna configurations in order to accommodate diverse vehicle mounting requirements and cable lengths. Relative positions need only be determined once per installation. Thales Navigation 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 Thales Navigation ADU3 standard and optional configurations, installation procedures, operation procedures, and requirements for a communications interface with external equipment.

Instructions are included for installing the ADU3 and calibrating the antenna array. For environments where the ADU3 default settings are not suitable, instructions are included to change the operating parameters using an external interface device such as a personal computer.

This manual is divided into the following parts:

- Chapter One: Introduction— general information on the ADU3 and interfacing cables, including pin assignments.
- Chapter Two: Quickstart—quick overview of the ADU3 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: Differential Operation - discussion of operating principles of GPS differential operation
- Chapter Six: Command/Response Formats— detailed discussion command and response formats
- Chapter Seven: Troubleshooting— suggestions for troubleshooting the ADU3 receiver.
- Chapter Eight: 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— background information

Description

The ADU3 provides real-time attitude information with accurate position and velocity at a 5 Hz update rate.

The ADU3 incorporates four GPS sensors (receivers) to make carrier phase measurements and perform real-time differential processing. The ADU3 can provide the following measurements at a 5 Hz update rate:

- attitude
- position
- velocity
- time data

The ADU3 is controlled and measurement data are output from two RS-232 ports at baud rates up to 115,200. The ADU3 computes accurate real-time heading, roll, and pitch information as shown in Figure 1.2.

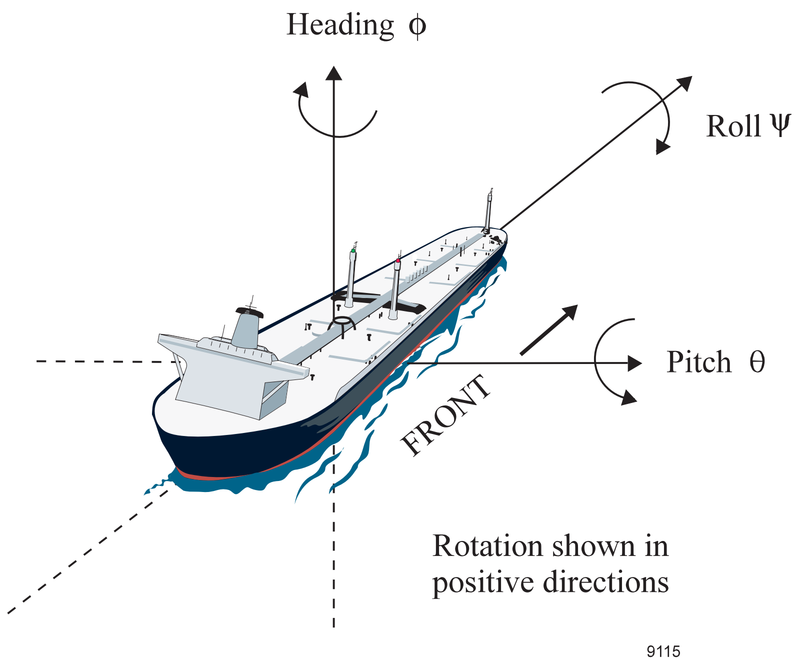

Figure 1.2. Attitude Components

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

Physical Description

The ADU3 is housed in an aluminum case 8.66 inches (22 cm) wide by 3.93 inches (10 cm) high by 7.87 inches (20 cm) deep (Figure 1.3). Four TNC connectors connect to four GPS antennas. Four LEDs along the bottom of the panel indicate satellite tracking on the associated antenna; these LEDs emit a green flash for each satellite being tracked. One LED in the top left corner indicates DGPS status.

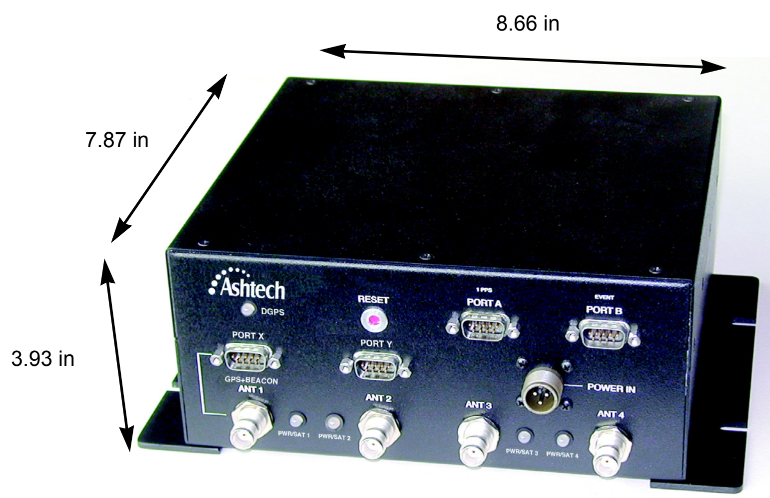

Figure 1.3. ADU3 Dimensions

Brackets are attached to the bottom of the case for easy mounting. Figure 1.4 shows the mounting hole configuration.

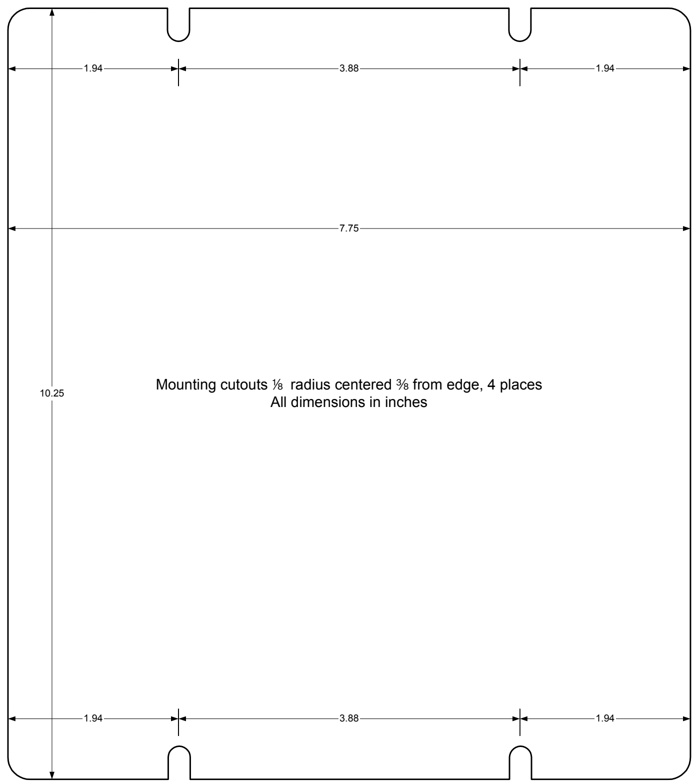

Figure 1.4. Mounting Configuration

Figure 1.5 shows the front panel components. Table 1.1 describes each component.

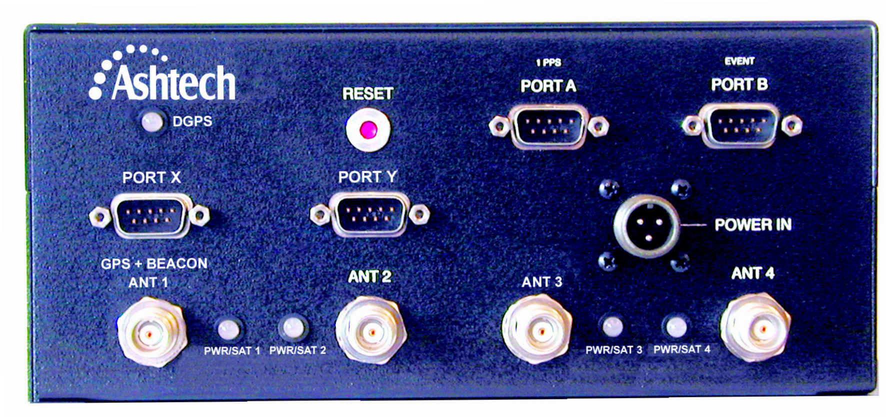

Figure 1.5. Front Panel

Table 1.1. Front Panel Controls, Connectors, and Indicators

Component	Description
RESET	Reboots the ADU3. If user-defined parameters are not saved, then RESET sets the parameters to the factory defaults.
1 PPS PORT A	A complete RS-232 port with full handshake. Port A can be used for communications with a hand-held computer, a personal computer, or a radio. Port A is used to transfer data from the receiver to a computer, from a PC to a receiver, and all other communication to and from the receiver.
EVENT PORT B	A complete RS-232 port with full handshake. Port B can be used for communications with a hand-held computer, a personal computer, or a radio. Port B is used to transfer data from the receiver to a computer, from a PC to a receiver, and all other communication to and from the receiver.
PORT X	
PORT Y	
DGPS	2-color LED indicates differential status of port X. See text for description.
PWR/SAT 1	3-color LED indicates power/satellites tracked for receiver 1. See text for description.
PWR/SAT 2	3-color LED indicates power/satellites tracked for receiver 2. See text for description.
PWR/SAT 3	3-color LED indicates power/satellites tracked for receiver 3. See text for description.

Table 1.1. Front Panel Controls, Connectors, and Indicators

Component	Description
PWR/SAT 4	3-color LED indicates power/satellites tracked for receiver 4. See text for description.
POWER IN	Three-pin power input connector.
ANT 1 through ANT 4	The RF antenna connectors are standard TNC-type female receptacles 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. ANT 1 should be connected to the GPS beacon antenna to receive the beacon signal.

PWR/SAT LEDs

Four PWR/SAT LEDs indicate the status of each of the four GPS receivers. Table 1.2 describes the LED indications.

Table 1.2. PWR/STAT LED Indications

LED Color	Description
Long red flash (0.75 sec)	Receiver is computing a position.
Short red flash (0.25 sec)	Receiver has lost the position computation.
Yellow flash	Satellite is locked, but not used in position computation. No preamble found.
Short green flash (0.25 sec)	Satellite is locked and available for position computation, but the ephemeris for the satellite has not been collected.
Long green flash (0.75 sec)	Satellite and its ephemeris are available and used in the position computation.

DGPS LED

The DGPS LED is a two-color LED which provides information on the availability of differential corrections to the receiver. The LED shows the number of corrections received for each type: SBAS, beacon, or serial. The LED blinks according to the following pattern:

- One red flash followed by one or more green flashes indicating the number of SBAS input corrections.
- Two red flashes followed by one or more green flashes indicating the number of beacon input corrections.
- Three red flashes followed by one or more green flashes indicating the number of serial input corrections.

Technical and Physical Specifications

Table 1.3 lists technical and physical specifications of the ADU3.

Table 1.3. Technical and Physical Specifications

Parameter	Description
Attitude accuracy (1x1M antenna array) • Heading • Pitch/Roll	• 0.4° static, 0.2° dynamic • 0.8° static, 0.4° dynamic
Positional accuracy • Stand-alone • Real-time differential (optional) • Post-processed	• 100m (95% with selective availability ON) • 2m (2D rms) 3m (3D rms) • 1cm + 2ppm
Velocity accuracy (PDOP<4)	1 cm/second
Time to first fix: • Warm start • No almanac (cold start)	• < 3 minutes • < 6 minutes
Update rate	5 Hz
Input voltage	12-32 VDC via 3-pin non-waterproof connector
Power requirements	12 watts maximum
Temperature limits	-20° to +55° C
Speed limit	1000 knots
Altitude	60,000 feet (higher available with special authorization)

Table 1.3. Technical and Physical Specifications (continued)

Parameter	Description
Physical characteristics • Weight • Size • Connectors	 • 5 lb 0.45 oz (2.29 Kg) • 22 cm W x 10 cm H x 20 cm D • 4 TNC connectors connect to 4 GPS antennas • 4 DB9 male connectors for serial communication
Port A and B	• DB9 RS-232 male connectors for communication with external equipment
Port X and Y	•
PWR/SAT 1-4	• Four LEDs indicate satellite tracking on the associated antenna. See text for description.
• Brackets	• Attached to bottom of case for mounting

Standard Equipment

Each ADU3 includes the following items:

- ADU3 unit
- ADU3 Operation and Reference Manual
- One power cable
- Two serial data cables
- ADU3 calibration software package (PN 600417)
- Real-time differential (remote only)—RTCM SC-104, Version 2 format
- EVALUATE software package and User's Guide

Optional Equipment

The following options are available; contact your Thales Navigation distributor for detailed information.

- 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
- Antenna line amplifier for beacon
- Waterproof line amplifier for beacon

Interfaces

Four TNC connectors provide the interface to four GPS antennas via 10-meter 50-ohm coaxial cables. Two standard RS-232 ports are accessible on DB9 connectors A and B. 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. Two limited-usage RS-232 ports are accessible on DB9 connectors X and Y.

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

Table 1.4 identifies the pin assignments for the four ports.

Table 1.4. Port Pin Assignments

Pin	Port A	Port B	Port X GPS + Beacon	Port Y
1	DCD	DCD	Reserved	Reserved
2	RXD	RXD	RXD	RXD
3	TXD	TXD	TXD	TXD
4	DTR	DTR	Reserved	Reserved
5	GND	GND	GND	GND
6	DSR	DSR	Reserved	Reserved
7	RTS	RTS	RTS	RTS
8	CTS	CTS	CTS	CTS
9	1 PPS	EVENT	Software upgrade	Reset

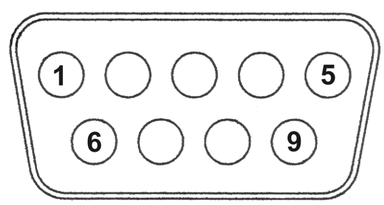

Figure 1.6 shows the power cable configuration and pinout.

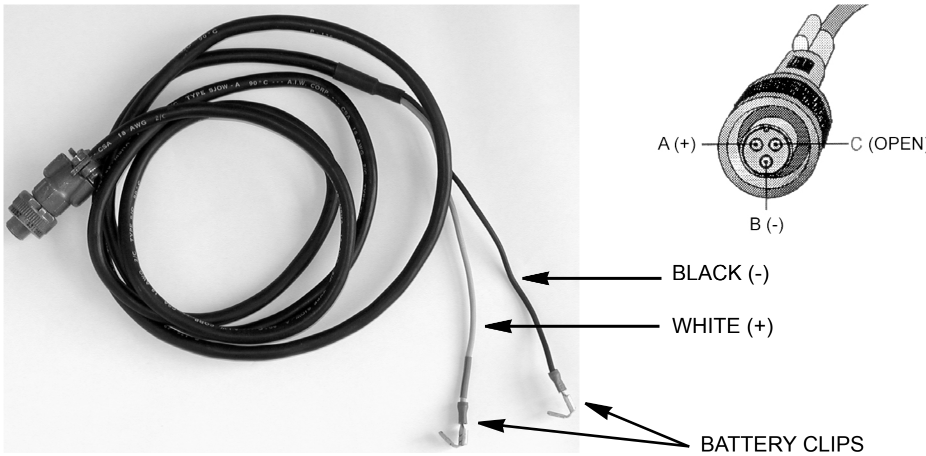

Figure 1.6. Power Cable Configuration and Pinout

The power cable is provided without fusing. If a fuse is desired, provide according to Table 1.5.

Table 1.5. Fuse Types

Input Voltage	Fuse Rating
12V	2A
24V	1A
32V	

2

Quickstart

This chapter provides a brief overview for setting up the ADU3. Users experienced with the ADU3 may use this chapter to accelerate installation and operation. Refer to the following chapters for detailed explanations: Chapter 3 for installation procedures, Chapter 4 for antenna calibration procedures, and Chapter 7 for troubleshooting.

Installation

The following procedure brings the ADU3 on-line.

1. Mount the antennas on any rigid platform as follows:
    a. If using the ADU3 fixed, portable antenna array, mount it using the 1- inch standard pipe fitting. Refer to *Appendix C, Reference*, for instructions to build the fixed portable antenna array.
    b. If using aircraft antennas, mount the antenna on a metallic ground plane with diameter at least 25 cm. If using aircraft-type antennas on a non-aircraft installation, multipath may be reduced by mounting the individual antennas on a metallic circular groundplane at least 25 cm in diameter. If

mounting to aircraft, these antennas need no ground plane and can be mounted flush with the aircraft skin.

c. If using geodetic or marine antennas, mount them on poles at least one meter above 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. If possible, place these antennas along (parallel to) the centerline of the vehicle. If this is not possible, a skew or offset angle can be determined and entered in the user parameters. Place antennas 3 and 4 to sides of antennas 1 and 2 to provide roll information (Figure 2.1).

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

Position and velocities are computed only for Antenna 1. The remaining antennas provide carrier phase data for attitude determination.

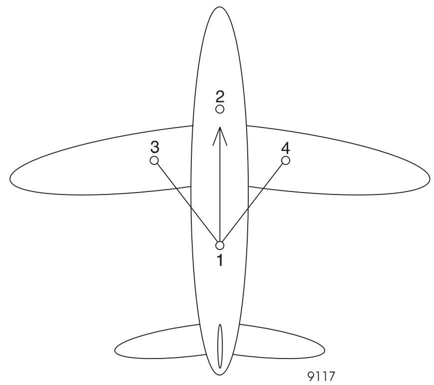

Figure 2.1 Example of Possible Antenna Locations on Aircraft

Quickstart

2. Connect the four antenna cables, labeled 1, 2, 3, and 4, to the antennas and the ADU3 ANT ports.
3. Turn off the external power source, and connect the power cable from the ADU3 to the power source. Turn on the power source.
4. Connect the interface cable from an RS-232 port (A or B) to a PC.

   The ADU3 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.
5. Insert the ADU software diskette into the appropriate drive. Type **a:install** (or **b:install**). Follow the installation program instructions that appear on the PC display.
6. If using the fixed portable antenna array, proceed to step 8 on page 19.

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. Inspect the **ADJENU** vector results in the file BRFVEC.XYZ. This file contains the calibration values for input to ADU3 attitude control parameters.

h. 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 **CALI3DF** 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

7. 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.

8. 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 ADU3 fixed portable antenna array, refer to Table 2.3 for vector information.

Table 2.3. Relative Antenna Position Vectors for 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

9. Set the data recording interval to 0.5 second (**$PASHS,RCI,0**).

10. 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 ADU3 has been calibrated and the offset vectors uploaded to the ADU3, the ADU3 is ready to output position velocity and attitude data.

Closely inspect the NMEA and raw data output formats, discussed in Chapter 6, *Command/Response Formats*, 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).

3

Installation

The ADU3 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	• 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 ADU3 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 ADU3. Refer to Appendix B for more information.
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 Mitigation	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 ADU3 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 ADU3 will be degraded.
Geometrical Configuration	• 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.

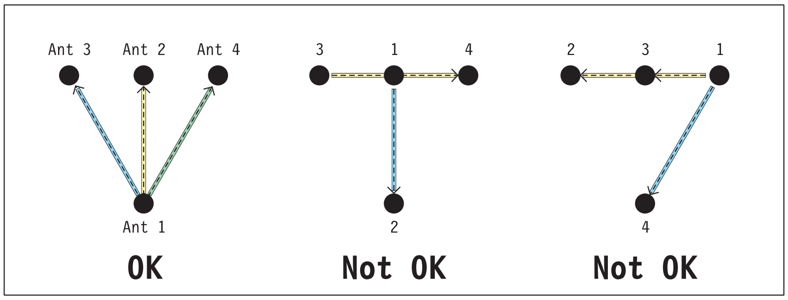

Figure 3.1. Configurations of Antennas (Top View)

1. The position computed by the ADU3 is referenced only to the primary antenna (Antenna 1).

   The other three 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, 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*.

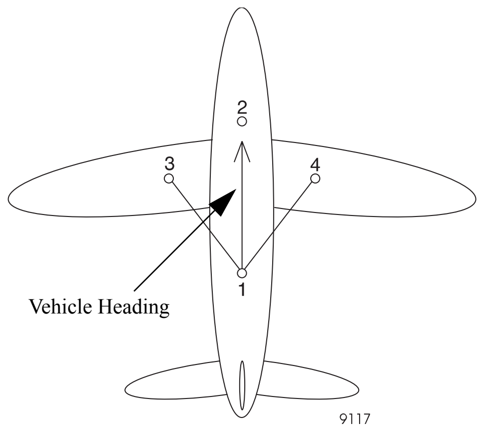

Figure 3.2. Suggested Locations for Antennas on Aircraft

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 ADU3 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 ADU3 package contains diskettes with software for the antenna calibration procedure. 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 ADU3 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 is 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 ADU3—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>**. The files listed in Table 3.2 should appear on the display.

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 BRFVEC.XYZ which contains the three vectors required for the ADU3.
ADULOG.EXE	Collects measurement data from the ADU3 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

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

File	Description
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.
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 ADU3 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.
PPLOT.EXE	Application to view more than one plot file.
PROCESS.EXE	Primary program that performs baseline processing for 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:

    a:\setup (or **b:\setup** if the diskette is in drive B).

17. Click **OK** to start the **EVALUATE** setup program.
18. Follow the setup program instructions that appear on the screen.
19. Refer to the ***EVALUATE*** *User's Guide* for additional information on **EVALUATE**.

Equipment Installation

1. Mount the ADU3 unit using the mounting brackets (Figure 3).

Figure 3.3 ADU3 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 ADU3. 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 ADU3 first, then the leads to the power supply.

3. Connect power supply cable to the power input on the ADU3.

Use a 12-to 32-volt regulated DC power supply. The Ashtech power supply cable is recommended. If you use your own power supply cable, make sure the cable length is less than 3 meters.

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 ADU3 unit is powered up, it beeps once, the LEDs flash orange and red several times, and then 10-15 seconds later, the ADU3 beeps a second time indicating that it has successfully booted. Communication through Port A or B can only be established after the ADU3 successfully booted.

Verify Antennas Tracking Satellites

After installing the ADU3 and antennas or antenna array, Thales Navigation recommends verifying that the antennas are connected to the ADU3, receiving information from satellites, and computing a position.

1. Verify all four antennas are connected to their respective port on the ADU3 as described in “Antenna Installation” on page 21.
2. Verify that the receivers 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 might be:

```
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 satellites tracked on each receiver for each antenna. Verify that each receiver 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 **$PASHS,POS** to verify the ADU3 is computing a position. **REMOTE** responds with a computed position for the ADU3.
4. Exit **REMOTE** by typing **<ALT>x**. At the prompt, type **Y**.

4

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 ADU3 can calculate attitudes.

A static calibration can be used in the following circumstances:

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

A dynamic calibration procedure should be used for a vessel, aircraft, or other vehicle which is in constant linear motion during the 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, or if damage and deformation of the array has occurred.

Try to set the antenna platform level during calibration.

The static calibration procedure comprises the following operations:

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 8, *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 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 the prompt, 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 receivers into one data file. The data must be split into a file for each antenna using **SPLIT3DF** so the data can be processed.

1. Start **SPLIT3DF** by typing **split3df <ENTER>** at the DOS prompt. The main screen of **SPLIT3DF** opens (Figure 4.2).

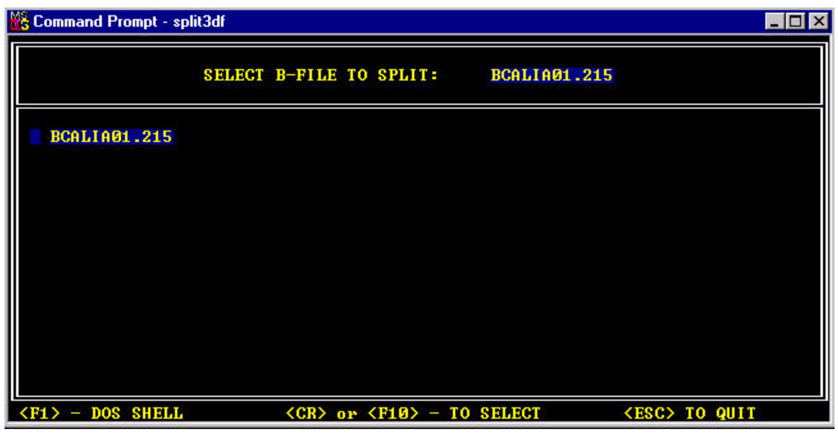

Figure 4.2 ADU3 B-File Selection

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-fields 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 that:
    - 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 form these, then repeat the calibration procedure or view the plotfile using PPLOT, 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 **<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, as shown in Figure 4.2.

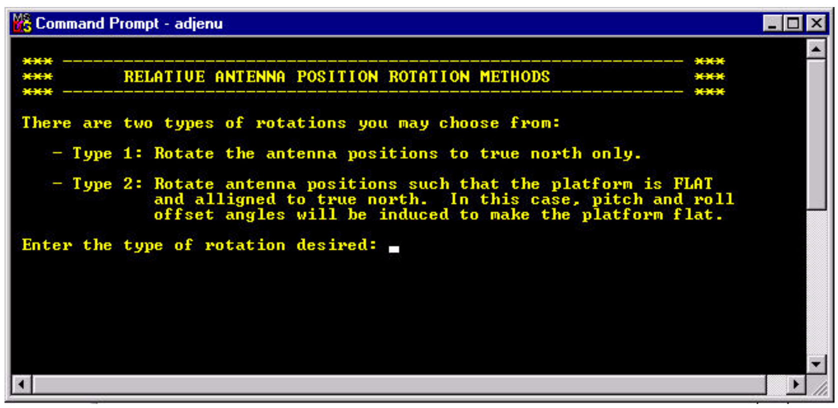

Figure 4.3 Relative Antenna Position Rotation Methods

2. Select Type 1 and press <ENTER>. The Defining a Heading Direction Using one of the Baselines screen opens (Figure 4.4).

Type 1 rotation rotates the relative antenna positions to true north only. This type is used if you performed the survey with 0 pitch and roll, or if 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. Press **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.

Try to set the antenna platform level during calibration. Type 1 is the recommended rotation method.

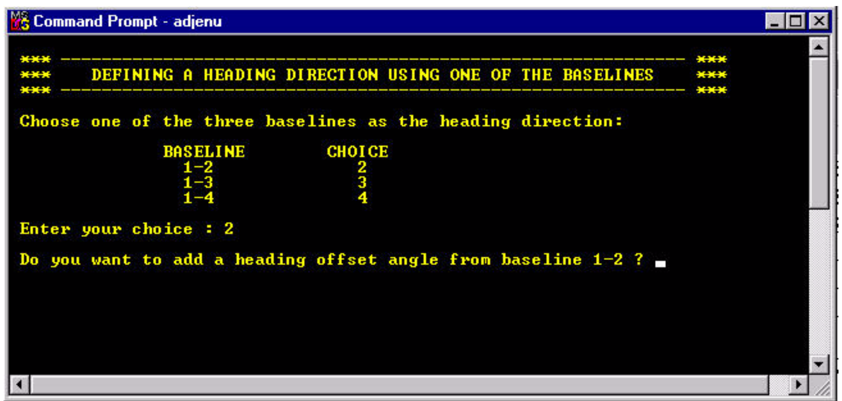

Figure 4.4 Relative Antenna Position Rotation Methods

4. ADJENU asks of 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 ADU3 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

It is possible to calibrate the ADU3 *in situ* while the vessel, vehicle, or aircraft is moving in its normal operating manner. The dynamic calibration process has more rigorous requirements for data collection than does the static calibration. Continuous lock must be maintained on a minimum of five satellites throughout the period of data acquisition. The data recording interval should be either one or two seconds, and the duration of the observations should be minimum one hour.

It is not necessary to maintain steady course or speed during the calibration data collection, but care should be taken to avoid sudden changes of attitude, such as steeply banked turns in an airplane or sharp course changes on ships. These may cause the ADU3 to lose lock on satellites and will jeopardize the success of the calibration.

The dynamic calibration procedure comprises the following operations:

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 calibration 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 per 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 1east 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 that 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. The CALI3DF software does not require this operation.

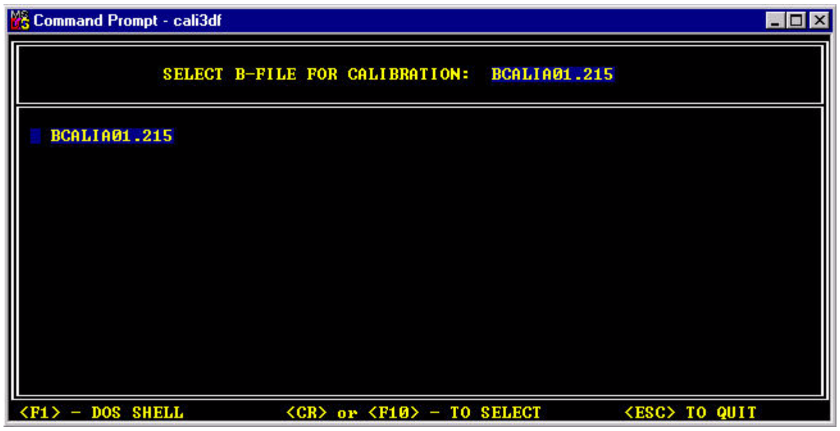

Figure 4.4: Select B-File for Calibration

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).

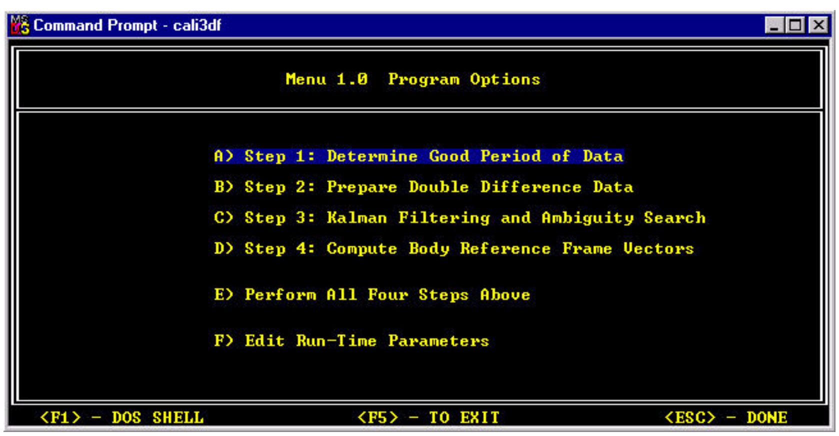

Figure 4.5 Calibration Program Options

4. The calibration program first checks a collected ADU3 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>**.

Step 1. Determine Good Data Period

Option A scans the selected ADU3 B-file to determine if a good data period of 1800 consecutive seconds of cycle-slip-free data containing a minimum of 5 SVs exists within the data set. Keep in mind this is 1800 *seconds*, not 1800 epochs or records. This is why it is good practice to always record at least 1 full hour of data, with a record interval of either 1 or 2 seconds. This will generally ensure that somewhere within that hour a good 1800-second data period will be found. If this program step successfully determines a valid reference satellite (usually the one with the highest elevation throughout the data set) and locates a sufficient “good data period”, it will terminate with the display shown in Figure 4.6.

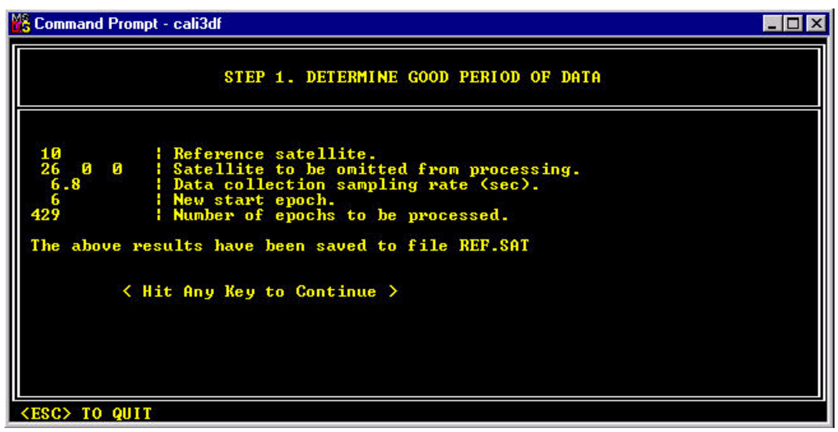

Figure 4.6 Good Period

This screen shows which satellite has been chosen as the reference satellite, which satellites will be omitted from the processing (if any), and how many epochs are contained in the “good period” and are therefore eligible for processing. If this step has been successful, you may **continue on directly to Step 2** of the processing.

If, on the other hand, the search for a good data period was unsuccessful, it is still possible to achieve a good calibration by means of some user intervention. An unsuccessful Step 1 will result in a screen similar to Figure 4.7.

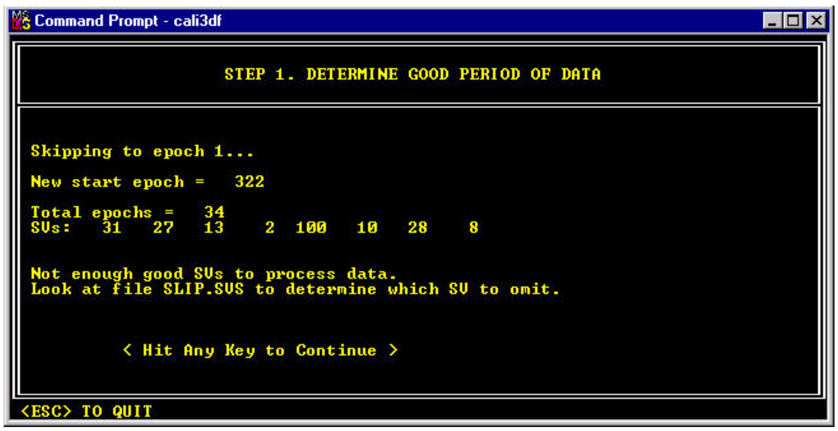

Figure 4.7 Unsuccessful Step 1

This screen indicates that a sufficient “good period” of data was not found, and suggests that the user inspect the processing file SLIP.SVS in order to determine which satellites had cycle slips and are therefore candidates for omission. It also lists the consecutive records obtained between cycle slips in the data. It will be shown that the user has two possible forms of intervention:

- Omit offending satellites (by editing runtime parameters) and rerun Step 1, or
- Determine the maximum existing “good period” in the data and shorten the required length of the good period accordingly (also by editing runtime parameters), then rerun Step 1.

Note: Of the two, the former is preferred. Sometimes a combination of the two is required. If neither results in a successful Step 1, there is usually no recourse except to perform a reobservation and obtain a new data set.

When attempting to recover a good calibration from a marginal data set, the first step is to inspect the SLIP.SVS text file. This file will look something like Figure 4.8.

t_begin	t_end	time_span	start_epoch	tot_epochs	good_svs	last_sv	curr_sv
594340	594805	460	1	93	8	1	100
594805	594810	2	93	2	7	100	1
594810	594935	120	94	26	8	1	100
594935	595030	90	119	20	7	1	100
595030	595040	7	138	3	7	100	1
595040	595070	26	140	7	7	100	1
595070	595220	145	146	31	8	1	100
595220	595265	40	176	10	7	3	28
595265	595370	100	185	22	7	100	1
595370	595375	2	206	2	8	1	100
595375	595380	2	207	2	7	100	1
595380	595385	2	208	2	8	1	100
595385	595405	16	209	5	7	1	100
595405	595420	11	213	4	7	1	100
595420	595990	565	216	106	7	28	100
595990	595995	2	321	2	6	100	28

Figure 4.8 Typical SLIP.SVS File

This cryptic looking file is a summary of the results of the Step 1 search for a "good data period". There are actually only four columns of data that have any significance for the user, and the other columns can be largely ignored. The file tabulates all the instances of cycle slips in the data, and a separate line or record is written to this file every time a slip occurs.

The first column to inspect is column 6, "good_svs". This column indicates how many satellites are being tracked by the ADU3 during the data collection period. Remember that the dynamic calibration needs a *minimum* of 5 cycle-slip free satellites in order to do its job. In the case shown here we see that we were tracking a minimum of 7 satellites for a large percentage of the data set. This is good, because it means that we can potentially omit two satellites and still meet the 5 SV criteria.

The next columns to inspect are the last two columns which indicate *which satellites* incurred cycle slips. They are listed by their PRN numbers. Ignore the "100" value, it is meaningless in this exercise. We see in this data that the culprits are SV numbers 1, 3 and 28. Satellites 1 and 28 are in fact involved in every cycle slip that occurred. Armed with this information we can now edit the runtime parameters and make another attempt at determining the "good data period. To do this we go back to Menu 1 of the CALI3DF program and select Option F, "Edit Runtime Parameters". This will call the screen shown in Figure 4.9.

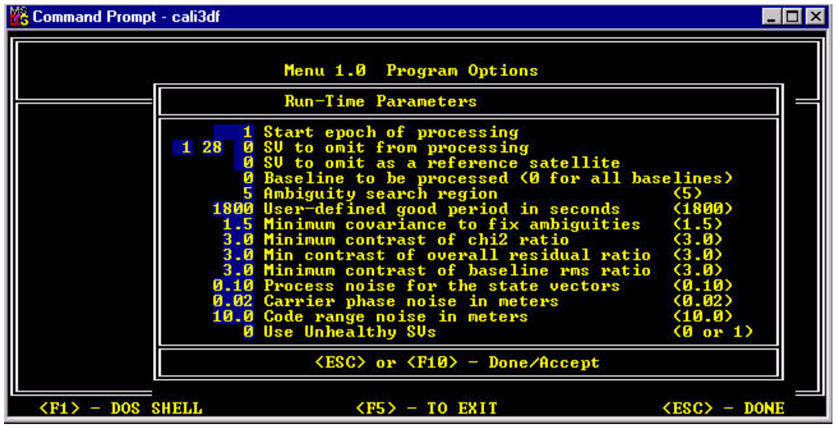

Figure 4.9 Edit Runtime Parameters

The runtime parameters list is displayed here. Blue boxes on the left side of the list are for user entries. Note that on the second line of the list, “SV to omit from processing”we have entered SV numbers 1 and 28, the prime offenders noted in the SLIP.SVS file. You can now proceed by pressing <F10> to save the new runtime parameters, return to Menu 1, and rerun Step 1. More often than not, a good data period will be found after omitting satellites from the processing. Occasionally there will be a case where 1800 consecutive seconds of cycle-slip free data can still not be found. This leads to the next strategy for achieving valid calibration. The newly generated SLIP.SVS file should once again be inspected. It may now look something like Figure 4.10.

t_begin	t_end	time_span	start_epoch	tot_epochs	good_svs	last_sv	curr_sv
594340	595265	920	1	185	7	9	100

Figure 4.10 Typical Slip File After SVs Omitted

A much shorter slip file than before, with only one cycle slip occurrence. This time inspect the third column “time_span”. This number is the total number of consecutive cycle-slip-free seconds. In this example there are only 920 seconds available, and there is no possible way to meet the 1800-second criteria. In actual fact, it is acceptable to reduce the 1800-second criteria, although it is never good to use fewer than 900 consecutive seconds. With the 920 seconds shown here, that threshold is barely met, and you can go back to the runtime parameters and change the number on Line 6 (User-defined good period) to something like 910. An acceptable good period will be found, and you can proceed to Step 2 of the CALI3DF procedure. In some cases the SLIP.SVS file will show several slip-free segments, all of which are shorter than the required 1800 seconds, but some of which may be longer than the bare minimum 900 seconds. In this case, pick the longest available time span and enter a number slightly less than that in the “user-defined good period” field on the runtime parameters screen. In most cases you can proceed to step 2.

Note: Do not attempt to alter any other runtime parameters except the ones discussed above. If your data fails after these two options, it is best to reobserve and obtain a better data set.

Step 2: Prepare Double Difference Data

This step requires no user interaction. Select Step 2 on the Program Options menu. The program will determine code and carrier phase double differences which are then used by a Kalman filter to estimate the phase ambiguities for each baseline in Step 3. A double difference data file, called BDDDATA.TMP will be created. Successful termination of Step 2 will result in the display shown in Figure 4.11

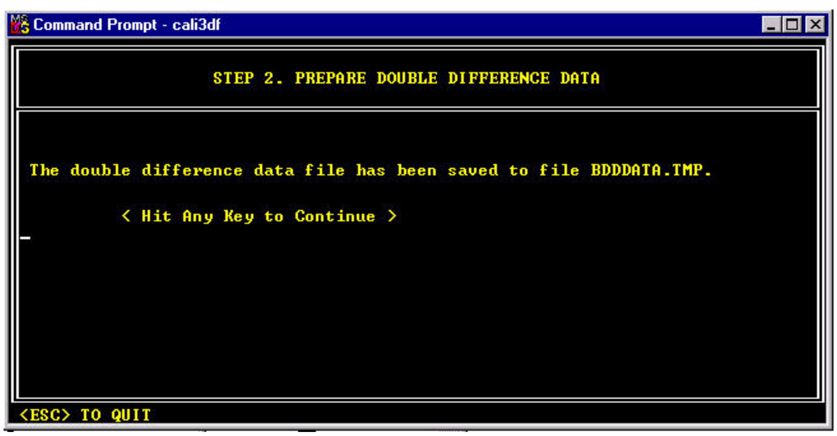

Figure 4.11 Step 2 Successful

Step 3: Kalman Filtering and Ambiguity Search

This is the most important step in the dynamic calibration processing. The Kalman filter recursively estimates a set of ambiguities for the three baselines using consecutive epochs of double difference measurement data. The successful completion of this step depends heavily on the quality and quantity of the measurement data obtained during the calibration period. If you had to omit satellites or shorten the user-defined good period in Step 1, the chances of a successful Step 3 are somewhat lessened.

From the Program Options Menu, select Step 3. The program begins the Kalman filter processing, which can take some time. Progress is displayed on the screen in a series of iterations, of which Figure 4.12 is typical.

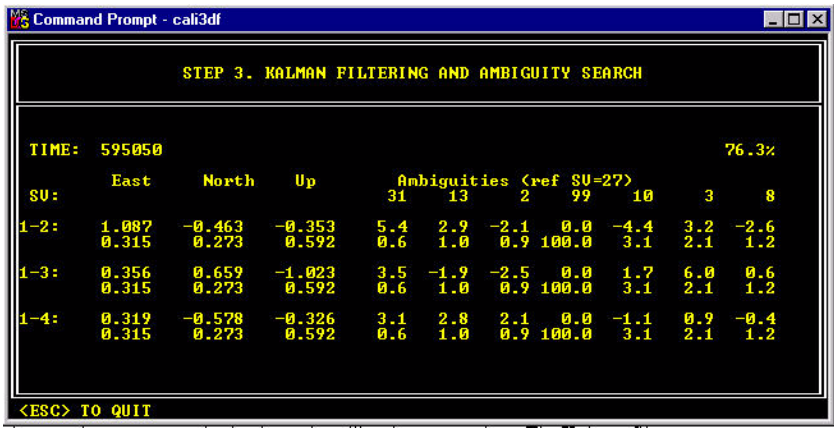

Figure 4.12 Typical Kalman Progress Display

If the Kalman filter ambiguity search fails, a warning screen will appear for several seconds, followed by a screen indicating a bad result. The warning screen looks like Figure 4.13.

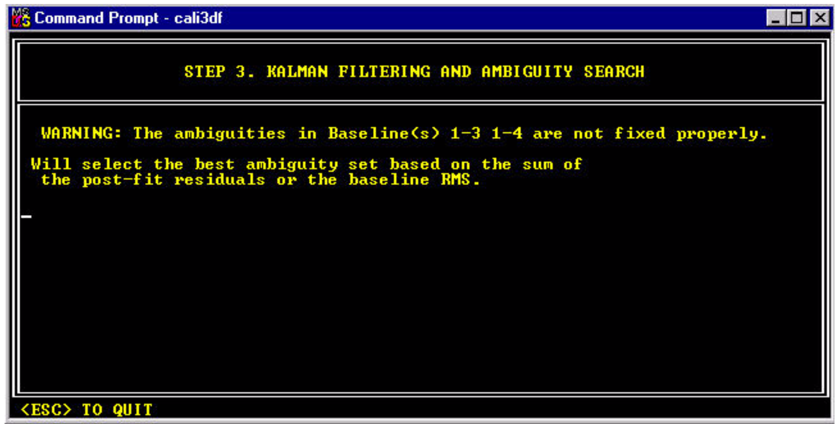

Figure 4.13 Ambiguity Warning

The failed Step 3 result screen will appear as shown in Figure 4.14.

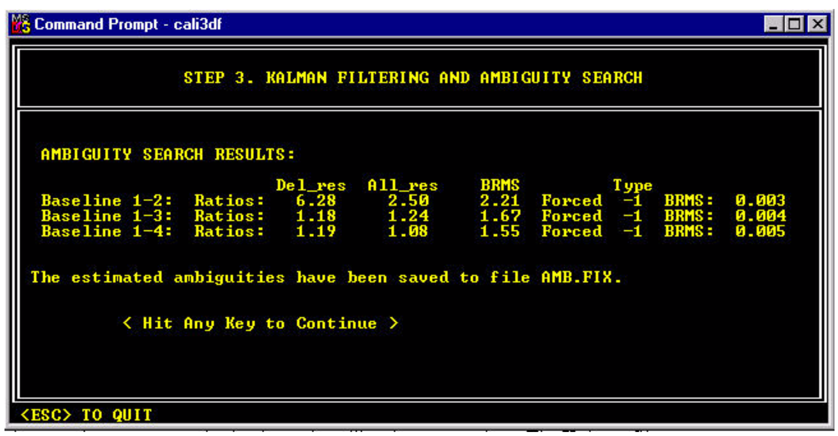

Figure 4.14 Typical Failed Step 3 Results

The computed vector solutions for each baseline are shown as “forced”, meaning that the exact ambiguity sets could not be determined and estimated ambiguities have been used. This is also indicated by the “-1” value shown in the solution Type column. At this point it is best to obtain another calibration data set. In rare cases an adequate calibration can still be obtained by doing some manipulation of the Kalman filter runtime parameters, but it is a difficult and time-consuming procedure and not guaranteed of success. For this reason it is always better to obtain a better data set and repeat the entire procedure. A successful completion of Step 3 will be indicated as shown in Figure 4.15.

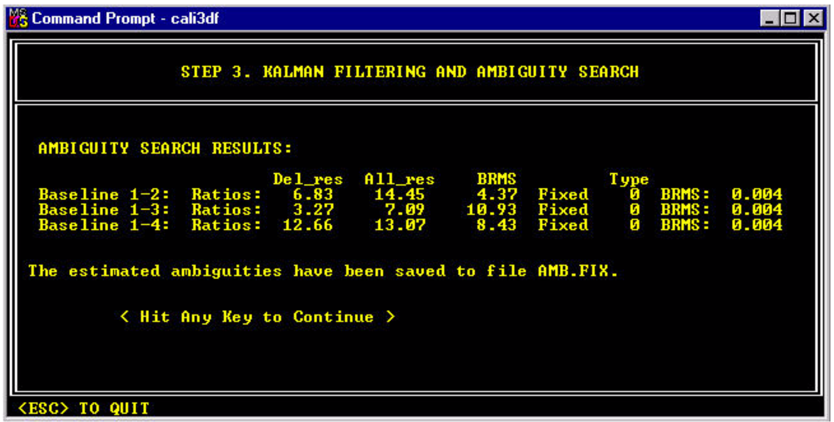

Figure 4.15 Typical Step 3 Successful Display

It can be seen now that all vectors have achieved fixed ambiguity solutions, as indicated by the term “Fixed” and solution Type “0”. At this point it is time to **proceed to Step 4** of the calibration processing.

Step 4: Compute Body Reference Frame Vectors

The final step in the dynamic calibration process is to compute the BRF vectors which will then be input to the ADU3 as attitude setup parameters. These vector components are the coordinates of the three secondary antennas (antennas 2, 3 and 4) relative to Antenna 1, the primary antenna.

From the **Program Options Menu**, select Step 4. The software quickly computes the relative antenna vectors and displays them on the screen. These results are also written into the BRFVEC.XYZ file. The final results screen appears as shown in Figure 4.16.

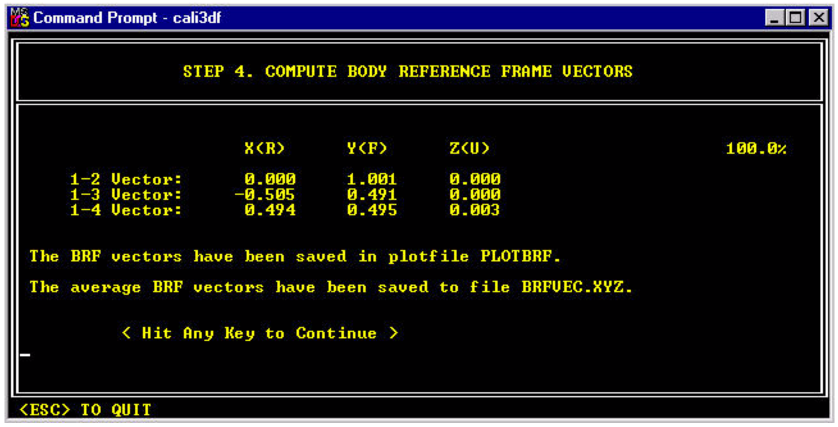

Figure 4.16 Final Results

Before entering these vector components in the ADU3, you should first inspect the BRFVEC.XYZ text file, and it may also be useful to view the resulting plotfile, called PLOTBRF. The plotfile can be viewed using the PPLOT.EXE utility program.

The BRFVEC.XYZ (the filename stands for Body Reference Frame Vectors in XYZ coordinates) differs from the file of the same name as generated by the static calibration procedure. A typical BRFVEC.XYZ file resembles Figure 4.17.

```
*** ------------------------------------------ ***
***   Input Relative Antenna Positions (meters)  ***
*** -------------------------------------------- ***
X(R)       Y(F)       Z(U)
1-2 Vector     0.000      1.001      0.000
1-3 Vector    -0.505      0.491      0.000
1-4 Vector     0.494      0.494      0.002
*** -------------------------------------------- ***
The RMS values of these three baselines are (meters):
Baseline 1-2:  0.004 Good
Baseline 1-3:  0.004 Good
Baseline 1-4:  0.004 Good
*** -------------------------------------------- ***
*** Adjusted Relative Antenna Positions (meters) ***
*** -------------------------------------------- ***
X(R)       Y(F)       Z(U)
1-2 Vector     0.000      1.001     -0.005
1-3 Vector    -0.504      0.491      0.009
1-4 Vector     0.494      0.494     -0.011
*** -------------------------------------------- ***
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:   -0.306 (degrees)
ROLL  OFFSET ANGLE:    1.295 (degrees)
If the adjusted relative antenna positions
are used, no pitch or roll offset angles
are needed.
*** -------------------------------------------- ***
```

Figure 4.17 Typical BRFVEC.XYZ File

Notice that in the first set of vectors shown (the “Input” relative vectors), three of the components are set to 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 have been induced by motion of the platform during the calibration period. The software computes those angular offsets and factors them into the second set of vector components (the "adjusted" relative antenna positions). The computed angular offsets are also displayed. If you choose to use the "adjusted" vector components in the attitude setup, the pitch and roll offset angles can be ignored. If using the "input" vector components, it is advisable to also enter the pitch and roll offsets. The effect will be the same either way. Only make sure not to use the adjusted vectors AND the offset angles, in which case you would be applying the offsets twice. Refer to the attitude setup and control commands section for information on entering the vectors and offsets. Important things to note in the BRFVEC.XYZ file are the baseline RMS values; these should generally be less than 0.015 meters to be considered adequate. RMS values less than 1 centimeter are a sign of a high quality calibration. To be absolutely certain that the calibration has been successful it is a good idea to check the PLOTBRF file and see that the average computed vector components (the green line in each plot) trends to flatness at the end of the data (Figure 4.18).

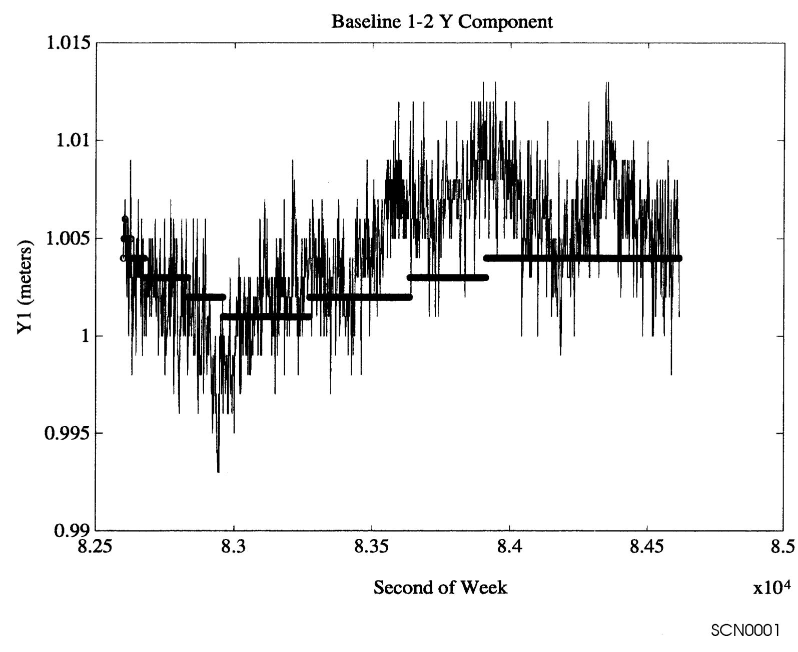

Figure 4.18 BRF Vectors Plot

Antenna Calibration

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.

6. 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 ADU3 system unless you replace an antenna or if there has been any changes made to the relative positions of the antennas.

5

Differential Operation

The ADU3 can operate as a remote station for differential GPS.

This chapter contains a general discussion of real-time differential operation, including available options, basic concepts, sources of error, and commands related to differential GPS. Differential Remote [Option U] is available as a receiver option; the Remote option must be installed for the ADU3 to support differential mode.

The ADU3 can perform differential positioning in any of four modes:

- Single automatic WAAS/EGNOS
- Single automatic beacon
- Single manual beacon
- Single local base station (serial/RS-232 RTCM)

The ADU3 accepts DGPS corrections from the following sources:

- Serial/RS-232 RTCM
- WAAS/EGNOS
- Beacon

General

Real-time differential positioning involves a reference (base) station calculating range corrections for each satellite it is tracking and transmitting them to the remote (rover) stations through a real-time data communications link. Remote receivers apply the corrections to their own range measurements and use the corrected ranges to compute positions.

The base receiver determines range correction by subtracting the measured range from the true range. A precise reference position must be entered in the base receiver before true range can be calculated.

RTCM type 1 corrections with a UDRE (User Differential Range Error) field set to 3 (one-sigma differential error > 8 meters) are not used.

For differential operation the ADU3 incorporates a Thales DG16 GPS receiver connected to ANT 1. The DG16 processes signals from GPS, SBAS, WAAS, EGNOS, MSAS, and 300 KHz beacon, providing real-time position, velocity, and time measurements. With the [Y] option installed, the DG16 uses 14 channels for Coarse/Acquisition (C/A) code-phase and carrier phase measurements on the L1 GPS band. With the [N] option installed, the DG16 can process two additional channels for beacon signals.

As a stand-alone receiver, the ADU3 can compute a position with ± 3 meter CEP (Circular Error of Probablility) of accuracy (on average) with Selective Availability (SA) off. Autonomous accuracy worsens to an average of ±100 meters with SA on. In differential mode, an ADU3 in rover mode can achieve sub-meter accuracy.

Real-time differential operation requires a communication link between the base and rover receivers. A wireless link, such as a radio-modem link or cellular/modem link is typically used, although any other medium that can transfer digital data can be used.

Sources of Error

The major sources of error affecting the accuracy of GPS range measurements are satellite orbit estimation, satellite clock estimation, ionosphere, troposphere, multipath, and receiver noise in measuring range. The first four sources of error are almost totally removed by differential corrections. The residual error is in the order of one millimeter for every kilometer of separation between base and remote receivers.

Receiver noise is not correlated between the base and the remote receiver and is not canceled by differential GPS. However, in the ADU3, integrated doppler measurements are used to smooth the range measurements and reduce the errors resulting from receiver noise.

At the instant an satellite is locked, there is also RMS noise affecting the range measurement. RMS noise is reduced over time by the square root of the number of measurements computed by the receiver. For example, after 100 seconds of locking to a satellite, the rms noise in range measurement is reduced by a factor of 10 (one meter of noise is reduced to 0.1 meter). The noise is further reduced with each additional measurement.

If the lock to a satellite is lost, the noise goes back to one meter and smoothing starts from the one-meter level. The loss of lock to a satellite is rare, and typically happens only when the ADU3 antenna’s line of sight to the satellite is blocked by an object, or when the satellite goes below the horizon.

Total position error (or error-in-position) is a function of the range errors (or errors-in-range) multiplied by the PDOP (three-coordinate position dilution of precision). PDOP is a function of satellite geometry; that is, the positions of the satellites in relation to one another.

RTCM Messages

The ADU3 accepts differential correction messages in the RTCM format (refer to *RTCM Recommended Standards for Differential GNSS*, version 3.0). The ADU3 can be set to receive RTCM messages through Port A or Port B by issuing the set command **$PASHS,RTC,s1,c2** where s1 is REM (remote mode) and c2 is the port designator for input of differential corrections. $PASHS,RTC,REM,ON can also be used, in which case Port B is used by default for receiving RTCM corrections. The ADU3 supports six different types of RTCM messages. Message type 3 contains base station status information. Message type 16 contains a special ASCII message of up to 90 characters. Type 16 messages are used to communicate special information. For example, a base station operator may wish to construct a message informing users that the base station will go offline temporarily in order to perform routine maintenance or repairs. Message types 1, 2, and 9 contain data used for position correction. The type 6 message is a null frame message which is used to establish and maintain RTCM message frame synchronization for remote differential stations. RTCM messages are processed automatically by the ADU3.

On initial power-up, or after issuing the **$PASHS,RST** command (restore defaults), the ADU3's setting for differential mode is OFF, and the setting for the maximum age of an RTCM differential correction is 60 seconds, meaning that an incoming correction whose age is greater than 60 seconds is not used. If automatic differential GPS mode is not enabled **($PASHS,DIF,AUT)**, and if the differential correction data is unavailable or is older than the maximum age specified by the **$PASHS,RTC,MAX** set command, an ADU3 set as a remote differential station will not output position data. If automatic differential mode is enabled, an ADU3 set as a remote differential station will output uncorrected positions if differential correction data is unavailable, or if the age of correction exceeds the maximum age setting.

Remote Station

When the RTCM Remote option [U] is installed and the ADU3 is set in differential remote mode, it can decode RTCM message types 1, 2, 3, 6, 9, and 16, but uses only types 1, 2, and 9 to correct its position calculations.

The ADU3 can accept differential corrections from an SBAS satellite, a beacon station, or through a serial port input. You can select the set of corrections you want to use in the navigation solution using the $PASHS,RTC,SLC command.

The ADU3 validates all received differential corrections including the checksum and parity validation checks included in the RTCM and SBAS specifications, and uses only the valid correction data in the navigation solution.

When in DGPS operation and using RTCM corrections, the ADU3 supports the Type 2 message for IODE changes.

A differential navigation solution is only computed when there is a sufficient number of matched sets of satellite parameters and corrections. The ADU3 will never calculate a partial differential solution. It there are enough corrected satellites to compute a position even though not all tracked satellites have corrections, the navigation solution disregards uncorrected measurement data and/or unused corrections and includes only corrected measurement data in the computation. The number of satellites required to produce a valid solution depends on the position mode: at least four satellites for a 3D solution, and at least three satellites for a 2D solution.

The ADU3 conducts validity tests on incoming RTCM messages before incorporating them into the navigation solution.

Setting Up a Differential Remote Station

You must have the differential remote option **[**Option U**]** installed in your receiver. Figure 4.1 shows a typical DGPS remote station configuration

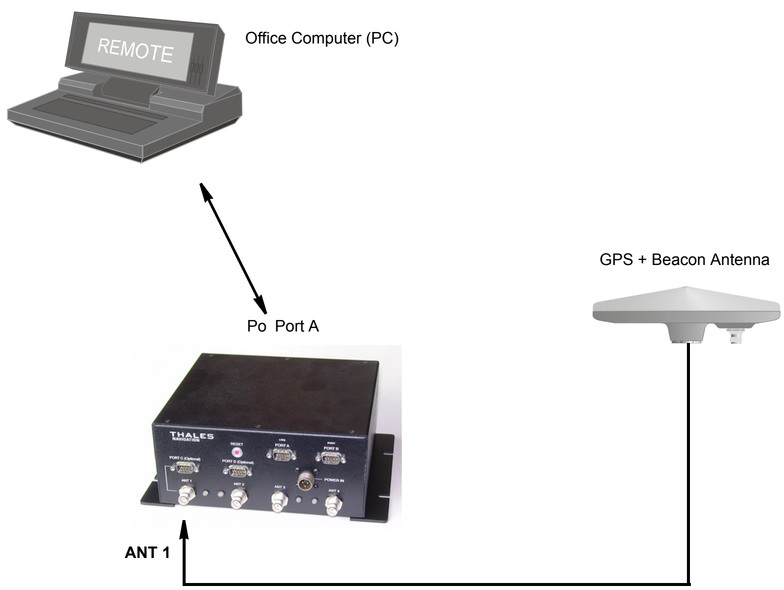

Figure 4.1. RTCM Remote System

You must have a source of differential corrections, usually a radio receiving a transmission from a base station. Connect this radio to either Port A or Port B. Alternatively, you can use differential corrections from a beacon signal through the built-in beacon receiver or SBAS (WAAS/EGNOS/MSAS) corrections utilizing the SBAS channels.

Send the commands listed in Table 4.4 to the receiver. The receiver accepts RTCM differential corrections in message types 1 or 9. You do not have to tell the receiver which message types to expect, it automatically uses what it receives on serial port x.

Table 4.4. Differential Remote Station Commands

Command	Description
$PASHS,RST	Reset receiver to factory defaults
$PASHS,RTC,REM,ON	Set receiver as a remote station, receiving corrections on serial port B or use $PASHS,RTC,REM,ON to receive corrections on a different port
$PASHS,RTC,SLC,xxx	Select source of corrections, where xxx is SBA for SBAS, BCN for beacon, or EXT for serial port.
$PASHS,SPD,x,n	Set baud rate of serial port x to same as radio providing the corrections.
$PASHS,SAV,Y	Save settings

You have now set up the remote station. Turn on the GGA, GLL, or POS message to obtain position.

Recommended Settings for Differential Remote Stations

There are many parameters that control the operation of the receiver. Most should be left at default values. The following settings are recommended for Differential Remote Stations.

$PASHS,CRR,S

$PASHS,LPS,10,3,1 (for high dynamic or high vibration applications)

Other parameter settings at factory default.

Base Data Latency

Differential operation works better the lower the latency of the Base-Remote data link. To minimize latency set the baud rate of the radios as high as possible, and use radios that are optimized for low latency GPS operation, such as the Ashtech SSRadio.

The actual Base-Remote data latency is given in the GGA message.

Maximum acceptable base-remote data latency is controlled by the **$PASHS,RTC,MAX** command.

Automatic Differential Mode

When you are using a rover receiver in differential mode (either code phase or carrier phase), a failure at the base station or in the data link causes the rover receiver to cease outputting differentially corrected positions. You can use the auto differential mode to output an autonomous position at the rover receiver if differential data from the base station is unavailable. Enable the auto differential mode with the **$PASHS,RTC,AUT,Y** command. Table 4.5 describes how auto differential mode affects position output at the rover receiver.

Table 4.5. Auto Differential Modes and Position Output

Mode	Position Output
Code Differential Auto Differential Off (Default code mode)	Differential position output if the age of corrections is less than maximum age (maximum age as defined in the rover by $PASHS,RTC,MAX,xx). No position otherwise.
Code Differential Auto Differential On	Differential position is output if the age of corrections is less than maximum age, otherwise an autonomous position is output.

SBAS Operation

The ADU3 utilizes the internal DG16 receiver to track SBAS satellites to receive SBAS differential corrections. The DG16 has two channels assigned to track SBAS satellites, and operates in single automatic mode.

Single Automatic Mode

In Single Automatic SBAS mode, the ADU3 automatically detects all available SBAS signals and selects the best ONE satellite, switching automatically as you move from one coverage area to another. The automatic selection uses both SBAS channels. Channel 1 tracks the best available SBAS signal and Channel 2 scans for another available SBAS satellite signals, maintaining a SBAS satellite directory in a battery-backed memory. The quality of the SBAS satellite tracked on Channel 1 (signal strength, elevation, etc.) is continuously compared to the quality threshold. When the quality of the signal on Channel 1 is less than the quality threshold, the ADU3 checks the quality of the signal of the Channel 2 satellite. If Channel 2 satellite has a better signal, the ADU3 switches to it. If, on the other hand, the signal on Channel 1 drops below the threshold and the signal on Channel 2 is no better or no SBAS satellite is available, the ADU3 continues to use and track the satellite on Channel 1.

The best SBAS satellite is determined based collectively on the satellite SNR, elevation angle, continuity of signal reception, etc.

Utilizing SBAS Corrections in DGPS Solution

The full SBAS set of corrections includes:

- fast corrections-satellite clock corrections
- long term or slow corrections-satellite ephemeris and long term satellite clock corrections
- ionosphere corrections

Use the **$PASHS,RTC,SLC,SBA** and **$PASHS,RTC,REM,ON** commands to utilize SBAS corrections in the DGPS solution.

SBAS message types 6, 8 and 10 are not used in position computation using SBAS corrections. These messages help determine and report the quality of the corrections/solution, but do not to allow or disallow position computation.

After a cold start, the first solution is corrected with all components, but the ionosphere and subsequent position fixes are corrected with all components.

Beacon Operation

The AD3U utilizes a built-in beacon receiver on the internal DG16 board to receive beacon signals.

The DG16 two-channel beacon receiver has two modes of operation: automatic or manual. In both modes, the beacon receiver can receive corrections from one beacon station.

The ADU3 has the following modes of beacon operation. Use the **$PASHS,BCN,MOD** command to set the beacon operation mode:

- **Single Automatic** - the receiver determines which beacon station to use
- **Single Manual** - you manually set which beacon station(s) to use

The default beacon mode is single automatic. On power up, the ADU3 recalls the last beacon stations used, and begins searching with those frequencies.

Single Automatic Mode

In single automatic mode, the beacon receiver automatically detects all available radio beacon signals and selects the best one, switching automatically as you move from one coverage area to another. Channel 1 tracks the best available beacon signal and sends the demodulated DGPS corrections to the receiver. Channel 2 scans for other available DGPS beacon signals, maintaining a DGPS beacon directory in a battery-backed memory. The beacon almanac/directory is automatically saved.

The quality of the beacon signal tracked on Channel 1 (signal strength, etc.) is continuously compared to a quality threshold. When the quality of the signal on Channel 1 is worse than the quality threshold, the beacon receiver checks the quality of the signal on Channel 2. If Channel 2 signal is better than Channel 1, the beacon receiver switches to it. If, on the other hand, the signal on Channel 1 drops below the threshold and the signal on Channel 2 is no better, or no beacon signal is available, the ADU3 continues to use and track the beacon signal on Channel 1.

Use the **$PASHS,BCN,MOD,AUT,SNG** command to set the ADU3 to operate in single automatic mode. Automatic mode is the default mode.

The best beacon signal is determined based on SNR, continuity of signal reception, etc.

Single Manual Mode

In single manual beacon mode, the ADU3 tracks the specified beacon signal on Channel 1. After enabling manual mode with the **$PASHS,BCN,MOD,MAN** command, use the **$PASHS,BCN,CHN** command to assign a frequency to Channel 1.

Use the **$PASHS,BCN,OUT** command to output the demodulated beacon data from Channel 1 to the serial port.

DGPS using beacon $PASHS,RTC,SLC,BCN & $PASHS,RTC,REM,ON ?

6

Command/Response Formats

Once the ADU3 has been calibrated and the offset vectors uploaded to the ADU3, the ADU3 is ready to output position velocity and attitude data.

Heading, pitch, roll, position, course over ground, and speed over ground data can be graphically displayed on a PC using **ADULOG** (DOS) and **EVALUATE** (Windows). Refer to Chapter 8 for more information on **ADULOG** and the *Evaluate User's Guide*.

The ADU3 configuration and operation are controlled by issuing ASCII serial commands from a PC (personal computer) through two RS-232 ports (ports A and B). You can use Ashtech EVALUATE or REMOTE, or any 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 applicable for the given application, and turn off the unused 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 ADU3. As noted previously, an external device such as a PC or a handheld controller must be used to input commands to the ADU3, and to monitor responses from the ADU3. 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 are grouped into the following functional categories:

Receiver Commands

NMEA Commands (page 88)

Raw Data Commands (page 114)

Differential (RTCM) Commands (page 136)

Beacon Commands (page 142)

Receiver Commands

Table 6.1 summarizes the receiver commands and responses by function (receiver control, attitude setup, etc.). The pages following Table 6.1 describe each command/response in detail, in alphabetical order.

Table 6.1. Summary of Receiver Commands

Command	Description	Page
RECEIVER CONTROL COMMANDS		
$PASHQ,PAR	Queries configuration of the general setup parameters	76
$PASHQ,PRT	Queries port being used and the baud rate	78
$PASHQ,RID	Queries receiver version ID	79
$PASHQ,RIO	Queries product type, receiver version, sensor version, installed options, receiver serial number	80
$PASHQ,STA	Queries current satellite tracking status for each antenna	81
$PASHQ,TST	Requests results from the power-up initialization test	82
$PASHS,ALT	Set altitude for fix mode 0 and 1	70
$PASHS,ELM	Set elevation mask	71
$PASHS,FIX	Set altitude fixed mode	71
$PASHS,HDP	Set HDOP mask	73
$PASHS,INI	Initialize receiver	73
$PASHS,MSV	Set minimum number of satellites	83
$PASHS,PDP	Set PDOP mask	83
$PASHS,PDS	Set satellite selection for best PDOP	84
$PASHS,POS	Set position mode	85
$PASHS,RST	Reset receiver parameters to defaults	85
$PASHS,SAV	Save receiver setup parameters	85
$PASHS,SIT	Assign site ID name	86
$PASHS,SPD	Set receiver serial port baud rate	86
$PASHS,SVS	Enable/disable satellites	86
$PASHS,USE	Use/not use a particular satellite	86
$PASHS,VDP	Set VDOP mask	87

Table 6.1. Summary of Receiver Commands (continued)

Command	Description	Page
ATTITUDE SETUP COMMANDS		
$PASHS,3DF,OFS	Set the offset angles in degrees	75
$PASHS,3DF,V12	The relative position vector from antenna 1 to antenna 2	83
$PASHS,3DF,V13	The relative position vector from antenna 1 to antenna 3	83
$PASHS,3DF,V14	The relative position vector from antenna 1 to antenna 4	83
ATTITUDE CONTROL COMMANDS		
$PASHQ,3DF	Queries for the configuration of the attitude parameters	69
$PASHS,3DF,ANG	Maximum angle above the horizon that the vehicle (or platform) is expected to tilt (pitch or roll) in degrees.	70
$PASHS,3DF,CYC	The phase error in cycles.	71
$PASHS,3DF,FLT	Smoothing filter	72
$PASHS,3DF,HKF	Identifies the heading Kalman filter parameters	73
$PASHS,3DF,MXB	The maximum baseline rms error (BRMS) in meters	74
$PASHS,3DF,MXM	Set maximum phase measurement rms error (MRMS) in meters	75
$PASHS,3DF,PKF	Identifies the pitch Kalman filter parameters	77
$PASHS,3DF,RAT	Set the ambiguity search ratio	79
$PASHS,3DF,RKF	Set the roll Kalman filter parameters	80
$PASHS,3DF,RST	Restart Kalman filters	80

3DF: Query Attitude

$PASHQ,3DF

Queries the configuration of the attitude parameters. An example response could be:

```
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
```

ALT: Set Altitude

$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.

ANG: Set Angle

$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 ADU3 first tries to determine the attitude therefore, allowing a quicker time to first fix for the attitude solution. Once the attitude solution has initialized, this angular restriction is lifted, and the maximum angles can be exceeded with no loss of attitude computation.

DEFAULT
15 degrees

ATT: Query Attitude Structure

CYC: Set Phase Error

$PASHS,3DF,CYC,d.ddd

Sets the phase error (CYC) in cycles (1 cycle = 19 cm). The maximum is 0.500. Normally, the default value is adequate. Only change this parameter if many noisy, low-elevation satellites are being used in the solution. This and all other attitude control parameters should only be increased in small steps, if at all.

DEFAULT
0.200

ELM: Elevation Mask

$PASHS,ELM,dd

Sets the elevation mask in degrees. Satellites with elevation lower than the mask value will not be used in position or attitude solution.

DEFAULT
10

FIX: Set Altitude Fix Mode

$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 - always use the altitude entered by the ALT input command.

DEFAULT
0 - most recent altitude

FLT: Set Smoothing Filter

$PASHS,3DF,FLT,Y

Sets the first order low-pass smoothing filter that provides acceptable results for stationary installations, or for vehicles experiencing very low dynamics. 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
OFF

HDP: Set Horizontal Dilution of Precision

$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.

DEFAULT
4

HKF: Heading Kalman Filter Parameters

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

Sets the heading Kalman filter parameters (HKF). It is not advisable to alter these parameters without thorough knowledge of Kalman filter theory and consultation with Thales Navigation technical support.

Table 6.2. 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)

INI: Reset Internal Memory

$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. This command also clears ephemeris and almanac from the ADU3. After using this command, it is normal for the receiver to take additional time to achieve satellite lock until new almanac can be obtained.

MXB: Set Maximum Baseline Error

$PASHS,3DF,MXB,d.ddd

Sets the maximum baseline rms error (BRMS) in meters. The maximum is 0.500. If the total error for all baselines exceeds this setting, the Kalman filter resets and the ambiguity search re-starts. In high-multipath environments it may be necessary to slightly increase the BRMS threshold. Always increase by small increments only. It is possible to monitor the BRMS field in the AT1 and AT2 output messages in order to determine whether or not to increase the BRMS threshold.

DEFAULT
0.035

MXM: Set Maximum Phase Error

$PASHS,3DF,MXM,d.ddd

Sets the maximum phase measurement rms error (MRMS) in meters. The maximum is 0.050 and the minimum is 0.001m. This is the carrier phase noise threshold, and rarely needs to be altered from the default. If doing so, only increase in small (1 mm) increments.

DEFAULT
0.005

OFS: Set Offset Angle

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

Sets 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 such that the surveyed relative antenna position vectors (from file BRFVEC.XYZ) do not coincide with 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 or parallel to the heading direction of the vehicle. The installation software can determine a 1-2 relative antenna position vector, but the heading offset angle must be determined with another independent measurement technique.

Roll and pitch offset angles can be determined empirically. Heading offset angle must usually be determined independently.

PAR: Query Setup Parameters

$PASHQ,PAR

Queries the configuration of the general setup parameters.

An example response is:

```
SVS:YYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYY
POS:0 FIX: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
```

PKF: Set Pitch Kalman Filter Parameters

$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) - 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).

DEFAULT
999,20,20

- To: Oscillation period (seconds) - 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.

DEFAULTS
0,0,0

- Q: Process noise power spectral density [(radian/sec2)2*sec]. The default values are valid for low to medium vehicle dynamics. High dynamics require higher values, such as 1.0.

DEFAULTS
1.0×10^{-2}, 4.0×10^{-2}, 4.0×10^{-2}

- R: Measurement noise scale factor.

  These Kalman filter parameters normally do not need adjustment. Do not alter them without thorough knowledge of Kalman filter theory, vehicle dynamics, and consultation with Thales Navigation technical support.

DEFAULTS
1,1,1

PRT: Query Port

$PASHQ,PRT

Queries the active port and the baud rate.

Example response:

$PASHR,PRT,A,5

This response indicates that the port is A and the baud rate is 9600 as set by the baud rate code of 5. Refer to Table 6.5 on page 86for baud rate codes.

RAT: Set Ambiguity Ratio

$PASHS,3DF,RAT,d.d

Sets the ambiguity search ratio. 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.

Position Accuracy = 2.0 * (RAT * 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. This parameter should rarely if ever need to be adjusted. Best to leave at default value.

DEFAULT
0.5

RID: Query Receiver ID

$PASHQ,RID

Queries the receiver version ID.

Example:

$PASHR,RID,38,00,AB00

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

RIO: Query Receiver Configuration

$PASHQ,RIO

Queries the receiver type, receiver version, sensor version, any options included, and 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 AB00, the sensor version is 1E8, there are no options, and the receiver serial number is 101.

RKF: Set Roll Kalman Filter Parameters

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

Sets the roll Kalman filter parameters described below: These Kalman filter parameters normally do not need adjustment. Do not alter them without thorough knowledge of Kalman filter theory, vehicle dynamics, and consultation with Thales Navigation technical support.

Table 6.3. 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)

3DF,RST: Reset Kalman Filter

$PASHS,3DF,RST

Restarts the Kalman filters for the attitude computation from time zero. This means that the Kalman filters do not use any previous information in attitude prediction for the current epoch. This command only affects the attitude computation, not position.

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. Do not confuse this command with the receiver reset command.

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

STA: Query Satellite Status

$PASHQ,STA

Queries current satellite tracking status for each antenna.

Example: An example response could be:

```
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 (SNR) of the satellites being tracked. Gives GPS time until GPS/UTC offset is received from satellite(s).

This is an important troubleshooting aid. Always make sure that all bands have similar SNRs for common satellites. Any antenna band that has consistently lower SNRs will cause problems.

TST: Query Test Results

$PASHQ,TST

Queries results from power-up initialization test.

An example response could be:

$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 fails, turn the power off, wait a few seconds, and turn the power on again. If any 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.

V12: Set Vector from Antenna 1 to Antenna 2

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

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

V13: Set Vector from Antenna 1 to Antenna 3

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

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

V14: Set Vector from Antenna 1 to Antenna 4

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

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

MSV: Set Minimum Satellites

$PASHS,MSV,dd

Sets the minimum number of satellites to record.

DEFAULT
3

PDP: Position Dilution of Precision

$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.

DEFAULT
40

PDS: Tracking Routine

$PASHS,PDS

Sets the satellite tracking routine to maximize for best PDOP. Default is ON. ADULOG sets PDS OFF for the purpose of antenna calibration, but resets PDS ON 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 is 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 calibration data acquisition. If used otherwise it will degrade the operation of the attitude determination algorithm.

DEFAULT
PDS ON

POS: Position Mode

$PASHS,POS,d

Sets the mode for the position computation:

Table 6.4. Position Computation Modes

Mode	Description
0 (default)	Indicates that only 3-dimensional positions are computed. This happens when four or more satellites are locked on antenna 1.
1	Indicates that either a 2D or 3D position is computed based on the number of satellites locked on antenna 1. If three satellites are locked, a 2D position is computed (altitude is fixed). If four or more satellites are locked, a 3D position is computed.
2	Indicates that a 2D, 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 2D, altitude-fixed position is computed with three SVs locked. If more than three SVs are locked and HDOP is less than HDOP mask, the receiver computes altitude.

DEFAULT
0

RST: Reset Parameters

$PASHS,RST

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

SAV: Save Configuration

$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.

SIT: Site Name

$PASHS,SIT,xxxx

Provides a four-character site name.

SPD: Port Speed (Baud Rate)

$PASHS,SPD,x,d

Sets a baud rate of specified port (x) to value (d) per Table 6.5.

Table 6.5. Serial Port Baud Rate Codes

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

DEFAULT
Code 5 (9600 baud)

SVS: Satellites Used

$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,YYYNYYY enables SV's 1,2,3,5,6,7 and disables all the remaining SV's (that is, 4,8,9,10,...32).

USE: Satellite Tracking

$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.

VDP: Vertical Dilution of Precision

$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.

DEFAULT
4

NMEA Commands

Table 6.6 summarizes the NMEA commands. The pages following Table 6.6 describe each command in detail.

Table 6.6. Summary of NMEA Commands

Command	Description	Page
$PASHS,NME,ALL,OFF	Disable all NMEA outputs	89
$PASHS,NME,ALM	Enable/disable NMEA NMEA almanac message	89
$PASHS,NME,DAL	Enable/disable NMEA decimal almanac message	91
$PASHS,NME,GGA	Enable/disable NMEA GPS position response message	92
$PASHS,NME,GLL	Enable/disable NMEA latitude/longitude message	94
$PASHS,NME,GRS	Enable/disable NMEA GRS (satellite range residual) message	94
$PASHS,NME,GSA	Enable/disable NMEA DOP and active satellite message	95
$PASHS,NME,GSN	Enable/disable NMEA GSN signal strength/satellite number	96
$PASHS,NME,GSS	Enable/disable NMEA GSS (satellite tracked & DOP messages)	98
$PASHS,NME,GSV	Enable/disable NMEA GSV (satellites in view) message	99
$PASHS,NME,GXP	Enable/disable NMEA GXP (horizontal position) message	100
$PASHS,NME,HDT	Enable/disable NMEA true heading message	101
$PASHS,NME,MSG	Enable/disable NMEA MSG (RTCM) message	101
$PASHS,NME,PAT	Enable/disable Ashtech proprietary position and altitude message	104
$PASHS,NME,PER	Set NMEA send interval	105
$PASHS,NME,POS	Enable/disable position message	105
$PASHS,NME,RRE	Enable/disable NMEA satellite residual & position error) message	106
$PASHS,NME,SA4	Enable/disable NMEA satellite tracking message	108
$PASHS,NME,SAT	Enable/disable NMEA SAT (satellite tracking) message	109

Table 6.6. Summary of NMEA Commands

Command	Description	Page
$PASHS,NME,TTT	Enable/disable output of time trigger message	111
$PASHS,NME,VTG	Enable/disable NMEA VTG (velocity/course) message	113

ALL: Disable All NMEA

$PASHS,NME,ALL,x,OFF

Turns off all NMEA output messages on port x.

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.

A Note on ADU3 Serial Data Outputs

The following section of this manual describes in detail the formats and information contained in the ADU3 output structures. These output structures fall into three main categories:

Standard NMEA messages

Ashtech Proprietary ASCII messages

Ashtech "raw" data structures (most can be binary or ASCII, some are limited to binary only).

There are two ways to stimulate the output of these messages. They can be queried for one-time output using the $PASHQ,xxx command or they can be set for periodic output using $PASHS,NME,xxx,a,ON… or $PASHS,OUT… commands. For the purposes of setting periodic outputs, the Ashtech proprietary ASCII messages are treated as NMEA standard messages. Their output interval is tied to the $PASHS,NME,PER,x command. Ashtech raw data output intervals are tied to the $PASHS,RCI command. It is important to keep this distinction straight when attempting to configure the receiver for periodic outputs.

In general, Ashtech proprietary messages always contain the header string "$PASHR,xxx" with the exception being the $GPPAT and $GPRRE messages which carry the standard NMEA header "$GPxxx,".

Each ADU3 output message also always terminates with an asterisk character (*) followed by a two-character hexadecimal checksum. The header fields and the checksum fields are not listed in the message structure tables in this manual, but do appear in the example strings provided with those tables.

ALM: Almanac Message

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

Turns almanac output message on or off on 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,ffff,gg,hhhh,iiii,jjjjjj,kkkkkk,ddmm.mmm,mmmmmmmm,nnn,ooo

where Table 6.7 defines the structure:

Table 6.7. Almanac Message Structure

Field	Description
aa	Total number of messages
bbb	Message number
cc	Satellite PRN number
ddd	GPS week
ee	SV health
ffff	Eccentricity
gg	Almanac reference time (seconds)
hhhh	Inclination angle (semicircles)
iiii	Rate of ascension (semicircles/sec)
jjjjjj	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,A10D27,BBD4EB,

8CB47B,E35E03,FFA,000

DAL: Display Almanac

$PASHR,NME,DAL,(x), ON/OFF

This message displays the NMEA almanac message in decimal almanac format, with the structure shown below,

$PASHS,NME,DAL,ss,hhh,e.eeeeeeeE±99,ttttttt,i.iiiiiiE±99,

±a.aaaaaaaE±99,±m.mmmmmmmE±99,±c,cccccccE±99, c.cccccccE±99, www

where the fields are as defined in Table 6.8.

Table 6.8. NMEA DAL Structure

Field	Description
ss	Satellite PRN number 1 through 32
hhh	Satellite health 0 through 255
e.eeeeeeeE±99	Eccentricity 9.9999999E±99
ttttttt	Reference time for orbit 0 through 9999999 seconds
i.iiiiiiE±99	Inclination angle 0 through 9.9999999E±99 semicircles
±a.aaaaaaaE±99	Omegadot, rate of right ascension ±9.9999999E±99 semicircles/sec
r.rrrrrrrE±99	Roota, square root of semi-major axis 0 through 9.9999999E±99 meters 1/2
±l.lllllllE±99	Omega0, longitude of right ascension node ±9.9999999±99
±a.aaaaaaaE±99	Omega, argument of perigee ±9.9999999±99 semicircles
±m.mmmmmmmE±99	M_0 mean anomaly at reference time ±9.9999999E±99
±c,cccccccE±99	af_0 clock parameter ±9.9999999E±99 seconds
c.cccccccE±99	af_1 clock parameter 0 through 9.9999999E±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 simultaneously with ALM, ALM takes precedence and DAL is not output.

GGA: GPS Position

$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

$GPGGA

NMEA response message for GGA (GPS position). The format is:

$GPGGA,hhmmss.ss,ddmm.mmmmm,s,dddmm.mmmmm,s,n, qq,pp.p,saaaaa.aa,M,±xxxx.xx,M,sss,aaaa *cc

where the structure is as defined in Table 6.9.

Table 6.9. $GPGGA Response Message Structure

Field	Description
hhmmss.ss	Current UTC time, hhmmss, of position fix in hours, minutes and seconds.
ddmm.mmmmmm	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, E - East, W - West.

Table 6.9. $GPGGA Response Message Structure (continued)

Field	Description
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, saaaaa 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.
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**

GLL: Present Latitude and Longitude

$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

where the structure is as defined in Table 6.10.

Table 6.10. 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

GRS: Satellite Range Residual

$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......

where Table 6.11 defines the structure.

Table 6.11. Satellite Range Residual Message Structure

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 position given in 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

GSA: Active Satellite

$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

$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

where Table 6.12 defines the GSA structure:

Table 6.12. GSA Structure

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

GSN: Satellite Number

$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

$GPGSN

NMEA response message for GSN signal strength/satellite number. The messge format is:

$GPGSN,aa,bb,ccc,xx,xxx,xx,xxx...

where the structure is as defined in Table 6.13.

Table 6.13. SNR of GPS Satellites Being Tracked

Field	Description
aa	Number of SVs currently being tracked. When 0, message terminates after this field. For a nonzero count, the subsequent fields give each satellite number and its SNR (signal-to-noise ratio).
bb	Satellite number
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

GSS: Satellite Tracked

$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

where Table 6.14 defines the structure:

Table 6.14. 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

GSV: Satellites in View

$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

where Table 6.15 defines the structure:

Table 6.15. 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,2,1,06,23,53,041,99,28,55,273,99,11,24,326,55,17,36,101,68

GXP: Horizontal Position

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

Enable/disable position horizontal message on port x, where x is 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

$GPGXP

NMEA response message for GXP (position horizontal).

Format:

$GPGXP,hhmmss.ss,aaaa.aaaa,N/S,bbbb.bbbb,E/W

where Table 6.16 defines the structure:

Table 6.16. Present Position Fix with Time of Fix

Field	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

HDT: Heading True

$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

where the structure is as defined in Table 6.17

Table 6.17. HDT: Heading Structure

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

MSG: Reference Station Messages

$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 ADU3 is sending or receiving differential corrections, this command is ignored.

Example: Enable MSG on port A

$PASHS,NME,MSG,A,ON

$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,lll,......

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,±iiiiiii.ii,±jjjjjj.jj

Message type 16 format:

$GPMSG,aa,bbbb,cccc.c,d,e,fff,hmmss,gggggg....

where the structure is as defined in Table 6.18.

Table 6.18. RTCM Message Structure

Field	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
hhmmss	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)
m	For type 1 only: same as 8,9,10,11,12 but for next SVs

Examples:

$GPMSG,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

$GPMSG,03,0000,1200.0,7,0,038,231958,-2691561.37, 4301271.02,+3851650.89

$GPMSG,16,0000,1209.6,5,0,038,232008,THIS IS A MESSAGE SENT FROM BASE

PAT: Position and Altitude

$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.ffff,g.gggg,h

where the structure is as defined in Table 6.19.

Table 6.19. Position and Attitude Message Structure

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.ff	Roll in degrees
h.hhhh	Attitude phase measurement rms error, MRMS (meters)
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

PER: Set Period

$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.

DEFAULT
000

POS: Position, Time, Speed, DOP

$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,ddddd.dddd,W,+ffff, g,iii,jjj,kk,ll,mm,oo,pp,qqqq

where the structure is as defined in Table 6.20.

Table 6.20. Position Message Structure

Field	Description
a	Raw/differential pos 0=raw position 2=differentially connected
bb	Number 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)
ddddd.dddd	GPS longitude
W	Longitude east (E) or west (W)
ffff	Altitude in meters

Table 6.20. Position Message Structure (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

RRE: Range Residual Error

$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*cc

A range residual (xxx.x) is computed for each satellite (ss) used in position computation. Residuals and position errors are not computed unless at least 5 satellites are used in position computation. The fields in the RRE message are defined in Table 6.21.

Table 6.21. 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 6.22 defines the structure:

Table 6.22. Typical RRE Response Structure

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

Table 6.22. Typical RRE Response Structure (continued)

Item	Description
-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

SA4: Satellite Status

$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,......

where the structure is as defined in Table 6.23.

Table 6.23. 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)
...	Same as 2,3,4,5,6 but for second satellite
...	Same as 2,3,4,5,6 but for third satellite

Examples:

$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

SAT: Satellite Status

$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,......

where the structure is as defined in Table 6.24.

Table 6.24. Satellite Information Message 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,
068,32,U,09,49,227,99,U,12,72,249,99,U**

STR: Set NMEA Message

$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 *NMEA Message Formats* for an explanation of the various message types.

TTT: Trigger Time Tag

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

The trigger signal is generated through the event input line, pin 9 of Port B. The following message outputs on the selected port on each trigger epoch being generated. If you plan to use the trigger time tag or one pulse per second, then you must make a cable as shown in Figure 1-4.

The format of the TTT message is:

$PASHS,NME,TTT,a,hh:mm:ss.sssssss

where Table 6.25 defines the structure:

Table 6.25. 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

$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 ADU3. The following message outputs on the selected port on each trigger epoch being generated. If you use the trigger time tag or one-pulse-per-second, then you must make a cable as described in Chapter 1.

Format:

$PASHR,TTT,a,hh:mm:ss.sssssss

where Table 6.26 lists the structure:

Table 6.26. 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

VTG: Velocity/Course

$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). The format is:

$GPVTG,ddd.dd,T,x,x,aaa.aa,N,bbb.b,K

where the structure is as defined in Table 6.27.

Table 6.27. $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

Raw Data Commands

Table 6.28 summarizes the raw data commands and responses. The pages following Table 6.28 describe the commands and responses in detail.

Table 6.28. Summary of Raw Data Commands

Command	Description	Page
$PASHQ,ATT	Attitude data	114
$PASHQ,AT2	Attitude, flags, PDOP data	116
$PASHQ,DSO	Attitude and position data	118
$PASHQ,MBN	Satellite measurement data	121
$PASHS,RAW,MCA	Enable/disable raw measurement data (MCA)	124
$PASHQ,MCA	Query raw measurement data (MCA)	124
$PASHQ,PBN	Position, velocity, DOP data	128
$PASHQ,PSA	Position and attitude data	133
$PASHS,RCI	Set raw data output message rate	134
$PASHQ,SNV	Ephemeris data	131
$PASHS,OUT,x,	Turns on the specified raw data output type.	135

$PASHQ,ATT

Queries ATT (attitude) structure. The structure can be ASCII or binary. Table 6.29 defines the ASCII format for attitude output.

Table 6.29. Attitude Data - ASCII Format

Variable	Description
Header String	$PASHR,ATT
GPS Receive Time	seconds of week
Heading	Degrees
Pitch	Degrees
Roll	Degrees
MRMS (measurement RMS error)	Meters

Table 6.29. Attitude Data - ASCII Format (continued)

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

An typical example of ASCII attitude output could be:

$PASHR,ATT,419721.5,226.58,-000.01,0.0010,0.0104,0*20

Table 6.30 defines the binary structure for attitude output.

Table 6.30. Attitude Data Structure - Binary

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	

AT2: Query AT2 Structure

$PASHQ,AT2

Queries the AT2 structure. The structure can be ASCII or binary. Table 6.31 defines the ASCII AT2 structure.

Table 6.31. AT2 Data - ASCII

Variable	Description
Header	$PASHR,AT2
GPS receive time	Seconds of week
Heading	Degrees
Pitch	Degrees
Roll	Degrees
Measurement rms error (MRMS)	Meters
Baseline rms error (BRMS)	Meters
Reset	Attitude reset flag 0 = good 1 = no solution (invalid)
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 Only the characters to the right of the decimal point have meaning.
PDOP	Position Dilution of Precision

A typical AT2 response message in ASCII is shown below

$PASHR,AT2,419721.0,226.56,-000.31,-000.24,0.0009,0.0077,0,00,0.555,01.9*5E

where the AT2 response parameters are described in Table 6.32.

Table 6.32. Typical AT2 Response Message - ASCII

Parameter	Description
$PASHR,AT2	Message header
419721.0	GPS receive time, seconds
226.56	Heading, degrees
-000.31	Pitch, degrees

Table 6.32. Typical AT2 Response Message - ASCII (continued)

Parameter	Description
-000.24	Roll, degrees
0.0009	Measurement rms error, meters
0.0077	Baseline rms error, meters
0	Attitude reset flag 0 = good 1 = no solution (invalid)
00	Last state, 0 = no search in progress >0 = search in progress
0.555	
01.9	
***5E**	Checksum

Table 6.33 defines the binary AT2 structure.

Table 6.33. AT2 Data - Binary

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

DSO: Query DSO Structure

$PASHQ,DSO

Queries the DSO structure. The structure can be ASCII or binary. Table 6.34 defines the ASCII DSO structure.

Table 6.34. DSO Data Structure - ASCII

Variable	Description
Header	$PASHR,DSO
GPS receive time	Seconds of week
Heading	Degrees
Pitch	Degrees
Roll	Degrees
Baseline (rms error)	Meters
Reset	Attitude reset flag 0 = good 1 = no solution
Latitude	Decimal degrees
Longitude	Decimal degrees
Altitude	Meters

A typical DSO string is shown below:

$PASHR,DSO,419720.5,226.55,-00.26,-00.07,0.0104,0,+37.3517317,-21.9339831,+0019.20*12

where the string values are described in Table 6.35.

Table 6.35. Typical DSO Response Message Data String - ASCII

Item	Description
$PASHR,DSO	Message header
419720.5	GPS receive time, seconds of week
226.55	Heading, degrees
-00.26	Pitch, degrees
-00.07	Roll, degrees
0.0104	Baseline error, meters
0	Altitude reset flag 0 = not reset 1 = reset
+37.3517317	Latitude, degrees + = north - = south
-21.9339831	Longitude, degrees - = west + = east
+0019.20	Altitude, meters
*12	Checksum

Table 6.36 defines the binary DSO structure.

Table 6.36. DSO Data Structure - Binary

Variable	Bytes	Description
$PASHR,DSO	11	Message 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	8	Altitude in meters

Table 6.36. DSO Data Structure - Binary (continued)

Variable	Bytes	Description
char spare	1	Spare byte not used
unsigned short checksum	2	
}	---	
Total bytes	64	

MBN: Query MBEN Structure

$PASHQ,MBN

Queries the MBEN structure for all four antennas, in order: 1, 2, 3, 4. Structure can be ASCII or binary. Table 6.37 defines the ASCII format. Table 6.38 defines the binary format.

Table 6.37. MBEN Data - ASCII

Variable	Description
Header	Indicates the type of data sent and allows 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 ADU3 channel assignment (1 to 32)
MEASUREMENT DATA	
Warning flag	Flag displaying status of receiver clock, carrier phase signal, and loss of lock. 0 = everything OK bit 1 set (1) = satellite range approaching 1 ms offset bit 2 set (2) = clock offset is close to 1 ms bit 3 set (4) = polarity known flag less than 5 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. bit 8 set (128) = loss of lock in previous epoch 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).

Table 6.37. MBEN Data - ASCII (continued)

Variable	Description
Measurement quality (good/bad flag)	Indicates the quality in the measurement of position. 0 = measurement not available and no additional data will be sent 22 = code and/or carrier phase measured 23 = code and/or carrier phase measured, and navigation message was obtained but measurement was not used to compute position. 24 = code and/or carrier phase measured, navigation message was obtained, and measurement was used to compute position.
Polarity known flag	Shows synchronization stage of receiver with NAV message 0 = looking for data bit transition 1 = looking for valid data bit 2 = looking for subframe preamble 3 = reading subframe ID 4 = waiting for first subframe ID 5 = receiver completely synchronized to NAV message
Signal-to-noise ratio (signal/noise)	High signal level with low noise level indicates good quality signal. Typical range 15 to 130.
Phase quality indicator (%)	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.
Full carrier phase (in cycles)	Total number of cycles plus fraction of the range between the antenna and the satellite.
Code transmit time (ms)	Length of time of code transmission (t or pseudorange). The satellite clock offset correction from GPS time is not included.
Doppler (10^{-4} Hz)	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.
Range smoothing correction (in meters)	Raw range minus smoothed range. The smoothed range is obtained by filtering the raw range with the integrated doppler.
Range smoothing quality	Indicates how long the raw range has been smoothed.
Footer	
Checksum (displayed in decimal)	Bytewise exclusive OR (XOR) on all bytes from the sequence tag to the checksum.

Table 6.38. MBEN Data - 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 (degrees).
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 ratio 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)

Table 6.38. MBEN Data - Binary (continued)

Field	Type (Bytes)	Contents
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 unsmooted. Bits 23-0 are smoote_corr, where bit 23 (MSB) is the sign and the LSBs (22-0) are the magnitude of correction (centimeters)
Footer, 3 bytes:		
checksum	Unsigned Char (1)	Checksum, a bytewise 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 block is not yet available, its warning flag is set to 7 and the rest of the block is zeroed out.

MCA: Raw Measurements (Ashtech Type 3 Data Structure)

$PASHS,RAW,MCA,c1,s2,[f1]

This command enables or disables the measurement data (MCAA) messages with Ashtech Type 3 data structure, where c1 is port A, B or C (optional port), s2 is ON or OFF, and f1 is the optional numeric output interval setting supporting a range of 0.05 to 999 seconds, depending on the measurement update rate option installed.

The DG16 outputs this message in binary format on every recording interval (RCI) for locked satellites with an elevation equal to or greater than the elevation mask (ELM), and only if the number of locked satellites is equal to or greater than the minimum satellite mask (MSV).

$PASHQ,MCA,[c1]

This command queries raw satellite measurement data contained in the Ashtech Type 3 data structure.

c1 is the optional port designator for the response. If a port is not specified, the receiver sends the response to the current port.

If the command is set without a period, the DG16 uses the period set by the **$PASHS,RCI** command If the **$PASHS,RCI** command is issued after this message period has been set, the period resets to the RCI setting.

$PASHR,MCA

This message is not output unless the receiver is tracking at least one satellite. The MCA message contains some of the same measurement information as is contained in the MBN message: doppler, raw pseudo-range, full carrier phase, satellite PRN number, elevation, and azimuth. A separate MCA message is output for each satellite being tracked. The structure of the message is:

```
$PASHR,MCA,<Ashtech type 3 data string + checksum>
```

Table 6.39 defines the data string format.

Table 6.39. $PASHR,MCA Data String

Field	Bytes	Content
unsigned short [sequence tag]	2	Sequence ID number in units of 50 ms, modulo 30 minutes
unsigned char [left]	1	Number of remaining MCA messages to be sent for current epoch
unsigned char [svprn]	1	Satellite PRN number (1 to 32 for GPS and 33 to 64 for SBAS)
unsigned char [elev]	1	Satellite elevation angle in degrees
unsigned char [azim]	1	Satellite azimuth angle in increments of 2 degrees
unsigned char [chnind]	1	Channel (1 to 14) assigned to the satellite
unsigned char [warning]	1	Warning flag: • Bit 1 set - See note below • Bit 2 set - See note below • Bit 3 set - Carrier phase questionable • Bit 4 set - Code phase questionable • Bit 5 set - Code phase integration questionable • Bit 6 set - Not used • Bit 7 set - Possible loss of lock • Bit 8 set - Loss of lock; counter reset The interpretation of bits 1 and 2 is as follows: [Bit 1, Bit 2] • [0, 0] Same as 22 in good/bad flag (see next field) • [1, 0] Same as 23 in good/bad flag • [0, 1] Same as 24 in good/bad flag Note that more than one bit may be set at the same time, e.g., if bits 1, 3, and 6 are set at the same time, the warning flag is 37 (1 + 4 + 32)

Table 6.39. $PASHR,MCA Data String (continued)

Field	Bytes	Content
unsigned char [goodbad]	1	Indicates the quality of the position measurement: • 24—Used and position computed. • 23—Used, position not computed • 22—RESERVED • 21—Satellite NOT used because of low elevation • 20—Satellite NOT used because the pseudo-range is not settled (transient is not over) • 19—Satellite NOT used because marked 'unhealthy' in ephemeris • 18—Satellite NOT used because of bad URA (or some accuracy problem indicated in navigational data) • 17—Satellite NOT used because marked 'unhealthy' in almanac • 16—Satellite NOT used because differential corrections are old or invalid • 15—Satellite NOT used because big code outlier was detected • 14—Satellite NOT used because RAIM or some other algorithm detected a pseudo-range bias. • 13—Satellite NOT used because SV disabled by external command SVP,USP) • 12—Satellite NOT used because signal-to-noise ratio is less than Mask • 11—Satellite NOT used because it's possibly a ghost satellite • 10—Satellite NOT used because computed satellite coordinates are suspicious • 09—Satellite NOT used because satellite true number unknown (for modes, where we need the true SV number • 08—Satellite NOT used because it was disabled by RTK engine (N/A in DG16) • 02—Satellite NOT used because of some other case • 01—Satellite NOT used because no navigational data (ephemeris) is available
unsigned char [polarity_known]	1	This number is either 0 or 5, 0 meaning satellite is just locked, and 5 meaning the beginning of the first frame has been found
unsigned char [ireg]	1	Signal-to-noise measurement for the satellite observation
unsigned char [qa_phase]	1	Not used; always zero
double [full phase]	8	Full carrier phase measurements in cycles. Not available unless carrier phase option is installed
double [raw_range]	8	Raw range to satellite in seconds, i.e., receive time - raw range = transmit time
long [doppler]	4	Doppler (10^{-4} Hz)

Table 6.39. $PASHR,MCA Data String (continued)

Field	Bytes	Content
long [smoothing]	4	32 bits where 31-24 are the smooth_count, unsigned, and normalized, representing the amount of smoothing specified in the **$PASHS,SMI** command: • 0 - Unsmoothed • 1 - Least smoothed • 255 - Most smoothed Bits 23-0 are smooth_corr, where bit 23 (MSB) is the sign and the LSBs (22-0) are the magnitude of correction in centimeters
checksum	1	Checksum, a bytewise exclusive OR (XOR) of all bytes from sequence_tag (just after header) to the byte before checksum
Total Bytes: 37		

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

This message is output for those satellites with elevation equal to or greater than the elevation mask, and only if the number of locked satellites is equal to or greater than the minimum satellite mask.

PBN: Query PBEN Data

$PASHQ,PBN

Queries the PBEN data for one epoch. Structure can be ASCII or binary. Table 6.40 defines the ASCII PBEN format.

Table 6.40. PBEN Data Structure - ASCII

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 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 6.40 defines the binary PBEN format.

Table 6.41. PBEN Data Structure - Binary

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)
navx	Double(8)	Station position: ECEF-X
navy	Double(8)	Station position: ECEF-Y
navz	Double(8)	Station position: ECEF-Z

Table 6.41. PBEN Data Structure - Binary

Field	Type (Bytes)	Contents
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	

SNV: Query SNAV

$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 6.42 defines the structure.

Table 6.42. SNAV Data Structure

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).
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).
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 6.42. SNAV Data Structure (continued)

Field	Type (Bytes)	Contents
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	

PSA: Query PSAT

$PASHQ,PSA

Requests a PSAT structure. Table 6.43 defines the format for PSAT in ASCII; characters following "*" are checksum.

Table 6.43. PSAT Data - ASCII

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
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

A typical PSA response message could be:

$PASHR,PSA,419721.00,-2685131.0,-4308145.6,3848507.7,000.01,000.01,-000.01,01,06,1,000.00,226.56,-00.31,-00.24,0,0,*3A

Table 6.44 defines the binary structure of the PSAT message.

Table 6.44. PSAT Data - Binary

Variable	Bytes	Description
$PASH,PSA	11	Header
long tow	4	Seconds of week in milliseconds
double nav*x*	8	ECEF-X in meters
double nav*y*	8	ECEF-Y in meters
double nav*z*	8	ECEF-Z in meters
float nav*x*dot	4	ECEF-X vel in m/s
float nav*y*dot	4	ECEF-Y vel in m/s
float nav*z*dot	4	ECEF-Z vel in m/s
float nav*t*	4	Clock offset in meters
float nav*t*dot	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
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	

RCI: Recording Interval (Update Rate)

$PASHS,RCI,ddd

Sets the raw data message update 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,RCI,1 will set the output interval to one second.

DEFAULT
0 (=0.5 second)

OUT: Set Output

$PASHS,OUT,x

Turns off previously specified types of output (refer to the next command), where x, the port, is 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 outputs 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

Differential Commands

RTCM commands allow you to control and monitor operation in differential mode. RTCM commands are available if the remote differential option [U] is installed. The RTCM mode is OFF by default.

All but one of the RTCM commands are set commands. The set commands allow you to enable and modify a variety of parameters affecting differential operation. There is only one query command: **$PASHQ,RTC**. This command is used to monitor differential parameters and status. Table 6.45 summarizes the RTCM commands. The pages following Table 6.45 describe the commands in detail.

Table 6.45. Summary of RTCM Commands

Command	Description	Default	Page
Remote Station Parameters			
$PASHS,RTC,AUT	Turns auto differential mode on or off	Y	136
$PASHS,RTC,MAX	Set maximum age of RTCM differential corrections	60	137
$PASHS,RTC,QAF	Set quality percentage mask	100	138
$PASHS,RTC,REM	Set receiver to operate as differential remote station		139
$PASHS,RTC,SLC	Select RTCM corrections type for navigation solution		141
General Parameters			
$PASHS,RTC,OFF	Disable differential mode		138
$PASHS,RTC,STI	Set station identification of base or remote	0000	141
$PASHQ,RTC	Request base or remote differential mode parameters & status		139

AUT: Automatic Differential Mode

$PASHS,RTC,AUT,s1

This command enables or disables automatic differential mode, where s1 is Y (enabled) or N (disabled). When auto differential mode is enabled, the receiver outputs raw positions automatically if differential corrections are older than the maximum age setting, or when differential corrections are not available. When auto differential mode is disabled, the receiver stops outputting positions when the age of the differential correction exceeds the maximum age setting or when differential corrections are not available, and does not resume position output until it receives RTCM corrections with age values lower than the maximum or differential mode is disabled. The automatic differential setting applies to remote differential stations only. You can view the current automatic differential setting by entering the **$PASHQ,RTC** command and checking the AUT field.

Example

Turn auto differential mode on:

$PASHS,RTC,AUT,Y

DEFAULT
RTC,AUT-Y

MAX: Maximum Age Threshold for Differential Corrections

$PASHS,RTC,MAX,d1

This command sets the maximum age for incoming RTCM differential corrections, where d1 is any number between 1 and 9999. The receiver ignores incoming corrections whose age exceeds the maximum age setting. The default value is 60. The maximum age setting applies to remote differential stations only. You can view the current maximum age setting by entering the query command **$PASHQ,RTC** and checking the MAX field.

Enter the following command to set the maximum age to 30 seconds:

$PASHS,RTC,MAX,30

DEFAULT
RTC,MAX 60

OFF: Disable Differential Operation

$PASHS,RTC,OFF

This command disables differential operation. You can view the current RTCM mode setting by entering the **$PASHQ,RTC** command and checking the MODE field.

QAF: Quality Factor

$PASHS,RTC,QAF,c1

This command sets the number of received differential correction frames in RTCM differential mode above which where c1 ranges from 0 and 999. When the total number of received messages reaches c1, c1 resets to 100. **$PASHS,RTC,QAF** is used only in REMOTE mode.

The c1 parameter is used to compute the QA value, where: QA = # of good messages ÷ QAF. The QA parameter allows you to evaluate the communication quality between the base and remote stations.

Example:

Set quality percentage mask to 99%:

$PASHS,RTC,QAF,99

DEFAULT
RTC,QAF—100

REM: Set Receiver in Differential Remote Station Mode

$PASHS,RTC,REM,c1

This command sets the ADU3 to operate as an RTCM differential remote station. The c1 parameter designates the switch (ON or OFF) for differential operation.

Example:

Set receiver as a differential remote station with port B as input port for RTCM differential corrections:

$PASHS,RTC,REM,ON

DEFAULT

Alternatively, you can use **$PASHS,RTC,REM,c1,s2**, where c1 is Port A or B, and s2 is ON or OFF.

If the $PASHS,RTC,SLC,s1 command is not used, the ADU3 uses port B by default. To use SBAS or beacon for differential corrections, use $PASHS,RTC,SLC,s1 and select s1 accordingly.

RTC: Query RTCM Operating Parameters and Status

$PASHQ,RTC,[c1]

This command queries for differential parameter settings and status, where c1 is the optional port designator for the output of the response. If a port is not specified, the receiver sends the response to the current port.

The response message has a free-form Ashtech format. Like the PAR response message, the RTC response message does not have a header or message identifier as shown in the following example:

```
SYNC:  *  QA:000%  AGE:001
STH: 0   QAF: 999    MAX AGE: 0120
```

```
REM STI: 0000   BASE STI: 0123
SOURCE: BCN
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. "SOURCE" indicates the source of differential correction (SBA/BCN/EXT).

Table 6.46 describes each field of the message.

Table 6.46. RTC Message Structure

Field	Description
SYNC	Asterisk (*) denotes sync to last received RTCM message between base and remote stations (remote only).
BASE STI	Station identification received from base station. 4 characters, 0 - 1023
AGE	Displays age of received messages in seconds.
QA	Displays 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 maximum age, in seconds, required for a message to be used (remote only). Range is 0 through 999, default. is 60.
QAF	Sets criteria to be applied when evaluating quality of communication between base and remote. Remote only. Range is 0 through 999, default is 100.
STH	Code number indicating the health of the base station. Range is 0 through F.
SOURCE	This field indicates the source of differential corrections: SBA - SBAS (WAAS/EGNOS/MSAS) BCN - Beacon ext - Serial port
REM STI	Remote station ID. The ID number is a user-entered parameter. A remote station with an ID number of 0000 can receive corrections from any RTCM base station. Otherwise, the remote station must be programmed with the same ID number as the base station in order to receive corrections from that base station. Default ID number is 0000.
AUTO DIFF	Indicates whether automatic differential mode is enabled (Y) or disabled (N). Default setting is N. When enabled, the receiver automatically switches to autonomous position when differential corrections are not available.

SLC: Navigational Solution

$PASHS,RTC,SLC,xxx

This command sets the corrections type to use in the navigational solution. You may select more than one type to use in the solution, where xxx is the type of correction: EXT (Serial Port), BCN (Beacon), or SBA (SBAS).

STI: Differential/Remote Station ID

$PASHS,RTC,STI,d1

This command sets differential station identification numbers, where d1 is any number between 0000 and 1023. A remote station with the ID number 0000 can receive corrections from any RTCM base station; otherwise, the remote station must be programmed with the same ID number as the base station in order to receive corrections from that base station.

Example:

Enter the following command to set the differential station ID number to 0001:

$PASHS,RTC,STI,0001

DEFAULT
RTC,STI— 0000

Beacon Commands

The ADU3 has two modes of operation: automatic or fixed. In both modes, the beacon receiver can provide corrections from one or two beacon stations. The beacon commands are only available with the beacon option (N) installed.

In the single automatic mode, the receiver determines the beacon station(s) to use. In the manual mode, you manually set which beacon station(s) to use:

The default beacon mode is single automatic. On power up, the ADU3 recalls the last beacon stations used, and begins searching using those frequencies.

Table 6.47 summarizes the beacon commands.

Table 6.47. Beacon Commands

Command	Description	Page
$PASHS,BCN,MOD,AUT,SNG	Set single automatic mode	142
$PASHS,BCN,MOD,MAN	Set beacon mode to manual	142
$PASHS,BCN,CHN	Specify stations to track in manual mode	142

MOD,AUT,SNG: Set Single Automatic Mode

$PASHS,BCN,MOD,AUT,SNG

This command sets the beacon mode to single automatic.

MOD,MAN: Set Mode to Manual

$PASHS,BCN,MOD,MAN

This command sets the ADU3 beacon mode to manual. After manual mode is set, both beacon channels stop operating until the channels are assigned specific stations/frequencies with the **$PASHS,BCN,CHN** command.

CHN: Assign Beacon Station Channel

$PASHS,BCN,CHN,d1,f1,[d2],[d3]

This command assigns the specified beacon station frequency to the ADU3 channel. You can only use this command when the receiver is in manual mode. Table 6.48

defines the parameters.

Table 6.48. $PASHS,BCN,CHN Parameters

Parameter	Description	Range
d1	Channel number	1 or 2
f1	Frequency in KHz	283.5 to 325.0
d2	Radio beacon broadcast ID (station ID)	0 to 1023
d3	Bit rate	25, 50, 100, 200

$PASHS,BCN,CHN,d1 OFF

This command disables the specified channel, where d1 is channel 1 or 2.

Example:

Disable channel 1:

$PASHS,BCN,CHN,1,OFF

$PASHQ,ATT

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

$PASHR,ATT,153663.5,092.09,-
00048,+000.04,0.0027,0.0103,0,000.48,+000.04,0.0027,0.0103,0

Table 6.49 defines the format for attitude data in ASCII. Table 6.50 defines the format in binary.

Table 6.49. Attitude Data in ASCII Format

Variable	Description
Header string	$PASHR,ATT
GPS receive time	seconds of week
Heading	Degrees
Pitch	Degrees
Roll	Degrees
MRMS (measurement RMS error)	Meters
BRMS (baseline RMS error)	Meters
Attitude reset flag	-

Table 6.50. 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 (time of week)	Long (4)	Seconds of week in milliseconds
Resetq	Char (1)	Attitude reset flag
Spare	Char (1)	Spare, not used
Unsigned checksum	Short (2)	Checksum, sum of words from head to spare
	Char (1)	Carriage return
	Char (1)	Line feed
Total bytes	61	

Commands/Responses

example string:

HR,DSO,419720.5,226.55,-00.26,-00.07,0.0104,0,+37.3517317,-21.9339831,+0019.2

example string:

HR,AT2,419721.0,226.56,-000.31,-000.24,0.0009,0.0077,0,00,0.555,01.9*5E

example string:

HR,ATT,419721.5,226.58,-000.28,-000.01,0.0010,0.0104,0*20

example string:

HR,PSA,419721.00,-2685131.0,-4308145.6,3848507.7,000.01,000.01,
)1,01,06,1,000.00,226.56,-00.31,-00.24,0,0*3A

7

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/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 - use the **$PASHQ,STA** command.

Receiver Computes Position But Not Attitude

- Verify that 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 ADU3, 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 BRMSwith 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).

8

ADULOG

ADULOG, provided with the ADU3 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 ADU3. The receiver must be connected to the computer for data transfer. See “Installation” on page 21, 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 8.1):

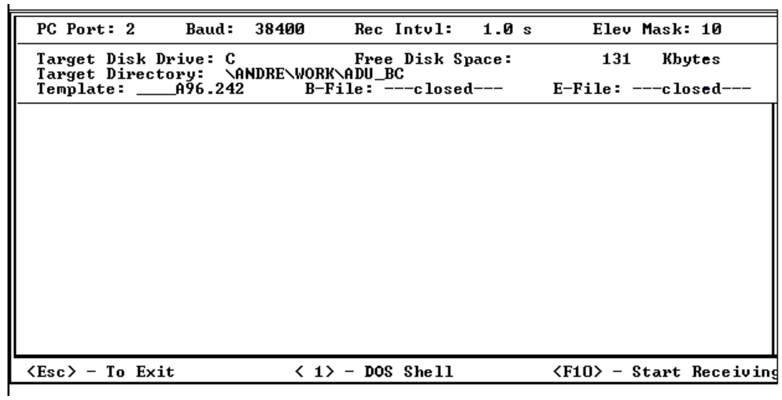

Figure 8.1. ADULOG Main Screen

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 8.1 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 8.2 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 8.2. 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. Pressing **<Esc>** interrupts the logging. The output files close and the data link terminates.
13. Press **<Esc>** again to exit **ADULOG**. At the 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 8.3)

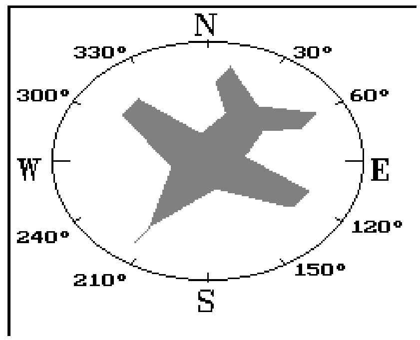

Figure 8.3. ADULOG Compass

The artificial horizon indicates the current roll and pitch (Figure 8.4).

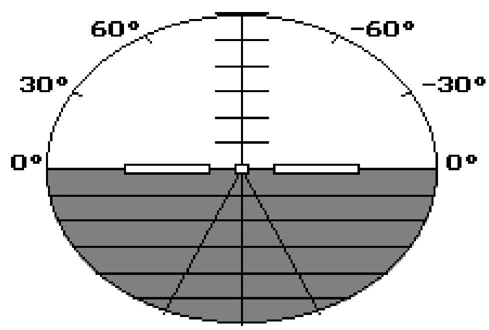

Figure 8.4. ADULOG Horizon Representation

ADULOG Options

Table 8.51 describes the command line options available for **ADULOG**.

Table 8.51. 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. You must specify the corresponding option and the almanac file name in order to have almanac downloaded. An almanac file constitutes 32 binary structures, each structure containing almanac data for one 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 is filled with zeros.

Byte order is LSB first. Table 8.52 describes the almanac structure. Total length is 70 bytes. File length is 2240 bytes.

Table 8.52. Almanac File Structure

Name	Type	Length	Description
e	float	4	Eccintricity
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	

ADULOG

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 to work in autonomous mode, arranging up to 10 sessions of data logging. Each session can have its own settings. Table 8.53 lists the parameters which can modify **ADULOG** behavior during logging. Some parameters are mandatory, others are optional.

Table 8.53. 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 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
```

Table 8.54 lists possible error messages while parsing sessions section of the parameters file:

Table 8.54. 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 message17, 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 message17, 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 the 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 appears:

```
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 8.55). Total length is 90 bytes.

Table 8.55. 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 8.56). Total length is 67 bytes.

Table 8.56. 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)

Table 8.56. B-file Epoch Rawnav structure (continued)

Type	Name	Length	Description
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)
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 8.57). Total length is 31 bytes.

Table 8.57. 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 ratio 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 8.58).

Table 8.58. 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)
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 8.59). Total length is 129 bytes.

Table 8.59. 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	Eccintricity
roota	double	8	Square root of semi-major axis (meters 1/2)

Table 8.59. E-file Structure (continued)

Name	Type	Length	Description
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)
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-cuircles/sec)
idot	float	4	Rate of inclination (semi-cuircles/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 8.60). Total length is 46 bytes.

Table 8.60. 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

A

Antennas and Cabling

Three different types of antennas are available for the ADU3 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 nearby metallic objects. For example, GPS signals 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 ADU3 system so severely that an attitude solution is not possible.

Antenna Cables

Antenna cables used with the ADU3 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 less loss
- 30-meter Belden 8214 (RG-8/U-type, but with less loss)

The cables use type-N male with center captured connectors at both ends. A cable provided from a source other than Thales Navigation 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 the electrical requirements listed in Table A.1:, or the GPS receiver may 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.

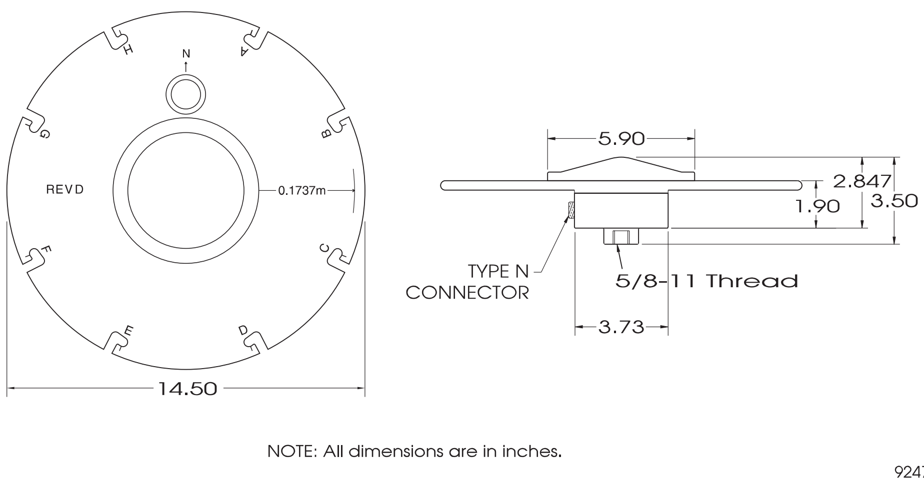

Figure A.1 Geodetic Antenna

Aircraft Antenna

The aircraft antenna is a patch antenna with integral LNA (Figure A.2.). These antennas provide precise carrier phase measurements when mounted on a smooth, metallic surface such as the roof of a van or the skin on an aircraft.

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.

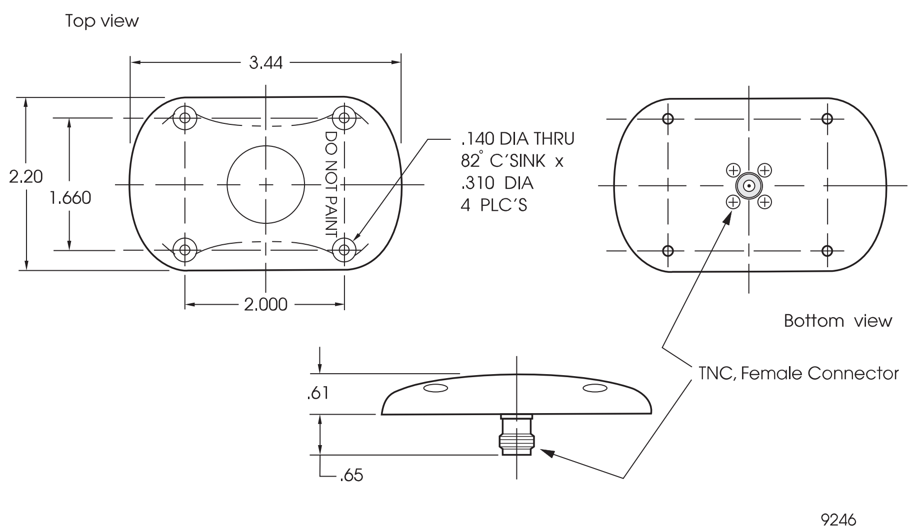

Figure A.2. Aircraft Antenna

Marine Antenna

The marine antenna, Figure A.3, contains a microstrip antenna and a low-noise amplifier (LNA) inside a sealed plastic housing, protecting the unit from corrosion as in a marine environment.

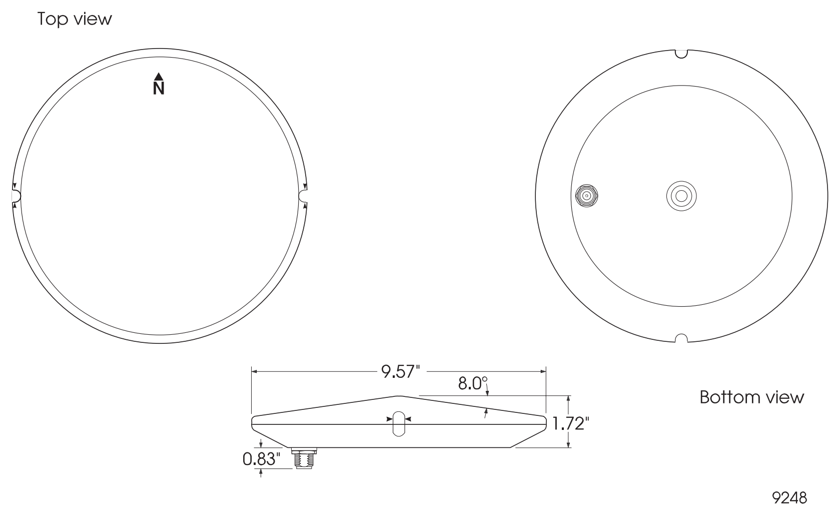

Figure A.3 Marine Antenna

Fixed Portable Antenna Array

The fixed portable antenna array available from Thales Navigation 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.

Thales Navigation 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.

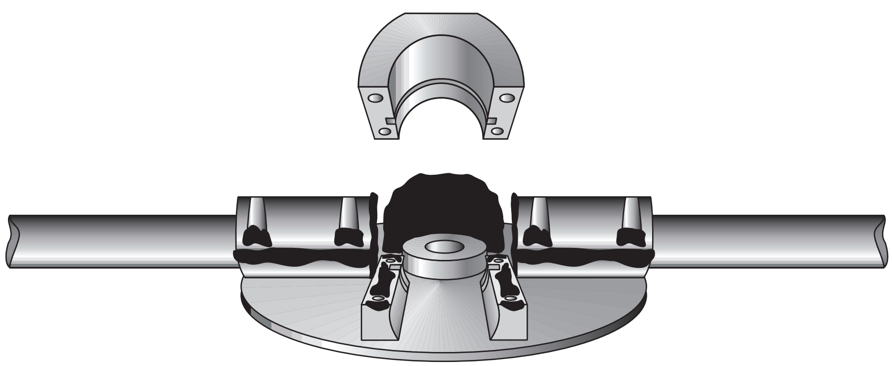

Figure A.4 Recommended Placement of Sealing Compound

Antennas and Cabling

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

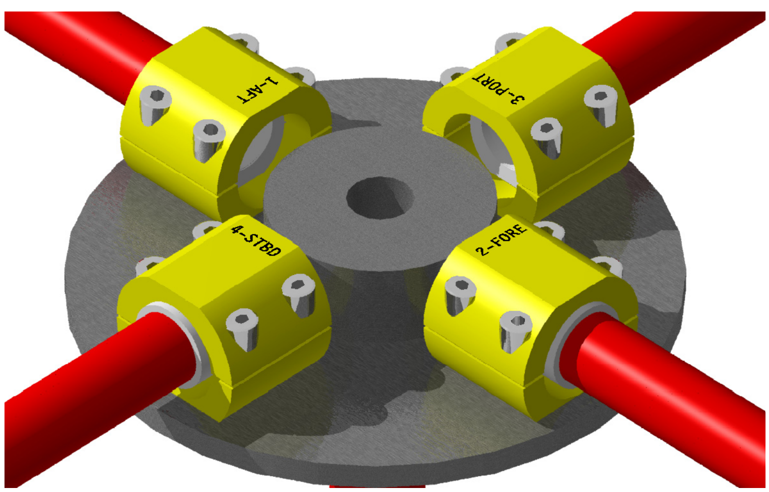

Figure A.5. Cross Arm Fitting with Engraved Number and Description

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 Thales Navigation 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.

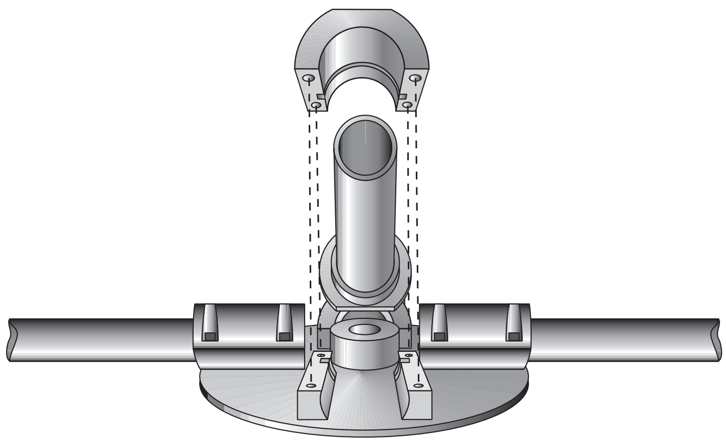

Figure A.6. Placing the Cross Arm in the Base Fitting

2. Place the clamp on top of the cross arm making sure the cross arm ridge seats in the clamp grove.
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.

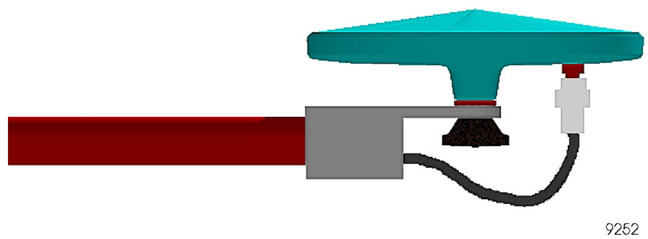

Figure A.7. Alignment of Cable Port, Cross Arm, and Antenna Bolt

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. Thales Navigation recommends using the 1 inch standard pipe fitting.

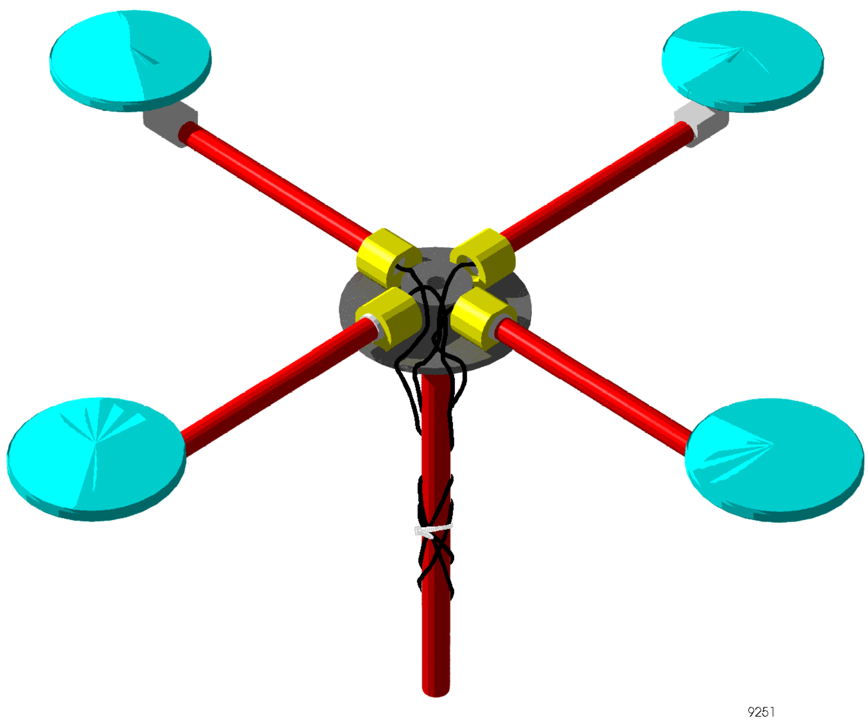

Figure A.8. Completed Fixed Portable Antenna Array

10. Connect the antenna cables to the respective ports on the ADU3 unit using the marked antenna cables as a guide. Connect the ADU3 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 Thales Navigation fixed portable antenna array.

Table A.3 Antenna Position Vectors for 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.

B

Performance Improvement

Attitude Accuracy

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

- Antenna separation
- Multipath effects

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

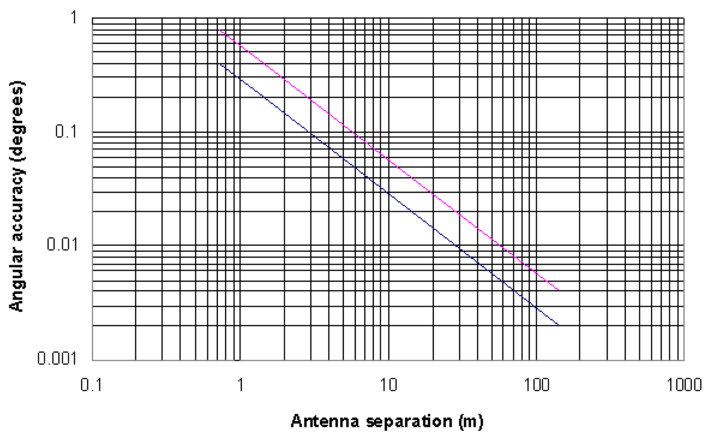

Figure B.1 Angle Accuracy vs. Antenna Separation

These figures are based on several different stationary attitude data sets collected for antenna separations ranging from 30 centimeters to 144 meters.

Note that:

- Heading accuracy is about a factor of 2 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 ADU 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 ADU3 antenna system and the vehicle (“truth”). These offset angles are essentially constant bias errors from truth. Since the attitude given by an ADU3 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 ADU3 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 sub-degree 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:

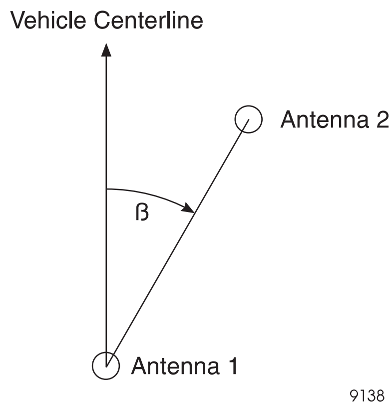

Figure B.2 Antenna Offset Angle

- 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

This section describes the error sources affecting the accuracy of any GPS attitude system.

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 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 ADU3 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 ADU3 heading vector and the vessel centerline is to perform a simple comparison of ADU3 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 ADU3 with any type of gyro, another error source should be considered. The ADU3'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 ADU3 and somehow defilter the gryro'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):

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

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 $|\mathbf{r}_{XYZ}|$ and $|\mathbf{r}_{BRF}|$.

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

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.

C

Reference

White Papers

[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**, **Dr. Xinhua Qin, Cottrell, William**, "*Design Considerations and Operational Results of an Attitude Determination Systej*", ION GPS-94 Proceedings, 689-696

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