MAGELLAN®
PROFESSIONAL

ADU5™

Operation & Reference Manual

Part Number: 630875, Revision C

June 2007

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For further information concerning this limited warranty, please call or write:

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Magellan Navigation SAS - ZAC La Fleuriaye - BP 433 - 44474 Carquefou Cedex - France Phone: +33 (0)2 28 09 38 00, Fax: +33 (0)2 28 09 39 39.

Magellan Professional Products Limited Warranty (Europe, Middle East, Africa)

All Magellan Navigation global positioning system (GPS) receivers are navigation aids, and are not intended to replace other methods of navigation. Purchaser is advised to perform careful position charting and use good judgment. READ THE USER GUIDE CAREFULLY BEFORE USING THE PRODUCT.

1. MAGELLAN NAVIGATION WARRANTY

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To obtain service, contact and return the product with a copy of the original sales receipt to the dealer from whom you purchased the product.

Magellan Navigation reserves the right to refuse to provide service free-of-charge if the sales receipt is not provided or if the information contained in it is incomplete or illegible or if the serial number is altered or removed. Magellan Navigation will not be responsible for any losses or damage to the product incurred while the product is in transit or is being shipped for repair. Insurance is recommended. Magellan Navigation suggests using a trackable shipping method such as UPS or FedEx when returning a product for service.

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EXCEPT AS SET FORTH IN ITEM 1 ABOVE, ALL OTHER EXPRESSED OR IMPLIED WARRANTIES, INCLUDING THOSE OF FITNESS FOR ANY PARTICULAR PURPOSE OR MERCHANTABILITY, ARE HEREBY DISCLAIMED AND IF APPLICABLE, IMPLIED WARRANTIES UNDER ARTICLE 35 OF THE UNITED NATIONS CONVENTION ON CONTRACTS FOR THE INTERNATIONAL SALE OF GOODS.

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(2) batteries;

(3) finishes;

(4) installations or defects resulting from installation;

(5) any damage caused by (i) shipping, misuse, abuse, negligence, tampering, or improper use; (ii) disasters such as fire, flood, wind, and lightning; (iii) unauthorized attachments or modification;

(6) service performed or attempted by anyone other than an authorized Magellan Navigations Service Center;

(7) any product, components or parts not manufactured by Magellan Navigation,

(8) that the receiver will be free from any claim for infringement of any patent, trademark, copyright or other proprietary right, including trade secrets

(9) any damage due to accident, resulting from inaccurate satellite transmissions. Inaccurate transmissions can occur due to changes in the position, health or geometry of a satellite or modifications to the receiver that may be required due to any change in the GPS. (Note: Magellan Navigation GPS receivers use GPS or GPS+GLONASS to obtain position, velocity and time information. GPS is operated by the U.S. Government and GLONASS is the Global Navigation Satellite System of the Russian Federation, which are solely responsible for the accuracy and maintenance of their systems. Certain conditions can cause inaccuracies which could require modifications to the receiver. Examples of such conditions include but are not limited to changes in the GPS or GLONASS transmission.).

Opening, dismantling or repairing of this product by anyone other than an authorized Magellan Navigation Service Center will void this warranty.

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7. COMPLETE AGREEMENT

This written warranty is the complete, final and exclusive agreement between Magellan Navigation and the purchaser with respect to the quality of performance of the goods and any and all warranties and representations. THIS WARRANTY SETS FORTH ALL OF MAGELLAN NAVIGATION'S RESPONSIBILITIES REGARDING THIS PRODUCT.

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For further information concerning this limited warranty, please call or write:

Magellan Navigation SAS - ZAC La Fleuriaye - BP 433 - 44474 Carquefou Cedex - France.

Phone: +33 (0)2 28 09 38 00, Fax: +33 (0)2 28 09 39 39

THALES
NAVIGATION

Declaration of Conformity

We

Thales Navigation
471 El Camino Real
Santa Clara, CA 95050
Tel: 408-615-5100

declare under our sole responsibility that the product:

ADU5 GPS Receiver
Model #: 800952

complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference that may cause undesired operation.

Shiva

Shiva Mogallur
OEM / Nav Product Manager
16 August 2002

Thales Navigation
Santa Clara, CA 95050
www.thalesnavigation.com

THALES
NAVIGATION

Declaration of Conformity

We

Thales Navigation
471 El Camino Real
Santa Clara, CA 95050
Tel: 408-615-5100

declare under our sole responsibility that the product:

ADU5 GPS Receiver
Model #: 800952

to which this declaration relates meets is in conformance with the following standard and normative directive:

EN 300 339 (1998-06):
Electromagnetic compatibility and Radio spectrum Matters (ERM); General ElectroMagnetic Compatibility (EMC) for radio communications equipment.

This product model listed above complies with the requirements of the R&TTE Directive 1999/5/EC.

We have an internal production control system that ensures compliance between the manufactured products and the technical documentation.

This product was CE marked in 2002, in Santa Clara, CA.

Shiva Mogallur
OEM / Nav Product Manager

Thales Navigation/ 471 El Camino Real/ Santa Clara, CA 95050/ Tel: 408-615-5100 / Fax: 408-615-5200 /
www.thalesnavigation.com

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

Table of Contents

List of Figures

List of Tables

1

Introduction

The Magellan ADU5, 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 ADU5 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. ADU5 Attitude Determination Unit

GPS attitude determination technology is based on differential carrier phase measurements between four antennas connected to the receiver. The ADU5 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 ADU5 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. Magellan 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 Magellan ADU5 standard and optional configurations, installation procedures, operation procedures, and requirements for a communications interface with external equipment.

Instructions are included for installing the ADU5 and calibrating the antenna array. For environments where the ADU5 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 ADU5 and interfacing cables, including pin assignments.
- Chapter Two: Quickstart—quick overview of the ADU5 installation process.
- Chapter Three: Installation Procedure— detailed explanation of the antenna and calibration software installation process.
- Chapter Four: Antenna Calibration— detailed explanation of the dynamic calibration procedure.
- 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 ADU5 receiver.
- Chapter Eight: File Formats - Description of different file formats
- Appendix A: Antennas and Cabling description of antenna types and mounting.
- Appendix B: Improving Performance - discussion on attitude accuracy, offset angles, and error sources.
- Appendix C: Reference - background information

Description

The ADU5 provides real-time attitude information with accurate position and velocity at a 5 Hz update rate.

The ADU5 incorporates four GPS sensors (receivers) to make carrier phase measurements and perform real-time differential processing. The ADU5 can provide the following measurements at a 5 Hz update rate:

- attitude
- position
- velocity
- time data

The ADU5 measurement data are output from two RS-232 ports at baud rates up to 115,200. The ADU5 computes accurate real-time heading, roll, and pitch information as shown in Figure 1.2.

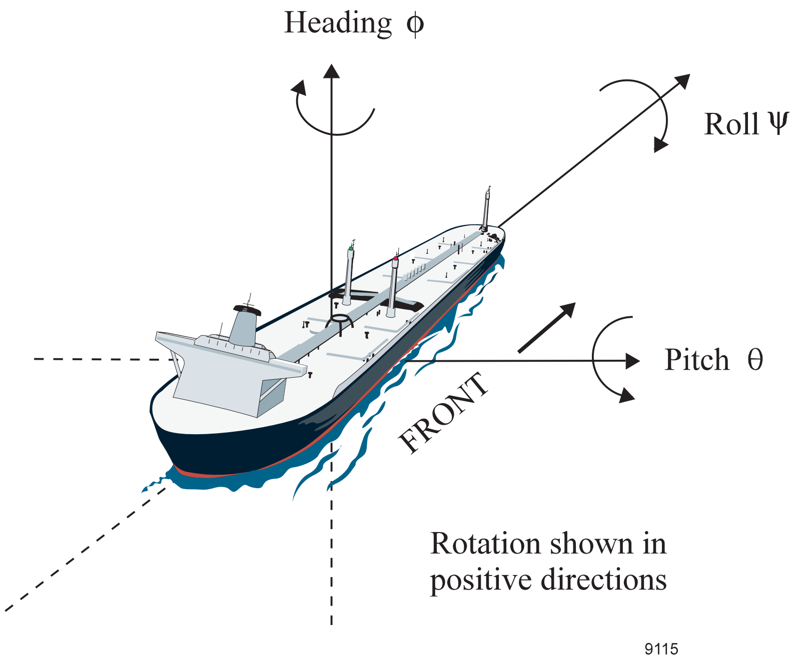

Figure 1.2. Attitude Components

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

Physical Description

The ADU5 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. ADU5 Dimensions

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

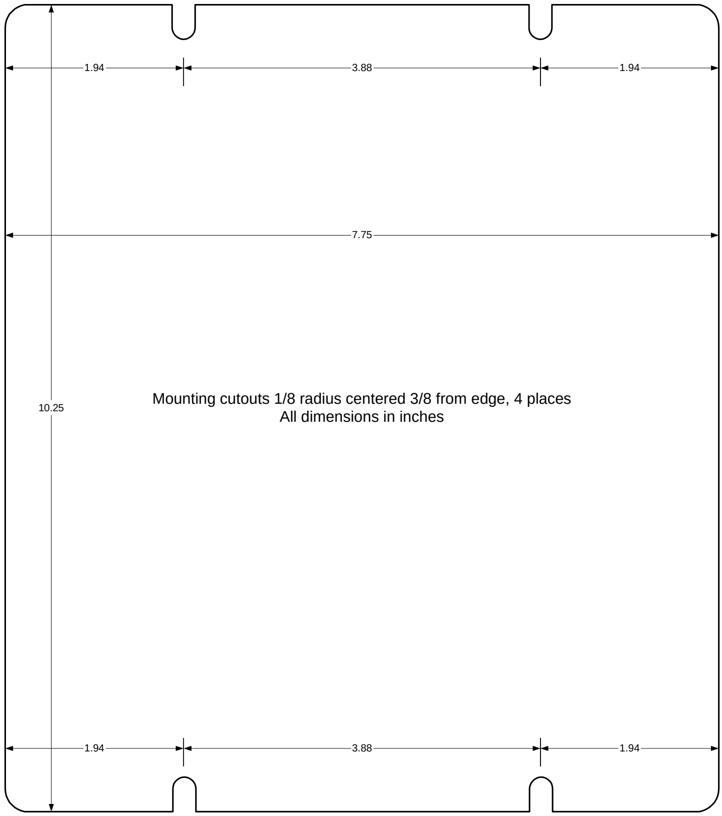

Figure 1.4. Mounting Configuration

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 ADU5. If user-defined parameters are not saved, then RESET sets the parameters to the factory defaults.
1 PPS PORT A	An RS-232 port with hardware flow control. 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	An RS-232 port with hardware flow control. 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	Reserved for internal use
PORT Y	Reserved for internal use
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.

Table 1.1. Front Panel Controls, Connectors, and Indicators (continued)

Component	Description
PWR/SAT 3	3-color LED indicates power/satellites tracked for receiver 3. See text for 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. **Caution!** The ADU5 may be damaged if power is applied with reverse polarity.
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 ADU5.

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 • Differential GPS (local correction) • Differential GPS (Beacon) • Differential GPS (SBAS) • Post-processed	 • 5 m (95% with selective availability OFF) • 90 cm (95%) • 1.6 m (95%) • 3.8 m (95%) • 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	10-29 VDC via 3-pin non-waterproof connector
Power requirements	6 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	• 4.125 lb (1.58 Kg) • 22 cm W x 10 cm H x 20 cm D (8.66 x 3.93 x 7.87 in) • 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
DGPS LED	• One LED to indicate source of incoming DGPS data
PWR/SAT 1-4	• Four LEDs indicate satellite tracking on the associated antenna. See text for description.

Standard Equipment

Each ADU5 includes the following items:

- ADU5 unit
- ADU5 Operation and Reference Manual
- One power cable
- Two serial data cables
- CalibADU Windows-based calibration software package
- 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 Magellan distributor for detailed information.

- 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
- Waterproof line amplifier for GPS + beacon
- GPS + beacon antenna kit

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.

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
1	NC	NC
2	RXD	RXD
3	TXD	TXD
4	DTR	DTR
5	GND	GND
6	NC	NC
7	RTS	RTS
8	CTS	CTS
9	1 PPS	EVENT

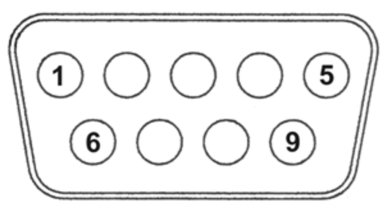

Figure 1.6 shows the power cable configuration and pinout.

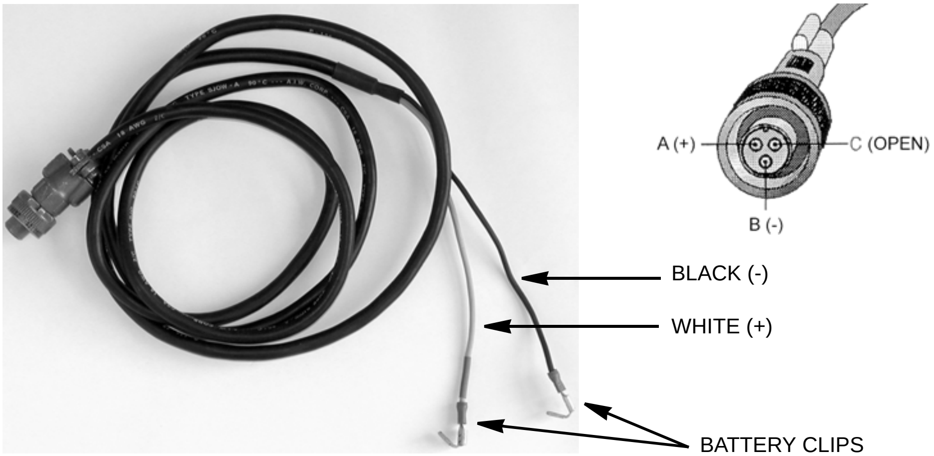

Figure 1.6. Power Cable Configuration and Pinout

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	1A
24V	0.5A

2

Quickstart

This chapter provides a brief overview for setting up the ADU5. Users experienced with the ADU5 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 ADU5 on-line.

1. Mount the antennas on any rigid platform as follows:
    a. If using the ADU5 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 a rigid frame 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.

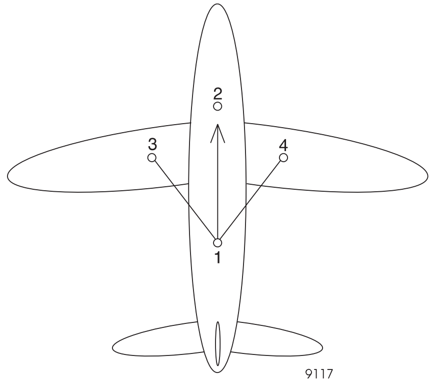

Figure 2.1 Example of Possible Antenna Locations on Aircraft

2. Connect the four antenna cables, labeled 1, 2, 3, and 4, to the antennas and the ADU5 ANT ports.
3. Turn off the external power source, and connect the power cable from the ADU5 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 ADU5 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 CD into the appropriate drive. Click on the Windows **Start** menu and select **Run**. Type **x:setup.exe**, where x is the letter of your CD-ROM drive. 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 18.

Quickstart

Antenna Calibration

Determine the relative antenna position vectors by conducting an antenna calibration of the ADU5 as follows:

Calibration

a. Verify that each antenna tracks at least six satellites: (**$PASHQ,STA**)

b. Make sure position is computed (**$PASHQ,POS**).

c. Collect data for at least one hour using the CalibADU program. Refer to ”Preparing Data Collection” on page 32 and “”Data Collection Process” on page 34 for detailed information on the collection procedure.

d. It is recommended that data be collected at a one-second update rate for moving vehicles, and at a two-second update rate for stationary vehicles.

e. Start the calibration procedure using the CalibADU program. Refer to ”Using Previously Collected B-files” on page 36 and ”Calibration Process” on page 38 for detailed information.

f. Inspect calibration results and enter any offset angles if necessary. See ”Calibration Results” on page 40 for detailed information.

g. The CalibADU program generates the file ADU5BASE.GPS that contains the relative antenna position vectors.

Enter Offset Vector Information.

7. Upload the ADU5BASE.GPS file to the ADU5 receiver using CalibADU or the Evaluate program. Refer to ”Uploading Calibration Vectors to the ADU Receiver” on page 44 for detailed information.
8. If you are using the ADU5 fixed portable antenna array, refer to Table 2.1 on page 19 for vector information.

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.

Table 2.1. 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 ADU5 has been calibrated and the offset vectors uploaded to the ADU5, the ADU5 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 **EVALUATE** program (Windows).

3

Installation

The ADU5 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 ADU5 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 ADU5. 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 ADU5 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 ADU5 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.

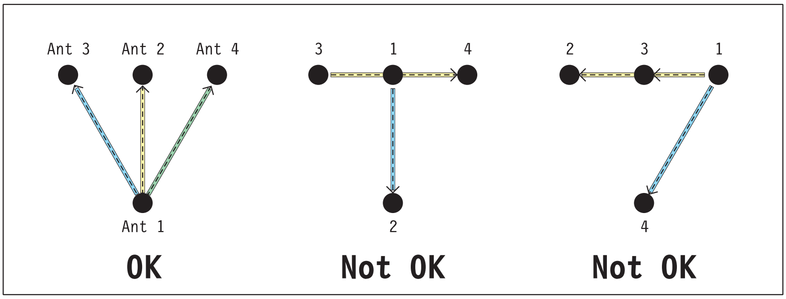

Figure 3.1. Configurations of Antennas (Top View)

1. The position computed by the ADU5 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*.

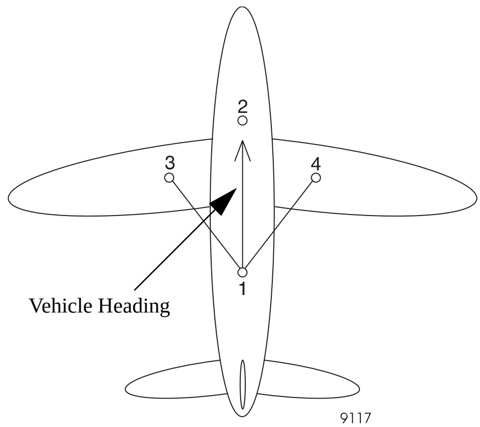

Figure 3.2. Suggested Locations for Antennas on Aircraft

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 ADU5 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 ADU5 package contains a CD with software for the antenna calibration procedure (CalibADU), and diskettes that contain the Evaluate software. The CalibADU and Evaluate software should be installed on a personal computer. CalibADU is designed for 32-bit operating systems: Windows 95, 98, NT4.0, Windows 2000. It is recommended to use a 486/66 computer or better.

To install the CalibADU program, perform the following steps.

1. Insert the CalibADU installation disk.
2. Click on the Windows **Start** menu and select **Run**.
3. Type **x:setup.exe**, where x is the letter of your CD-ROM drive.
4. Follow the instructions displayed on the PC screen.
5. Insert the Evaluate software diskette into the appropriate drive on the PC.
6. Select **Run** from the **File** menu.
7. Enter the following command in the **Command Line** of the **Run** dialog:
   a:setup (or b:setup if the diskette is in drive b).
8. Click OK to start the Evaluate setup program.
9. Follow the setup instructions that appear on the screen.
10. Refer to the Evaluate *User's Guide* for additional information on Evaluate.

Equipment Installation

1. Mount the ADU5 unit using the mounting brackets (Figure 3.3).

Figure 3.3. ADU5 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 ADU5. 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 ADU5 first, then the leads to the power supply.

3. Connect power supply cable to the power input on the ADU5.

Use a 10-to 29-volt regulated DC power supply. The Magellan 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 ADU5 unit is powered up, the LEDs flash orange and red several times, indicating the ADU5 is in the boot-up mode. The ADU5 typically takes about 20-25 seconds to boot up. Communication through Port A or B can only be established after the ADU5 has successfully booted.

Verify Antennas Tracking Satellites

After installing the ADU5 and antennas or antenna array, Magellan recommends verifying that the antennas are connected to the ADU5, receiving information from satellites, and computing a position.

1. Verify all four antennas are connected to their respective port on the ADU5 as described in “Antenna Installation” on page 21.
2. Verify that the receivers are tracking satellites using any communicaion program, such as Procomm or Evaluate.
3. 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.

4. Type **$PASHQ,POS** to verify the ADU5 is computing a position.
5. The ADU5 should respond with a computed position.

4

Antenna Calibration

This chapter describes the antenna calibration process for stationary and moving vehicles using GPS carrier phase measurements. An antenna calibration must be performed and the resultant vector components entered before the ADU5 can compute an attitude solution. The term “calibration” in this sense refers to the determination of the exact spatial relationship between the four antennas, and the translation of that relationship into a three-dimensional local coordinate system with the origin being the phase center of the primary antenna (antenna #1).

The antenna array consists of three vectors of interest; those being the radial vectors from antenna 1 to antennas 2,3 and 4 respectively. The length and relationship of these vectors must be determined to millimetric level and this is one of the tasks of the CalibADU software.

The accuracy of the calibration has a profound influence on the success of subsequent GPS attitude determination with the ADU5. For this reason, it is suggested that you clearly understand the data acquisition requirements of the calibration procedure and make every effort to adhere to those requirements. In theory, the calibration procedure need only be performed one time unless for some reason the antenna array becomes deformed or is otherwise changed. In practice, it is best to perform the calibration procedure more than once, during time periods several hours apart (to take advantage of the changing GPS satellite constellation geometry). This provides independent verification of the original calibration quality and removes the slight chance that one or more of the vectors did not “fix” properly.

NOTE: An accidental change or deformation of the antenna array is not always easily discernible, and it does sometimes occur. For this reason it is never bad practice to perform a “check calibration” periodically. After some time in operation, if for some reason the ADU5 attitude

solution appears to be degrading or suffering from untimely solution outages, a re-calibration is certainly indicated as a useful first step in solving the problem.

As with any differential GPS carrier-phase measurement exercise, redundant measurement data is a critical factor. For this reason it is always best to do some form of mission planning in order to choose the best time to perform the calibration. **It is <u>not</u> recommended to perform the calibration procedure if less than six GPS satellites are available during the course of the data logging.** The ADU5 antenna array should be located so that skyward visibility is optimal. The occurrence of cycle slips (carrier phase discontinuities—or temporary loss of lock) is destructive to the calibration procedure and hence locations with skyward obstructions should be avoided. Duration of the data acquisition session for calibration should be 30 to 60 minutes, with a record interval of 1 or 2 seconds.

The calibration processing software, CalibADU, performs three tasks:

- Collects raw GPS measurement data from the ADU5 receiver
- Computes relative antenna positions and determines the calibration vectors
- Presents the computation results and uploads calibration vectors to the ADU5 receiver.

CalibADU software can operate in two modes:

- Static, the antenna array is motionless
- Kinematic or dynamic, the antenna array is in motion

The software takes a different algorithmic approach, depending on which of these modes is actually the case with the collected raw measurements. This is the only runtime parameter that you need to be concerned with. Successful calibrations can readily be achieved in both static and kinematic modes.

CalibADU Environment Overview

CalibADU is designed as a chain of dialogs appearing sequentially and covering the calibration process from the start- logging raw measurement data and computing relative antenna vectors, to the end- presenting the calibration results and uploading them to the receiver. Table 4.1 lists the dialogs in the calibration procedure.

Table 4.1 Dynamic Calibration Dialogs

Dialog	Description	Page
Start ADU Calibration Figure 4.1	The first dialog allows you to select the method of collecting data. Choices are: collect data now, or use previously collected data	32
Download Settings Figure 4.2	Appears after the **Startup** dialog, if you are going to collect data	33
Collecting Measurement Data Figure 4.3	A display-only dialog. Shows the status of the data logging session.	35
Select B-file for Calibration Figure 4.4	Appears after the **Startup** dialog, if you are using data collected previously.	37
Calibrating Information Figure 4.5	A display-only dialog. Shows the status of the calibration processing.	38
Calibrating Failed Figure 4.6	A display-only dialog. Shows calibration failure.	39
Calibrating Successful Figure 4.7	A display-only dialog. Shows calibration successful.	40
Adjusted Relative Antenna Position Figure 4.8	One of the two dialogs appearing after the calibration processing is complete. It contains the results of the calibration.	41
Input Relative Antenna Position Figure 4.9		43
Dynamic Calibration Is Completed Figure 4.10	The result dialog which allows you the choice to immediately upload the calibration results or save them to a *GPS file for uploading later.	44

CalibADU Operation

Start CalibADU Software

You can launch CalibADU from your Windows desktop. To run CalibADU from the Windows **Start** menu, select **Programs**, choose **ADU Tools folder**, and then choose **ADU Dynamic Calibration**. The **Start ADU Dynamic Calibration** appears, as shown in Figure 4.1.

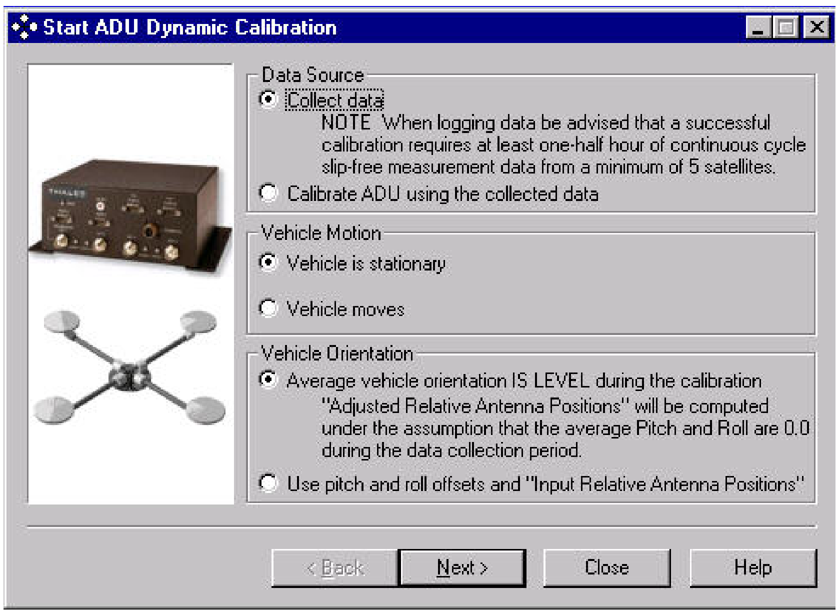

Figure 4.1 Start ADU Dynamic Calibration Dialog

Preparing Data Collection

You start the calibration by logging raw measurement data or by choosing to use a previously collected data set. In order to determine the calibration vectors of the four antennas properly, CalibADU has some specific requirements of the collection of raw measurement data. The major requirement is that the data from at least six common satellites tracked by all four antenna banks must be free of cycle slips for at least 30 minutes. The data should be collected at a two-second update rate for stationary vehicles and a one-second update rate for moving vehicles. Before collecting data, make sure that your receiver, all antennas, and PC are properly connected and the receiver is powered up and is tracking satellites on all four antenna banks. To collect measurement data, do the following steps:

1. Start the calibration software
2. Select the **Collect Data** button in the **Start ADU Dynamic Calibration** dialog (Figure 4.1)
3. Select vehicle motion, stationary or moving.
4. Select **Average vehicle orientation is LEVEL** or **Use pitch and roll offsets.** For detailed information on offset angles, see Supplementary Information on page __ and Appendix B of this manual.
5. Click **Next**. The **Download Settings** dialog box appears, Figure 4.2.

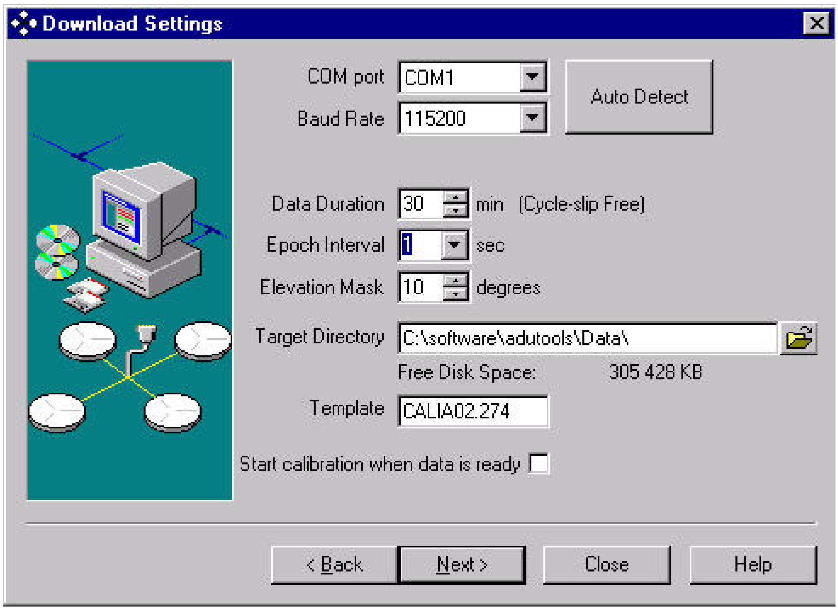

Figure 4.2 Download Settings Dialog

1. In the **Download Settings** dialog, select the **COM Port** settings. The default and recommended baud rate is 115.2 Kbaud.
2. Enter the number of minutes for data collection in the **Data Duration** field. The software will log enough data to ensure that a session of this length with no cycle slips will be recorded. The default value is 30 minutes but can be increased.
3. Select the **Epoch Interval** recording rate. Default value is 1 second, but it can be changed to 2 seconds.
4. In the **Target Directory** enter the full path name for the destination of the data

files. The default is the **ADUTools\Data** folder (which is automatically created by the software), but the browse button can be used to select another folder if desired, or one can be created at this point.

5. Pay attention to the **Template** field. This field displays the filename template for the B, E and A files created during the logging process. See detailed information on the file naming convention in the **File Types** section of this chapter. In order for the software to recognize the raw data files, this convention must be followed.
6. Check or uncheck the **Start calibration when data is ready** box. If this box is checked, calibration processing will continue automatically after data logging. If you prefer to do the processing later, uncheck this box. This may be the case when you intend to log multiple consecutive sessions.
7. Click **Next**. The **Collecting Measurement Data** dialog appears, as shown in Figure 4.3.

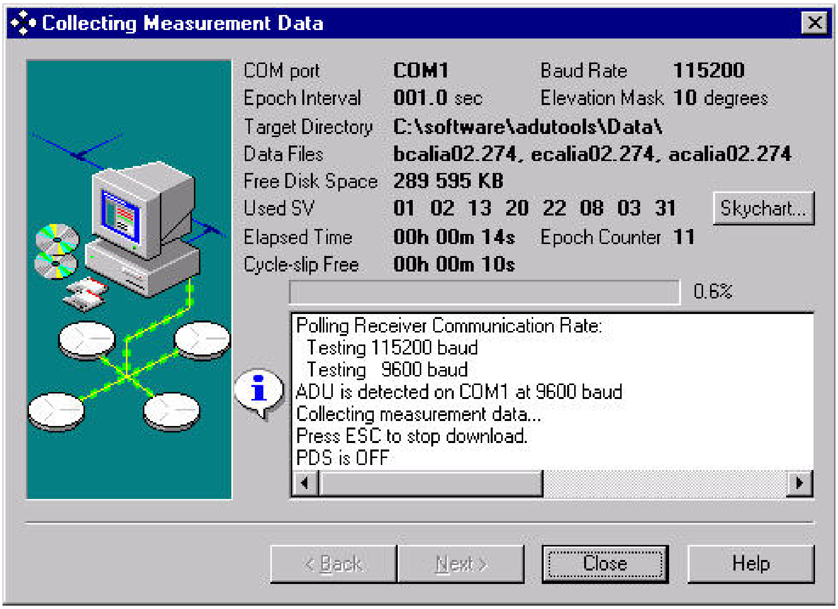

Figure 4.3 Collecting Measurement Data dialog

Data Collection Process

You can observe and monitor the data collection process in the **Collecting Measurement Data** dialog window. It displays the percentage of acceptable data collected in the progress bar, displays the B, E and A files names currently being logged and shows satellite tracking status, among other things which are self-explanatory. Table 4.2 is a detailed description of this dialog.

Table 4.2 Collecting Measurement Data

<table>
<tr><th>Item</th><th>Description</th></tr>
<tr><td>COM port</td><td rowspan="5">You specify these settings in the Download Settings dialog.</td></tr>
<tr><td>Baud rate</td></tr>
<tr><td>Epoch Interval</td></tr>
<tr><td>Elevation Mask</td></tr>
<tr><td>Target Directory</td></tr>
<tr><td>Data Files</td><td>These will be the B-, E-, and A-files. The filename is combined with the template and the file designators A, B , or E .</td></tr>
<tr><td>Free Disk Space</td><td>Indicates the amount of free disk space available for writing data files on the disk.</td></tr>
<tr><td>Used SV</td><td>Displays the satellites that are being tracked in common by all four antennas and used in the calibration routine.</td></tr>
<tr><td>Skychart Button</td><td>Opens the Skychart window.</td></tr>
</table>

The **Skychart** window provides detailed information regarding the satellite constellation. The window consists of two parts: **Polar Plot** and **Satellite** information summary.

The **Polar Plot** displays the position of satellites in the sky. There are four concentric circles representing elevation above the horizon. The outermost circle represents 0 degrees above the horizon, the next circle is 30 degrees, and the smallest is 60 degrees. The center of the circle represents 90 degrees above the horizon. The red circle indicates the user-defined elevation mask.

The **Satellite** information summary represents channel numbers, antenna numbers, satellite azimuth, elevation and signal-to-noise ratio. The green satellite numbers mean that the satellites are being tracked on all four antennas. The red satellite numbers mean that the satellites are being tracked on one, two or three antennas. To close the **Skychart** window, double-click on it or press <Esc>. **Elapsed Time** displays the time elapsed from the start of the data logging. **Epoch Counter** displays the number of measurement epochs from the start of the data collection. If incrementing at the selected recording interval, this indicates that the logging process is operating normally. **Cycle-slip Free** displays the good data period. This is the amount of data logged which meets the cycle-slip free criteria. The progress bar displays the amount of the collected data as a percentage of the user-selected good period.

It is always good practice to try to obtain calibration data during those times when there is a large available constellation, i.e. a minimum of 8 satellites are being tracked above the elevation mask.When the data collection is completed successfully, click **Next**, to start the calibration, or let the calibration run automatically, if you checked **Start Calibration** when data is ready in **Download Settings**.

Using Previously Collected B-files

CalibADU allows you to use previously collected measurement data for the calibration procedure. The program first prompts you to choose a B-file, then scans it to determine if there is a sufficient good data (i.e. cycle slip free) period. If this step is successful the calibration process begins.

Before running the calibration make sure that the B-file and its corresponding E-file are located in the same directory. To run the calibration process using a B-file, perform the following steps:

1. Select **Calibrate ADU using collected data** radio button in the **Start ADU Dynamic Calibration** dialog.
2. Select vehicle motion, stationary or moving
3. Select **Average vehicle orientation is LEVEL** or **Use Pitch and Roll offsets**. The default is the LEVEL orientation choice. This should be selected in all cases unless it is apparent that the vehicle orientation was definitely not in its normal level state during a static calibration logging session. If the vehicle was in motion during the data collection, always choose the default option.
4. Click **Next**. The **Select B-file for Calibration** dialog appears, Figure 4.4.

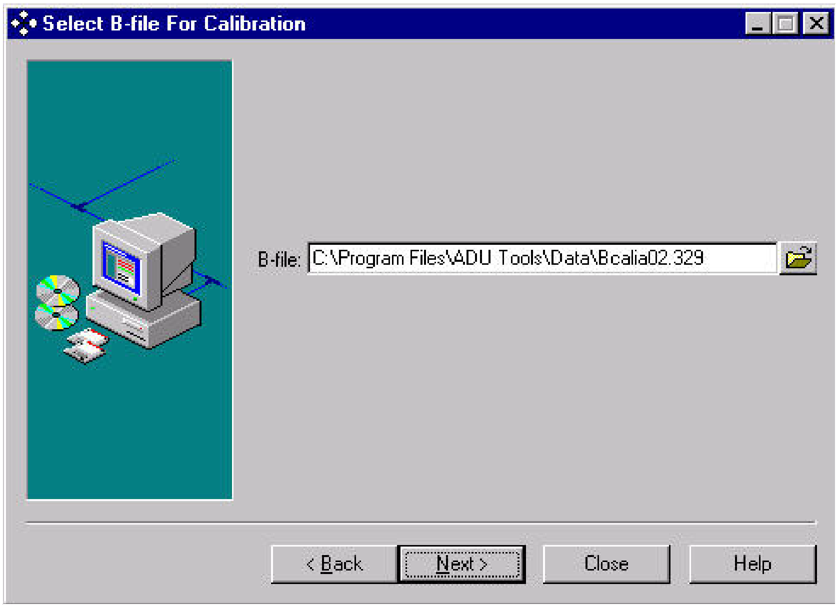

Figure 4.4 Select B-file for Calibration Dialog

5. Specify the full name of the desired B-file in the B-file field. Type in the filename or press the browse button and select the directory path and filename you wish to use.
6. Click Next. The Calibrating dialog appears, as shown in Figure 4.5.

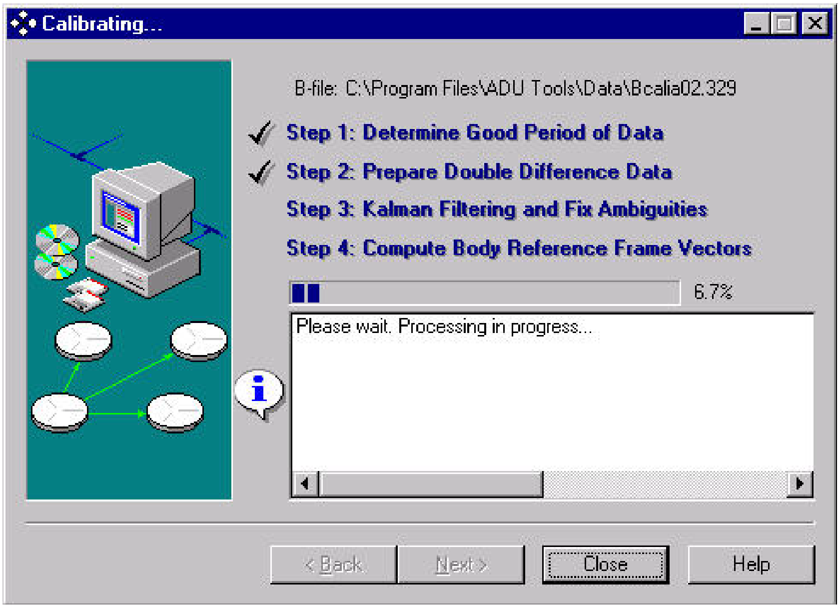

Figure 4.5 Calibrating… Information

Calibration Process

You can observe the calibration process in the **Calibrating…** information box. The calibration process includes the following four steps:

1. **Determine good period of data**- the B-file is scanned to determine if enough good data exists to perform the calibration successfully.
2. **Prepare double-difference data**- the carrier phase double differences are generated and stored.
3. **Kalman Filtering and Fix Ambiguities**- the data is processed forward and backward to fix the carrier phase ambiguities and estimate the antenna-to-antenna baseline lengths.
4. **Compute Body Reference Frame Vectors-** if ambiguity fixing is successful, the relative antenna positions, called the BRF vectors, are generated and written to the BRFVEC.XYZ results file.

If the processing fails, the **Calibrating…** information box will display a warning dialog similar to Figure 4.6.

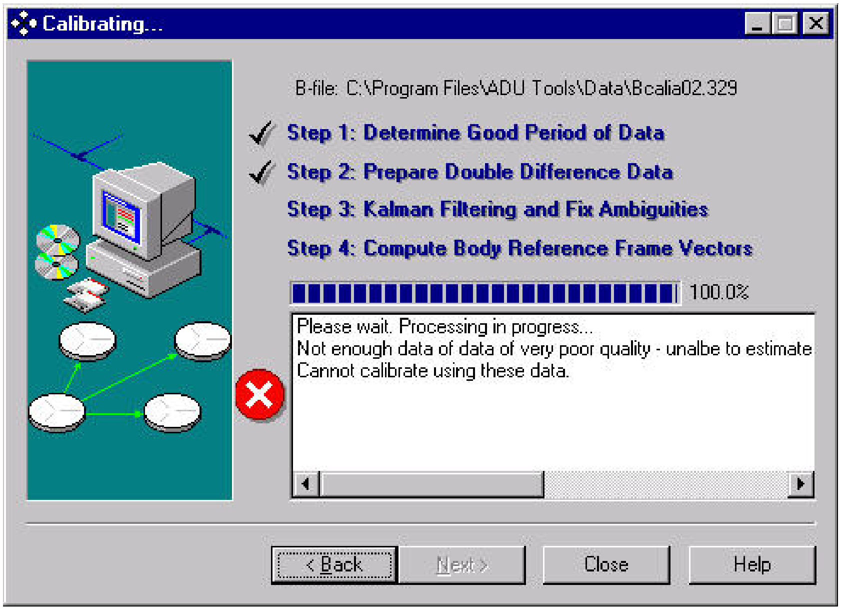

Figure 4.6 Calibrating… Failed

In this case, a new logging session must be started or a different B-file must be used for the calibration.

If on the other hand the software determines that the data was sufficient for good calibration and can compute the Body Reference Frame vectors successfully, an information screen will appear as below in Figure 4.7.

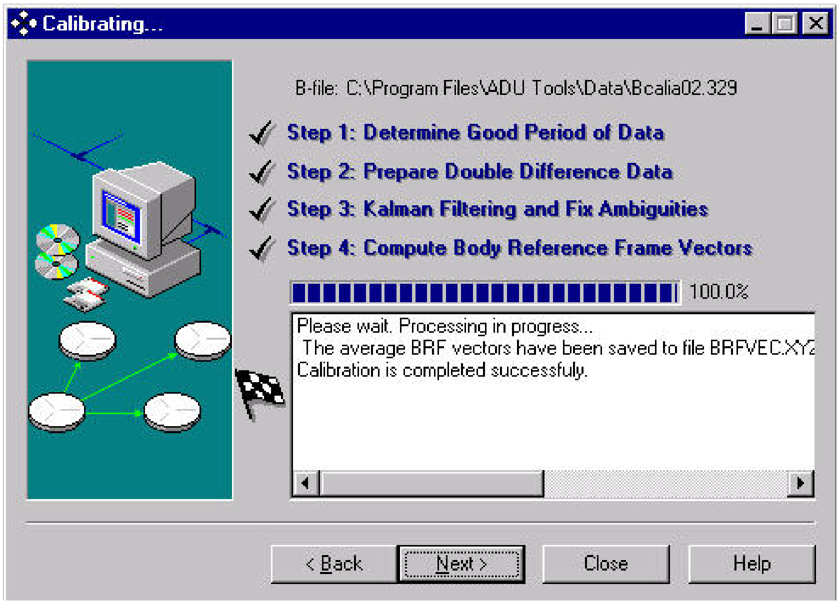

Figure 4.7 Calibrating… Successful

If calibration has completed successfully, click **Next** to view the calibration results in the **Adjusted Relative Antenna Positions** screen or the **Input Relative Antenna Positions** screen (which of these two screens appears depends on your selection of vehicle orientation at the beginning of the exercise). At this point you can continue on to complete the calibration procedure.

Calibration Results

The calibration results are the relative antenna positions or calibrated vectors. If you selected to use **Average Vehicle Orientation is LEVEL** in the **Start ADU Dynamic Calibration** dialog at the beginning of the procedure, CalibADU displays the results in the **Adjusted Relative Antenna Positions** screen, as shown in Figure 4.8.

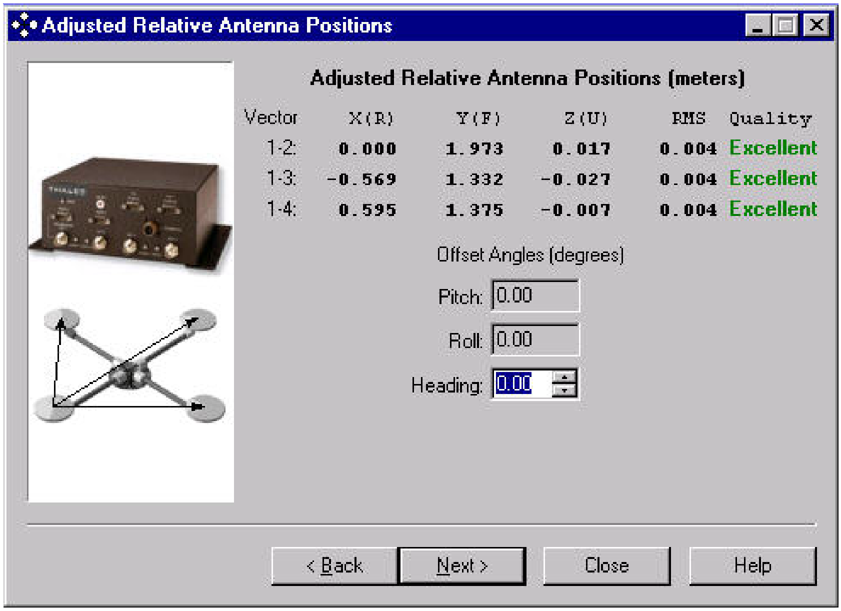

Figure 4.8 Adjusted Relative Antenna Positions

Adjusted Relative Antenna Positions

The **Adjusted Relative Antenna Positions** dialog appears if you initially selected **Average Vehicle Orientation is LEVEL** in the **Start ADU Dynamic Calibration** dialog. The program computes the relative antenna positions and displays these in the table. The rows are the three antenna vectors (1 to 2, 1 to 3 and 1 to 4) radial from antenna 1, and the columns are the vector components X (Right), Y (Fore) and Z (Up) in the local coordinate system with origin (0,0,0) being the phase center of antenna 1. The last column is the computed RMS of the vector solution and a color-coded quality indicator (Table 4.3). If the calibration quality is shown as “fair” or “poor” it is an indication that perhaps another calibration should be performed for verification purposes. If multiple calibrations are done, they should agree within about 5 millimeters in the X and Y components. The Z (Up) components may show a greater disagreement. This is normal and generally acceptable because the vertical component is always the weakest in any GPS solution.

Table 4.3 Color Codes and Quality Indicators

Average of 3 RMS	Quality	Quality Color Code
>0.015 m	Poor	Red
>0.010 and <= 0.015m	Fair	Yellow
>0.005 and <= 0.010m	Good	Cyan
<=0.005m	Excellent	Green

Furthermore, the program displays a heading offset angle dialog box. The pitch and roll offset angles are zeroed and grayed out because of the assumption that the vehicle was level during the calibration. If you have determined that the antenna 1-2 vector is not coincident with or parallel to the centerline of the vehicle, the heading offset angle should be independently determined and entered in this box. This parameter will then be included in the ADU5BASE.GPS configuration file.

To conclude the calibration, do the following:

1. Enter the heading offset angle if there is any.
2. Click **Next** to write the final output in the ADU5BASE.GPS file. This will open the **Dynamic Calibration is Completed** dialog. This dialog will be shown in Figure 4.10, after a discussion on the **Input Relative Antenna Positions** dialog, Figure 4.9.

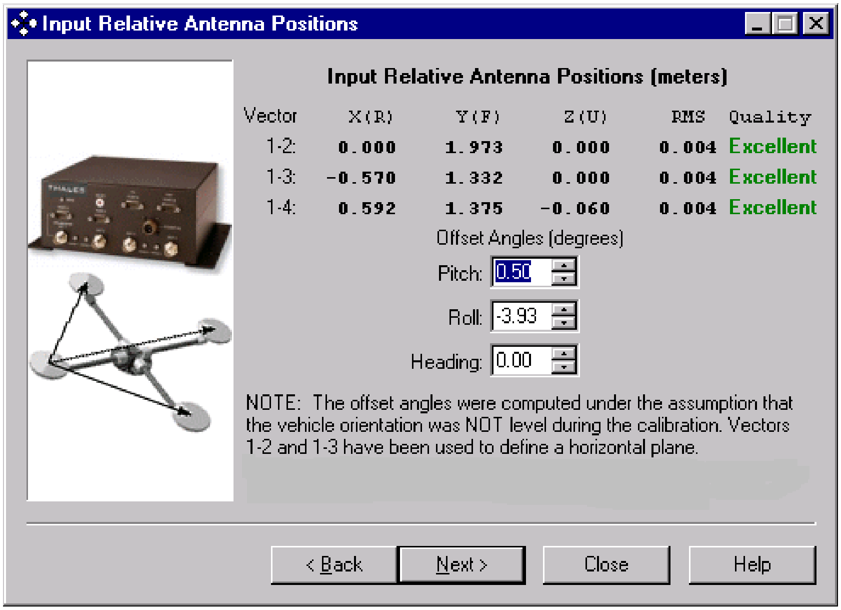

Figure 4.9 Input Relative Antenna Positions

Input Relative Antenna Positions

This dialog screen appears if your initial selection for vehicle orientation was to **Use Pitch and Roll Offsets** in the **Start ADU Dynamic Calibration** dialog. In this screen the word “Input” may cause confusion and bears explanation. These are the vectors that were used as input values for the position adjustment that takes place if vehicle orientation was selected as LEVEL. They appear in the BRFVEC.XYZ file along with the “adjusted” vectors, RMS values and the computed pitch and roll offset angles. Note that the Z values for both vectors 1-2 and 1-3 are zeros. This is because the program has used those vectors to define a horizontal plane from which to compute the pitch and roll offsets.

The pitch and roll offset values have been loaded into the respective dialog boxes, and they will be written to the ADU5BASE.GPS configuration file for upload to the receiver. Additionally, you may enter a heading offset angle if any is required. To conclude the calibration, do the following:

1. Enter heading offset angle, if any.
2. Click **Next** to write the final output into the ADU5BASE.GPS file. This will open

the **Dynamic Calibration is Completed** dialog. See Figure 4.10 below.

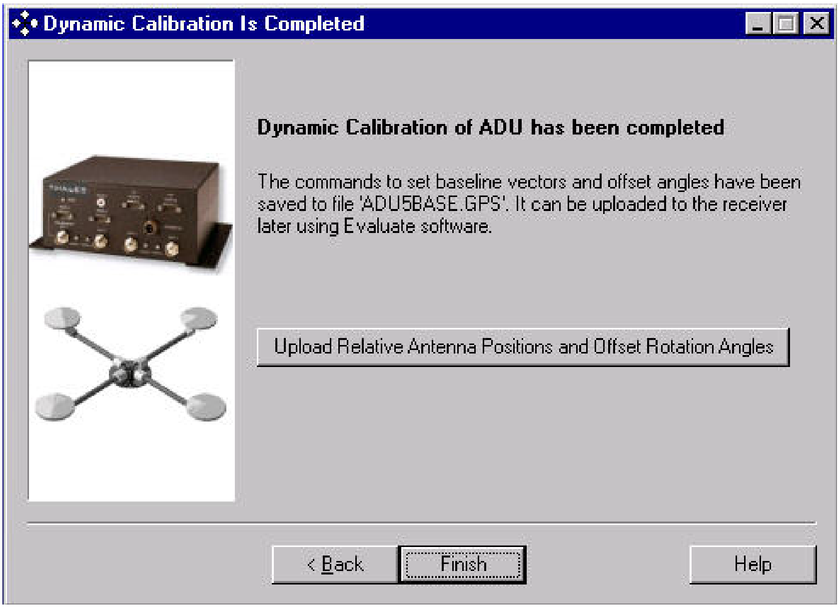

Figure 4.10 Dynamic Calibration is Completed

Uploading Calibration Vectors to the ADU Receiver

At this final stage of the calibration process, CalibADU allows you to upload the ADU5BASE.GPS configuration file to the receiver. To do this, make sure that the PC and ADU receiver are properly connected with the serial I/O cable, then click on the **Upload bar.** The program will reconnect with the receiver and the upload will take place. The software will notify you when the successful upload is complete.

Being a simple ASCII text file, the ADU5BASE.GPS file may be edited later to include other user setup parameters and serial commands as desired, and then uploaded during connection with Evaluate software. If you prefer to upload the *.gps file later with Eval32 software, click **Finish** to end the program.

Reference Information

File Types

B-files

B-files are the collected satellite measurement files. The name for B-file is the site name, session designator letter, year, and day of year as extension. For example, for a typical file named BCALIA02.163,

B stands for binary satellite measurement file

CALI is a user-defined site name, four-character filename template

A is the session designator, a letter from A to Z

02 is the last two digits of current year

163 is the day of the year

E-files

E-files are the ephemeris files. The name for E-file is the site name, letter, year, and day of year as extension. For example, ECALIA02.163, where

E = Ephemeris file

CALI = Site name

A = Session letter, from A to Z

02 = Last two digits of current year

163 = Day of year

ADU5BASE.GPS

This file is created by Dynamic Calibration of ADU and contains the relative antenna vector components and offset angles. This is an ASCII text file, which is composed of standard Magellan serial interface commands. It can be edited to include other parameter setting commands.

A-files and S-files

The A-file is named in the same fashion as the B and E files. The A-file contains computed attitude information if valid calibration vectors have already been entered into the ADU5 setup parameters when new calibration data is being logged. This is a binary data file. The BIN2ASC.EXE software utility can be used to convert this binary file to an ASCII tabular text file. The ASCII file is known as the “S” file because it has the same name as the A-file with the exception of the first character which will be an “S”. The format of each individual record in the attitude S-files will correspond to the format of the $PASHR,ATT output message, described on page 116.

Supplementary Information

Attitude Offset Angles

Attitude offset angles are defined as the angle differences (positive clockwise) in heading, pitch, and roll that exist between the ADU antenna system and the vehicle.

Attitude offset angles will exist for the ADU system only for the two cases described below:

1. A heading offset angle is induced when it is not possible to mount two of the antennas parallel to or coincident with the vehicle centerline.
2. Pitch and roll offset angles are induced when the vehicle's orientation is not at the assumed zero pitch and zero roll attitude during the calibration logging process, or when the vehicle is in motion and undergoing changes in pitch and roll. Pitch and roll offset angles can be determined empirically by analysis of recorded data during normal ADU operations. This is not the case for heading offset angles, which must be determined by independent methods. A discussion on this topic can be found elsewhere in this manual.

BIN2ASC.EXE Utility Software

This included software allows you to convert the binary attitude data files (A-files) to an ASCII data file. The ASCII file is known as the S-file. Operation of this program is simple and intuitive. You can find the executable file for this program under **ADU Tools** folder along with other calibration software programs. Launch the program and use the A-file selection browser to identify the desired A-files for conversion. The S-files will be generated and stored in the same folder as the selected A-files. For description of the S-file record, see the description of the $PASHR,ATT data output message (page 116).

5

Command/Response Formats

Overview

Once the ADU5 has been calibrated and the offset vectors uploaded to the ADU5, the ADU5 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 **EVALUATE** software for Windows. Refer to the *Evaluate User's Guide* for detailed information.

The ADU5 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 Magellan 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 section of the manual describes in detail the formats and information contained in the ADU5 output structures. These output structures fall into three main categories:

- Standard NMEA messages
- Magellan proprietary ASCII messages
- Magellan raw data structures (most are binary or ASCII, some are limited to binary).

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 Magellan proprietary ASCII messages are treated as NMEA standard messages. Their output interval is tied to the $PASHS,NME,PER,x command.

Magellan 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, Magellan 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 ADU5 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.

 As noted previously, an external device such as a PC or a handheld controller must be used to input commands to the ADU5, and to monitor responses from the ADU5. 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 (next page)

NMEA Commands (page 80)

Raw Data Commands (page 113)

Differential (RTCM) Commands (page 137)

SBAS Commands (page 70)

Beacon Commands (page 68)

Receiver Commands

Table 5.1 summarizes the receiver commands and responses by function (receiver control, attitude setup, etc.). The pages following Table 5.1 describe each command/response in detail, in alphabetical order.

Table 5.1. Summary of Receiver Commands

Command	Description	Page
Receiver Control Commands		
$PASHS,ALT	Set altitude for fix mode 0 and 1	51
$PASHS,BCN	Beacon commands	68
$PASHQ,BIT	Built-in test	51
$PASHS,DYN	Set dynamic mode for position solution	52
$PASHS,ELM	Sets elevation mask	53
$PASHS,FIX	Sets altitude fixed mode	54
$PASHS,GPS,CHN	Assign number of GPS channels	54
$PASHS,HDP	Sets HDOP mask	54
$PASHS,INI	Initialize receiver	76
$PASHS,KFP	Enable/disable Kalman filter for position solution	55
$PASHQ,KFP	Query Kalman filter parameters for position solution	56
$PASHS,KFP,PRI	Set Kalman filter prediction interval	56
$PASHS,KFP,FDE	Set tKalman filter probability of detection for position solution	55
$PASHS,MSV	Sets minimum number of satellites	58
$PASHQ,PAR	Query configuration of general setup parameters	58
$PASHS,PDP	Sets PDOP mask	59
$PASHS,PDS	Sets satellite selection for best PDOP	59
$PASHS,PMD	Set altitude mode - fixed or computed	60
$PASHS,POP	Set rate of position fix	61
$PASHS,POS	Sets position mode	61
$PASHS,POS,	Sets antenna position	62
$PASHQ,PRT	Queries port being used and the baud rate	63
$PASHQ,RID	Queries receiver version ID	63

Table 5.1. Summary of Receiver Commands (continued)

Command	Description	Page
$PASHQ,RIO	Queries product type, receiver version, sensor version, installed options, and receiver serial number	64
$PASHS,RST	Resets receiver parameters to defaults	64
$PASHS,SAV	Saves receiver setup parameters	64
$PASHS,SBA	SBAS Commands	70
$PASHS,SIT	Assigns site ID name	64
$PASHQ,STA	Queries current satellite tracking status for each antenna	65
$PASHS,SPD	Sets receiver serial port baud rate	65
$PASHS,SVS	Enables/disables satellites	66
$PASHQ,TST	Requests results from the power-up initialization test	66
$PASHS,USE	Use/not use a particular satellite	67
$PASHS,VDP	Sets VDOP mask	67

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 command is used in conjunction with Position Mode 1, 2, and 3.

BIT: Operational Diagnostic Tests

$PASHQ,BIT[,c]

This command queries the results of the periodic operational diagnostic tests, where c 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.

$PASHR,BIT

The response message is in the format:

$PASHR,BIT,d1,d2,d3,d4,d5*hh

where the structure is as defined in Table 5.2.

Table 5.2. $PASHR,BIT Response Parameters

Parameter	Description	Range
d1	Battery test result	P = Pass F = Fail
d2	Parameter test result	P = Pass F = Fail
d3	Fatal error test result	P = Pass F = Fail
d4	Number of inactive sensors	1 - 4
d5	Percentage of failed data blocks	0.0 - 100.0
*hh	Checksum	00-FF

DYN: Dynamic Mode for Position Solution

$PASHS,DYN

This command sets the dynamic mode for the receiver. The command structure is $PASHS,DYN,d where d is as defined in Table 5.3.

Table 5.3. Dynamic Modes

d (Dynamic Mode)	Description	Maximum Horizontal Velocity (m/s)	Maximum Vertical Velocity (m/s)	Maximum Horizontal Acceleration (m/s^2)	Maximum Vertical Acceleration (m/s^2)
1	Static	0	0	0	0
2	Quasi-static *	0.1	0.02	0.1	0.02
3	Walking	2	0.5	1	0.5
4	Ship	20	1	1	0.5
5	Automobile	50	3	10	1.0
6	Aircraft	1000	1000	100	100
7	Unlimited	1000	1000	100	100
8	Adaptive dynamic **	N/A		N/A	N/A

*Quasi-static represents a static condition with some tolerance for slight movements within a decimeter or two. An example would be an antenna on a handheld pole or on the back of a person; obviously a person can try to be static but will inevitably move within a decimeter or two. This is unlike “Static” mode where the antenna is placed on a tripod or any other stationary structure with zero tolerance for actual movement.

*”Adaptive dynamic adapts the filter dynamics settings to any of the modes 1 through 6 in real time, allowing the switch from one mode to the other based on the witnessed behavior.

If you are unsure which is the appropriate model for your application, choose the Adaptive Dynamic mode. If you select Mode 0 through 6, the ADU5 will not accommodate the other dynamic modes.

Example: Set dynamic mode to aircraft:

$PASHS,DYN,5

DEFAULT
$PASHS,DYN— 8 (Adaptive Dynamic)

ELM: Elevation Mask

$PASHS,ELM,dd

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

Example: Set elevation mask to 15 degrees:

$PASHS,ELM,15

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.

Example: Set altitude to most recent computed:

$PASHS,FIX,0

DEFAULT
0 - most recent altitude

GPS,CHN: Assign No. of Channels for GPS Operation

$PASHS,GPS,CHN,d

This command assigns the number of channels to use for tracking GPS satellites, where d indicates the number of channels.

Example: Assign 12 GPS channels:

$PASHS,GPS,CHN,12

This command can be used in conjunction with $PASHS,SBA,OFF to turn off SBAS and to configure the receiver for 12-channel operation to be compliant with NMEA standards. The current NMEA standard only allows for 12-channel satellite information to be displayed in the NMEA messages.

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.

Example: Set HDOP mask to 6:

$PASHS,HDP,6

DEFAULT
4

KFP: Position Kalman Filter

$PASHS,KFP,d

This command enables/disables the position Kalman filter, where d is ON or OFF. If you issue this command again, it will reset the Kalman filter.

The Kalman filter supports known point initialization.

Example: Enable Kalman filter:

$PASHS,KFP,ON

DEFAULT
KFP—OFF

KFP,FDE:Position Kalman Filter Fault Detection & Elimination

$PASHS,KFP,FDE,f

This command sets the probability of fault detection for the position Kalman filter, where f is percent as defined in Table 5.4.

Table 5.4. Kalman FDE Command Structure

Parameter	Description	Range
f	Probability of fault detection	95,99,99.9

Example: Set reliability to 99 percent:

$PASHS,KFP,FDE,99

DEFAULT
KFP,FDE—99

KFP,PRI: Kalman Filter Prediction Interval

$PASHS,KFP,PRI,f

This command sets the position Kalman filter maximum prediction interval, where f is the prediction interval, from 0 to 100 seconds. The Kalman filter stops outputting the predicted position if the prediction interval is longer than f or if the position error mask (ERM) is exceeded. If f is set to zero, the prediction mode is disabled.

The predicted position is flagged in the $PASHR,POS message as 8.

Example: Set Kalman filter maximum prediction interval to 45:

$PASHS,KFP,PRI,45

DEFAULT
KFP,PRI—10 seconds

$PASHQ,KFP,[c1]

This command queries the position Kalman filter parameter settings, where c1 is the optional port for the output of the response. If a port is not specified, the receiver sends the response to the current port.

The response message is in the format shown below:

KFP SETUP:

MODE:OFF PRI:010.0 FDE:99.0 PAR:001.00,001.00

Table 5.5 defines the message structure.

Table 5.5. KFP Message Structure

Parameter	Description	Range
KFP SETUP	Message heading	
MODE	The currently set Kalman filter mode.	ON, OFF
PRI	The current setting for the prediction interval.	0 to 100
FDE	The fault detection value for the Kalman filter.	95, 99, or 99.9
PAR	Reserved for internal use.	

KPI: Known Point Initialization for Position Kalman Filter

$PASHS,KPI,m1,c1,m2,c2,m3,s1,s2,s3

This command sets the known coordinates for an antenna phase center, where Table 5.6 defines the parameters:

Table 5.6. $PASHS,KPI Parameters

Parameter	Description	Format and Range
m1	WGS84 latitude in degrees and decimal minutes	ddmm.mmmmmmm 0 to 8959.9999999
c1	Direction of latitude	N = North, S = South
m2	WGS84 longitude in degrees and decimal minutes	dddmm.mmmmmmm 0 to 17959.9999999
c2	Direction of longitude	E = East, W = West
m3	WGS84 ellipsoidal height in meters	mmmm.mmm -9999.999 to +9999.999
s1, s2, s3	*A priori* expected sigmas of entered coordinates (meters)	

The receiver will not acknowledge the command if the entered and computed positions differ by more than 500 meters.

Empty m fields are interpreted as having no *a priori* information for the direction (to cover 3D, 2D and 1D initializations).

Empty s fields are interpreted as taking value 0.01 > m.

If you set an s field to 100 m the receiver interprets this as having no *a priori* information for this direction.

This command is applied only to Kalman filtered positioning (KFP > ON). If the receiver is set to LMS positioning (KFP OFF), the KPI command has no effect. After you have issued this command, the Kalman filter resets and is initialized with specified coordinates and sigmas. The Kalman filter uses the KPI settings only once for initialization, so you can safely move a few seconds after issuing this command.

MSV: Set Minimum Satellites

$PASHS,MSV,dd

Sets the minimum number of satellites to record.

DEFAULT
3

PAR: Query Setup Parameters

$PASHQ,PAR

Queries the configuration of the general setup parameters.

An example response is (setup to use SBAS DGPS corrections):

```
SPDA:5 SPDB:5 SPDC:5
GPS:YYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYY
SBAS:YYYYYYYYYYYYYYYYYYY
SYS:GPS DTM:W84 TDP:04
PMD:0 FIX:0 ALT:+00000.00 PDP:40 HDP:04 VDP:04 ERM:600,1200,300,600
PEM:05 SEM:OFF UNH:N ION:Y TRO:Y SAV:Y
RTC:REM PRT:Z
SBA:SAM
RCI:001.00 MSV:3 ELM:05 ANH:0.0000 SIT:SC01 EPG:000
OUT:  ATT AT2 PSA DSO MBN PBN SNV SAL  BIN
PRTA: OFF OFF OFF OFF OFF OFF OFF OFF  OFF
PRTB: OFF OFF OFF OFF OFF OFF OFF OFF  OFF
PRTC: OFF OFF OFF OFF OFF OFF OFF OFF  OFF
NMEA: LTN ZDA GLL GXP GGA VTG GSN ALM DAL MSG PAT HDT GSA GSV GRS GSS
PRTA: OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF
PRTB: OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF
PRTC: OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF
NMEA: POS SAT RRE TTT SA4 ROT ROP ROR
PRTA: OFF OFF OFF OFF OFF OFF OFF OFF
PRTB: OFF OFF OFF OFF OFF OFF OFF OFF
PRTC: OFF OFF OFF OFF OFF OFF OFF OFF
PER:001.00
NOTE: Port C is for internal use only. Do not enable any messages on port C.
```

PDP: Position Dilution of Precision

$PASHS,PDP,dd

Sets the PDOP (position dilution of precision) mask for the position computation, where dd is the mask value. A position is not computed if the PDOP rises above this number.

Example: Set PDOP mask to 10;

$PASHS,PDP,10

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

PMD:Altitude Mode - Hold Fixed or Compute

$PASHS,PMD,d

This command sets the position mode. The position mode determines the minimum number of satellites required to compute a position, whether the receiver switches automatically from 2-D to 3-D positioning, or is manually locked in 2-D or 3-D positioning mode, and, in 2-D mode, whether the altitude used is the most recently computed “good” altitude or a fixed altitude value set by the ALT command. Enter 0, 1, 2, or 3 for d1. You can view the current position mode by entering the query command **$PASHQ,PAR** and checking the PMD field. See the section in chapter 3 entitled “Position Modes” for more information on the position mode settings.

- **Position Mode 0: Manual 3-D Mode**

  Sets the receiver for 3-D position computation. The receiver must be tracking a minimum of four satellites in order to compute a position.

- **Position Mode 1: Automatic 3-D Mode**

  The receiver must track a minimum of three satellites to compute a position. With three satellites, latitude and longitude are computed and altitude is held to a fixed value (2-D positioning). With four satellites or more, altitude is computed (3-D positioning).

- **Position Mode 2: Manual 2-D Mode**

  The receiver must track a minimum of three satellites to compute a position. This mode locks the receiver to 2-D positioning, meaning latitude and longitude are computed and altitude is always held fixed regardless of the number of satellites tracked.

- **Position Mode 3: Automatic 3-D Mode**

  The receiver must track a minimum of three satellites to compute a position. With 3 satellites, longitude and latitude are computed and altitude is held fixed (2-D positioning). With 4 satellites, altitude is computed (3-D positioning) unless the calculated HDOP value is greater than HDOP mask setting.

Example: Select position mode 3, automatic 3-D:

$PASHS,PMD,3

DEFAULT
PMD—0

POP: Rate of Position Fix

$PASHS,POP,d

This command sets the rate of position and attitude fix, where d is the rate per Table 5.7.

Table 5.7. $PASHS,POP Parameters

Parameter	Description	Range
d	Rate of position and attitude fixing	2, 5 Default = 5

Example: Set rate to 2:

$PASHS,POP,2

DEFAULT
5

POS: Position Mode

$PASHS,POS,d

Sets mode for position computation, where d is the mode, as defined in Table 5.8.

NOTE: This POS command is the same as the PMD command. The settings can be verified by issuing the $PASHQ,PAR command and looking at the PMD field.

Table 5.8. 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.

Example: Set mode to 3D:

$PASHS,POS,3721.0725,N,12156.1078,W,-1.39

DEFAULT
0

POS: Antenna Position

$PASHS,POS,d1f1,c1,d2f2,c2,f3

This command sets the antenna position. The structure is $PASHS,POS,d1f1,c1,d2f2,c2,f3<CR><LF> where the position parameters are as defined in Table 5.9. Use the $PASHQ,RTC command to verify entered parameters.

Table 5.9. POS Command Structure

Parameter	Description	Range
d1	Degree part of latitude	0 - 90 degrees
f1	Minute part of latitude	59.9999
c1	Direction of latitude	S or N
d2	Degree part of longitude	0 - 180 degrees
f2	Minute part of longitude	59.9999
c2	Direction of longitude	E or W
f3	Altitude in meters	-999.99 to +99999.99

Example:

$PASHR,POS,0,12,221206.60,3721.08743,N,12156.12723,W,-00004.84,SC01,000.00,000.01,-000.00,01.4,00.7,01.2,00.6,AG00*31

PRT: Query Port

$PASHQ,PRT

Queries the active port and the baud rate.

Example response:

$PASHR,PRT,A,5*56

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 5.10 on page 65 for baud rate codes.

RID: Query Receiver ID

$PASHQ,RID

Queries the receiver version ID.

Example:

$PASHR,RID,38,00,AG00,_____*0C

This response indicates that the receiver type is 38 for ADU, and the firmware version is AG00.

RIO: Query Receiver Configuration

$PASHQ,RIO

Queries the receiver type, receiver version, sensor version, any options included, and receiver serial number.

Example:

$PASHR,RIO,ADU5-0,____,AG00,D-P12-X--L-,800952(2)AD520023904*3A

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.

Example: Set site name to SC01:

$PASHS,SIT,SC01

SPD: Port Speed (Baud Rate)

$PASHS,SPD,x,d

Sets baud rate of specified port (x) to value (d) per Table 5.10.

Table 5.10. 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)

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 banks have similar SNRs for common satellites. Any antenna band that has consistently lower SNRs will cause problems.

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).

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 Magellan representative for repair.

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).
Example: Disable satellite 8:

$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

Beacon Commands

The ADU5 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 ADU5 recalls the last beacon stations used, and begins searching using those frequencies.

Table 5.11 summarizes the beacon commands.

Table 5.11. Summary of Beacon Commands

Command	Description	Page
$PASHS,BCN,MOD,AUT,SNG	Set single automatic mode	68
$PASHS,BCN,MOD,MAN	Set beacon mode to manual	68
$PASHS,BCN,CHN	Specify stations to track in manual mode	69

MOD,AUT,SNG: Set Single Automatic Mode

$PASHS,BCN,MOD,AUT,SNG

This command sets the beacon receiver to single automatic mode.

MOD,MAN: Set Mode to Manual

$PASHS,BCN,MOD,MAN

This command sets the ADU5 beacon receiver to manual mode. After manual mode is set, both beacon channels stop operating until the channels are assigned specific stations/frequencies with the **$PASHS,BCN,CHN** command.

BCN,CHN: Assign Beacon Station Channel

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

This command assigns the specified beacon station frequency to the ADU5 channel. You can only use this command when the receiver is in manual mode. Table 5.12 defines the parameters.

Table 5.12. $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

SBAS Commands

The ADU5 incorporates two commands that permit it to use SBAS (Satellite-Based Augmentation System). Table 5.13 summarizes the SBAS commands.

Table 5.13. SBAS Commands

Command	Description	Page
$PASHS,SBA,OFF	Turns WAAS processing off and sets receiver to GPS-only mode	70
$PASHS,SBA,SAM	Sets single automatic mode	70

OFF: SBA Off

$PASHS,SBA,OFF

This command turns SBAS processing off and sets the receiver to operate in GPS-only mode.

SAM: SBA Single Automatic Mode

$PASHS,SBA,SAM

This command sets the ADU5 to operate in the single automatic SBAS mode. Use this command to turn SBAS on.

Attitude Setup and Control Commands

Table 5.14. Attitude Setup and Control Commands

Command	Description	Page
$PASHS,3DF,OFS	Sets offset angles in degrees	72
$PASHS,3DF,V12	Relative position vector from antenna 1 to antenna 2	72
$PASHS,3DF,V13	Relative position vector from antenna 1 to antenna 3	72
$PASHS,3DF,V14	Relative position vector from antenna 1 to antenna 4	73
$PASHQ,3DF	Queries for the configuration of the attitude parameters	73
$PASHS,3DF,ANG	Maximum angle above horizon that vehicle (or platform) is expected to tilt (pitch or roll) (degrees).	73
$PASHS,3DF,CYC	Phase error in cycles.	74
$PASHS,3DF,FLT	Smoothing filter for attitude solution	74
$PASHS,3DF,HKF	Identifies the heading Kalman filter parameters	75
$PASHS,3DF,MXB	Maximum baseline rms error (BRMS) in meters	76
$PASHS,3DF,MXM	Sets maximum phase measurement rms error (MRMS) in meters	77
$PASHS,3DF,PKF	Identifies the pitch Kalman filter parameters	77
$PASHS,3DF,RAT	Sets the ambiguity search ratio	78
$PASHS,3DF,RKF	Sets the roll Kalman filter parameters	79
$PASHS,3DF,RST	Restarts Kalman filters for attitude solution	79

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 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 axes of rotation (heading, pitch, roll). In this situation, some other accurate measurement method is required to measure the offset angles.

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. See Appendix B, Attitude Offset Angles, page 168, for more information.

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.

3DF: Query Attitude

$PASHQ,3DF

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

V12: +000.000 +000.903 +000.003
V13: -000.456 +000.450 +000.000
V14: +000.454 +000.459 -000.020
OFFSET ANG: +000.000 +000.000 +000.000
MAX CYCL: 0.200 SMOOTHING: N
MAX BRMS: 0.035 MAX ANGLE: 15
MAX MRMS: 0.005 SRCH RAT: 0.5
HKF: 999 000 1.0E-2 1.0E0
PKF: 020 000 4.0E-2 1.0E0
RKF: 020 000 4.0E-2 1.0E0
STATIC: Y

ANG: Set Maximum Angle Threshold for Attitude Solution

$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 ADU5 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

CYC: Set Phase Error Threshold for Attitude Solution

$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

FLT: Set Smoothing Filter for Attitude Solution

$PASHS,3DF,FLT,x

Sets the first order low-pass smoothing filter that provides acceptable results for stationary installations, or for vehicles experiencing very low dynamics, where x is Y for ON, N for OFF. Medium to high dynamics, such as those experienced by aircraft, may introduce too much lag in the output attitude for this filter.

Example: Set filter ON:

$PASHS,3DF,FLT,Y

DEFAULT
N = OFF

HKF: Heading Kalman Filter Parameters for Attitude Solution

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

Sets the heading Kalman filter parameters (HKF) (Table 5.15). It is not advisable to alter these parameters without thorough knowledge of Kalman filter theory and consultation with Magellan technical support.

Table 5.15. Kalman Filter Parameters

Field	Description
uuu	Value of tau (default is 020)
vvv	Value of To (default is 000)
w.w	Root decimal value for Q (default is 1.0)
sx	Signed exponential value for Q (default is -1)
y.y	Root decimal value for R (default is 1.0)
sz	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 ADU5. 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 Threshold for Attitude Solution

$PASHS,3DF,MXB,d.ddd

Sets the maximum baseline rms error (BRMS), where d.ddd is the error in meters. 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 ATT and AT2 output messages in order to determine whether or not to increase the BRMS threshold.

Example: Set maximum baseline rms error to 0.045 m:

$PASHS,3DF,MXB,0.045

DEFAULT
0.035

MXM: Set Maximum Phase Error for Attitude Soltuion

$PASHS,3DF,MXM,d.ddd

Sets the maximum phase measurement rms error (MRMS), where d.ddd is the rms error 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.

Example: Set maximum phase measurement error to 0.006 m:

$PASHS,3DF,MXM,0.006

DEFAULT
0.005

PKF: Set Pitch Kalman Filter Parameters for Attitude Solution

$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 Magellan technical support.

DEFAULTS
1,1,1

RAT: Set Ambiguity Ratio for Attitude Solution

$PASHS,3DF,RAT,d.d

Sets the ambiguity search ratio, where d.d is the ratio. Minimum is 0.1, 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.

Example: Set abmiguity ratio to 1:

$PASHS,3DF,RAT,1

DEFAULT
0.5

RKF: Set Roll Kalman Filter Parameters for Attitude Solution

$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 Magellan technical support.

Table 5.16. Kalman Filter Parameters

Field	Description
uuu	Value of tau (default is 020)
vvv	Value of To (default is 000)
w.w	Root decimal value for Q (default is 1.0)
sx	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 for Attitude Solution

$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.

NMEA and Proprietary Outputs

Table 5.17 summarizes the NMEA and proprietary outputs. The pages following Table 5.17 describe each output in detail.

Table 5.17. Summary of NMEA Commands

Command	Description	Page
$PASHS,NME,ALL,OFF	Disable all NMEA outputs	81
$PASHS,NME,ALM	Enable/disable NMEA NMEA almanac message	81
$PASHS,NME,DAL	Enable/disable NMEA decimal almanac message	84
$PASHS,NME,GGA	Enable/disable NMEA GPS position response message	86
$PASHS,NME,GLL	Enable/disable NMEA latitude/longitude message	88
$PASHS,NME,GRS	Enable/disable NMEA GRS (SV range residual) message	89
$PASHS,NME,GSA	Enable/disable NMEA DOP and active SV message	89
$PASHS,NME,GSN	Enable/disable NMEA GSN signal strength/satellite number	90
$PASHS,NME,GSS	Enable/disable NMEA GSS (SV tracked & DOP messages)	91
$PASHS,NME,GSV	Enable/disable NMEA GSV (SV in view) message	92
$PASHS,NME,GXP	Enable/disable NMEA GXP (horizontal position) message	94
$PASHS,NME,HDT	Enable/disable NMEA true heading message	95
$PASHS,NME,LTN	Enable/disable latency of serial data output	96
$PASHS,NME,MSG	Enable/disable NMEA MSG (RTCM) message	96
$PASHS,NME,PAT	Enable/disable Magellan proprietary position/attitude message	99
$PASHS,NME,PER	Set NMEA send interval	100
$PASHS,NME,POS	Enable/disable position message	101
$PASHS,NME,ROP	Enable/disable Rate Of Pitch (ROP) message	103
$PASHS,NME,ROR	Enable/disable Rate Of Roll (ROR) message	103
$PASHS,NME,ROT	Enable/disable Rate Of Turn (ROT) message	103
$PASHS,NME,RRE	Enable/disable NMEA satellite residual & position error message	105

Table 5.17. Summary of NMEA Commands (continued)

Command	Description	Page
$PASHS,NME,SA4	Enable/disable satellite status message	107
$PASHS,NME,SAT	Enable/disable SAT information message	108
$PASHS,NME,TTT	Enable/disable output of time trigger message	110
$PASHS,NME,VTG	Enable/disable NMEA VTG (velocity/course) message	111
$PASHS,NME,ZDA	Time-date message	112

ALL: Disable All NMEA

$PASHS,NME,ALL,x,OFF

Turns off all NMEA output messages.

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.

ALM: Almanac Message

$PASHS,NME,ALM,x,y

Turns almanac output message on or off, where x is port A or B and y is ON or OFF.

$PASHQ,ALM,[c1]

This command queries the almanac message, 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.

$GPALM

There is one response message for each satellite in the GPS constellation. The length of the message is calculated by the characters, in halves of bytes, not full bytes. The response to the set or query command is in the form shown below and defined in Table 5.18.

$GPALM,d1,d2,d3,d4,h5,h6,h7,h8,h9,h10,h11,h12,h13,h14, h15*cc <Enter>

Table 5.18. ALM Response Message

Parameter	Description	Range
d1	Total number of messages	01 -32
d2	Number of this message	01 -32
d3	Satellite PRN number	01 - 32
d4	GPS week	4 digits
h5	SV health (In ASCII hex)	2 bytes
h6	e. Eccentricity (In ASCII hex)	4 bytes
h7	toe. Almanac reference time (seconds. In ASCII hex)	2 bytes
h8	Io. Inclination angle (semicircles. In ASCII hex)	4 bytes
h9	OMEGADOT. Rate of ascension (semicircles/sec. In ASCII hex)	4 bytes
h10	$A^{1/2}$. Square Root of semi-major axis (Meters & ½ In ASCII hex)	6 bytes
h11	ω. Argument of perigee (semicircle. In ASCII hex)	6 bytes
h12	OMEGA0. Longitude of ascension mode (semicircle. In ASCII hex)	6 bytes
h13	Mo. Mean anomaly (semicircle. In ASCII hex)	6 bytes
h14	afo. Clock parameter (seconds. In ASCII hex)	3 bytes
h15	af1. Clock parameter (sec/sec. In ASCII hex)	3 bytes
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.	0 - 9 and A - F

Typical ALM response message:

```
$GPALM,32,11,11,1290,00,1B13,7B,E765,FD04,A10CE9,02C29B,
C412D5,D14F7F,0A1,001*76
```

Table 5.19. Typical ALM Response Message

Item	Significance
$GPALM	Header
32	Total number of messages
11	Number of this message
11	Satellite PRN Number
1290	GPS week number
00	Satellite health
1B13	Eccentricity
7B	Almanac reference time
E765	Inclination angle
FD04	Rate of ascension
A10CE9	Root of semi-major axis
02C29B	Argument of perigree
C412D5	Longitude of ascension mode
D14F7F	Mean anomaly
0A1	Clock parameter
001	Clock parameter
*76	checksum

DAL: Almanac Message in Decimal Format

$PASHS,NME,DAL,x,y

This message displays the NMEA almanac message in decimal almanac format, where x is port A or B and y is ON or OFF.

$PASHQ,DAL,[c1]

This command queries the almanac message in decimal format, 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.

$GPDAL,NME,DAL,ss,hhh,e.eeeeeeeE±99,ttttttt,i.iiiiiiiE±99,±a.aaaaaaaE±99,±m.mmmmmmmE±99,±l.lllllllE±99,±a.aaaaaaaE±99,±m.mmmmmmmE±99,±c.cccccccE±99,c.cccccccE±99,www

Table 5.20. NME,DAL Response Message 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 9 999 999 seconds
i.iiiiiiiE±99	Inclination angle, 0 through 9.9999999E±99 semi-circles
±a.aaaaaaaE±99	Omegadot, rate of right ascension 9.9999999E±99 semi-circles/second
±m.mmmmmmmE±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 ±9.9999999E±99
±a.aaaaaaaE±99	Omega, argument of perigee, ±9.9999999E±99 semi-circles
±m.mmmmmmmE±99	Mo mean anomaly at reference time, ±9.9999999E±99
±c.cccccccE±99	af0 clock parameter, ±9.9999999E±99 seconds
c.cccccccE±99	af1 clock parameter, 0 through 9.9999999E±99 seconds/second
www	GPS week number, 3 digits

$GPDAL

NMEA response almanac message in decimal almanac format.

Example:

```
$GPDAL,31,000,1.2133121E-02,0503808,2.9814032E-01,
-2.5283953E-09,5.1536719E+03,
-7.8296340E-01,3.2100046E-01,-7.3369241E-01,
1.0490417E-05,7.2759576E-012,1290*2E
```

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, y

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

$PASHQ,GGA,[c1]

This command queries the GGA position message, 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.

$GPGGA

The NMEA response message for GGA (GPS position) is in the format shown below and defined in Table 5.21.

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

Table 5.21. $GPGGA Response Message Structure

Field	Description
hhmmss.ss	Current UTC time, hhmmss, of position fix in hours, minutes and seconds.
ddmm.mmmmm	Latitude component of position, ddmm.mmmmm, in degrees, minutes and fraction of minutes.
s	Latitude sector, s = N - North, s = S - South.
dddmm.mmmmm	Longitude component of position, dddmm.mmmmm, in degrees, minutes and fraction of minutes.
s	Longitude sector, E - East, W - West.
n	Raw/differential position, n n = 1 - Raw; position is not differential corrected n = 2 - position is deferentially corrected. n = 9 - position computed using almanac information
qq	qq = number of SVs used in position computation.
pp.p	HDOP - horizontal dilution of precision, pp.p = 00.0 to 99.9.

Table 5.21. $GPGGA Response Message Structure (continued)

Field	Description
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 position
M	Altitude units, M = meters.
±xxxx.xx	Geoidal separation (value output only if geoidal height option (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.
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.

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,222411.00,3721.08623,N,12156.12739,W,2,09,0.9,29.09,M,-31.33,M,7,0267*55

GLL: Present Latitude and Longitude

$PASHS,NME,GLL,x, y

Enable/disable the GLL message for latitude and longitude of present vessel position, where x is port A or B and y is ON or OFF.

$PASHQ,GLL,[c1]

This command queries the GLL position message, 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.

$GPGLL

The NMEA response message for latitude and longitude is in the format shown below and defined in Table 5.22.

$GPGLL,xxxx.xxxxx,N,xxxxx.xxxxx,W,hhmmss.ss,A,A*cc

Table 5.22. Latitude/Longitude for Position

Fields	Description
ddmm.mmmmm	Latitude of the position fix, in degrees, minutes (0° to 90°)
N/S	N = north, S = south
dddmm.mmmmm	Longitude of the position fix, in degrees, minutes (0° to 180°)
E/W	W = west, E = east
hhmmss.ss	UTC of the position fix (hours, minutes, seconds, hundredths of seconds) (000000.00 to 235959.90)
A	Status of the position fix (always A): A = valid V = invalid
A	Positioning system mode indicator: A: Autonomous mode D: Differential mode E: Estimated (Dead-Reckoning) mode M: Manual input mode S: Simulator mode N: Data not valid
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.

Example:

$GPGLL,3721.08750,N,12156.12662,W,220850.20,A,A*79

GRS: Satellite Range Residual

$PASHS,NME,GRS,x, y

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

Example: Enable GRS message on port A

$PASHS,NME,GRS,A,ON

$PASHQ,GRS,[c1]

This command queries the GRS message, 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.

$GPGRS

The NMEA response message for GRS (satellite range residual) is in the format shown below.

$GPGRS,hhmmss.ss,a,sxx.x,syy.y......*cc

Example:

$GPGRS,220857.80,1,-000.9,001.1,-001.8,002.5,000.9,001.0,-000.3,-000.4,001.6,-000.7,-076.7*40

GSA: Active Satellite

$PASHS,NME,GSA,x, y

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

$PASHQ,GSA,[c1]

This command queries the GSA message, 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.

$GPGSA

The NMEA response message for DOP and active satellite is in the format shown below and defined in Table 5.23.

$GPGSA,a,b,cc,dd,ee,ff,gg,hh,... ,i.i,j.j,k.k*cc

Table 5.23. 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,hh,...	Satellites used in solution (null for unused fields)
i.i	PDOP
j.j	HDOP
k.k	VDOP
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.

Example:

$GPGSA,M,3,27,28,13,19,31,10,29,08,07,26,,,47,,01.6,00.8,01.4*01

GSN: Satellite Number

$PASHS,NME,GSN,x,y

Enable/disable the signal strength/satellite number response message on port x, 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 GSN message on port B:

$PASHS,NME,GSN,B,ON

$PASHQ,GSN,[c1]

This command queries the GSN message, where c1 is the optional port for the output of the response. If a port is not specified, the receiver sends the response to the current port.

$GPGSN

The NMEA response message for GSN signal strength/satellite number is in the format shown below and defined in Table 5.24.

$GPGSN,aa,ss,rr,ss,rr,ss,rr..., bbbb*cc

Table 5.24. 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).
ss	Satellite number
rr	Signal-to-noise ratio for satellite
ss,rr...	Next satellite number and signal-to-noise ratio.
bbbb	RTCM age
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.

Example:

$GPGSN,11,27,49,28,52,13,45,19,47,31,48,10,42,29,49,08,51,07,37,26,44,47,41,9999*42

GSS: Satellite Tracked

$PASHS,NME,GSS,x, y

Enable/disable NMEA satellite tracked and DOP messages, where x is port A or B, and y is ON or OFF.

$PASHQ,GSS,[c1]

This command queries the GSS satellite tracked message, 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.

$GPGSS

NMEA response message for satellite used. The format is shown below and defined in Table 5.25.

$GPGSS,00,aa,bb,cc,cc,... d.dd*cc

Table 5.25. Satellites Tracked and PDOP Message

Field	Description
00	Always “00”
aa	Flag to indicate whether an altitude-fixed (02) or 3-dimensional (03) position was computed
bb	Number of satellites used in position computation
cc,cc,cc...	Satellite PRN number
d,dd	PDOP
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.

Example:

$GPGSS,00,03,11,27,28,13,19,31,10,29,08,07,26,47,1.59*69

GSV: Satellites in View

$PASHS,NME,GSV,x, y

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.

$PASHQ,GSV,[c1]

This command queries the GSV message, where c1 is the optional port for output of the response. If a port is not specified, the receiver sends the response to the current port.

$GPGSV

The NMEA response message for GSV (satellites in view) is in the format shown below and defined in Table 5.26.

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

Table 5.26. Satellites Tracked

Field	Description
a	Total number of messages (1 to 3)
b	Message number (1 to 3)
cc	Total number of satellites in view
dd	Satellite PRN number
ee	Elevation (degrees)
fff	Azimuth (degrees)
gg	SNR (0 to 99 dB), null when not tracking
hh	Same as 4,5,6,7 but for second satellite
ii	Same as 4,5,6,7 but for third satellite
jjj	Same as 4,5,6,7 but for fourth satellite
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.

Example:

$GPGSV,4,1,13,27,61,076,50,28,61,262,52,13,23,158,45,19,26,049,47*78

$GPGSV,4,2,13,31,30,183,48,10,18,270,42,29,24,317,49,08,70,014,50*7B

$GPGSV,4,3,13,07,19,191,37,26,14,320,44,11,09,107,00,47,15,250,41*74

$GPGSV,4,4,13,35,09,104,00*41

GXP: Horizontal Position

$PASHS,NME,GXP,x, y

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

$PASHQ,GXP,[c1]

This command queries horizontal position, where c1 is the optional output serial port for the output of the response. If a port is not specified, the receiver sends the response to the current port.

$GPGXP

The NMEA response message for GXP (position horizontal) is in the format shown below and defined in Table 5.27.

$GPGXP,hhmmss.ss,aaaa.aaaaa,N/S,bbbbb.bbbbb,E/W*cc

Table 5.27. Present Position Fix with Time of Fix

Field	Description
hhmmss.ss	UTC of position (hours, minutes, seconds, hundredths of second)
aaaa.aaaaa	Latitude (in degrees, with decimal minutes) - ddmm.mmmmm
N/S	North or south of fix
bbbbb.bbbbb	Longitude (in degrees, decimal minutes) - dddmm.mmmmm
E/W	East or West of fix
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.

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

Example:

$GPGXP,220946.80,3721.08743,N,12156.12665,W*78

HDT: Heading True

$PASHS,NME,HDT,x, y

Enable/disable true vessel heading in degrees true produced by any device or system producing true heading, where x is port A or B and y is ON or OFF.

$PASHQ,HDT,[c1]

This command queries the HDT heading true message, where c1 is the optional port for the output of the response. If a port is not specified, the receiver sends the response to the current port.

$GPHDT

The NMEA response message for HDT true heading is in the format shown below and defined in Table 5.28.

$GPHDT,xxx.xxx,T*cc

Table 5.28. HDT: Heading Structure

Field	Description
xxx.xxx	Vehicle heading in degrees
T	“T” for true north reference
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.

Example:

$GPHDT,251.262,T*35

LTN: Latency, Reference Mark to Data Availability

$PASHS,NME,LTN,x,y

This command enables or disables the latency value message, where x is port A or B and y is ON or OFF. The LTN message response displays the latency in milliseconds from a reference time mark (1PPS) until the time data becomes available.

$PASHQ,LTN,[c1]

This command queries the LTN message, 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.

$PASHR,LTN

The response is in the form $PASHR,LTN,dd*hh<CR><LF>

where dd is the latency in integer number of milliseconds.

The number d represents the number of milliseconds it takes the receiver to compute a position (from the measurement tag time) and prepare data to be transmitted through the serial port. This number is dependent upon the number of locked satellites.

Example: latency= 91 ms:

"$PASHR,LTN,91*06

MSG: Reference Station Messages

$PASHS,NME,MSG,x,y

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 ADU5 is sending or receiving differential corrections, this command is ignored.

Example: Enable MSG on port A:

$PASHS,NME,MSG,A,ON

$PASHQ,MSG,[c1]

This command queries the MSG message, 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. This command is ignored if the ADU5 is not sending or receiving differential corrections.

$GPMSG

NMEA response message for MSG (RTCM) message. Format may be 1, 3, or 16, as shown below and defined in Table 5.29.

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....

Table 5.29. 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

Table 5.29. RTCM Message Structure (continued)

Field	Description
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,y

Enable/disable Magellan proprietary position and altitude message, where x is port A or B and y is ON or OFF.

$PASHQ,PAT,[c1]

This command queries the Magellan proprietary position and altitude message, where c1 is the optional port for the output of the response. If a port is not specified, the receiver sends the response to the current port.

$GPPAT

The NMEA response message for the Magellan proprietary position and altitude message is in the format shown below and defined in Table 5.30.

$GPPAT,hhmmss.ss,ddmm.mmmmm,N,dddmm.mmmmm,W,
±aaaaa.aa,bbb.bbbb,±eee.ee,±fff.ff,g.gggg,h.hhhh,b.bbbb,a*cc

Table 5.30. Position and Attitude Message Structure

Field	Description
hhmmss.ss	UTC of position (hours, minutes, seconds, tenths of second)
ddmm.mmmmm	GPS latitude in degrees (d) and minutes (m): ddmm.mmmm
N	Latitude north (N) or south (S)
dddmm.mmmmm	GPS longitude in degrees (d) and minutes (m) dddmm.mmmm
W	Longitude east (E) or west (W)
±aaaaa.aa	Altitude in meters
bbb.bbbb	Heading in degrees
eee.ee	Pitch in degrees
± fff.ff	Roll in degrees
h.hhhh	Attitude phase measurement rms error, MRMS (meters)
b.bbbb	Attitude baseline length rms error, BRMS (meters)
a	Attitude reset flag (0:good attitude, 1:rough estimate or bad attitude)
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.

Example:

$GPPAT,221018.40,3721.08743,N,12156.12672,W,-00005.75, 251.3329,000.03,000.11,0.0009,0.0105,0*4E

PER: Set Period

$PASHS,NME,PER,ddd

Sets the send interval time in NMEA messages, where ddd is the period in seconds. The send interval for NMEA messages is unaffected by the RCI or ONE settings.

To verify PER setting, use the parameter query command $PASHQ,PAR described on page 58.

Example: Set period to 0.2 seconds:

$PASHS,NME,PER,0.2

DEFAULT
1

When set to 0, the periodicity is tied to <$PASHS,POP,…> setting (page 61).

POP = 5 (default): When PER is set to 0 or 0.2, then periodicity will be 5 Hz (2 Hz not available)

POP = 2: When PER is set to 0 or 0.5, then periodicity will be set to 2 Hz (5 Hz not available).

NMEA messages can also be set to periodicity not tied to PER command by adding the time at the end of the activation string. Example: SET GGA to be output every 5 seconds on port A: $PASHS,NME,GGA,A,ON,5

POS: Position, Time, Speed, DOP

$PASHS,NME,POS,x,y

Enable/disable position message, where x is port A or B and y is ON or OFF..

$PASHQ,POS,[c1]

Query position message for one epoch, where c1 is the optional output port.

$PASHR,POS

The NMEA response message indicating the time, position, speed, and DOP values, is in the format shown below and defined in Table 5.31.

$PASHR,POS,a,bb,hhmmss.ss,cccc.ccccc,N,ddddd.ddddd,W,
±fffff.ff,g,iii.ii,jjj.jj,±kkk.kk,ll.l,mm.m,oo.o,pp.p,qqqq*cc

Table 5.31. 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.ccccc	GPS latitude
N	Latitude north (N) or south (S)
ddddd.ddddd	GPS longitude
W	Longitude east (E) or west (W)
±fffff.ff	Altitude in meters
gggg	Unit ID set with command <$PASHS,SIT,xxxx>
iii.ii	Course over ground (COG) in degrees
jjj.jj	Speed over ground (SOG) in knots
±kkk.kk	Vertical velocity in meters/sec
ll.l	PDOP
mm.m	HDOP
oo.o	VDOP
pp.p	TDOP

Table 5.31. Position Message Structure (continued)

Field	Description
qqqq	Receiver firmware version
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.

Example:

$PASHR,POS,0,12,221206.60,3721.08743,N,12156.12723,W,
-00004.84,SC01,000.00,000.01,-000.00,01.4,00.7,01.2,00.6,AG00*31

ROP: Rate of Pitch

$PASHS,NME,ROP,x,y

Enables/disables the rate of pitch message to port x, where x is A or B and y is ON or OFF.

$PASHQ,ROP,[C1]

This command queries the rate of pitch message, where c1 is the optional port for the output of the response. If a port is not specified, the receiver sends the response to the current port.

$PASHR,ROP

The response message is in the format $PASHR,ROP,x.xxxx,A*cc, where the parameters are as defined in Table 5.32.

Table 5.32. ROP Response Message Structure

Parameter	Description	Range
x,xxxx	Rate of pitch, degrees/second Minus sign "-" indicates pitch downwards, "+" indicates pitch upwards. "No sign" means "+".	- or +
A	Data validity	A = valid V = invalid
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.	0 - 9 and A - F

Example:

$PASHR,ROP,0.2690,A*6B

ROR: Rate of Roll

$PASHS,NME,ROR,x,y

Enables/disables the rate of roll message to port x, where x is A or B and y is ON or OFF.

$PASHQ,ROR,[C1]

This command queries the rate of roll message, where c1 is the optional port for the output of the response. If a port is not specified, the receiver sends the response to the current port.

$PASHR,ROR

The response message is in the format $PASHR,ROR,x.xxxx,A*cc, where the parameters are as defined in Table 5.33.

Table 5.33. ROR Response Message Structure

Parameter	Description	Range
x,xxxx	Rate of roll, degrees/second Minus sign "-" indicates roll to port/left, "+" indicates roll to starboard/right. "No sign" means "+".	- or +
A	Data validity	A = valid V = invalid
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.	0 - 9 and A - F

Example:

$PASHR,ROR,-0.1053,A*4E

ROT: Rate of Turn

$PASHS,NME,ROT,x,y

Enables/disables the rate of turn message to port x, where x is A or B and y is ON or OFF.

$PASHQ,ROT,[C1]

This command queries the rate of turn message, where c1 is the optional port for the output of the response. If a port is not specified, the receiver sends the response to the current port.

$GPROT

The response message is in the format $GPROT,x.xxxx,A*cc, where the parameters are as defined in Table 5.34.

Table 5.34. ROT Response Message Structure

Parameter	Description	Range
x,xxxx	Rate of turn, degrees/minute Minus sign “-” turns bow left, “+” turns bow right. “No sign” means “+”.	- or +
A	Data validity	A = valid V = invalid
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.	0 - 9 and A - F

Example:

$GPROT,2.6610,A*02

RRE: Range Residual Error

$PASHS,NME,RRE,x,y

Enables/disables the satellite residual and position error message to port x, where x is port A,or B 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

$PASHQ,RRE,[c1]

This command queries the range residual message, 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.

$GPRRE

NMEA response message for RRE (satellite residual and position error). The format is shown below and defined in Table 5.35

$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.

Table 5.35. 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.hvvvv.v	Last 2 fields: hhhh.h = horizontal RMS position error in meters vvvv.v = vertical RMS position error in meters
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.

Example:

$GPRRE,12,27,-001.1,28,+001.7,13,-001.8,19,+001.8,
31,+001.3,10,+001.6,29,-000.1,08,-000.9,07,-000.4,26,-001.6,
11,+002.3,47,-074.1,0003.8,0005.3*78

where the structure is as defined in Table 5.36.

Table 5.36. Typical RRE Response Structure

Item	Description
$GPRRE	Header
12	Number of SVs used to compute position
27	PRN of first SV
-001.1	Range residual for first SV in meters
28	PRN of second SV
+001.7	Range residual for second SV in meters
13	PRN of third SV
-001.8	Range residual for third SV in meters
19	PRN of fourth SV
+001.8	Range residual for fourth SV in meters
31	PRN of fifth SV
+001.3	Range residual for fifth SV in meters
...	...
0003.8	Horizontal position error in meters
0005.3	Vertical position error in meters
78	Message checksum in hexadecimal

SA4: Satellite Status

$PASHS,NME,SA4,x, y

Enables/disables the SA4 (satellite status message). The structure is

$PASHS,NME,SA4,x,y

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

Example: Enable SA4 message on port A:

$PASHS,NME,SA4,A,ON

$PASHQ,SA4,[c1]

This command queries the satellite status message, where c1 is the optional port for the output of the response. If a port is not specified, the receiver sends the response to the current port.

$PASHR,SA4

The satellite status response message is in the format shown below and defined in Table 5.37.

$PASHR,SA4,a,bb,cc,dd,...... *cc

Table 5.37. Satellite Information Messages Structure

Field no.	Field	Description
1	a	Antenna number
2	bb	Total number of satellites in the message
3	cc	Satellite PRN number
4	dd	Signal-to-noise ratio (SNR) (0 to 99)
	...	Same as 3, 4 but for second satellite
	...	Same as 3, 4 but for third satellite
	*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.

Examples:

$PASHR,SA4,1,12,27,51,28,52,13,44,19,47,31,48,10,43,29,49,08,51,07,41,26,47,11,39,47,39*61
$PASHR,SA4,2,11,27,51,28,50,13,42,19,45,31,49,10,42,08,51,29,48,07,38,26,42,11,38*65
$PASHR,SA4,3,11,27,49,28,49,13,41,19,46,31,48,10,41,29,43,08,49,07,41,26,39,11,38*67
$PASHR,SA4,4,11,27,49,28,52,13,43,19,47,31,49,08,51,10,42,29,47,07,40,26,45,11,38*6C

SAT: Satellite Status

$PASHS,NME,SAT,x,y

Enables/disables the SAT (satellite status message), where x is the output port A or B, and y is ON or OFF.

Example: Enable SAT message on port B:

$PASHS,NME,SAT,B,ON

$PASHQ,SAT,[c1]

This command queries the SAT message, 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.

$PASHR,SAT

The SAT response message structure is shown below and defined in Table 5.38.

$PASHR,SAT,a,bb,cc,ddd,ee,ff,U,...... *cc

Table 5.38. Satellite Information Message Structure

Field No.	Field	Description
1	a	Antenna number
2	bb	Total number of satellites in the message
3	cc	Satellite PRN number (1 to 32 for GPS, 33 to 64 for SBAS)
4	ddd	Satellite azimuth angle (0 to 359 degrees)
5	ee	Satellite elevation angle (0 to 90 degrees)
6	ff	Signal-to-noise ratio (SNR) (0 to 99 dBHz)

Table 5.38. Satellite Information Message Structure (continued)

Field No.	Field	Description
7	U	Indicates whether the locked satellite is used in position computations: • U—Used • A dash (-) indicates that the satellite is not being used in position computations • M—Satellite NOT used because of low elevation • S—Satellite NOT used because the pseudo-range is not settled (transient is not over) • H—Satellite NOT used because marked 'unhealthy' in ephemeris • B—Satellite NOT used because of bad URA (or some accuracy problem indicated in navigational data) • Z—Satellite NOT used because marked 'unhealthy' in almanac • D—Satellite NOT used because differential corrections are old or invalid • J—Satellite NOT used because big code outlier was detected • R—Satellite NOT used because RAIM or some other algorithm detected a pseudo-range bias. • I—Satellite NOT used because SV disabled by external command SVP,USP) • L—Satellite NOT used because Signal To Noise Ratio is less than Mask • G—Satellite NOT used because it's possibly a ghost satellite • V—Satellite NOT used because computed satellite coordinates are suspicious • N—Satellite NOT used because satellite true number unknown (for modes, where we need the true SV number • K—Satellite NOT used because it was disabled by RTK engine (N/A in DG16) • O—Satellite NOT used because of some other case • E—Satellite NOT used because no navigational data (ephemeris) is available • p—Satellite NOT used because no full range is available
	...	Same as field Nos 3, 4, 5, 6, 7 but for 2nd satellite
	...	Same as field Nos 3, 4, 5, 6, 7 but for 3rd satellite
	*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.

Example:

$PASHR,SAT,12,27,079,59,50,U,28,266,62,52,U,13,158,21,44,U,19,047,25,48,U,31,183,32,49,U,10,268,17,42,U,29,316,25,49,U,08,020,70,50,U,07,191,21,41,U,26,320,16,47,U,11,105,10,38,U,47,250,15,39,U*10

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.

$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 ADU5. 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.

The message format is shown below and defined in Table 5.39.

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

Table 5.39. 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,y

Enable/disable the actual track made good and speed relative to the ground message. X is the output port A or B, and y is ON or OFF.

$PASHQ,VTG,[c1]

This command queries the receiver for the VTG message, 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.

$GPVTG

NMEA response message for VTG (velocity/course). The format is shown below and defined in Table 5.40.

$GPVTG,ddd.dd,T,eee.ee,M,aaa.aa,N,bbb.bb,K,A*cc

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

Table 5.40. $GPVTG Structure

Field	Description
ddd.dd	Course over ground; referenced to true north
T	North reference indicator (always T; true north)
eee.ee	Course over the ground; referenced to magnetic north
M	North reference indicator (always M; magnetic north)
aaa.aa	Speed over ground (knots)
N	Speed unit of measure (always N; nautical miles per hour or knot)
bbb.bb	Speed over ground (kilometers per hour)
k	Speed unit of measure (always K; KPH)
A	Positioning system mode indicator • A—Autonomous mode • D—Differential mode • E—Estimated (dead reckoning) mode • M—Manual input mode • S—Simulator mode • N—Data not valid
*cc	Checksum (2 characters)

Example: **$GPVTG,000.00,T,344.94,M,000.02,N,000.03,K,A*2C**

ZDA: Time-Date Message

$PASHS,NME,ZDA,x,y

This command enables/disables the ZDA message, where x is port A or B and y is ON or OFF.

$PASHQ,ZDA,[c1]

This command queries the receiver for the ZDA message, 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.

$GPZDA

The response message is in the format shown below and defined in Table 5.41.

$GPZDA,f1,d1,d2,d3,d4,d5*cc

Table 5.41. ZDA Time-Date Response Message Structure

Parameter	Description	Range
f1	UTC in format hhmmss.ss	000000.00 - 235959.99..
d1	Day	01 - 31
d2	Month	01 - 12
d3	Year	0000 - 9999
d4	Local zone offset from UTC (hours) with sign + or -	-13 to +13
d5	Local zone offset from UTS (minutes) with same sign as d4	00 - 59
*cc	Hexadecimal checksum computed by exclusive ORing all bytes between, but not including, $ and *.	0 - 9 and A - F

Example:

$GPZDA,221554.00,29,09,2004,+00,00*4C

Raw Data Commands

Table 5.42 summarizes the raw data commands and responses. The pages following Table 5.42 describe the commands and responses in detail.

The $PASHS,OUT command can be used to turn on the specified raw data output type at a paticular interval set by RCI command. The command structure is $PASHS,OUT,str where str identifies the data; str can be: MBN, PBN, SNV,ATT, AT2, or BIN. For details, refer to the $PASHS,OUT discussion on page 128.

Table 5.42. Summary of Raw Data Commands

Command	Description	Page
$PASHQ,ATT	Attitude data	114
$PASHQ,AT2	Attitude, flags, PDOP data	114
$PASHQ,DSO	Attitude and position data	118
$PASHQ,MBN	Satellite measurement data	120
$PASHQ,MCA	Query raw measurement data (MCA)	125
$PASHS,OUT,x,	Turns on the specified raw data output type.	128
$PASHQ,PBN	Position, velocity, DOP data	130
$PASHQ,PSA	Position and attitude data	133
$PASHS,RCI	Set raw data output message rate	135
$PASHQ,SNV	Ephemeris data	135

AT2: Query AT2 Structure

$PASHQ,AT2[,c1]

Queries the AT2 structure, 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 structure can be ASCII or binary. Table 5.43 defines the ASCII AT2 structure.

Table 5.43. 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 ASCII response message is shown below and defined in Table 5.44.

```
$PASHR,AT2,343951.0000,251.0951,-0.5974,-
0.2901,0.0008,0.0054,0,00,0.777,2.2760*6B
```

Table 5.44. Typical AT2 Response Message - ASCII

Parameter	Description
$PASHR,AT2	Message header
343951.0000	GPS receive time, seconds
251.0951	Heading, degrees
-0.5974	Pitch, degrees
-0.2901	Roll, degrees
0.0008	Measurement rms error, meters
0.0054	Baseline rms error, meters
0	Attitude reset flag 0 = good 1 = no solution (invalid)
00	Last state, 00 = no search in progress >00 = search in progress
0.777	Double Difference V1, V2 and V3
2.2760	PDOP
*6B	Checksum

Table 5.45 defines the binary AT2 structure.

Table 5.45. 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

ATT: Query Attitude Structure

$PASHQ,ATT,[c1]

Queries the ATT structure, 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 structure of the attitude output can be ASCII or binary. An ASCII example is shown below and defined in Table 5.46.

$PASHR,ATT,339455.0000,251.2064,0.0789,-0.4657,0.0013,0.0146,0*38

Table 5.46. 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 5.47 defines the structure of the attitude output when it is transmitted in binary format.

Table 5.47. Attitude Data in Binary Format

Variable	Type (Bytes)	Description
$PASHR,ATT,	11	Header
Head	Double (8)	Heading in degrees
Pitch	Double (8)	Pitch in degrees
Roll	Double (8)	Roll in degrees
BRMS	Double (8)	BRMS in meters
MRMS	Double (8)	MRMS in meters
Tow	Long (4)	Seconds-of-Week in milliseconds

Table 5.47. Attitude Data in Binary Format (continued)

Variable	Type (Bytes)	Description
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	

DSO: Query DSO Structure

$PASHQ,DSO,[c1]

Queries the DSO structure, where c1 is the optional port for output of the response. If a port is not specified, the receiver sends the response to the current port. The structure can be ASCII or binary. Table 5.48 defines the ASCII DSO structure.

Table 5.48. 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,339468.8000,251.2219,0.3662,-0.2378,0.0114,0,37.3515,-121.9355,-5.0035*1E

where the string values are described in Table 5.49.

Table 5.49. Typical DSO Response Message Data String - ASCII

Item	Description
$PASHR,DSO	Message header
339468.8000	GPS receive time, seconds of week
251.2219	Heading, degrees
0.3662	Pitch, degrees
-0.2378	Roll, degrees

Table 5.49. Typical DSO Response Message Data String - ASCII (contin-

Item	Description
0.0114	Baseline error, meters
0	Altitude reset flag 0 = not reset 1 = reset
37.3515	Latitude, degrees; "-" means "South", no sign for "North"
-121.9355	Longitude, degrees "-" means "West", no sign for "East"
-5.0035	Altitude, meters
*1E	Checksum

Table 5.50 defines the binary DSO structure.

Table 5.50. 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
char spare	1	Spare byte not used
unsigned short checksum	2	
}	---	
Total bytes	64	

MBN: Query MBEN Structure

$PASHQ,MBN,[c1]

Queries the MBEN structure for all four antennas, in order: 1, 2, 3, 4. Structure can be ASCII or binary, 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. Table 5.51 defines the ASCII format. Table 5.52 defines the binary format.

Table 5.51. 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 ADU5 channel assignment (1 to 32)

Table 5.51. MBEN Data - ASCII (continued)

Variable	Description
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).
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.

Table 5.51. MBEN Data - ASCII (continued)

Variable	Description
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 5.52. 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 - 5 and 95 -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 5.52. 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 (Magellan Type 3 Data Structure)

$PASHQ,MCA,[c1]

This command queries raw satellite measurement data contained in the Magellan Type 3 data structure, where c1 is the optional port for the output response. If a port is not specified, the receiver sends the response to the current port.

$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,<Magellan type 3 data string + checksum>

Table 5.53 defines the data string format.

Table 5.53. $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 5.53. $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 5.53. $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		

Example:

PASHR,MCA,22780,33,11,11,104,12,2,24,5,41,0,443480.5603,0.0817,-19150316, 65,100*20

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.

OUT: Set Output

$PASHS,OUT,x

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

$PASHS,OUT,c1,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: Set both ATT and AT2:

$PASHS,OUT,B,ATT,ATT2

Example: Turn ATT on, and ATT off, AT2 on:

$PASHS,OUT,B,ATT

$PASHS,OUT,B,AT2

PBN: Query PBEN Data

$PASHQ,PBN ,[c1]

Queries the PBEN data for one epoch, where c1 is the optional port for the output of the response. If a port is not specified, the receiver sends the response to the current port. Structure can be ASCII or binary. Table 5.54 defines the ASCII PBEN format.

Table 5.54. 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,339502.0000,-2685240.9249,-4308075.7825,
3848468.4033,37:21.08739,-121:56.12717,-5.4840,
0.0027,0.0013,0.0030,12,SC01,1.37,0.71,1.16,0.65*3F**

Table 5.54 defines the binary PBEN format.

Table 5.55. 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
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	

PSA: Query PSAT

$PASHQ,PSA

Requests a PSAT structure. Table 5.56 defines the format for PSAT in ASCII; characters following “*” are checksum.

Table 5.56. 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,339672,-2685241.6867,-4308075.8896,3848468.2452,0.0003,-0.0068,0.0047,1.3650,12,1,,251.0227,0.4656,-0.6129,0,0*02

Table 5.57 defines the binary structure of the typical PSAT message.

Table 5.57. 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 in seconds. 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 sets the output interval to one second.

DEFAULT
0 (=0.5 second)

SNV: Query SNAV

$PASHQ,SNV,[c1]

Query SNAV ephemeris data response message, 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.

Example: Display SNV on port A

$PASHQ,SNV,A

The SNAV data (ephemeris data) is output only in binary. Its record definitions and the units for orbit data conform to the GPS-ICD-200 standard. Table 5.58 defines the structure.

Table 5.58. 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).

Table 5.58. SNAV Data Structure (continued)

Field	Type (Bytes)	Contents
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).
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	

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 5.59 summarizes the RTCM commands. The pages following Table 5.59 describe the commands in detail.

Table 5.59. Summary of RTCM Commands

Command	Description	Default	Page
Remote Station Parameters			
$PASHS,RTC,AUT	Turns auto differential mode on or off	N	137
$PASHS,RTC,MAX	Set maximum age of RTCM differential corrections	60	138
$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	142
$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 ON (enabled) or OFF (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,ON

DEFAULT
RTC,AUT-OFF

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.

Example: Set 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 issuing **$PASHQ,RTC** 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 ADU5 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
OFF

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 ADU5 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 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 Magellan format. Like the PAR response message, the RTC response message does not have a header or message identifier as shown in the following example:

```
STATUS:
  SYNC:* TYPE:09 STID:0267 STHE:3
  AGE:+999 QA:100.0% OFFSET:00
SETUP:
  MODE:OFF PORT:A SOURCE:SLC,EXT AUT:OFF FMT:RTCM
  SPD:0300 STI:0000 STH:0 IOD:20
  MAX:0060 QAF:100 SEQ:N RTCM:V22
  TYP:1  2  3  6   7  9  16 18 19 22 31 32 34 36 6G
  FRQ:99 00 00 OFF 00 00 00 00 00 00 99 00 00 00 OFF
BASE:   LAT:0000.000000,N LON:00000.000000,E ALT:+00000.000 W84
MSG:
```

"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 5.60 describes each field of the message.

Table 5.60. 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	Age of received messages in seconds.
QA	Communication quality factor between base and remote. Defined as 100 x number of good measurements, divided by total number of messages. Remote only.
MAX	Maximum age, in seconds, required for a message to be used (remote only). Range is 0 through 999, default. is 60.
QAF	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

Table 5.60. RTC Message Structure (continued)

Field	Description
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 is N. When enabled, 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, where xxx is the type of correction: EXT (Serial Port), BCN (Beacon), or SBA (SBAS).

NOTE: If EXT is selected and $PASHS,RTC,REM,ON is used to turn on remote mode, the receiver automatically detects and utilizes corrections from either or both ports A and B in the navigation solution.

Example: Use SBA corrections:

$PASHS,RTC,SLC,SBA

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: Set differential station ID number to 0001:

$PASHS,RTC,STI,0001

DEFAULT
RTC,STI— 0000

6

Troubleshooting

This chapter contains information for troubleshooting problems with the operation of the ADU5. 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 10 to 29 V at 1A.
- 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 ADU5. The ADU5 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 ADU5 and the PC.
- If the interface cable was not supplied by Magellan, check the J1 connector's pin-out diagram of the RS-232 ports with the cable you manufactured. (Refer to the Overview.)
- If user's cable is not using RTS and CTS, then RTS/CTS must be disabled using command (example port A): <$PASHS,CTS,A,OFF>.
- Clear internal memory with the **$PASHS,INI** command. (You may need to toggle the power to the receiver after this command is issued.)

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 ADU5 receiver;
  - Cable 2 is connected to antenna 2 and the Ant 2 port of the ADU5 receiver;
  - Cable 3 is connected to antenna 3 and the Ant 3 port of the ADU5 receiver;
  - Cable 4 is connected to antenna 4 and the Ant 4 port of the ADU5 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 **$PASHQ,3DF** command.
- The initial relative antenna position survey is very important. Determine that the survey provided valid results. (Refer to Chapter 4 for dynamic calibration.) Perform the survey more than once to validate the results. The static survey should provide nearly the same results every time. Conversely, a dynamic survey does not provide exactly the same relative antenna position vectors each time (if the vehicle was indeed moving), but a good check is to make sure that the baseline lengths for each vector agree for each survey.
- Verify that the antennas have not moved since the initial survey. The antennas should be mounted on a rigid platform. Very little relative movement between the antennas (less than 2 cm) can be tolerated.
- At least four satellites must be locked on all four antennas before attitude information can be computed. Verify this condition with the **$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 ADU5, 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. Magellan recommends that you keep the default satellite elevation mask angle of 10 degrees (or even increase it to 15 degrees) since satellites at lower elevations have a high level of multipath on their signals due to reflections from the ground and nearby metal objects. Multipath is a major error source affecting attitude accuracy and reliability (See Appendix A).
- Check the PDOP computed by the receiver. It should be less than 6 for “clean” attitude data. The attitude data becomes very noisy and the solution may even be lost when PDOP rises above 6. A high PDOP causes the BRMS error go above 4 cm. Increase the maximum allowable value of BRMS with the **$PASHS,3DF,MXB,d.ddd** command**.**

Notes on Attitude Data

Antenna Separations

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

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

Attitude Quality Indicators

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

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

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

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

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

7

File Formats

This chapter discusses the various ADU5 file formats. The file formats are:

- B-file: Raw data
- E-file: Ephemeris data
- A-file: Attitude data

B-file Format

Each B-file starts with a ***rawheader*** structure as listed in Table 7.1. Total length is 90 bytes.

Table 7.1. B-file Rawheader Structure

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

Each epoch starts with a ***rawnav*** structure (Table 7.2). Total length is 67 bytes.

Table 7.2. B-file Epoch Rawnav structure

Type	Name	Length	Description
char	sitename[4]	4	4-character site name (operator entered)
double	rcv_time	8	Signal reception time at the receiver (sec)
double	navx	8	Station position: ECEF-X (m)
double	navy	8	Station position: ECEF-Y (m)
double	navz	8	Station position: ECEF-Z (m)
float	navxdot	4	Velocity in ECEF-X (m/sec)
float	navydot	4	Velocity in ECEF-Y (m/sec)
float	navzdot	4	Velocity in ECEF-Z (m/sec)
double	navt	8	Clock offset (meters)
double	navtdot	8	Clock offset rate (m/s)
unsigned int	pdop	2	PDOP
char	num_sats	1	Number of satellites

The **rawdata** structures follow. **Rawdata** contains **chan_obs** within its structure (Table 7.3). Total length is 31 bytes.

Table 7.3. 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

Table 7.3. B-file Rawdata Structure (continued)

char	qa_phase	1	Phase quality indicator: 0 - always
long	doppler	4	Doppler (Hz)
double	carphase	8	Full carrier phase measurements in cycles

Each epoch has a ***rawdata*** structure per satellite (Table 7.4).

Table 7.4. 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 ephemerides for a satellite (Table 7.5). Total length is 129 bytes.

Table 7.5. 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)

Table 7.5. E-file Structure (continued)

Name	Type	Length	Description
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)
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

The A-file constitutes a sequence of binary structures containing attitude data (Table 7.6). Total length is 46 bytes.

Table 7.6. 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

Table 7.6. A-file Structure (continued)

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 ADU5 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 ADU5 system so severely that an attitude solution is not possible.

Antenna Cables

Antenna cables used with the ADU5 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 Magellan 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.

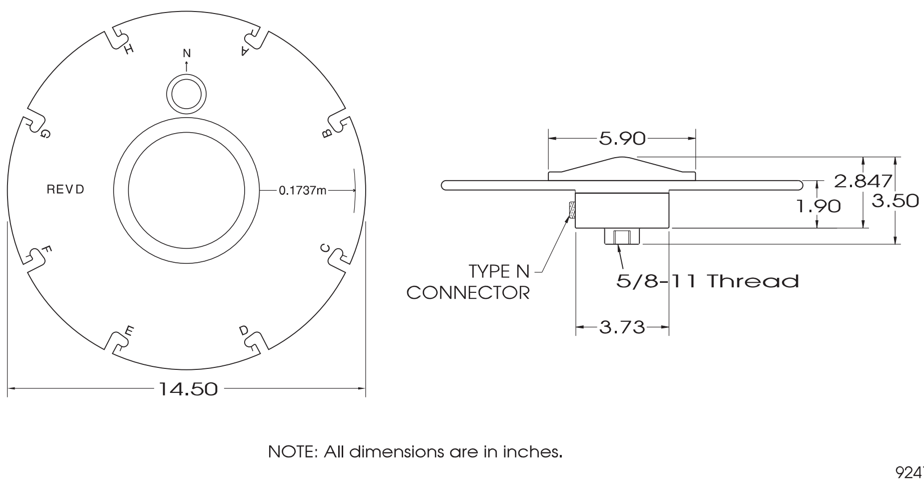

Figure A.1 Geodetic Antenna

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.

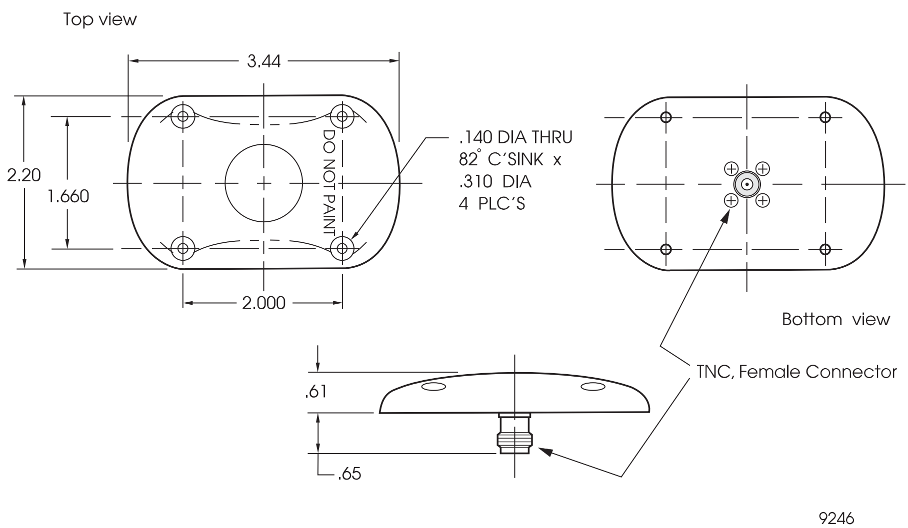

Figure A.2. Aircraft Antenna

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.

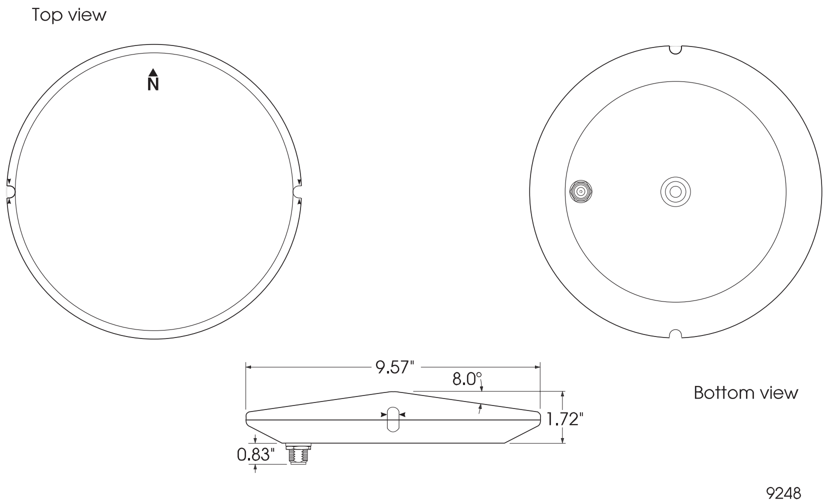

Figure A.3 Marine Antenna

Fixed Portable Antenna Array

The fixed portable antenna array available from Magellan 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.

Magellan 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.

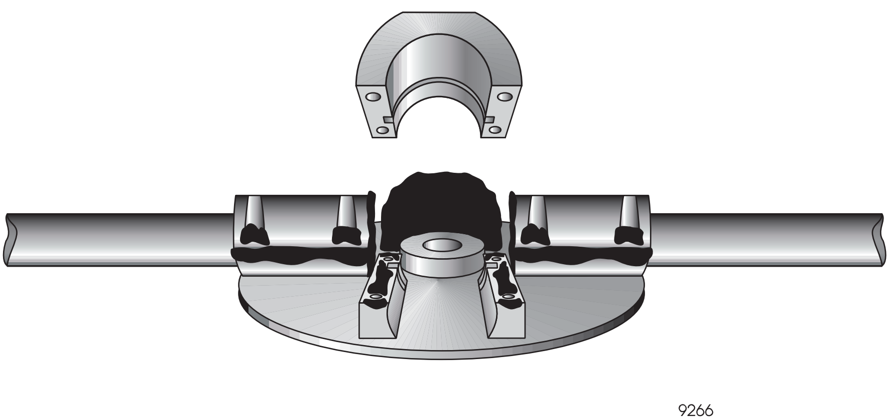

Figure A.4 Recommended Placement of Sealing Compound

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

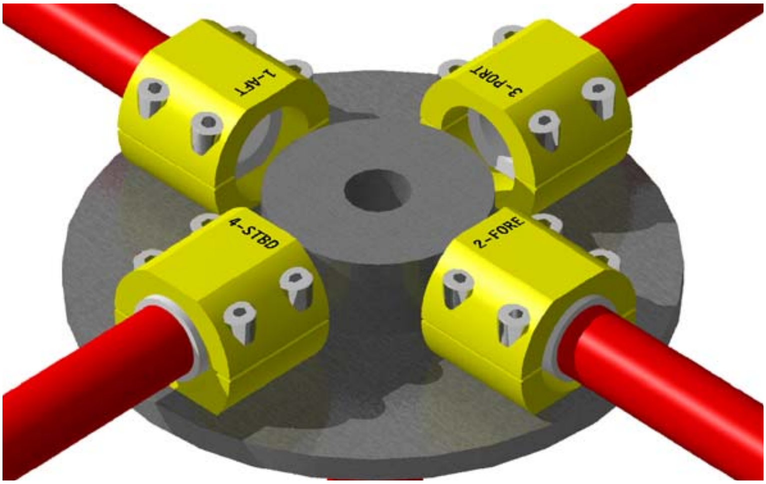

Figure A.5. Cross Arm Fitting with Engraved Number and Description

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 Magellan cables provided with the antenna kits, RG58 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.

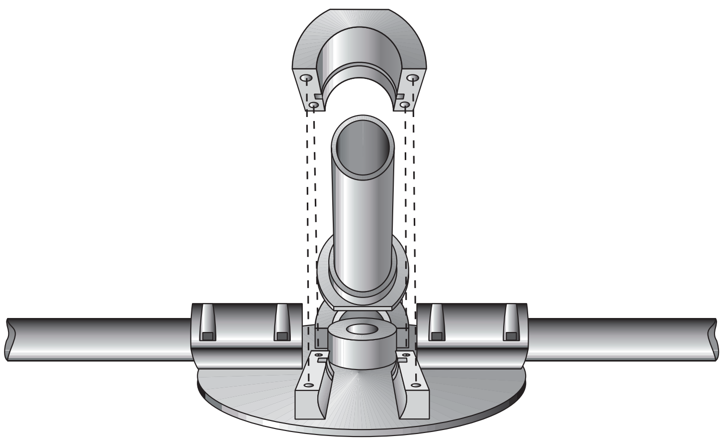

Figure A.6. Placing the Cross Arm in the Base Fitting

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.

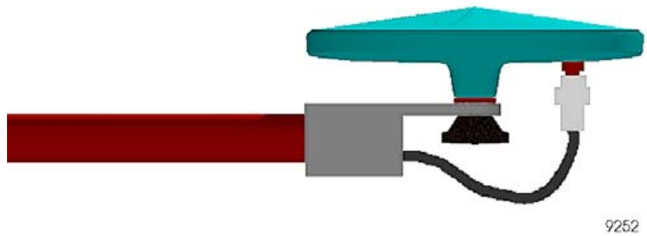

Figure A.7. Alignment of Cable Port, Cross Arm, and Antenna Bolt

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. Magellan recommends using the 1 inch standard pipe fitting.

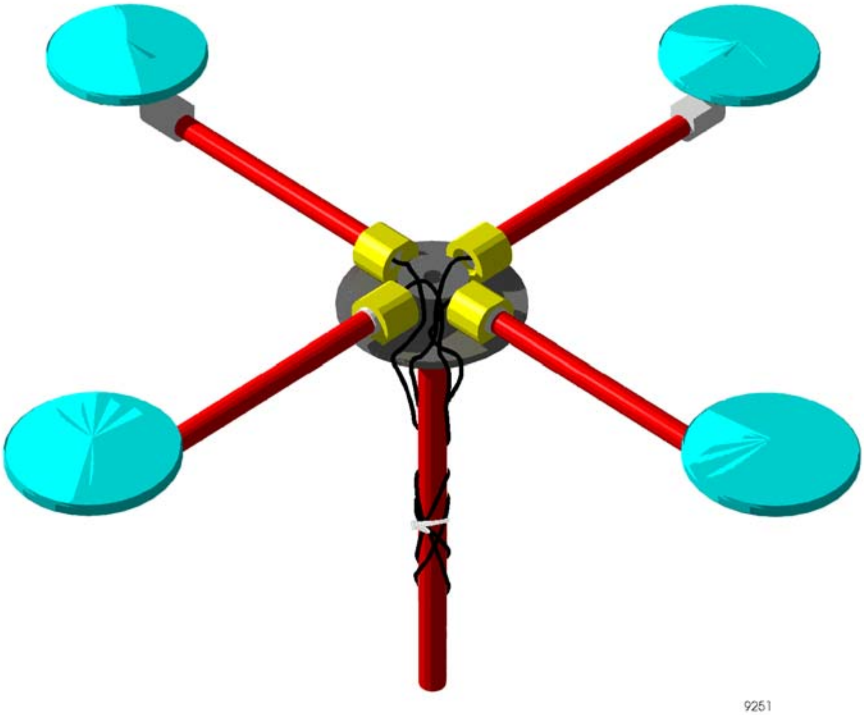

Figure A.8. Completed Fixed Portable Antenna Array

10. Connect the antenna cables to the respective ports on the ADU5 unit using the marked antenna cables as a guide. Connect the ADU5 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 Magellan 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.

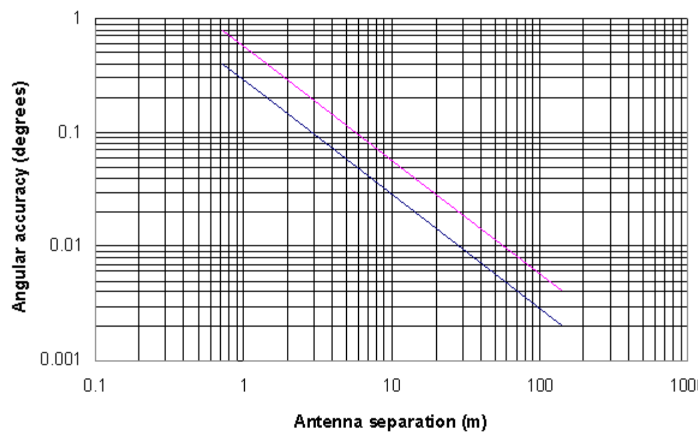

Figure B.1. Angle Accuracy vs. Antenna Separation

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 ADU5 antenna system and the vehicle (“truth”). These offset angles are essentially constant bias errors from truth. Since the attitude given by an ADU5 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 ADU5 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:

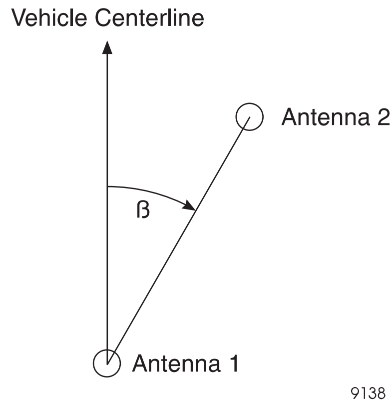

Figure B.2 Antenna Offset Angle

- 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 ADU5 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 ADU5 heading vector and the vessel centerline is to perform a simple comparison of ADU5 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 ADU5 with any type of gyro, another error source should be considered. The ADU5'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 ADU5 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 System*", ION GPS-94 Proceedings, 689-696

INDEX

Symbols

Numerics

A

B

Q

R

S

T

U

V

W

Y

Z

ADU5™

Operation & Reference Manual

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