POLHEMUS
INNOVATION IN MOTION™

3SPACE®
FASTRAK®
USER MANUAL

OPM00PI002 REV. G
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FCC Statement
This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause interference to radio communications. Operation of this equipment in a residential area is likely to cause interference in which case the user will be required to correct the interference at the user's expense.

EC-Declaration of Incorporation
For all FASTRAK models produced as of January 2012, this product conforms to the following European Community Directives:

EMC Directive 2004/108/EC
LVD 2006/95/EC

The following standards were used to verify compliance with the directives:

EMC: EN 61326-1:2006 EMC requirements
Class A (Emissions)
Class A (Harmonics)
EN 55011:1998/A1:1999/A2:2002 (Radiated & Conducted Emissions)
NOTE: The conducted emission here-in only applies if a Polhemus supplied power supply is used with the FASTRAK electronics unit.
EN 61000-3-2:2000 (Harmonics)
EN 61000-3-3:1995/A1:2001 (Flicker)
EN 61000-4-2:1995/A1:1998/A2:2001 (ESD)
EN 61000-4-3:2002 (Radiated RF Immunity)
EN 61000-4-4:2004 (Electrical Fast Transient/Burst)
EN 61000-4-5:1995 (Surge Immunity)
EN 61000-4-6:1996 (Conducted RF Immunity)
EN 61000-4-11:2004 (Voltage Dips & Interruptions)

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DUE TO SOFTWARE AND HARDWARE MODIFICATIONS
SCREEN OR PRODUCT EXAMPLES APPEARING IN THIS MANUAL
MAY VARY SLIGHTLY FROM THE ACTUAL
SCREENS OR PRODUCTS THE USER ACCESSES.

1. Getting Started

Congratulations on buying the finest 3D tracker system yet! This section of the user manual has been provided to help get your project under way as quickly as possible.

There are two ways to get started with your FASTRAK system, as with any new system. You could “wing it,” which involves a great deal of assumptions based on either previous experience and/or visual inspection, and hope for the best. Alternatively, you could sit down and read the whole manual, line-by-line, and then start. What we provide here is a middle ground to cover the basics to get you going quickly. However, this approach does not preclude using the manual as a precise guide, reference and final arbiter.

NOTE: This approach assumes a single receiver, use of the USB port communicating with a Windows PC, and use of the FASTRAK Host Software.

Unpack the FASTRAK SEU, transmitter, receiver(s), and power supply.

Figure 1-1 Complete FASTRAK System

1. Set up the system close to your host computer and away from large metal objects like file cabinets, metal desks, etc. and away from the floor and walls.
2. Identify the transmitter (the two-inch gray cube or the four-inch black cube) and insert the transmitter connector into the transmitter receptacle, being careful to firmly engage it. Using your fingers or a small, flat blade screwdriver, lock the connector by tightening the two retaining screws.

Figure 1-2 Transmitter Connection

3. For getting started, use only one receiver. Identify the receiver and insert it into the receiver receptacle labeled “one” as shown below. Firmly engage and lock the receiver connector into place in the same manner as the transmitter connector in Step 2.

Figure 1-3 Receiver Connection

4. For testing purposes, it is convenient to mount both the transmitter and the receiver on a single block of wood (2X4 or equivalent) about 16 inches apart. Exact placement of the transmitter and receiver is not important for this test; just make sure the cables of both devices are <u>not routed together</u> and they come off opposite ends of the 2X4.

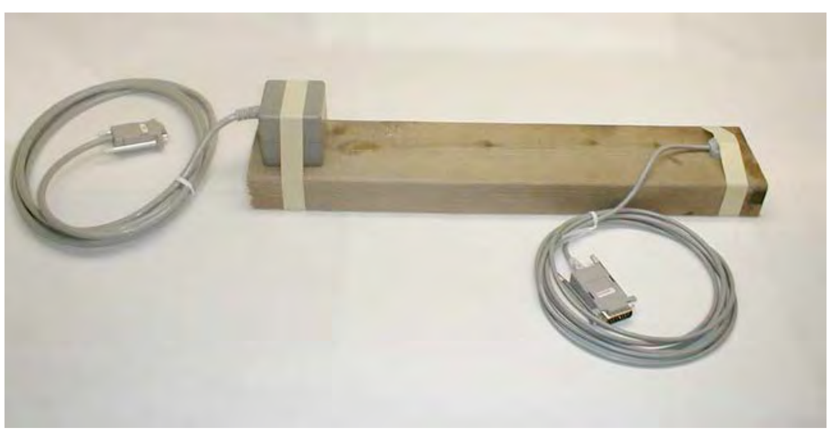


Figure 1-4 Mounting Transmitter and Receiver on 2x4

5. Identify the five pin "DIN" type power input connector on the back panel of the electronics unit.

Figure 1-5 Power Connector

With the separate Power Supply ("brick") **UNPLUGGED** from the outlet of the wall, plug the "brick's" DIN connector into the power-input connector on the rear panel of the electronics unit and firmly seat.

Figure 1-6 DC Power Cable Installation

Identify the power ON/OFF rocker switch located on the rear panel of the electronics unit. Ensure this switch is in the <u>OFF</u> position (logic "0", DOWN) before inserting the "brick's" convenience plug into the 110/220 VAC outlet.

6. Connect the USB cable to the FASTRAK as shown below, and the remaining end of the cable into a USB port on the host computer.

Figure 1-7 DC USB Cable Installation

7. Install the Host Software

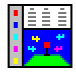
NOTE: FASTRAK Host Software is intended to be installed on a computer running Windows XP/Vista/Win 7 only.

- Insert the FASTRAK Host Software CD-ROM into your computer's CD-ROM drive.
- If the FASTRAK Host Software Installation Panel does not run automatically, then navigate to the CD-ROM drive using Windows Explorer. Run "Setup.exe". The Host Software Installation Panel will appear. Select "Install Host Software." The installation wizard will walk you through the installation.
- For simplicity, it is recommended that you use the default installation settings suggested by the installation wizard.
- When the installation is complete, if you are planning to use your computer's USB port to connect to the FASTRAK System, leave the CD-ROM in the drive. It will be needed when the initial USB connection is made.
- If you are not planning to use the USB port, you may remove the CD-ROM from the drive now.

USB Driver Installation

- When FASTRAK is connected via USB to a Windows host for the first time, the host will display a "Found New Hardware" message. The host will then launch the "Found New Hardware Wizard" to locate and install the USB drivers for FASTRAK.
- If the CD-ROM is not already in the drive, load it now.
- When the Found New Hardware Wizard displays, select the "Install software automatically" option and then "Next."
- The wizard will install the FASTRAK Loader. When it has completed, select "Finish."
- The same process will be launched again automatically to install the Polhemus FASTRAK USB Driver. Repeat the same selections and the process will be complete.

8. Use the Polhemus PiMgr GUI

If you selected the default settings when you installed the FASTRAK Host Software on your computer, you will find a shortcut to the PiMgr application on your Windows XP/Vista/Win 7 desktop. It looks like this: 

Otherwise, navigate to the program through the windows Start menu:

Start⇨All Programs⇨Polhemus⇨PiMgr

The initial PiMgr screen will look like this:

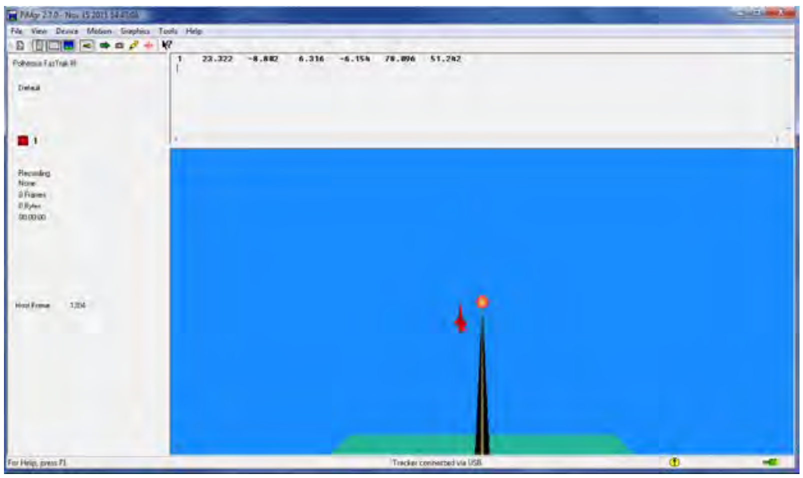
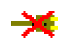


Figure 1-8 PiMgr Screen Display

a. With no FASTRAK system connected, notice that the  icon appears in the lower right corner. Once connected, the icon will change to .

b. If the FASTRAK system is already powered up and connected to the computer, the PiMgr will discover the connection immediately upon startup. If not, you will need to manually create the connection once you have powered up FASTRAK. To do this, first you must select the type of connection you wish to create.

c. If you want to create a USB connection, skip to Step 9. PiMgr defaults to a USB connection. If you want to create an RS-232 connection, first configure the serial port settings by opening the Device Configuration dialog. Open this dialog off the Device menu: **Device⇨Device Configuration…,** and select the **Connection** tab. Select the **RS-232** Connection Type on the left, and the appropriate **RS-232 Properties** on the right. Then select **OK**.

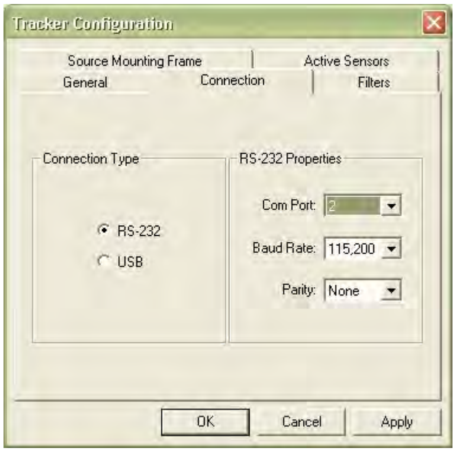
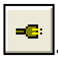
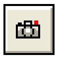


Figure 1-9 RS-232 Configuration Settings

d. To create a connection, select the **Connect** button on the PiMgr toolbar: . When the connection has been established, the connection icon at the lower right will change to .

e. To collect a single frame of motion data from the FASTRAK system, select the **Single** button on the toolbar: 

f. You can also do this by typing '**p**' or '**P**' anywhere on the PiMgr window. This will cause PiMgr to request a single data frame from the FASTRAK system. The contents of the frame will be displayed in the text window at the top of the PiMgr display. The airplane image(s) in the graphics portion of the screen will move to the retrieved position and orientation:

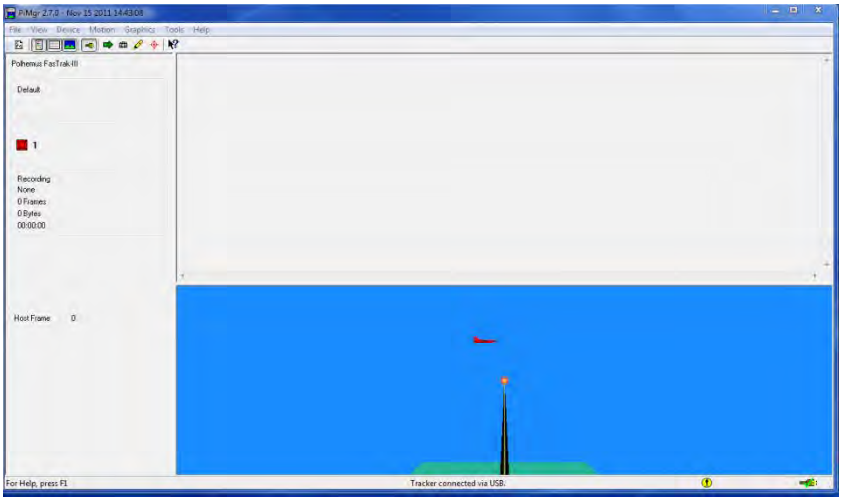


Figure 1-10 FASTRAK Data Record Display

9. At this point, you may turn on the FASTRAK using the power switch located on the back panel of the SEU. Note the "power on" indicator located on the front panel of the electronics unit. It should flash for approximately 10 seconds indicating self-test and set-

up. When these routines are completed (after the flashing), the indicator will turn to a steady-on state thereby indicating that the system is ready to operate.

10. You may now use the PiMgr to exercise the system. After clicking a single button or sending a ‘P’ – Single Data Record Output command (see page 63) to the system, the 6 Degree-Of-Freedom (6DOF) output data will be sent to the host. The data consists of a header (0*s*, where *s* equals the station number) and six columns of data as follows: (**NOTE:** These values represent an arbitrary placement of the receiver and transmitter.)

1	2	3	4	5	6	7
01	16.08	-0.38	0.71	3.05	1.12	-0.67

FASTRAK Data Record

Column	Function
1	01 Header (not shown above)
2	X position in inches
3	Y position in inches
4	Z position in inches
5	Azimuth attitude in degrees
6	Elevation attitude in degrees
7	Roll attitude in degrees

Because you have locked the receiver in one position relative to the transmitter (Step **4**), the data output will not change regardless of the number of data samples you take.

11. Remove the receiver, move it approximately six inches toward the transmitter, secure it in place, and take a data point. The value of the X position data will decrease by approximately six inches. The Y and Z values will remain roughly the same as the original data. If you left the attitude of the receiver approximately the same as it was when you started, then the attitude data will be approximately the same also.

12. Again, remove the receiver and without moving its position, try twisting it in azimuth (in the same plane as the 2 x 4) approximately 45 degrees and lock it down with tape. Now take another data point by clicking a single button or using the ‘P’ – Single Data Record Output command (page 63). The first four columns will be approximately as they were in Step **10**, but the Azimuth data in column 5 will have changed by approximately 45 degrees.

13. Experiment with the system as shown in Step **12** to demonstrate that it measures the position and orientation (6DOF) of the receiver with respect to the transmitter.

14. If the system fails to produce 6DOF data, carefully go over the above procedure in a systematic fashion, checking connections and switch settings especially. When all else fails, call us.

2. Contacting Polhemus Customer Service

If problems are encountered with the FASTRAK system or if you are having difficulty understanding how the commands work, help is just a telephone call away. Call Polhemus at (800) 357-4777 and select “2” for Customer Service and then “1” for Technical Support. Polhemus is open Monday through Friday, 8:00 AM to 5:00 PM, Eastern Standard Time. For the most part, our customer service engineers are usually able to solve problems over the telephone and get you back into the fast lane right away. Help is also available on our web page at www.polhemus.com. Simply double-click Technical Support, then select techsupport@polhemus.com to send us an email describing the problem or question.

If a problem requires repair of your system, the customer service engineer will issue a Return Merchandise Authorization (RMA) number so you can return the system to the factory. Please retain and use the original shipping container, if possible, to avoid transportation damages (for which you or your shipper would be liable). Please do not return any equipment without first obtaining an RMA number. If your system is still under warranty, Polhemus will repair it free of charge according to the provisions of the warranty as stated in APPENDIX A of this document. The proper return address is:

Polhemus
40 Hercules Drive
Colchester, VT 05446
Attention RMA #____

Telephone (From the U.S. and Canada):	**(800) 357-4777**
Telephone (From outside the U.S. and Canada):	**(802) 655-3159**
Fax #:	**(802) 655-1439**

3. Current FASTRAK vs. Previous Versions

Congratulations on purchasing our FASTRAK system! For our customers who presently own one or more of our tracker products, there are some minor differences which should be noted for all FASTRAKs produced as of January 2012:

- Fan has been removed
- 16 bit binary has been removed
- Master/Slave mode has been removed
- External sync output has been removed

4. FASTRAK Commands Index

5. Technical Overview

The FASTRAK tracking system uses electro-magnetic fields to determine the position and orientation of a remote object. The technology is based on generating near field, low frequency magnetic field vectors from a single assembly of three concentric, stationary antennas called a transmitter, and detecting the field vectors with a single assembly of three concentric, remote sensing antennas called a receiver. The sensed signals are input to a mathematical algorithm that computes the receiver's position and orientation relative to the transmitter.

The FASTRAK consists of a System Electronics Unit (SEU), one to four receivers, a single transmitter, a power supply and a power cord. The system is capable of operating at any of four discrete carrier frequencies. Different carrier frequencies allow operation of up to four FASTRAKs simultaneously and in close proximity to one another. The FASTRAK interfaces to the host computer via RS-232 and USB serial communication. Any single receiver may be operated at the fastest update rate (120 Hz); any two receivers at one half this rate; any three at one-third this rate; or all four at one fourth the fastest rate. Of course, the unit must be set to output at a high enough baud rate to receive these updates. Mixed rates are not permitted meaning that all active receivers operate at the same update rate, i.e. one cannot be operated faster than another. Active receivers are selected by physical receiver cable connections and software configuration commands.

Additionally, the FASTRAK may be used with a stylus instead of a standard package receiver. Tip offsets are automatically calculated for the stylus and no special commands are required for this mode of operation. Switch functionality is provided with the stylus. The stylus may be used in any of the Receiver Ports. Operation of these devices is covered in Default Operation with a Stylus on page 90.

6. Specification

Position Coverage

The system will provide the specified accuracy when standard* receivers are located within 30 inches (76 cm.) of the standard transmitter. Operation with separations up to 120 inches (305 cm.) is possible with reduced accuracy.

***NOTE:** Alternative devices of larger/smaller size are available as options and operate to longer/shorter ranges.

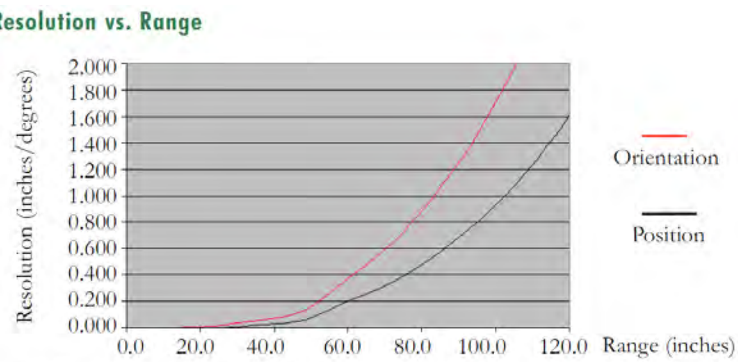
Angular Coverage

The receivers are all-attitude.

Static Accuracy

0.03” (0.08 cm) RMS for the X,Y,or Z receiver position, and 0.15° RMS for receiver orientation.

Resolution vs. Range



Range (inches)	Position Resolution (inches)	Orientation Resolution (degrees)
12.0	0.00023	0.0026
24.0	0.0030	0.0147
36.0	0.019	0.0558
48.0	0.055	0.1266
72.0	0.346	0.369
120.0	1.605	2.960

Latency

4.0 milliseconds from center of receiver measurement period to beginning of transfer from output port.

Output

Software selectable including extended precision. Cartesian coordinates of position and Euler orientation angles are standard. Direction cosines and quaternions are selectable. English or metric units and ASCII or binary outputs also are selectable.

Update Rate

One receiver	120 updates/second
Two receivers	60 updates/second

Three receivers	40 updates/second
Four receivers	30 updates/second

Carrier Frequency

The FASTRAK may be configured with any one of four discrete carrier frequencies to allow simultaneous operation of up to four systems in close proximity. Carrier frequencies are selected via color coded Frequency Select Modules (FSM). These frequencies are:

Reference #	Frequency Color Code
1	**8013 Hz Black**
2	**10016 Hz Red**
3	**12019 Hz (Std) Yellow**
4	**14022 Hz Blue**
5	**14022 Hz Green TX1**
6	**12019 Hz White TX1**

A colored dot can be found on the FSM, on the end closest to the connector and on the back panel of the FASTRAK SEU as it comes from the factory. FSMs different from the standard can be specified by the user at time of order or can be purchased for a nominal fee at any time. Field installation of a FSM should prompt user change out of the SEU color dot in order to facilitate easy identification among multiple FASTRAKs.

RS-232 Interface

RS-232C serial port with software selectable baud rates of 1200, 2400, 4800, 9600, 19200, 38400, 57600 and 115200; ASCII or Binary formats. The factory default setting is 115.2K baud. An RS-422 port is available as an optional serial port in lieu of the RS-232 at the same baud rates.

USB Interface

USB (Universal Serial Bus) has become the predominant interface standard. It removes transmission speed limitations (due to maximum baud rate) and allows transmission speeds up to 12 Mbps. USB utilizes differential signaling for better signal quality and noise rejection and therefore allows the use of longer communication cables between the host computer and the FASTRAK system.

Operating Environment

Large metallic objects, such as desks or cabinets, located near the transmitter or receivers may adversely affect the performance of the system. Many walls, floors, and ceilings also contain significant amounts of metal.

Operating Temperature

10°C to 40°C at a relative humidity of 10% to 95% non-condensing.

Physical Characteristics

- **SEU:** Width 11.5” (29.20 cm.), length 10.3” (26.2 cm.), height 2.2” (6.10 cm.), weight 3.0 lb. (1.40 Kg.).

- **Transmitter:** Width 2.2” (5.6 cm.), length 2.2” (5.6 cm.), height 2.3” (5.8 cm.), weight 0.6 lb. (0.27 Kg.) excluding attached cable. The Transmitter may be purchased with either 10’ or 20’ cables.

- **Receiver:** Width 1.1” (2.83 cm.), length 0.90” (2.29 cm.), height 0.60” (1.52 cm.), weight 0.6 oz. (17.0 gm.) excluding attached cable. Receivers may be purchased with either 10’ or 20’ cables.

- **Stylus:** Length 7.00” (17.78 cm.) including tip, or the shorter version Stylus, length 3.5” (6.04 cm), maximum barrel diameter 0.75” (1.9 cm.), handle diameter 0.375” (0.95 cm.), tip length 0.8” (2.03 cm.), tip diameter 0.156” (0.4 cm.), weight 2.5 oz. (28.3 gm.) excluding attached cable. Either stylus may be purchased with either 10’ or 20’ cables.

Power Requirements

International Power Sources Supply: Input power is 100-240 VAC, 47-63 Hz, and single phase at 15 watts.

7. Component Description

7.1 SEU

The System Electronics Unit (SEU) is a stand-alone unit that may be located anywhere that is convenient to the work area, AC power and the host computer. It contains the required input and output connectors and controls to support up to four receivers, a single transmitter and the RS-232 and USB output ports. Receiver Input(s), Transmitter Input, I/O Cables, I/O Select Switch, External Sync I/O, Video Sync Input, and Power Input connections are located on the SEU as shown in Figure 7-1 and Figure 7-2, below.

Figure 7-1 FASTRAK SEU, Front View

Figure 7-2 FASTRAK SEU, Rear View

7.2 Transmitter Port

The single Transmitter receptacle port is a 15 pin, male "D" type connector located on the front of the SEU as shown in Figure 7-1. The transmitter should be connected to the SEU before the unit is powered on and disconnected after the unit is powered off. **CAUTION:** Do not disconnect the transmitter while the FASTRAK SEU is powered on. Also, do not power on the SEU without a transmitter connected. When routing cables, please be sure the transmitter cable is routed separately from the receiver cables.

7.3 Receiver Ports (4)

The four Receiver receptacle ports are 15 pin, female "D" type connectors located on the front of the SEU as shown in Figure 7-1. The receiver(s) should be connected to the SEU before the unit is powered on and disconnected after the unit is powered off. It is permissible to disconnect and re-connect receivers while the SEU is powered on, however, it is necessary to send the '^Y' – *Reinitialize System command (page 88) after doing so. This will allow the receiver's precise characterization matrix to be loaded into the FASTRAK memory. Again, rout the receiver cables separately from the transmitter cable.

7.4 Power Indicator

A green LED power on indicator is located on the front of the SEU as shown in Figure 7-1 on page 15. Upon power up, the indicator will blink for several seconds while the system performs its initialization and self-test routines. When these routines are complete, the indicator changes from blink mode to steady-on mode indicating that the system is ready for operation.

7.5 I/O Select Switch

The I/O Select Switch is an 8 position switch located on the rear panel of the SEU as shown in Figure 7-2 on page 15, and is only read on power up or system re-initialization (see '^Y' – *Reinitialize System on page 88). The purpose of these switches is to select the RS-232 serial port parameters including baud rate, character width, and parity. The modes with switch positions and their corresponding functions are as follows:

NOTE: UP position is a logic **"1"** and **DOWN** is a logic **"0"**.

Switch Position	Function
1	Baud rate select
2	Baud rate select
3	Baud rate select
4	Not used
5	Character width: "0" = 7 bits "1" = 8 bits
6	Parity select
7	Parity select
8	I/O Select -- **UP** for **RS-232**

The Baud rate select logic for switches 1, 2 and 3 is as follows: (Again, 1=Up and 0=Down)

Baud Rate	1	2	3	
1200	0	0	0	
2400	1	0	0	
4800	0	1	0	
9600	1	1	0	
19200	0	0	1	
38400	1	0	1	
57600	0	1	1	
115200	1	1	1	(factory setting)

The system reads the baud rate switches only on power up or system re-initialization. Therefore, if you change the switches to obtain a different baud rate, you must restart the system either by recycling the power or by using the '^Y' – *Reinitialize System command (see page 88).

The 'o' – Set Output Port command (page 62) may be used to override the switch settings during operation and select other baud rates. Although it is possible to save the new baud rate with the '^K' – *Save Operational Configuration command (see page 85, the next time you power up (or re-initialize the system with the '^Y' – *Reinitialize System command [page 88]), the system will ignore the EEPROM baud rate setting and read the dip switch settings to operate at that baud rate.

NOTE: High baud rates such as 115.2K generally require a short, well-made RS-232 cable in order to achieve error-free performance. (The Hardware Handshake function has been discontinued in this FASTRAK version. Switch #4 has no effect.)

The Parity select logic for switches 6 and 7 is as follows:

Parity	6	7	
None	0	0	
Odd	1	0	
Even	0	1	
Not used	1	1	– **Caution:** *System will not operate in this position*

Figure 7-3 Default I/O Select Dip Switch Settings

7.6 External Sync I/O

The External Sync I/O module is located on the rear panel of the SEU as shown in Figure 7-4. The connector contains two modular telephone sockets with the one closest to the I/O Select Switch being "Sync In". The input signal must be a single-ended TTL signal. If the output is employed in the user's system, it should be interfaced with differential TTL circuitry. The Sync Out signals are also compatible with RS-422 specifications. The signal logic is as follows:

Input: START = Logic LOW to HIGH transition, 50 µsec. pulse, min.
Output: START = Logic LOW to HIGH transition, 50 µsec. pulse, min.

NOTE: The "Sync Out" feature is no longer available on FASTRAK models produced as of January 2012.

The pin assignments for each plug are as follows and their numbering is shown in Figure 7-4:

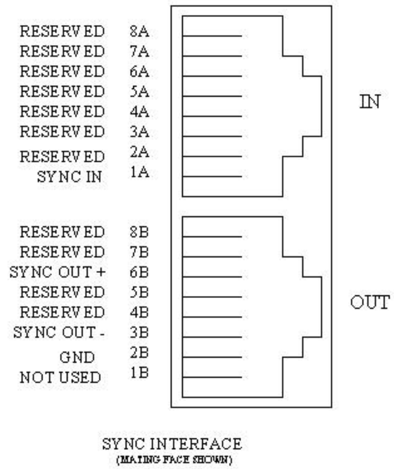


Figure 7-4 Sync Connector Identification (Input and Output)

NOTE: If a ground is required, use a shielded cable and use the shield as the ground reference.

7.7 Frequency Select Module

The Frequency Select Module is used to select the operating carrier frequency of the FASTRAK system. It is located inside the SEU, directly behind the Transmitter input connector. The alternate carrier frequencies are produced by inserting the required tuning module in the socket provided. The Frequency Select Modules are color coded for carrier frequency identification as described in Carrier Frequency, page 13.

IMPORTANT NOTE: As with any handling of an electronics printed circuit board (PCB), when inserting other frequency select modules to change the carrier frequency, static electricity precautions must be observed. Do not remove and replace frequency select modules with power applied to the SEU. Also, do not handle or touch the main PCB without first being grounded at an “ESD-safe” workstation.

7.8 RS-232 I/O

The RS-232 I/O serial connector is a standard, 9 pin, male, “D type” connector located on the rear panel of the SEU as shown in Figure 7-2 on page 15. The pinout identification for this connector is as follows:

FASTRAK End		User End
1	Not used	
2	RxD (Receive Data) ----------------------------------	TxD (Transmit Data to the FASTRAK)
3	TxD (Transmit Data) --------------------------------	RxD (Receive Data from the FASTRAK)
4	Not used	
5	GND --	GND
6	Not used	
7	Not used	
8	Not used	
9	Not used	

Figure 7-5 RS-232 Cable Connection

NOTE: Many commercially available cables do not include connections for all pins, so do not assume that these connections are made. Please refer to APPENDIX F: Cable Diagrams on page F-1 to find the specific interconnection scheme for your host computer in order to obtain a reliable serial interface.

If you do not find your particular host's RS-232 I/O interconnection scheme in APPENDIX F: Cable Diagrams on page F-1, refer to Contacting Polhemus Customer Service on page 8 and FAX a copy of your host computer's pin out identification from its user's manual. Polhemus will respond with advice on how to make the serial connection between your FASTRAK and your host computer.

NOTE: THE FASTRAK SYSTEM BEHAVES AS A TRANSMITTER ON THE RS-232 AND THEREFORE A NULL MODEM CABLE IS REQUIRED.

7.9 USB I/O

The USB I/O connector is a standard Series B connector located on the rear panel of the FASTRAK SEU as shown in Figure 7-2 on page 15. The connector on the FASTRAK is a square shaped connector with two corners shaved off for correct orientation upon insertion. The connector on the host PC is a Series A connector and is rectangular shaped. Since the connectors on each end of the USB cable are different, it is impossible to connect the cable incorrectly. The signals on the FASTRAK USB connector conform to the USB standard. The USB communication cable used to connect the FASTRAK to the host computer is a standard cable that is commercially available.

7.10 Optional RS-422 I/O

The optional RS-422 connector is identical to the RS-232 connector in form, fit, function, and location on the rear of the SEU.

IMPORTANT NOTE: In order to use this interface, the FASTRAK system must be ordered from the factory configured for RS-422 communication. A system can be configured for RS-422

or RS-232 communication, but not both. Once ordered, a system can be returned to the factory to have its interface configuration changed for a nominal fee.

RS-422 is a differential transmit and receive I/O standard with a maximum error-free speed of 10 Megabits/second (technical specifications for RS-422, not FASTRAK) with operation possible at a distance of 1200 meters with a speed of 100Kbits/second. The RS-422 does not use Handshake functions for transmission and reception. The RS-422 transfer rate on a FASTRAK is the same as for RS-232, but larger communication cables can be used, which is very important at higher baud rates. The pinouts for this connector are as follow:

FASTRAK End		User End
1	TxB ---	RxB (Non-inverting receive input)
2	Not used	
3	Not used	
4	RxB ---	TxB (Non-inverting transmit output)
5	Not used	
6	TxA ---	RxA (Inverting receive input)
7	Not used	
8	Not used	
9	RxA ---	TxA (Inverting transmit output)

7.11 Video Sync Input

The Video Sync Input is a subminiature telephone receptacle that mates with the video pickup coil assembly (Video Sync Detector, optional). The Video Sync Input is located on the rear of the SEU as shown in Figure 7-2 on page 15. Video sync is available to minimize noise generated by computer monitors, detected by the receivers. In order to use the video sync capability, the Video Sync Detector cable must be connected to the video sync input connector on the FASTRAK. The detector can then be positioned on the monitor surface where it will detect a sync pulse. After sending the y2 external sync command to the FASTRAK, it will be synced to the monitor. See Synchronization on page 31 for more information on synchronization.

7.12 Power Input Receptacle

The Power Input is a 5 contact, female, shielded DIN type receptacle located on the rear panel of the SEU as shown in Figure 7-2 on page 15. Pin outs for this receptacle are as follows:

Pin #	Function
1	GROUND (Digital)
2	GROUND (Analog)
3	+5 VDC
4	-15 VDC
5	+15 VDC

NOTE: Digital ground, pin 1 is **not** electrically shorted to analog ground, Pin 2 on the PCB. (They are electrically connected in the power supply.)

7.13 Transmitter

The Transmitter is the device which produces the electro-magnetic field and is the reference for the position and orientation measurements of the receivers. It is usually mounted in a fixed position to a non-metallic surface or stand, which is located in close proximity to the receivers. The Transmitter is dimensionally shown in Figure 7-6 including the position of the electrical center. There are four ¼" - 20 NC tapped holes provided on the bottom surface for mounting. Nylon hardware (supplied) should be used when locating the Transmitter in a fixed position. **NOTE:** Please be sure to route the transmitter cable separate from the receiver cables in order to avoid possible noise problems.

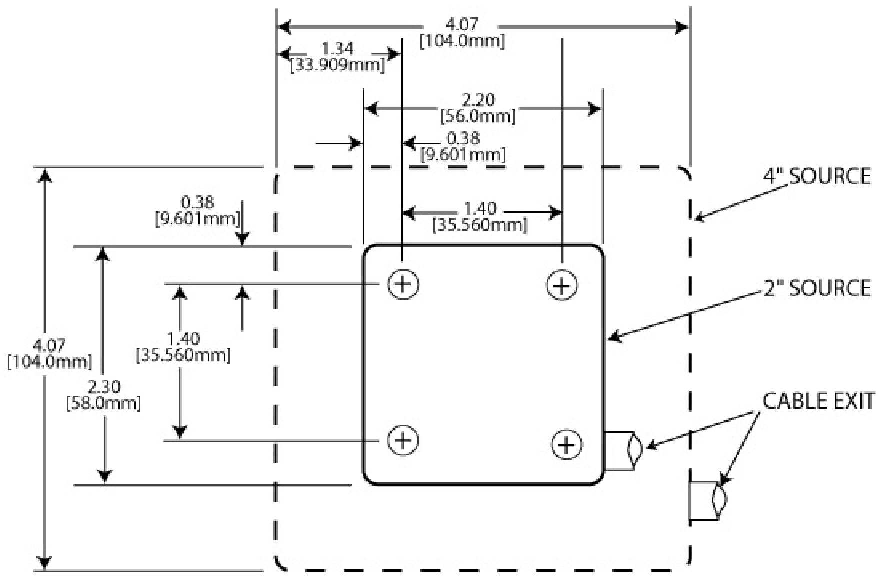


Figure 7-6 Transmitter Diagram

Figure 7-7 Transmitter

7.14 Receiver(s)

The receiver is the smaller device whose position and orientation is measured relative to the Transmitter. The Receiver is dimensionally shown in Figure 7-8 including the position of the electrical center. The Receiver package provides two mounting holes for #4 nylon screws (supplied) in the event that Receiver mounting is required.

NOTE: Nylon hardware is only required when the hardware will be **in direct contact with the transmitter or receiver.** A testing surface where the devices will be used (a table for example), could have small metal hardware like screws, nuts, and bolts which probably would not affect the accuracy of the system. Again, please be sure to route the receiver cables separate from the transmitter cable.

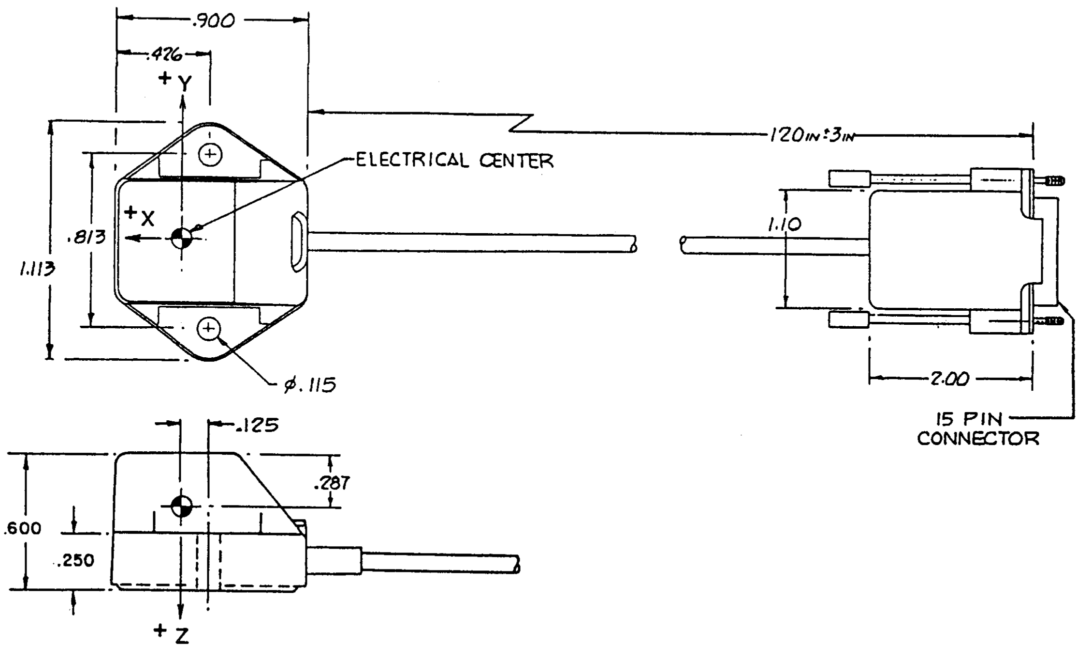


Figure 7-8 RX2 Receiver Dimensions (in Inches)

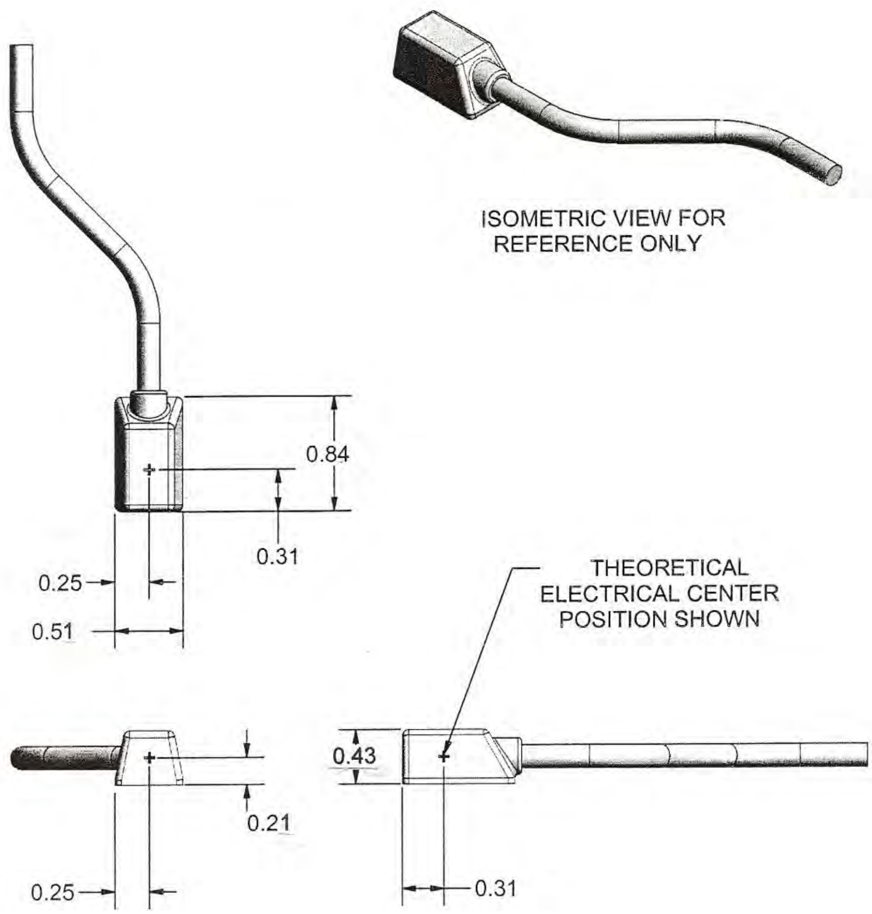


Figure 7-9 RX1-D Receiver (in inches)

Figure 7-10 Receiver

7.15 Stylus

The stylus is a pen shaped device with a receiver coil assembly built inside and a push button switch mounted on the handle to effect data output. The Position measurements are relative to the tip of the stylus, due to a precise factory calibration. The Stylus is dimensionally shown in

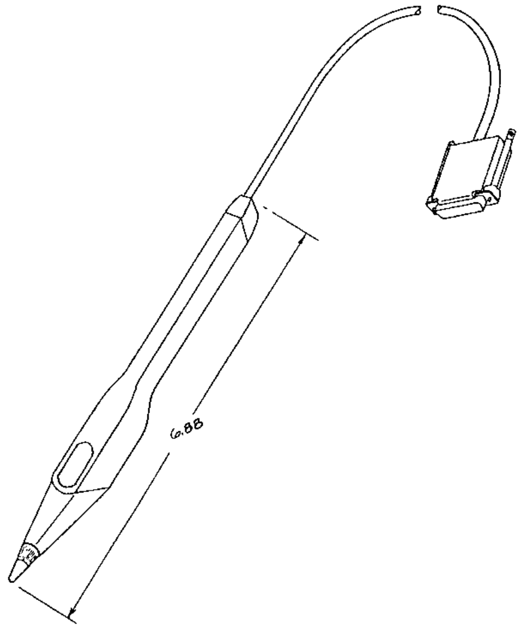


Figure 7-11 and may be used *as a receiver* in any of the receiver ports. However, the button on the stylus will only work when the stylus is connected to Station 1. The stylus functions as a receiver with the electrical center offset from the tip of the stylus via software. Single or Continuous output records may be obtained as a function of the integral switch. See Default Operation with a Stylus on page 90 for operation with a stylus.

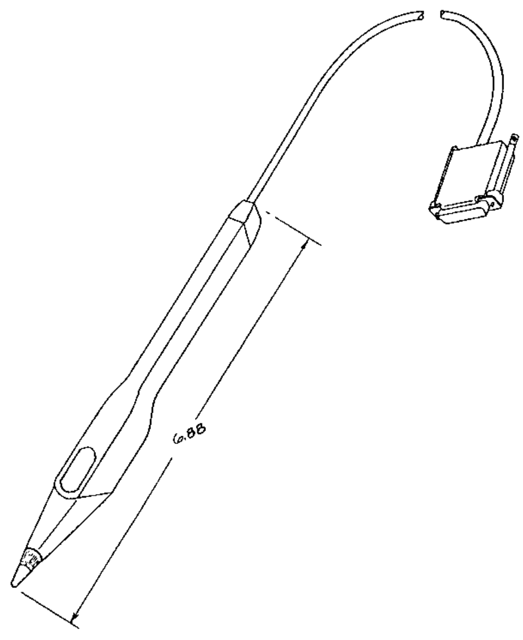


Figure 7-11 Stylus Dimensions

Figure 7-12 Stylus

7.16 Video Sync Detector

The Video Sync Detector consists of a suction cup pickup coil with a 3' cable terminated with a subminiature telephone plug. The Video Sync is used when the system's data exhibits objectionable noise when operating a receiver in close proximity to any CRT monitor. If this condition occurs, then Video Sync may be employed using the Video Sync Detector through the software command 'y2'.

The pickup coil of the Video Sync Detector is attached to the CRT (Monitor) case and the connector inserted into the Video Sync Detector input. After issuing the 'y2' command, the system checks for sufficient signal level from the video pickup coil. If the signal level from the pickup coil is below a preset threshold, the message **"no video sync available"** will be displayed. If this condition exists, move the pickup coil to another part of the Monitor case. This procedure should be repeated until the message **“no video sync available”** ceases to occur. The video synchronization mode may be exited at any time by selecting another type of synchronization mode using the ‘y’ command.

Figure 7-13 Video Sync Detector

7.17 Long Ranger Transmitter

The Long Ranger Transmitter is an optional device which produces a larger electro-magnetic field and therefore enables greater range capabilities. The 18” acrylic sphere is attached to a pedestal, which is typically mounted on the optional tripod assembly, or suspended from the ceiling. The advantage (besides longer range, when using the Long Ranger Transmitter in lieu of the standard transmitter) is a better signal-to-noise ratio (less noise) so that whole body tracking can easily be done.

7.18 4” Transmitter

The 4” Transmitter is an optional device which allows up to 40% more range than the standard 2” Transmitter. The 4” Transmitter can be employed in virtually the same environments as the standard transmitter, and even uses the same mounting hole pattern–allowing increased range without degradation in the data.

7.19 Short Ranger Transmitter

The Short Ranger Transmitter (TX1) is an optional device, which produces a smaller electro-magnetic field for precision work in a restricted space. It is dimensionally the same as the receiver and is shown in Figure 7-6 on page 21. There are two advantages when using the Short Ranger Transmitter in lieu of the standard transmitter: a small volume means 1) less susceptibility to field distortions with metals nearby; and 2) no concern about transmitter aperture when closely approaching the device. The Short Ranger requires a factory modification to the SEU which needs to be addressed when the product is ordered; other transmitters can no longer be operated by the modified SEU.

7.20 Mini Receiver

The Mini Receiver is an optional device, 10-12 mm in size, whose position and orientation is measured relative to the transmitter, like all receivers. Because of its small size, its maximum range from the transmitter is reduced to 35-40% that of a standard receiver. Refer to Figure 7-9 on page 23.

8. System Operation

8.1 I/O Considerations

Currently, there are two possible interface configuration options available on the FASTRAK system; the standard RS-232 serial configuration or the optional RS-422 configuration. Each configuration supports either Binary or ASCII formats.

RS-232 The RS-232 is the most commonly used port both in binary and ASCII formats because of its commonality and the fact that it supports high baud rates. The RS-232 port should be used where host to FASTRAK physical separation distances are no greater than 50 feet and baud rates can be kept low. (Higher baud rates will require shorter cable lengths for reliable operation.)

Ensure that your RS-232 cable connects the **FASTRAK TRANSMIT** data pin (pin 3) to the **HOST'S RECEIVE** data pin and that the **FASTRAK RECEIVE** data pin (pin 2) is connected to the **HOST'S TRANSMIT** data pin. Also ensure that the RS-232 cable connects the **FASTRAK GROUND** (pin 5) to the **HOST'S GROUND** pin. Note that the host computer's ground pin may be designated as "Signal Ground" or some other comparable phrase.

RS-232 Cable Connections

FASTRAK		HOST
Transmit (pin 3)	--	Receive
Receive (pin 2)	---	Transmit
Ground (pin 5)	--	Ground

RS-422 The optional RS-422 port is used where large separation distances between the FASTRAK and the host are anticipated. If high baud rate operation over a long communication cable is required but the host computer does not have an RS-422, inexpensive RS-422/RS-232 conversion modules are available commercially. Please contact Polhemus Customer Service (see Contacting Polhemus Customer Service on page 8) should you need suggestions on where to locate these modules.

As with the RS-232 port, the RS-422 transmit signals from the FASTRAK must be connected to the Host's Receive signals and the FASTRAK's Receive signals must be connected to the Host's Transmit signals. Signal polarity conventions must be strictly observed. See diagram below for connections.

RS-422 Cable Connections

FASTRAK		HOST
RxB; receive high (pin 1)	-----------------	TxB; transmit high
TxB; transmit high (pin 4)	-----------------	RxB; receive high
RxA; receive low (pin 6)	-----------------	TxA; transmit low
TxA; transmit low (pin 9)	-----------------	RxA; receive low

8.2 Powering Up FASTRAK

To power-up your FASTRAK system, first ensure that the power switch on the back panel of the FASTRAK is in the "off" position and the power supply brick is not plugged into the AC wall outlet. Then connect the power cable from the power supply to the DIN power connector on the rear panel of the FASTRAK. Connect the power cord to the power supply brick and plug it into the AC wall outlet. Configure the dip switch settings on the I/O select switch. Plug in transmitter, receivers and RS-232 cable and turn the power switch to the ON position. On power up, the power indicator will blink for several seconds to indicate the system's performance of an initialization and self test routine. During this time, system operation is not possible. At the completion of this routine, the power indicator will change from a "blink" state to "steady-on" which indicates that the system is now operational.

IMPORTANT NOTE: Do not connect or disconnect the power cable to the FASTRAK while it is powered on or while the power supply brick is energized. Internal component damage could result.

Initial Power Up Procedure

- Verify FASTRAK power switch is off
- Verify power supply brick is not energized (plugged into the wall outlet)
- Connect power cable from the brick to the power connector on rear panel of FASTRAK
- Plug power supply brick into AC wall outlet
- Configure switch settings on I/O select switch
- Plug in transmitter, receivers, and RS-232 cable
- Turn on FASTRAK power switch

8.3 Configuration Changes

Although receivers can be connected or disconnected while the unit is powered on, it is not normal operating practice. However, if it is necessary to do this, it is important to either cycle the system power or send the '^Y' reset command. This allows the device characterization data for the receiver to be read and applied to future measurements. Normal system accuracy cannot be achieved unless the receiver characterization data has been read properly.

IMPORTANT NOTE: Do not connect or disconnect the transmitter while the FASTRAK system is powered on.

8.4 Using the USB Interface

When the FASTRAK is powered on, it is enabled for RS-232 communication. As soon as the USB cable is plugged in, the FASTRAK will shift to USB operation (see Figure 8-1 on page 29). It takes the FASTRAK approximately 3-4 seconds to shift to USB mode. Since the FASTRAK ***can not*** communicate over the RS-232 port and the USB port simultaneously, the user needs to choose which interface will be used and cease communication over the other port. Once the FASTRAK is in the USB mode, simply disconnecting the USB cable will not put the FASTRAK back in RS-232 mode. In order to switch the FASTRAK back to RS-232 mode, the user must disconnect the USB cable and then cycle the power on the FASTRAK (turn it off, then turn it back on again). Note that at anytime during RS-232 operation, the USB cable can be plugged into the FASTRAK and it will switch to USB mode, without having to cycle the power. However, it is best to disable continuous output mode and close any programs communicating with the FASTRAK via RS-232 first, in order to avoid error messages or program lock-ups while switching to the USB mode.

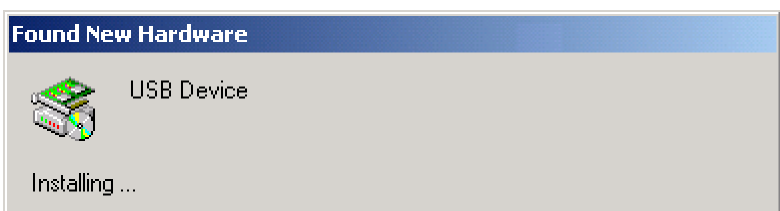
Figure 8-1 Connection of USB Cable to Switch to USB Mode

8.5 Installing USB Device Drivers

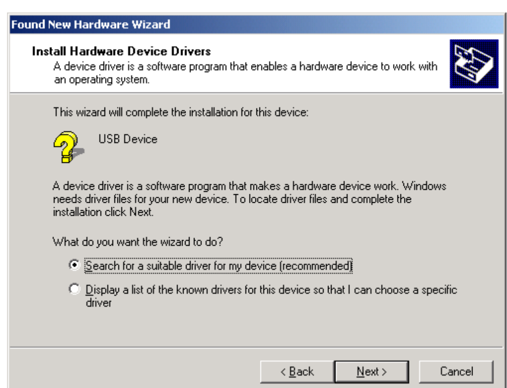
NOTE: The following USB Device Driver was designed to run on Windows 2000 and Windows XP.

The first time the FASTRAK is connected to a new host computer (via USB), a device driver must be installed on that computer before USB communication can be established. This process is somewhat automatic, but requires occasional key strokes by the user during the installation process. (**NOTE:** the FASTRAK USB port was designed to operate in accordance with the USB 1.0 standard.)

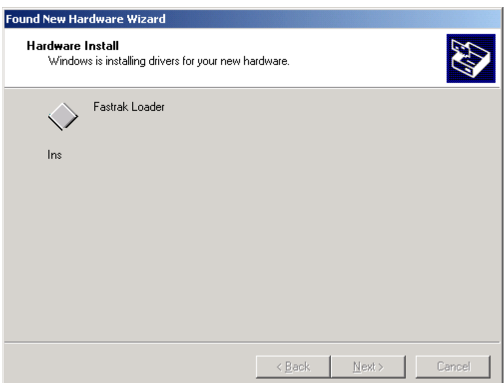
When the USB cable is connected from the FASTRAK to the host computer for the first time, the following message will appear:



Shortly after this message, the ‘Found New Hardware Wizard’ will be launched.

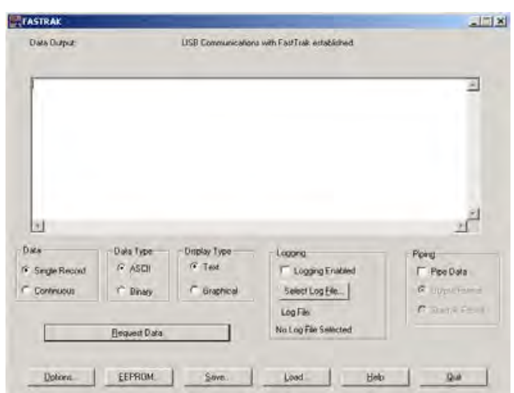


Make sure the CD containing the USB device driver is inserted into the drive before pressing 'Next' in the following window.

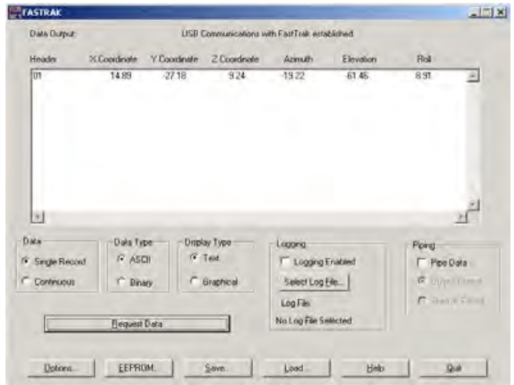


At this point, the device driver installation is complete and the host computer should be ready to communicate with the FASTRAK over the USB port with the user's application software.

To verify USB communication using the Polhemus GUI, double-click on the FASTRAK GUI icon (FT GUI). In the 'Data Output' field, the message "USB Communications with FASTRAK established" should be displayed as shown below:



Select the "Request Data" button to get data from the FASTRAK over the USB port.



Receiving data from the FASTRAK using the GUI confirms that the USB device drivers have been successfully installed on the host computer and the FASTRAK should now be able to communicate with the host application over the USB port. For subsequent utilization of the USB I/O, simply make sure that the USB communication cable is connected to the FASTRAK and the host computer, before turning on the FASTRAK power.

To return to RS-232 communication, disconnect the USB cable and cycle the power on the FASTRAK system. (Make sure the RS-232 cable is connected and that the host communication software settings are set correctly, i.e. com port selection, baud rate, parity, etc.)

8.6 Synchronization

Synchronization defines and controls the precise time that a FASTRAK system measurement cycle will start and thereby controls the tracking output from an application system point of view. The FASTRAK system has three distinct synchronization modes that are controlled by the 'y' – Set Synchronization Mode commands (page 83) and are defined as:

Command	Synchronization Mode
y0<>	Internal Sync. (Default)
y1<>	External Sync.
y2<>	Video Sync.

8.7 Internal Sync

In the Internal Sync mode, each measurement cycle of the FASTRAK system starts immediately after the previous cycle ends. The system update rate is slightly greater than 120 Hz, and cycle-to-cycle variations on the order of microseconds are possible in this mode. Only the 'y0' command is required to initiate the Internal Sync mode and no input is required for the system's SYNC IN port.

8.8 External Sync

The External Sync mode allows the user to define when the FASTRAK system measurement cycle will start, by means of a user supplied external sync pulse. This mode may be used to synchronize other peripheral instrumentation to the FASTRAK data collection cycle or to slow the FASTRAK to a known and desired rate. To initiate the External Sync mode an external signal as detailed in External Sync I/O on page 17 must be input to the SYNC IN port and the 'y1' command issued.

8.9 Video Sync

The Video Sync mode should be used when a receiver will be operating in close proximity to a CRT monitor and the FASTRAK measurements appear noisy. (The amount of noise detected will ultimately determine the definition of "close proximity," but it is usually when the receiver is less than 24 inches away from the monitor.) The reason this can occur is that all CRT monitors produce a magnetic field during the vertical refresh cycle. After connecting the video sync detector and sending the 'y2' command, the detector will sense the magnetic field and cause the FASTRAK to begin each measurement cycle after a slight pause for settling time. This ensures that the FASTRAK measurement cycle will not occur during the monitor refresh cycle and eliminate noisy data.

8.10 Multiple Systems Operation – FASTRAKS produced as of January 2012

When using more than one FASTRAK in the same area, it is important to ensure that each unit have a different Frequency Select Module.

NOTE: Separation distance is defined as the distance between the transmitter of one system and the receiver of another system when both systems are operating.

Without changing the frequency module, the minimum separation distance is 23 feet or 7 meters. If the Frequency Select Modules are different, then the minimum separation distance is 15 inches or 38 centimeters. Clearly, the latter option offers the greatest set up flexibility and user freedom. The separation distance guidelines are restated below for further clarification:

If systems have **identical Frequency Select Modules**:

- Separation distance should be 23 feet or 7 meters

If systems have **different Frequency Select Modules**:

- Separation distance should be 15 inches or 38 centimeters, with transmitter-to-transmitter adjacent spacing no closer than 6 inches or 15.2 centimeters

Again, separation distance is defined as the distance between the transmitter of one system and the receiver of another system. **NOTE:** These separation distances assume FASTRAK systems using standard 2-inch transmitters and standard receivers.

8.11 Output Considerations

Most applications of the FASTRAK system involve using its data output to manipulate some type of computer graphics in real time. In this condition, it is extremely important to allow the data to be utilized as quickly as possible and to avoid latency or lag. Lag is defined as the interval of time between requesting a tracker data point and receiving it into the host computer. Factors that could increase this lag are:

- Baud Rate
- Output Record Length

- Data Format (binary is more efficient than ASCII)
- Filtering

The FASTRAK baud rate should be set to the highest setting that is compatible with the host computer and the communication software. Although the FASTRAK system runs at 120 Hz, it may appear that it is running slower if the output is constrained by a slow baud rate. The FASTRAK is capable of running at speeds of up to 115,200 as selected by the I/O Select Switches on the back panel or as selected by the software command 'o' (see 'o' – Set Output Port on page 62 for full description). Of course, the USB interface can be utilized without concern for these limitations.

The FASTRAK default output record contains measurements for X, Y, Z in inches and Azimuth, Elevation, and Roll in degrees. This output format can be easily modified by using 'O' – Output Data List on page 57. Although the FASTRAK offers a variety of output selections, it is best to keep the output record length constrained only to the data that is needed. Excessive data in the output record can slow down the transmission and not allow the system to output data to the host at the maximum update rate.

The FASTRAK contains an adaptive filter that is designed to control noise in the data output. The filter can be applied to Position or Orientation or both and can be activated with "simple" commands that select "low", "medium", or "heavy" filtering. It should be noted that the effect that is seen in the data may have or appear to have a slower dynamic response with medium or heavy filtering selected.

9. System Commands

There are two classes of system commands: one class for configuring the state of the system, and the other for controlling its operation. The commands are presented in functional, alphabetical order. Where applicable, examples of the command in use will be given. All commands are input on the RS-232 serial port and consist of ASCII characters. Additionally, format notations and conventions for commands and outputs are presented first.

9.1 Command Format Notation and Convention

Use the following format notation to enter commands:

[ ] Items shown inside square brackets are optional. To include optional items, type only the information inside the brackets. *Do not type the brackets.*

<> Represents an ASCII carriage return or “enter”. Whenever shown this value must be present to terminate the command sequence.

... An ellipsis indicates that you can repeat an item.

, A comma represents a delimiter in a list of optional parameters. The comma must be present for those parameters which are omitted except for the case of trailing commas. For example:

Qs,p1,,,p4<>

is the proper command format when omitting parameters p2 and p3. Commas following the parameter p4 are not required if parameters p5 and p6 are omitted.

| A vertical bar means either/or. Choose one of the separated items and type it as part of the command. For example,

ON|OFF

indicates that you should enter either ON or OFF, but not both. *Do not enter the vertical bar.*

^ Represents the “Ctrl” key.

9.2 Command Format Notes

- All commands and alphabetic parameters are case sensitive. They must be entered in upper or lower case as defined in the syntax.

- Any command with a * next to it means that it cannot be stored in EEPROM; i.e., if a ‘^K’ – *Save Operational Configuration command (see page 85) is executed, the information will not be saved after the system power is turned off.

- For those commands involving an optional list of parameters, if some of the parameter values are omitted the current system-retained value of that parameter is used in its place.

- The RELATIVES field contains a list of those commands which provide related information to the system. For example, the ‘b’ – *Unboresight command (page 40) is a relative to the ‘B’ – *Boresight command (page 39).

- The term *station* is a transmitter-receiver pair. The four receivers paired with the one available transmitter are assigned station numbers one through four (1-4).

- FASTRAKs are shipped configured in one of four (4) possible frequencies. The frequencies are referenced as follows:

Ref. Number	Frequency
1	8013 Hz
2	10016 Hz
3	12019 Hz (Standard)
4	14022 Hz

- A numeric floating point value will be accepted by the FASTRAK if any of the following formats are used. **FOR EXAMPLE:** 3.0 may be specified as: 3, 3., 3.0 or 3.0 E+00.

  See each command’s format for generally accepted accuracy range.

- The notation R(Sxx.xxxB) represents the ASCII output format for the specific data element, where:

  R is the repeat count and what follows in parenthesis is repeated R times
  S is the sign byte, either +, -, or space (for +)
  X is a decimal digit (0...9)
  . is a decimal point
  B is a blank
  H is a hexadecimal digit (0...F)

  Example: A format 3(Sx.xxxxB), would be output as:

  -1.1111 2.2222 -3.3333

- For discussion purposes, all “Examples” assume only 1 receiver is used, connected to the station 1 receptacle.

9.3 Command/Output Listing

See pages that follow.

NOTE: Any command with a * next to it means that it cannot be stored in EEPROM; i.e., if a '^K' – *Save Operational Configuration command (see page 85) is executed, the information will not be saved after the system power is turned off.

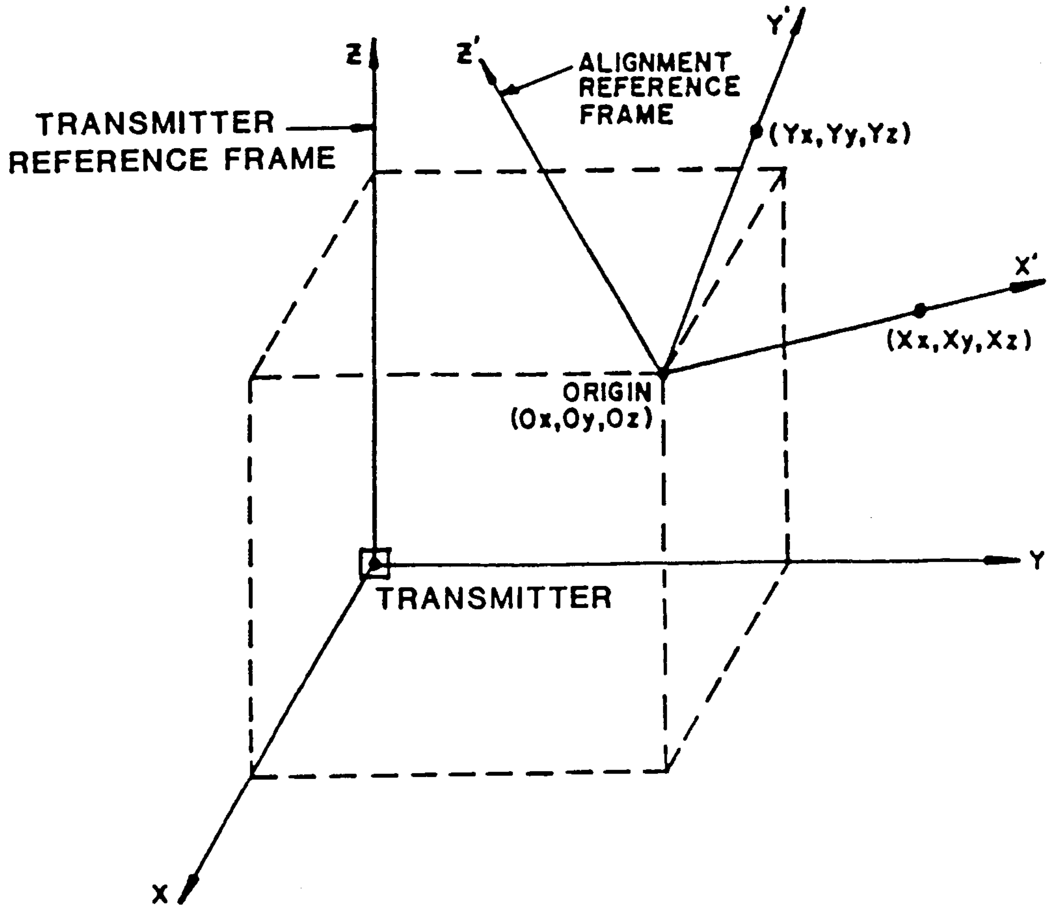


Figure 9-1 System Alignment

'A' – Alignment Reference Frame

Syntax: A*station*,[Ox],[Oy],[Oz],[Xx],[Xy],[Xz],[Yx],[Yy],[Yz]<>

or

A*station*<> to read back the current alignment

Purpose: The alignment command does two things. It defines a reference frame to which all position and orientation output data is referred. In addition, it creates a new origin point where the X, Y, Z measurements would equal 0,0,0 if the receiver were placed there. See Figure 9-1 on page 36. An example of where this command would be useful is a sloped test surface that the user wanted referenced to the transmitter. This would obtain congruence between the FASTRAK and the axes of the sloped surface.

NOTE: This command operates incrementally. If the command is entered and the user then decides to change it, the 'R' – *Reset Alignment Reference Frame command (page 66) must be used to reset the alignment reference frame ***BEFORE*** the command is re-entered. This is ***ESPECIALLY IMPORTANT*** to remember if the user makes an error and wants to correct the erroneous input because the new alignment would be additive to the mistake. The command parameters are:

station	1 to 4, which specifies the relevant transmitter/receiver pair.
Ox,Oy,Oz	the Cartesian coordinates of the origin of the new reference frame.
Xx,Xy,Xz	the coordinates of the point defining the positive direction of the X-axis of the new reference frame.
Yx,Yy,Yz	the coordinates of a third point that is in the positive Y direction from the X-axis.

Relatives: R

Range: No Range Restriction Enforced

Default: The transmitter reference frame is the default alignment reference frame. (0,0,0,200,0,0,0,200,0) in centimeters

Example: To perform an alignment on station 1, follow the steps listed below:

Standard Alignment Procedure

1. Send the command R1<>
2. Place the receiver at the proposed origin location
3. Press P and write down the X,Y,Z measurements (These will be Ox,Oy,Oz)
4. Move the receiver along the proposed X axis from the origin defined in step 2 and place it about 24 inches in front of this origin.
5. Press P and write down the X,Y,Z measurements (These will be Xx,Xy,Xz)

6. Move the receiver along the proposed Y-axis from the origin defined in step 2 and place it about 24 inches from the transmitter.
7. Press P and write down the X,Y,Z measurements (These will be Yx,Yy,Yz)
8. Using all of the data that has been written down in steps 1-7, send the command A1,Ox,Oy,Oz,Xx,Xy,Xz,Yx,Yy,Yz<>

Enhanced Alignment Procedure
A capability of the alignment command is called the Enhanced Alignment. The Enhanced Alignment feature allows the user to perform an alignment quickly and easily. The procedure is as follows:

1. Select the lowest station number receiver selected (usually station 1).
2. Issue the command A0<>. Sending this command prepares the system for collection of alignment data (3 data points) and resets previous alignments by sending the commands R1<>, R2<>, R3<>, and R4<>.
3. Place the receiver at the proposed origin location and press P once.
4. Move the receiver along the proposed positive X-axis from the origin and place it about 18” to 24” from the transmitter and press P once.
5. Move the receiver along the proposed positive Y-axis from the origin and place it about 18” to 24” from the transmitter and press P once.
6. The system then composes the alignment coordinates and prints the new alignment parameters to the screen.

SUB-RECORD IDENTIFIER .... A

INITIATING COMMAND .... A

byte(s)	Identification	Format
1	Record type, “2”	A1
2	Station Number	A1
3	Sub-record type “A”	A1
4-24	Origin coordinates	3(Sxxx.xx)
25-45	Positive X-axis coordinates	3(Sxxx.xx)
46-66	Positive Y-axis coordinates	3(Sxxx.xx)
67-68	Carriage return, line feed	

‘B’ – *Boresight

Syntax: B*station*<>

Purpose: This command causes the tracking receiver to be electronically aligned in orientation with the user system coordinates. This results in azimuth, elevation and roll outputs equal to the boresight reference values (usually 0,0,0 which is the system default) at the current orientation. The tracker then produces outputs relative to this reference. Any receiver orientation can be designated as the zero orientation point. The command parameter is defined as:

station the number of the station to be boresighted.

Relatives: b, G

Default: The zero orientation condition occurs when the receiver orientation corresponds to the transmitter orientation.

Example: The receiver may be mounted on a person’s head to measure where it is pointing. When the subject’s head is looking at a given object, the user may want the system angular outputs to be zero. The user can designate this receiver orientation as the zero orientation by sending the boresight command:

B1<>

This results in azimuth, elevation, and roll outputs of zero at this orientation. As the subject’s head moves away from the boresight point, the orientation angles are still measured relative to the transmitter, with the zero points shifted to the point where the boresight occurred.

‘b’ – *Unboresight

Syntax: b*station*<>

Purpose: This command removes the current boresight. The system boresight rotation matrix is reset to the identity matrix for the specified station. The command parameter is defined as:

station the number of the station to be boresighted.

Relatives: B, G

Example: If the user issued the ‘B’ – *Boresight command (page 39) while the receiver was at a particular orientation and then later decided that it would be best not to use a Boresight, or there was a need to see what the system reads without the Boresight, then the Unboresight command could be used as follows:

b1<>

(P, the command to request a single data record, could then be used to read the default orientation angles.)

'C' – Continuous Output Mode

Syntax: C

Description: Output transmit mode refers to whether the system automatically transmits data records to the host (continuous mode), or the host must request data records by sending a command to the system each time (non-continuous mode).

Purpose: This command enables the continuous print output mode. When the system is in continuous mode, the data points from all stations are requested automatically and are scrolled one after the other in a continuous "stream". If more than one station is enabled, then the data from each station will be displayed in numerical order (station 1 first, station 2 second, etc).

Relatives: c, P

Default: Continuous output mode is disabled.

Example: If the system is being used in an application where a fast update rate is critical, (driving real-time computer graphics, e.g. an animated character) then the continuous output configuration should be enabled. To enable continuous output mode, send the command as follows:

C

Data from the FASTRAK will now scroll continuously across the serial port to the host computer.

‘c’ – Disable Continuous Printing

Syntax: c

Purpose: This command disables the continuous print output mode. After sending this command, the continuous data stream from the FASTRAK to the host computer will stop.

Relatives: C, P

Default: Continuous output mode is disabled

Example: If the system is set to continuous output mode with the ‘C’ command, the user may wish to stop the data stream to adjust other system parameters. This can be accomplished by sending the command:

c

The continuous data output mode will be disabled and the data stream will stop.

'D' – Enable Fixed Metal Compensation

Syntax: D

Description: Compensation refers to programmed offsets that allow system computations to be accurate, while the system is used in an environment containing metal within close proximity of the transmitter and receiver. (Generating compensation requires the use of special fixtures and proprietary software and is usually performed by a Polhemus technician.)

Purpose: This command is used to turn on compensation offsets. If a custom calibration has not been performed by a Polhemus technician at the user location, then enabling this command will yield no change in the system outputs.

Relatives: D, d

Default: The default condition is compensation disabled.

Example: In most cases, the user is able to locate a test set up where compensation is not required. If it is required and Polhemus is contracted to perform a calibration, then the system will be left with compensation enabled. The command to enable compensation on all active stations is simply:

D

The compensation offsets will now be applied to all position and orientation measurements.

‘d’ – Disable Fixed Metal Compensation

Syntax: d

Purpose: This command disables fixed metal compensation. If a custom calibration has been performed by a Polhemus technician at the user location, then issuing this command will disable the compensation offsets in the system outputs.

Relatives: D

Default: The default condition is compensation disabled.

Example: A system could be calibrated (by Polhemus) at a particular user location and then later moved to a different location where the calibration is no longer required. The user should then disable the calibration that is no longer applicable. This could be accomplished with the command:

```
d
```

System measurements would no longer contain the compensation offset.

'e' – Define Stylus Button Function

Syntax: e[*station*],f*button*<>

Purpose: This command allows the user to put the FASTRAK stylus into different output modes by controlling the button function. The command parameters are defined as:

station the number of a station.

f*button* defines the function of the stylus button.

An entry of f*button* = 0 defines the output interaction as "mouse mode." The pushing of the stylus switch has no change on system output except that if the user has defined (by use of the 'O' – Output Data List command, page 57) an output with item 16 (switch status), then the status of the switch is reported in the output record. In this case, a 1 is reported in the output record when the switch is pressed and a 0 when it is not pressed.

An entry of f*button* = 1 defines a pseudo "point" or "track" mode interaction with the switch. In non-continuous mode of output, pressing the stylus switch has the same effect as sending a 'P' – Single Data Record Output command (page 63) to the system (point mode). In point mode, every time the button is pressed, a data record is sent to the host. In continuous output mode, pressing the stylus switch serves as a toggle for continuous output (track mode). The first time the button is pressed, continuous output mode is turned off. The next time the button is pressed, continuous output mode is turned back on again and so on.

Default: System default is f*button* = 1 (point and track mode stylus interaction)

Relatives: None.

NOTE: The stylus may be used *as a receiver* in any of the receiver ports. However, the button on the stylus will only work when the stylus is connected to Station 1. The stylus functions as a receiver with the electrical center offset from the tip of the stylus via software.

‘F’ – Enable ASCII Output Format

Syntax: F

Purpose: This command enables the ASCII output data format. ASCII format means that the data is generally human readable, while binary format is generally computer readable. Regardless of output data format selected, all input data (commands) to the FASTRAK system must be in ASCII format.

Relatives: f

Default: The default output data format is ASCII

Example: If a software application is written to receive binary data from the FASTRAK system and there was a requirement to take it offline temporarily to do visual checks, the user would enable the ASCII output data format in order to be able to easily read the FASTRAK data on the PC monitor. To do so, the following command should be sent:

F

The system will now be in ASCII output data format and can be read by the user.

‘f’ – Enable Binary Output Format

Syntax: f

Purpose: This command enables the binary output data format. Binary format is generally computer readable while ASCII format is human readable. This format is a 32 bit, floating point output that is in accordance with the format specified by ANSI/IEEE Std 754-1985 Specification for Binary Floating Point Arithmetic.

Relatives: F

Default: The default output data format is ASCII.

Example: The user may wish to write a software application for the FASTRAK where a fast update rate is crucial. In order to reduce data packet size, the FASTRAK could be set to output in binary instead of ASCII. This can be accomplished with the command:

f

The FASTRAK will now output binary data.

The notation SingleFP refers to the ANSI/IEEE Standard for Binary Floating-Point Arithmetic 754-1985 format of data. This is defined in the standard as:

MSB			LSB
Bit 31	Bit 30-23	Bit 22-0	
Sign	Exponent	Fraction	
Byte 3	Byte 2	Byte 1	Byte 0

The IEEE floating-point format uses sign magnitude notation for the mantissa, and an exponent offset by 127. In a 32-bit word representing a floating-point number, the first bit is the sign bit. The next 8 bits the exponent, offset by 127 (i.e. the actual exponent is e - 127). The last 23 bits are the absolute value of the mantissa with the most significant 1 implied. The decimal point is after the implied 1, or in other words, the mantissa is actually expressed in 24 bits. In the normal case an IEEE value is expressed as:

(-1)S * (2**(e-127)) * (01.f) If 0 < e < 255

In special cases:

(-1)S * 0.0	If e = 0 and f = 0
(-1)S * (2**(-126)) * (0.f)	If e = 0 and f <> 0 (denormalized)
(-1)S * infinity	If e = 255 and f = 0 (infinity)
NaN (not a number)	If e = 255 and f <>0

The actual I/O byte sequence is system specific. For the greatest compatibility, Polhemus has adopted for output the following Intel 80X86 byte ordering:

The lowest physical address for a byte is a0, a1 has address a0+1, etc. The least significant byte of data is b0, with b3 the most significant byte. For IEEE FP output from the Tracker/Digitizer, the byte output sequence is b0, b1, b2, & b3.

a0	a1	a2	a3	
b0	b1	b2	b3	80X86
b2	b3	b0	b1	DEC PDP-11
b3	b2	b1	b0	Z8000 / M680XX

‘G’ – Boresight Reference Angles

Syntax: G*station*,[Az*ref*],[El*ref*],[Rl*ref*]<>

or

G*station*<> to read back the current boresight reference angles

Purpose: This command establishes the bore-sight reference angles for a particular station. When the system is boresighted with the ‘B’ – *Boresight command (see page 39), the line-of-sight vector (Azimuth, Elevation, and Roll angles) will assume these values. If all the optional parameters are omitted, the system returns the boresight reference angles for the specified station as an output record of type ‘G’. The command parameters are defined as:

station the number of the station whose reference angles are to be fixed.

Az*ref* the azimuth reference angle.

El*ref* the elevation reference angle.

Rl*ref* the roll reference angle.

Relatives: B, b

Default: The system default boresight reference values are: 0, 0, 0

Example: The user may wish to set the boresight reference values to an orientation that corresponds with the application. For example, if the application required an output of 0, -15, 0 following a boresight, reference angles should be applied with the G command:

G1,0,-15,0<>

The boresight command (B1<>) will now cause the azimuth, elevation, and roll data output to be 0, -15, 0 respectively.

SUB-RECORD IDENTIFIER .... G

INITIATING COMMAND .... G

byte(s)	Identification	Format
1 ...	Record type, “2”	A1
2 ...	Station Number	A1
3 ...	Sub-record type ‘G’	A1
4-10 ...	Azimuth reference angle	Sxxx.xx
11-17 ...	Elevation reference angle	Sxxx.xx
18-24 ...	Roll reference angle	Sxxx.xx
25-26 ...	Carriage return, line feed	

'H' – Hemisphere of Operation

Syntax: H*station*,[p1],[p2],[p3]<>

or

H*station*<> to read back the current hemisphere selection

Description: Because of the symmetry of the magnetic fields generated by the transmitter, there are two mathematical solutions to each set of receiver data processed. Therefore, only half of the total spatial sphere surrounding the transmitter is practically used at any one time without experiencing an ambiguity (usually sign flips) in the X, Y, Z measurements. This half sphere is referred to as the current hemisphere. The chosen hemisphere is defined by an LOS (line-of-sight) vector from the transmitter through a point at the zenith of the hemisphere, and is specified by the LOS direction cosines.

Purpose: Since the receiver(s) can only operate in one hemisphere at a time relative to the transmitter, it is necessary to tell the FASTRAK system which side of the transmitter they will be on, for each station. A "hemisphere tracking" option is available, but important criteria must be met in order for it to work properly (see pages that follow for more information). Identification of command parameters is as follows.

station	the number of the station whose operational hemisphere is to be modified.
p1	the x-component of a vector pointing in the direction of the operational hemisphere. (Set to 0 to enable hemisphere tracking.)
p2	the y-component of a vector pointing in the direction of the operational hemisphere. (Set to 0 to enable hemisphere tracking.)
p3	the z-component of a vector pointing in the direction of the operational hemisphere. (Set to 0 to enable hemisphere tracking.)

If all of the optional parameters are set to 0, then hemisphere tracking will be enabled for the specified station.

IMPORTANT NOTES ABOUT HEMISPHERE TRACKING:

"Hemisphere tracking" is a feature whereby the tracker can continuously modify its operating hemisphere, given that it is started in a known, valid hemisphere.

1. When this command (H1,0,0,0<>) is sent to the FASTRAK system, the receiver of the specified station <u>must</u> be located in the currently set hemisphere.
2. If the '^K' – *Save Operational Configuration command (page 85) is sent to the FASTRAK system while hemisphere tracking is enabled, the **currently**

computed hemisphere will be saved (***not*** the hemisphere tracking feature) to the EEPROM. Therefore, sending '^K' during hemisphere tracking is not advised.

Relatives: None.

Default: The default hemisphere value is: 1,0,0 which is positive X or "forward" hemisphere. In addition, the hemisphere tracking feature is disabled in the default condition.

Example 1: The user may decide to mount the transmitter above the test area in order to be able to move the receiver to the positive and negative sides of X and the positive and negative sides of Y. (**NOTE:** since the default hemisphere value is "forward", the user cannot move the receiver to the negative X side of the transmitter, because the signs will flip and it will appear as if the X measurement never goes negative.) If the transmitter is positioned above the test area, the positive Z or "lower" hemisphere should be selected. This can be accomplished with the following command:

H1,0,0,1<>

Station 1 of the FASTRAK will now be set for the positive Z or "lower" hemisphere.

Although the hemisphere vector is not limited to 1s and Os, the following table of hemisphere commands may be useful:

Forward Hemisphere (+X)	H1,1,0,0<>
Back Hemisphere (-X)	H1,-1,0,0<>
Right Hemisphere (+Y)	H1,0,1,0<>
Left Hemisphere (-Y)	H1,0,-1,0<>
Lower Hemisphere (+Z)	H1,0,0,1<>
Upper Hemisphere (-Z)	H1,0,0,-1<>

Example 2: The user may decide to take advantage of the hemisphere tracking feature. Assuming the system is in the default hemisphere (forward), the following procedure should be used to enable hemisphere tracking on station 1:

1. Position the receiver on the positive X side of the transmitter (the side opposite from where the cable comes out of the transmitter shell) and turn the system on.
2. While the receiver is located in the forward hemisphere, send the hemisphere tracking command to the FASTRAK. The command should be: H1,0,0,0<>
3. The receiver can now be moved to any side of the transmitter, without worrying about hemisphere selection.
4. Do not save this configuration to the system EEPROM (using the '^K' command) because it will save whatever the current computed hemisphere selection happens to be for that position of the receiver relative to the transmitter.
5. If necessary, the user can disable the hemisphere tracking feature by sending a

"normal" hemisphere selection, e.g. H1,1,0,0<> to go back to the "forward" hemisphere selection.

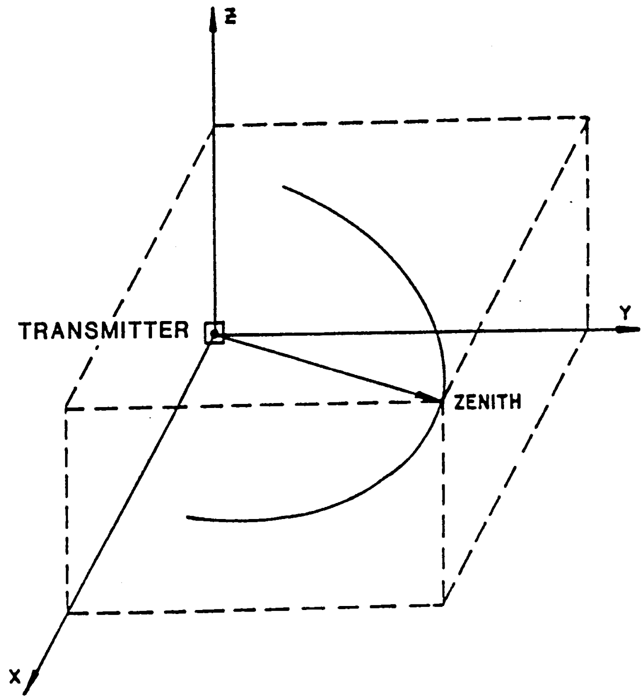


Figure 9-2 Hemisphere Vector
(Zenith represents the hemisphere vector)

RECORD IDENTIFIER .... H

INITIATING COMMAND .... H

byte(s)	Identification	Format
1	Record type, "2"	A1
2	Station number	A1
3	Sub-record type 'H'	A1
4-10	Vector x-component	Sxx.xxx
11-17	Vector y-component	Sxx.xxx
18-24	Vector z-component	Sxx.xxx
25-26	Carriage return, line feed	

'I' – Define Increment

Syntax: I*station*,[distance]<>

or

I*station*<> to read back the current increment selection.

Purpose: This command allows the user to control when data records will be sent to the host, based on receiver movement. The "distance" selection allows the user to specify exactly how much movement will be required before data is produced. If the user enters 'I*station*<>', the system outputs the current distance value selection. **NOTE:** The system should be in continuous output mode in order for this command to work properly. Definitions of the command parameters are listed below:

station the number of the station whose increment is to be changed.

distance the minimum distance a receiver must move before a data record is output to the host computer. The units of measure (inches or centimeters) for the distance value must be consistent with the current selection of system units.

Relatives: None.

Default: The default value is 0.0 inches, which disables the increment feature.

Example: If the user wants the system to output data each time the receiver on station 1 moves 2" in any axis, the following command should be entered:

I1,2<>

C

The system will now output a data record each time station 1 receiver moves 2" in any axis.

RECORD IDENTIFIER I

INITIATING COMMAND I

byte(s)	Identification	Format
1	Record type, "2"	A1
2	Station number	A1
3	Sub-record type 'I'	A1
4-10	Distance required to move	Sxxx.xx
11-12	Carriage return, line feed	

‘l’ – Active Station State

Syntax: l*station*,[state]<>

or

l*station*<> to read back the current station state

Description: A *station* is defined as a transmitter/receiver pair. The four receivers paired with the one transmitter are assigned station numbers one through four (1-4). Although stations are enabled simply by plugging the receivers into the ports on the FASTRAK SEU, the stations can then be disabled (or enabled again) by using a software command. When a station is enabled, data records for that receiver will be transmitted from that station. If the station is disabled, no data records from that station will be transmitted.

Purpose: The purpose of this command is to allow the host to turn a station “on” or “off” in software. The command parameters are identified as follows:

station 1 to 4

state 0 = off
1 = on

Relatives: None.

Default: The default condition depends on the number of receivers that are currently connected to the FASTRAK SEU. The default condition of a station that has a receiver connected to it is a “1” or station “on”. The default condition of a station that does not have a receiver connected to it is a “0” or station “off”.

Example: A user could connect four receivers to a FASTRAK and then collect a data point from two receivers at a time, after disabling the other two. To do so, the following commands would be sent:

1. Send the command l3,0<> to turn station 3 off.
2. Send the command l4,0<> to turn station 4 off.
3. Press P to collect a data point from stations 1 and 2.
4. Send the command l3,1<> to turn station 3 on.
5. Send the command l4,1<> to turn station 4 on.
6. Send the command l1,0<> to turn station 1 off.
7. Send the command l2,0<> to turn station 2 off.
8. Press P to collect a data point from stations 3 and 4.
9. Repeat steps 1 through 8 as necessary.

RECORD IDENTIFIER l

INITIATING COMMAND l

byte(s)	Identification	Format
1	Record type, “2”	A1
2	Station number	A1
3	Sub-record type ‘l’	A1
4	Station 1 = 1 if active, else 0	A1
5	Station 2 = 1 if active, else 0	A1
6	Station 3 = 1 if active, else 0	A1
7	Station 4 = 1 if active, else 0	A1
8-9	Carriage return, line feed	

'N' – *Define Tip Offsets

Syntax: N*station*,[xoff,yoff,zoff]<>

or

N*station*<> to read back the current tip offsets

Description: Each stylus has been factory calibrated with custom tip offsets. This is the offset of the receiver from the tip of the stylus. The tip offsets allow the tip to act as the measurement reference instead of the receiver coil inside the handle.

Purpose: This command allows the user to override the factory defaults for the stylus tip offsets. Although changing the tip offsets is not recommended, the ability to do so is available. The command parameters are listed below:

station	1-4
xoff	x-direction tip offset
yoff	y-direction tip offset
zoff	z-direction tip offset

Relatives: None

Default: Factory default tip offsets are read from the PROM inside the stylus connector on power-up. As a result, the 'N' command can only override the factory defaults during the current operational session.

Example: If the user created a special stylus tip attachment that extended exactly one inch from the end of the stylus, an adjustment to the tip offsets would have to be made. To do so, the following steps should be taken.

1. Verify that the FASTRAK system is in "inches" unit measurement by sending the 'u' command.
2. Read the factory tip offsets from the PROM in the connector by sending the command N1<>. (A typical factory tip offset might be 2.523, 0.004, 0.03.)
3. To add one inch to the factory calibration, type N1,3.523,0.004,0.03<>
4. To verify that the tip offset was entered correctly, type N1<> to read it back.

'O' – Output Data List

Syntax: O*station*,[p1],[p2],...,[p*n*]<>

Description: The output list refers to the subset of data items to be included in a data record. Any combination of up to 32 data items that total less than or equal to 254 bytes is permissible.

Purpose: This command allows the user to define the list of variables to be output to the host computer for the specified station. Any combination of up to 32 data items that total less than or equal 254 bytes is permissible. The allowable values of the parameters are:

0	ASCII space character
1	ASCII carriage return, line feed pair
2	x,y,z Cartesian coordinates of position
3	relative movement, x,y,z Cartesian coordinates of position; i.e., the difference in position from the last output. This item should only be selected if the specified station's Increment is = 0.0. See the 'I' – Define Increment command (page 53).
4	azimuth, elevation, roll Euler orientation angles
5	x direction cosines of the receiver's x,y,z axes - See Note 1.
6	y direction cosines of the receiver's x,y,z axes - See Note 1.
7	z direction cosines of the receiver's x,y,z axes - See Note 1.
8	not used
9	not used
10	not used
11	orientation quaternion
12	not used
13	not used
14	not used
15	not used
16	stylus switch status
17	not used
18	not used
19	16not used
20	not used
21-49	not used (reserved for future use)

Extended precision (50-66)

50	ASCII space character (same as 0)
51	ASCII carriage return, line feed pair (same as 1)
52	x,y,z Cartesian coordinates of position
53	relative movement - x,y,z Cartesian coordinates of position; i.e., the difference in position from the last output. This item should only be selected if the specified station's Increment is = 0.0. See the 'I' – Define Increment command (page 53).
54	az,el,roll Euler orientation angles
55	x direction cosines of the receiver's x, y, z axes - See Note 1.

56	y direction cosines of the receiver's x, y, z axes - See Note 1.
57	z direction cosines of the receiver's x, y, z axes - See Note 1.
58	not used
59	not used
60	not used
61	orientation quaternion
62	not used
63	not used
64	not used
65	not used
66	stylus switch status
67	not used (reserved for factory use)
68-98	not used (reserved for factory use)
99	not used (reserved for factory use)

Relatives: None.

Default: 0s,2,4,1<>; i.e., the three Cartesian coordinates, the three Euler orientation angles, carriage return, and line feed for stations 1 through 4.

Example: The user may decide to use X,Y,Z direction cosines instead of the default output format. In order to do so, the following command should be sent:

O1,5,6,7,1<>

The output data for station will now be displayed as X,Y,Z direction cosines.

RECORD IDENTIFIER .... O

INITIATING COMMAND .... O

byte(s)	Identification	Format
1	Record type, "2"	A1
2	Station number	A1
3	Sub-record type 'O'	A1
4-5	Data item 01 identification	I2
6-7	Data item 02 identification	I2
8-9	Data item 03 identification	I2
. ....		
. ....		
2*n+2 - 2*n+3	Data item n identification	I2
2*n+4 – 2*n+5	Carriage return, line feed	

System Data Record: ASCII Format

RECORD IDENTIFIER .... none

INITIATING COMMANDS ..... P or in continuous mode

Item	byte(s)	Identification	Format
	1 ..	Record type, "0"	A1
	2 ..	Station Number	A1
	3 ..	System Error Code (See note 2)	A1
Original Precision:			
0 or 50 ?* ..	ASCII space character		A1
1 or 51	?* ..	Carriage return, line feed	
2	?* ..	x,y,z position Cartesian Coordinates	3(Sxxx.xx)
4	?* ..	az,el,roll Euler orientation angles	3(Sxxx.xx)
5	?* ..	X-direction cosines of the receiver's x,y,z axis *(See Note 3.)*	3(Sx.xxxx)
6	?* ..	Y-direction cosines of the receiver's x,y,z axis *(See Note 3.)*	3(Sx.xxxx)
7	?* ..	Z-direction cosine of the receiver's x,y,z axis *(See Note 3.)*	3(Sx.xxxx)
11	?* ..	Orientation Quaternion (Q0-Q3)	4(Sx.xxxx)
16	?* ..	Stylus Switch	x where: x = 0 or 1
Extended precision:			
52	?* ..	x,y,z position Cartesian coordinates	3(Sx.xxxxxESxxb)
54	?* ..	az,el,roll Euler orientation angles	3(Sx.xxxxxESxxb)
55	?* ..	X-direction cosines of the receiver's x,y,z axis *(See Note 3.)*	3(Sx.xxxxxESxxb)
56	?* ..	Y-direction cosines of the receiver's x,y,z axis *(See Note 3.)*	3(Sx.xxxxxESxxb)
57	?* ..	Z-direction cosines of the receiver's x,y,z axis *(See Note 3.)*	3(Sx.xxxxxESxxb)
61	?* ..	Orientation Quaternion (Q0-Q3)	4(Sx.xxxxxESxxb)
66	?* ..	Stylus Switch	x where: x = 0 or 1

Factory use only:
8-10
12-15
17-49
58-60
62-65
67-69

* The system data record contents are specified by the user using the 'O' command and may vary from configuration to configuration. Therefore, the specific location of a data item in the output record is not determined until the record contents are defined.

Note 1. Original precision is retained for compatibility with previous Polhemus 3SPACE systems. Also, note that some item values are repeated as extended precision items, although no output difference is made (i.e., space, <cr lf>. Original and extended precision may be freely mixed in an output record, but it is recommended that extended precision be used if compatibility is not required, as the original precision may be deleted in future systems.

Note 2. This code will in general output the last error that the system BIT (Built-In-Test) routines found prior to the output of this system data record. If any BIT clearing has been commanded (see the 'T' – Built-In-Test Information command, page 70), the system will search for an error that is currently set, starting at the largest numeric error code value, and then output the first error code found in the search that is set. See 'T' – Built-In-Test Information, page 70, for specified definitions of each error code.

Note 3. Items 5, 6, and 7 or 55, 56, and 57 may be obtained to construct the line-of-sight, line-of-hear, and line-of-plumb vectors as follows:

Three (3) values are obtained from each item above.

Item 5 or 55 = | 5a 5b 5c | | 55a 55b 55c |
Item 6 or 56 = | 6a 6b 6c | | 56a 56b 56c |
Item 7 or 57 = | 7a 7b 7c | | 57a 57b 57c |

Then the a-column above is the line-of-sight vector, the b-column above is the line-of-hear vector, and the c-column above is the line-of-plumb vector.

System Data Record: IEEE Floating-Point Format

RECORD IDENTIFIER .... none

INITIATING COMMANDS ..... P or in continuous mode

byte(s)	Identification	Format
1	Record type, "0"	A1
2	Station Number	A1
3	System error code (See Note 2 on previous page.)	A1
?*	ASCII space character	A1
?*	Carriage return, line feed	
?*	x,y,z position Cartesian coordinates	3(SingleFP)
?*	az,el,roll Euler orientation angles	3(SingleFP)
?*	X-direction cosines of the receiver's x,y,z axes. *(See Note 1.)*	3(SingleFP)
?*	Y-direction cosines of the receiver's x,y,z axes. *(See Note 1.)*	3(SingleFP)
?*	Z-direction cosines of the receiver's x,y,z axes. *(See Note 1.)*	3(SingleFP)

?* The system data record contents are specified by the user using the 'O' – Output Data List command (page 57) and may vary from configuration to configuration. Therefore, the specific location of a data item in the output record is not determined until the record contents are defined.

‘o’ – Set Output Port

Syntax: o*rate,parity,bits,HHS*<>

Description: The system output port settings including RS-232 BAUD rate, parity, and number of bits per character may be established to specified values.

Purpose: Sets the output BAUD rate for RS-232 port to a specified rate. The parameters are:

rate is specified as follows:

24	=	2,400
48	=	4,800
96	=	9,600
192	=	19,200
384	=	38,400
576	=	57,600
1152	=	115,200

parity N = none, O = Odd, E = even

bits 7 or 8

Note 1. The number of stop bits is always one (1).

Note 2. For seven (7) bits, parity may be NONE, ODD, or EVEN. For eight (8) bits there is never a parity bit; i.e., NONE.

Note 3. 8 data bits are required when using either the standard binary format or the 16 BIT format.

Relatives: None.

Default: Based on I/O switch settings.

Example: Suppose there is a requirement to change the baud rate (in software) to 19,200 baud, while the rate set by the I/O select switches is 115.2K baud. It can be accomplished with the following command, without turning off and restarting the system.

o192,N,8,0<>

The system serial communication parameters will now be 19200-baud, no parity, 8 data bits, and 1 stop bit. **NOTE:** The communication software will now have to be re-set to the new baud rate (19,200) in order for communication with the system to continue.

‘P’ – Single Data Record Output

Syntax: P

Description: Output transmit mode refers to whether the system automatically transmits data records to the host (continuous output mode), or the host must request data records by sending a command to the system each time (non-continuous output mode).

Purpose: In non-continuous output mode, this command requests a single data record to be transmitted to the host. If more than one station is enabled, then data from each active station will be displayed in numerical order (station 1 first, station 2 second, etc. That is, a complete cycle of active stations will be output.)

Relatives: C, c

Default: Continuous output mode is disabled

Example: If the system is being used in an application where data is only needed a certain number of times, then the single data record output should be used. To request a single data record from the system, send the command as follows:

P

One data record from the FASTRAK system will be sent across the serial port to the host computer.

‘Q’ – Angular Operational Envelope

Syntax: Qs,[az*max*],[el*max*],[rl*max*],[az*min*],[el*min*],[rl*min*]<>

or

Qs<> to read back the current orientation limits

Purpose: This command allows the user to set maximum and minimum limits for the azimuth, elevation, and roll outputs. If the orientation outputs are outside of the limits defined by this command, the system will output an error ‘y’.

The specific parameters are:

s	the number of the station whose angular limits are to be established.
az*max*	the maximum azimuth value for the angular operational envelope.
el*max*	the maximum elevation value for the angular operational envelope.
rl*max*	the maximum roll value for the angular operational envelope.
az*min*	the minimum azimuth value for the angular operational envelope.
el*min*	the minimum elevation value for the angular operational envelope.
rl*min*	the minimum roll value for the angular operational envelope.

Relatives: V

Default: 180, 90, 180, -180, -90, -180

Example: If the FASTRAK system outputs were to be used to drive a gimbaled system that had physical orientation limits, then it would be a good idea to set the FASTRAK angular operational envelope to those limits. Suppose the gimbaled system had azimuth and elevation limits of +/-45 degrees. The following command should be sent:

Q1,45,45,180,-45,-45,-180<>

The FASTRAK data will now contain an error ‘y’ each time the azimuth or elevation limit is exceeded. In addition, the application software should be programmed to ignore any data record containing the ‘y’ error to avoid causing the gimbaled system to slam into a limit.

RECORD IDENTIFIER .... Q

INITIATING COMMAND .... Q

byte(s)	Identification	Format
1	Record type, “2”	A1
2	Station number	A1
3	Sub-record type ‘Q’	A1
4-12	Maximum azimuth value	Sxxx.xxxb
13-21	Maximum elevation value	Sxxx.xxxb
22-30	Maximum roll value	Sxxx.xxxb
31-39	Minimum azimuth value	Sxxx.xxxb
40-48	Minimum elevation value	Sxxx.xxxb
49-57	Minimum roll value	Sxxx.xxxb
58-59	Carriage return, line feed	

‘R’ – *Reset Alignment Reference Frame

Syntax: R*station*<>

Purpose: This command resets the alignment reference frame for the specified station to the station reference frame. It provides an easy way to re-align the reference frame to the factory default values. The command parameter is defined as:

station the number of the station to be reset.

Relatives: A

Example: Any time the alignment command (A1...) is used, it is best to send the reset alignment command (R1<>) first. That way, there is no risk of building one alignment on top of another. See ‘A’ – Alignment Reference Frame on page 37 for the Standard Alignment Procedure.

‘r’ – Transmitter Mounting Frame

Syntax: r*station*,[*A*],[*E*],[*R*]<>

or

r*station*<> to read back the current transmitter mounting frame

Purpose: This command allows the user to modify the mounting frame coordinates of the transmitter relative to a particular receiver. It is basically a non-physical rotation of the transmitter and becomes the new orientation reference for the specified receiver’s measurements. The command parameters are as follows:

station	the station to be defined
A	azimuth mounting frame angle
E	elevation mounting frame angle
R	roll mounting frame angle

Relatives: None.

Default: 0,0,0

Example: If there was a requirement to mount the transmitter upside down, (more mechanically feasible) then the following command should be used.

r1,0,0,180<>

The orientation measurements for station 1 will now look as if the transmitter had not been mounted upside down.

RECORD IDENTIFIER .... r

INITIATING COMMAND .... r

byte(s)	Identification	Format
1 ...	Record type, “2”	A1
2 ...	Station Number	A1
3 ...	Sub-record type ‘r’	A1
4-11 ...	Azimuth mounting frame angle	Sxxx.xxx
12-19 ...	Elevation mounting frame angle	Sxxx.xxx
20-27 ...	Roll mounting frame angle	Sxxx.xxx
28-29 ...	Carriage return, line feed	

‘S’ – System Status Record

Syntax: S

Description: Status refers to the capability to determine information about the system that is not available from other commands. This command allows the operator to verify communication, determine system configuration, check for BIT errors, determine the firmware version number and read system identification information.

Purpose: This command allows the operator to request a status record from the FASTRAK system.

Relatives: T

Default: N/A

Example: Sending the ‘S’ command to the system will yield an output similar to the following (where “_” indicates a space):

2aSfffbbb_F3c_ _ _ j.k.lmxxxx…

- The fact that the status record was received verifies communication
- **2** is the record type
- **a** is the station number
- **S is the command**
- **fff** is the hex code for system configuration (see following pages for explanation)
- **bbb** is the BIT error code (three spaces indicate “no errors”)
- **F3** is the ID tag
- **c** is the map of present sensors
- **j.k.lm** is the firmware version number
- The remainder (xxxx…) is system identification information that can be programmed by the operator, using the ‘X’ – Configuration Control Data command (page 80)

NOTE: The station listed is chosen by the FASTRAK, depending on when the ‘S’ command is sent during the cycle. The user may have to issue this command several times in order to get the status data for a particular station.

RECORD IDENTIFIER .... S

INITIATING COMMAND .... S

byte(s)	Identification		Format
1	Record type, "2"		A1
2	Station number		A1
3	Sub-record type 'S'		A1
4-6	System flags		H3
	LSBit		
	0	Output Format	(0=ASCII,1=Binary)
	1	Units	(0=Inches, =Centimeters)
	2	Compensation	(0=Off, 1=On)
	3	Transmit Mode	(0=Non-Continuous, =Continuous)
	4	Configuration	(1=Tracker)
	5	Always 1	(Reserved for future use)
	6-9	Reserved	
	10-23	Reserved for future use	
	MSBit		
7-9	BIT error		I3
10	Blank (Reserved for future use)		A1
11-12	F3 ID Tag		A2
13	Sensor Map		A1
14-15	Blank/Reserved		A2
16-21	Software Version ID		A6
22-53	System Identification (See 'X')		A32
54-55	Carriage return, line feed		

The system's configuration status is contained as a hexadecimal number in the fourth, fifth, and sixth columns of the 'S' command output. For convenience, the following table lists the hexadecimal number and corresponding system configuration.

HEX Code	Continuous Mode	Compensation	Units	Output
3FF	ON	ON	CM	Binary
3FE	ON	ON	CM	ASCII
3FD	ON	ON	IN	Binary
3FC	ON	ON	IN	ASCII
3FB	ON	OFF	CM	Binary
3FA	ON	OFF	CM	ASCII
3F9	ON	OFF	IN	Binary
3F8	ON	OFF	IN	ASCII
3F7	OFF	ON	CM	Binary
3F6	OFF	ON	CM	ASCII
3F5	OFF	ON	IN	Binary
3F4	OFF	ON	IN	ASCII
3F3	OFF	OFF	CM	Binary
3F2	OFF	OFF	CM	ASCII
3F1	OFF	OFF	IN	Binary
3F0	OFF	OFF	IN	ASCII

'T' – Built-In-Test Information

Syntax: TBIT*number*[,0]<>

Purpose: This command allows the user to obtain additional information about a particular BIT and clear a BIT error. The additional information is meaningful only to factory personnel. The 'T' command is useful to attempt to clear a problem; however, if an error re-occurs, and after you have verified your setup configuration, consultation with the factory is recommended. The parameters are:

BIT*number* The BIT number for which added information is requested (see below).

0 This parameter, if used, is specified as a 0 (zero). If present the BIT*number* specified is reset/cleared.

Relatives: S

Default: N/A

Example:

BIT number	Code	Transmitter & Receiver Error Codes
65	A	X Driver Linearity
66	B	Y Driver Linearity
67	C	Z Driver Linearity
68	D	x Gain Linearity
69	E	y Gain Linearity
70	F	z Gain Linearity
71	G	X Slope of Driver X Linearity Line
72	H	Y Slope of Driver Y Linearity Line
73	I	Z Slope of Driver Z Linearity Line
74	J	X Slope of Coil / Receiver X Linearity
75	K	Y Slope of Coil / Receiver Y Linearity
76	L	Z Slope of Coil / Receiver Z Linearity
77-83		Not Used (Reserved for future use)
84	T	Receiver PROM Error
85	U	Transmitter PROM Error
86	V	Receiver PROM Circuit Error
87	W	Transmitter PROM Circuit Error
88	X	Driver Characterization Validity
89	Y	Receiver Characterization Validity
90	Z	Receiver Coil Validity

BIT number	Code	Self Calibration Error Codes
97	a	X Driver Limits Self-Calibration
98	b	Y Driver Limits Self-Calibration
99	c	Z Driver Limits Self-Calibration
100	d	x Gain Limits Self-Calibration
101	e	y Gain Limits Self-Calibration
102	f	z Gain Limits Self-Calibration
103	g	Coil Limits Self-Calibration
104	h	Not Used in FASTRAK

BIT number	Code	Signal Matrix Error Codes
105	i	Not Used in FASTRAK
106	j	A Signal Saturation
107	k	A Low Signal
108	l	A Maximum Signal Element Zero

BIT number	Code	EEPROM Error Codes
109	m	EEPROM Validity Checksum Error or Data Validity Discrepancy
110	n	Reserved for Future Use
111	o	Reserved for Future Use
112	p	Reserved for Future Use
113	q	Reserved for Future Use
114	r	Reserved for Future Use

BIT number	Code	Soft Error Codes
115	s	Unit Normal Position Vector Reset (P/R-Norm)

BIT number	Code	Miscellaneous Error Codes
116	t	Compensation Structure Errors (Array Size Not In Specification Limits)
117	u	Compensation Point Not Within Mapped Bounds
118	v	No CRT Sync Signal Available
119	w	Write Error on Configuration EEPROM
120	x	Receiver Out of Motion Box
121	y	Euler Angles Outside Allowed Angular Envelope
122	z	Reserved

RECORD IDENTIFIER .... T

INITIATING COMMAND .... T

byte(s)	Identification	Format
1 ...	Record type, “2”	A1
2 ...	Blank	A1
3 ...	Sub-record type ‘T’	A1
4-6 ...	BIT number	I3
7-?? ...	BIT information (Factory meaningful only)	A??
??-?? ...	Carriage return, line feed	

‘U’ – English Conversion Units

Syntax: U

Description: Input/output unit is a reference to the distance unit assumed by the system when interpreting input and generating output data.

Purpose: This command sets the distance unit to English (or inches.) Subsequent input and output lengths will be interpreted as inches.

Relatives: u

Default: The system default unit is inches.

Example: Assuming the system units had already been changed to centimeters (with the ‘u’ command), the following command could be sent to change back to inches:

U

The system will now output data in inches and interpret input data in inches.

'u' – Metric Conversion Units

Syntax: u

Purpose: This command sets the distance unit to metric (or centimeters.) Subsequent input and output lengths will be interpreted as centimeters.

Relatives: U

Default: The system default unit is centimeters.

Example: If the operator wanted the system to output its measurements in centimeters, the following command should be sent:

u

The system will now output data in centimeters.

'V' – Position Operational Envelope

Syntax: Vs,[x*max*],[y*max*],[z*max*],[x*min*],[y*min*],[z*min*]<>

or

Vs<> to read back the current limits

Description: The position operational envelope is an area defined by X, Y, Z minimum and maximum limits. It provides the user with a means of specifying the location of the limits and notifies the user when the limits have been exceeded.

Purpose: This command establishes the position operational envelope limits. If the X, Y, Z output measurements are outside the limits defined by this command, the system will produce a BIT error 'x'. The specific parameters are:

s	the number of the station whose position limits is to be returned or established.
x*max*	the maximum x-coordinate for the position operational envelope.
y*max*	the maximum y-coordinate for the position operational envelope.
z*max*	the maximum z-coordinate for the position operational envelope.
x*min*	the minimum x-coordinate for the position operational envelope.
y*min*	the minimum y-coordinate for the position operational envelope.
z*min*	the minimum z-coordinate for the position operational envelope.

Relatives: Q

Default: 78.74,78.74,78.74,-78.74,-78.74,-78.74

200,200,200,-200,-200,-200 (in centimeters)

Example: If the user wanted to reduce the position operation envelope to a 30" cube, the following command should be sent:

V1,30,30,30,-30,-30,-30<>

The system will now output an error 'x' any time the 30-inch limit is exceeded in any of the axis for station 1.

RECORD IDENTIFIER V

INITIATING COMMAND V

byte(s)	Identification	Format
1	Record type, “2”	A1
2	Station number	A1
3	Sub-record type ‘V’	A1
4-11	Maximum x-coordinate value	Sxxx.xxx
12-19	Maximum y-coordinate value	Sxxx.xxx
20-27	Maximum z-coordinate value	Sxxx.xxx
28-35	Minimum x-coordinate value	Sxxx.xxx
36-43	Minimum y-coordinate value	Sxxx.xxx
44-51	Minimum z-coordinate value	Sxxx.xxx
52-53	Carriage return, line feed	

‘v’ – Attitude Filter Parameters

Syntax: v[*F*],[*FLOW*],[*FHIGH*],[*FACTOR*]<>

or

v[*n*]<> Macro filter command

or

v<> to return the current filter values selected

Purpose: This command establishes the sensitivity, boundary, and transition control parameters for the adaptive filter that operates on the attitude outputs of the tracking system. The user can adjust the parameters of this command to fine-tune the overall dynamic response of the tracker.

F a scalar value that establishes the sensitivity of the filter to dynamic input conditions by specifying the proportion of new input data to recent average data that is to be used in updating the floating filter parameter/ variable.

Allowable range of values: 0 < *F* < 1

FLOW a scalar value that specifies the maximum allowable filtering to be applied to the outputs during periods of relatively static input conditions. Setting this value to 1.0 disables the filter completely.

Allowable range of values: 0 < *FLOW* < *FHIGH* or 1.0 to disable filter

FHIGH a scalar value that specifies the minimum allowable filtering to be applied to the outputs during periods of highly dynamic input conditions.

Allowable range of values: *FLOW* < *FHIGH* < 1

FACTOR a scalar value that specifies the maximum allowable transition rate from minimum filtering (for highly dynamic input conditions) to maximum filtering (for relatively static input conditions) by proportionately limiting the decay to the low filter limit whenever the input conditions effect a transition to a narrower bandwidth.

Allowable range of values: 0 < *FACTOR* < 1

When the form of the command is v,1<> the attitude filter is disabled. This is the system default configuration.

n Macro filter is enabled when *n*>=2 as defined below: (Note this also sets the macro filter setting for position. See 'x' command.)

n=2 No Filter (This macro has the same effect as v,1<> above)
n=3 Low Filter
n=4 Medium Filter
n=5 Heavy Filter

Example: To select medium filtering, type v4<>

The filter is a single-pole low-pass type with an adaptive pole location (i.e., a floating filter "parameter/variable"). The pole location is constrained within the boundary values *FLOW* and *FHIGH* but is continuously self-adaptive between these limits as a function of the sensitivity parameter F and the sensed (ambient noise plus rotational rate) input conditions. For input "rate" conditions that fall within the adaptive range, the adaptive feature varies the pole location between the *FLOW* and *FHIGH* limits so as to maximize the output resolution for static inputs while minimizing the output lag for dynamic inputs. Whenever the input conditions cause the filter to make a transition to a narrower bandwidth (i.e., increased filtering), the transition rate of the pole location is constrained to a maximum allowable rate by the parameter *FACTOR*. If all of the optional parameters are omitted the current value of each parameter is returned to the user as an output record of type 'v'.

Relatives: None.

Default: The default mode for all filter parameters is "medium." These settings may be used as a starting point for determining optimum filtering in your particular environment.

F	0.2
FLOW	0.2
FHIGH	0.8
FACTOR	0.95

Example: Although they are already stored in the system EEPROM, medium filtering can be selected by sending the following command to the system:

v.2,.2,.8,.95<>

All active stations will now have medium filtering applied to the attitude measurements.

RECORD IDENTIFIER v

INITIATING COMMAND v

byte(s)	Identification	Format
1	Record type, “2”	A1
2	Blank	A1
3	Sub-record type ‘v’	A1
4-10	Filter sensitivity	bSx.xxx
11-17	Floating filter low value	bSx.xxx
18-24	Floating filter high value	bSx.xxx
25-31	Transition rate maximum	bSx.xxx
32-33	Carriage return, line feed	

'W' – Reset System to Defaults

Syntax: W

Purpose: This command resets all of the system EEPROM variables to their factory default values. When using this command, the '^K' – *Save Operational Configuration command (page 85) could be used afterwards to save the factory default values to the EEPROM if that is desired. Then the '^Y' – *Reinitialize System command (page 88) can be used to reinitialize the system and verify that the factory defaults are now stored in the system EEPROM.

Relatives: ^K, ^Y, X

Default: N/A

Example: If the FASTRAK EEPROM had been altered (by sending various other commands and saving the result to the EEPROM) and the user wanted to return the system to its original factory default settings, then the following commands should be sent:

W

^K

^Y

The green light on the front panel of the FASTRAK will now blink several times while the system is initializing. After initialization, the system EEPROM will be set with all of the factory default parameters. This exercise is especially useful when the system has been modified to the point where the user is not sure how to get back to factory defaults. However, care should be taken because **all** custom settings will be lost as a result of the reset.

NOTE: This command should only be used after consultation with Polhemus.

'X' – Configuration Control Data

Syntax: X[*string*]<>

or

X<> to retrieve the current configuration control data.

Definition: Configuration control data is user-specified information that is stored in the status record. (The status record is retrieved with the 'S' – System Status Record command, page 68.) This gives the user the ability to identify a particular FASTRAK system in the status record.

Purpose: A maximum of 32 ASCII characters may be entered as configuration control data in EEPROM with this command. The '^K' – *Save Operational Configuration command (page 85) must be used to save the new configuration control data in the FASTRAK EEPROM. The specific parameters are:

string a maximum of 32 ASCII characters can be used to identify the configuration control data.

Relatives: ^K, ^Y, W

Default: The default configuration control data retrieved with the 'X' command is as follows:

OutputCompensat CPG2030-003-10 (This is a Polhemus configuration code.)

Example: A user could enter project specific information with the 'X' command as follows:

XF18 Simulator05 Saint Louis<>

Sending the 'S' command to the system would yield the following result:

21S3F0 0 103.00F18 Simulator05 Saint Louis

NOTE: Resetting the EEPROM with the 'W' – Reset System to Defaults command (page 79) alters the contents of this data area to:

OutputCompensat CPG2030-003-10.

RECORD IDENTIFIER X
INITIATING COMMAND X

byte(s)	Identification	Format
1	Record type, "2"	A1
2	Blank	A1
3	Sub-record type 'X'	A1
4-35	Configuration identification	A32
36-37	Carriage return, line feed	

'x' – Position Filter Parameters

Syntax: x[*F*],[*FLOW*],[*FHIGH*],[*FACTOR*]<>

or

x[*n*]<> Macro filter command

Purpose: This command establishes the sensitivity, boundary, and transition control parameters for the adaptive filter that operates on the position outputs of the tracking system. The user can adjust these parameters to fine-tune the overall dynamic response of the system.

F a scalar value that establishes the sensitivity of the filter to dynamic input conditions by specifying the proportion of new input data to recent average data that is to be used in updating the floating filter parameter/variable.

Allowable range of values: 0 < *F* < 1

FLOW a scalar value that specifies the maximum allowable filtering to be applied to the outputs during periods of relatively static input conditions. Setting this value to 1.0 disables the filter completely.

Allowable range of values: 0 < *FLOW* < *FHIGH* or 1.0 to disable

FHIGH a scalar value that specifies the minimum allowable filtering to be applied to the outputs during periods of highly dynamic input conditions.

Allowable range of values: *FLOW* < *FHIGH* < 1

FACTOR a scalar value that specifies the maximum allowable transition rate from minimum filtering (for highly dynamic input conditions) to maximum filtering (for relatively static input conditions) by proportionately limiting the decay to the low filter limit whenever the input conditions effect a transition to a narrower bandwidth.

Allowable range of values: 0 < *FACTOR* < 1

When the form of the command is x,1<> the position filter is disabled. This is the system default configuration.

n Macro filter is enabled when n>=2 as defined below: (Note this also sets the macro filter setting for attitude. See 'v' command.)

n=2 No Filter (This macro has the same effect as x,1<> above)
n=3 Low Filter
n=4 Medium Filter
n=5 Heavy Filter

Example: To select medium filtering, type x4<>

The filter is a single-pole low-pass type with an adaptive pole location (i.e., a floating filter "parameter/variable"). The pole location is constrained within the boundary values *FLOW* and *FHIGH* but is continuously self-adaptive between these limits as a function of the sensitivity parameter *F* and the sensed (ambient noise plus translational rate) input conditions. For input "rate" conditions that fall within the adaptive range, the adaptive feature varies the pole location between the *FLOW* and *FHIGH* limits so as to minimize the output resolution for static inputs while minimizing the output lag for dynamic inputs. Whenever the input conditions cause the filter to make a transition to a narrower bandwidth (i.e., increased filtering), the transition rate of the pole location is constrained to a maximum allowable rate by the parameter *FACTOR*. If all of the optional parameters are omitted, the current value of each parameter is returned to the caller as an output record of type 'x'.

Relatives: None.

Default: The default mode for all filter parameters is "medium." These settings may be used as a starting point for determining optimum filtering in your particular environment.

F	0.2
FLOW	0.2
FHIGH	0.8
FACTOR	0.95

Example: Although they are already stored in the system EEPROM, medium filtering can be selected by sending the following command to the system:

x.2,.2,.8,.95<>

All active stations will now have medium filtering applied to the position measurements.

RECORD IDENTIFIER x
INITIATING COMMAND x

byte(s)	Identification	Format
1 ...	Record type, "2"	A1
2 ...	Blank	A1
3 ...	Sub-record type 'x'	A1
4-10 ...	Filter sensitivity	bSx.xxx
11-17 ...	Floating filter low value	bSx.xxx
18-24 ...	Floating filter high value	bSx.xxx
25-31 ...	Transition rate maximum	bSx.xxx
32-33 ...	Carriage return, line feed	

‘y’ – Set Synchronization Mode

Syntax: y[*smode*]<>
or
y<> to read back the current synchronization mode

Description: Synchronization allows for any one of four conditions:

1. The FASTRAK system can operate in its default condition with the data cycle time set to 8.3 milliseconds. This can be achieved by setting the system to Internal Sync Mode.
2. One to four FASTRAK systems can operate in relatively close proximity without interfering with each other. (The interference is generally seen as noise, where measurements change without physically moving receiver position or orientation.) This can be achieved by setting the system to External Sync Mode and linking the systems together with a sync cable.
3. The FASTRAK cycle time can be set externally with a sync pulse generator. This can be achieved by setting the system to External Sync Mode and connecting to the external pulse.
4. The FASTRAK receivers can operate in relatively close proximity to a CRT video monitor without picking up interference. This can be achieved by setting the system to Video Sync Mode and connecting the video sync detector between the FASTRAK and the CRT monitor.

Purpose: This command allows the host to set the system synchronization mode. The specific parameters are:

smode	Description
0	**Internal Sync Mode**. Signifies that the system is synced internally (8.3 milliseconds/cycle time).
1	**External Sync Mode**. Signifies that the system is externally synced to another FASTRAK system or an external sync source. (Note: This setting can not be saved to EEPROM with the ‘^K’ command.)
2	**Video Sync Mode**. Signifies that the system is synced via a video frequency pickup coil.

Relatives: None.

Default: 0 Internal Sync Mode

Example: If the user had a requirement to operate two FASTRAK systems in relatively close proximity, the following steps should be taken:

1. Designate one FASTRAK system as the master and the other as the slave. **NOTE:** Make sure that the two FASTRAKs have different colored dots on them so you will know that they are operating at different frequencies.
2. Connect one end of the sync cable to the “sync out” receptacle of the master FASTRAK.
3. Connect the other end of the sync cable to the “sync in” receptacle of the slave FASTRAK.
4. Send the command y0<> to the master FASTRAK.
5. Send the command y1<> to the slave FASTRAK.

The two systems will now be synced together. **NOTE:** Although synchronization allows two FASTRAKs to operate in relatively close proximity, make sure the receiver of one system does not get closer to the transmitter of the other system than it is to the transmitter of its own system.

See Multiple Systems (page 32) for multiple systems synchronization.

RECORD IDENTIFIER .... y

INITIATING COMMAND .... y

byte(s)	Identification	Format
1	Record type, “2”	A1
2	Blank	A1
3	Sub-record type ‘y’	A1
4	Synchronization mode 0 - none - free run 1 = External 2 = CRT	I1
5-6	Carriage return, line feed	

'^K' – *Save Operational Configuration

Syntax: ^K

Definition: EEPROM (Electronically Erasable Programmable Read Only Memory) is memory that can be altered by the system, but is not lost when the power is turned off. System variables are stored in the EEPROM. All of these variables are assigned default values. The values are assigned to these variables at the factory and are therefore called the factory defaults. The default values are applied to the variables at initial power-up and system reset.

Purpose: This command allows the user to save the current state of the system configuration parameters to the system EEPROM. This state is henceforth the power up state until another '^K' – *Save Operational Configuration command (page 85) is issued. **NOTE:** There may be a short pause of several seconds while the system executes this command.

Relatives: ^Y, W, X

Default: N/A

Example: If the system were used in an application where only position measurements on station 1 were required and they had to be in metric units, the following commands should be sent:

1. O1,2,1<>
2. u
3. ^K

The system will now be configured to output metric, position measurements only on station one, each time it is powered on.

'^Q' – *Resume Data Transmission

Syntax: ^Q

Purpose: Resumes data transmission to the host device following suspension of transmission by a ^S command. If a previous ^Q command has been issued, without an intervening ^S, this command will have no effect.

Relatives: ^S

Default: N/A

Example: If the FASTRAK system had been issued the 'C' – Continuous Output Mode command (page 41) to output data continuously and then the '^S' – *Suspend Data Transmission command (page 68) had been used to suspend or temporarily stop the data transmission, the following command could be used to start the data again:

^Q

The continuous data stream will now resume.

'^S' – *Suspend Data Transmission

Syntax: ^S

Purpose: This command suspends data transmission to the host device until a subsequent '^Q' – *Resume Data Transmission (page 86) is received. If a previous '^S' command has been issued, without an intervening '^Q', this command will have no effect.

Relatives: ^Q

Default: N/A

Example: If the FASTRAK system had been issued the 'C' – Continuous Output Mode command (page 41) to output data continuously the following command could be used to suspend or temporarily stop the data transmission:

^S

The data stream will stop scrolling and will not begin again until a '^Q' – *Resume Data Transmission (page 86) is issued.

'^Y' – *Reinitialize System

Syntax: ^Y

Purpose: Reinitializes the entire system to the power up state. The user should allow sufficient time for the system to run through its self test and initialization (wait for the green light to stop flashing) before attempting to send the system additional commands.

Relatives: ^K, W, X

Default: N/A

Example: If the user wanted to set the system EEPROM back to its original, factory default condition, the following commands should be sent:

1. W
2. ^K
3. ^Y

The system will now be in its original factory default condition. The '^Y' simulates turning the system power off, then back on again to allow user to verify the '^K' – *Save Operational Configuration command (page 85) worked properly.

10. Command Error

Command errors are defined as follows:

COMMAND ERROR

RECORD IDENTIFIER .... *

INITIATING COMMAND .... all invalid commands

byte(s)	Identification	Format
1 ...	Record Type, “2”	A1
2 ...	Blank	A1
3 ...	Sub-record type ‘E’	A1
4-10 ...	“*ERROR*”	
11-?? ...	Erroneous command as it was input	
??-+11...	“*ERROR* EC”	
??-?? ...	Error code from following list: -1 Required field missing -2 Required numeric is non-numeric -3 Value is outside required range -4 Specified frequency not hardware configured -5 Internal buffer limits exceeded -99 Undefined input - cannot identify command	
??-+3 ...	“*PS” (position)	
??-?? ...	Character position in the input record - note numbering starts 0,1,2...	
??-+3 ...	“*FL” (field)	
??-?? ...	Field number causing the error - note numbering of the field is 0,1,2... and starts at ‘0’ following the command identifier.	
??-+3 ...	“*ST” (station)	
??-?? ...	Number of the affected system station less 1; i.e., this value ranges from 0-3, stations are numbered in commands as 1-4.	

11. Default Operation with a Stylus

The stylus may be used *as a receiver* in any of the receiver ports. However, the button on the stylus will only work when the stylus is connected to Station 1. The stylus functions as a receiver with the electrical center offset from the tip of the stylus via software.

Operation of the switch on the Stylus will cause the following actions as a function of the various FASTRAK commands and modes.

No other actions are possible.

In NON-continuous output mode pressing the switch defines to the FASTRAK system a 'P' command. When a 'C' – Continuous Output Mode command (see page 41) is entered via RS-232 or USB to enable continuous mode, the system immediately responds with output as defined in the manual; however, when the Stylus switch is pressed, output is interrupted (but this cycle is completed; i.e., all currently configured stations complete output for this cycle). The Stylus switch then serves as a toggle for system output from then on until an RS-232 or USB 'c' command is issued. Each toggle will initiate or terminate a continuous stream of output that begins with station one (1) and terminates (by a subsequent switch pressing) with output for the last station in the cycle list.

Note that all output begins with the FIRST station (in the sequence 1, 2, 3, 4) that is configured ON and ends with the LAST station in the sequence list that is configured ON. Configured ON requires both a proper selection switch at power-on, or enabling the station via the 'l' – Active Station State command (page 54).

Increment functions are as previously defined in this document. That is, if any receiver does NOT move, since its last cycle, by an amount equal to or greater than its defined increment, output is skipped for the receiver when the above actions cause an output.

A switch cycle takes 40 system cycles. At 8.33 msec per cycle, the switch is responsive at a speed of 333 msec or about 1/3 second. In other words, if the switch is held down while the system is in NON-continuous mode, an output cycle is generated as if a 'P' – Single Data Record Output command (page 63) is entered at the rate of 3/second. If the switch is pressed twice within the 333 msec window, the second pressing is ignored.

See the 'e' – Define Stylus Button Function command (page 45) for other options and operational information.

APPENDIX A. Limited Warranty and Limitation of Liability

Polhemus warrants that the Product shall be free from defects in material and workmanship for a period of two years from the date of Polhemus' delivery to the Buyer, or two years and 30 days from the date ownership of Product passed to the Buyer, whichever occurs first, with the exception of FastSCAN, Marker, and mechanical failure of a battery assembly which have a warranty period of only one year. Batteries have a 90 day warranty period. Polhemus shall, upon notification within the warranty period, correct such defects by repair or replacement with a like serviceable item at Polhemus's option. This warranty shall be considered void if the Product is operated other than in accordance with the instructions in Polhemus's User Manual or is damaged by accident or mishandling. Parts or material which are disposable or expendable or subject to normal wear beyond usefulness within the warranty period such as lamps, fuses, etc., are not covered by this warranty.

In the event any Product or portion thereof is defective, Buyer shall promptly, and within the warranty period, notify Polhemus in writing of the nature of the defect and return the defective parts to Polhemus at the direction of Polhemus's Customer Service representative. Upon determination by Polhemus that the parts or Products are defective and covered by the warranty set forth above, Polhemus, at its option shall repair or replace the same without cost to Buyer. Buyer shall be responsible for any import/export duties/tariffs and pay all charges for transportation and delivery costs to Polhemus's factory for defective parts where directed to be sent to Polhemus, and Polhemus shall pay for transportation costs to Buyer's facility only for warranty replacement parts and Products. Removed parts covered by claims under this warranty shall become the property of Polhemus.

In the event that allegedly defective parts are found not to be defective, or not covered by warranty, Buyer agrees that Polhemus may invoice Buyer for all reasonable expenses incurred in inspecting, testing, repairing and returning the Products and that Buyer will pay such costs on being invoiced therefor. Buyer shall bear the risk of loss or damage during transit in all cases.

Any repaired or replaced part or Product shall be warranted for the remaining period of the original warranty or thirty (30) days, whichever is longer.

Warranties shall not apply to any Products which have been:

- repaired or altered other than by Polhemus, except when so authorized in writing by Polhemus; or
- used in an unauthorized or improper manner, or without following normal operating procedures; or
- improperly maintained and where such activities in Polhemus's sole judgment, have adversely affected the Products. Neither shall warranties apply in the case of damage through accidents or acts of nature such as flood, earthquake, lightning, tornado, typhoon, power surge(s) or failure(s), environmental extremes or other external causes. Warranties shall not apply to any Products if the Products are defective because of normal wear and tear; or
- used for any purpose without obtaining any applicable regulatory approvals.

POLHEMUS DOES NOT WARRANT AND SPECIFICALLY DISCLAIMS THE WARRANTY OF MERCHANTABILITY OF THE PRODUCTS OR THE WARRANTY OF FITNESS OF THE PRODUCTS FOR ANY PARTICULAR PURPOSE. POLHEMUS MAKES NO WARRANTIES, EXPRESS OR IMPLIED, EXCEPT OF TITLE AND AGAINST PATENT INFRINGEMENT, OTHER THAN THOSE SPECIFICALLY SET FORTH HEREIN.

IN NO EVENT SHALL POLHEMUS BE LIABLE UNDER ANY CIRCUMSTANCES FOR SPECIAL INCIDENTAL OR CONSEQUENTIAL DAMAGES, INCLUDING, BUT NOT LIMITED TO LOSS OF PROFITS OR REVENUE. WITHOUT LIMITING THE FOREGOING POLHEMUS'S MAXIMUM LIABILITY FOR DAMAGES FOR ANY CAUSE WHATSOEVER, EXCLUSIVE OF CLAIMS FOR PATENT INFRINGEMENT AND REGARDLESS OF THE FORM OF THE ACTION (INCLUDING BUT NOT LIMITED TO CONTRACT NEGLIGENCE OR STRICT LIABILITY) SHALL BE LIMITED TO BUYER'S ACTUAL DIRECT DAMAGES, NOT TO EXCEED THE PRICE OF THE GOODS UPON WHICH SUCH LIABILITY IS BASED.

The Products are not certified for medical or bio-medical use. Any references to medical or bio-medical use are examples of what medical companies have done with the Products after obtaining all necessary or appropriate medical certifications. The end user/OEM/VAR must comply with all pertinent FDA/CE and all other regulatory requirements.

APPENDIX B. Trouble Shooting

Symptom	Possible Solution
FASTRAK Won't Communicate	Check Dipswitch Settings Check RS-232 Cable Check Communication Program Settings Check PC COM Port Return SEU for Repair
Green Light Won't Stop Flashing	Download New Firmware Return SEU for Repair
Solid Light Without Flashing First	Return SEU for Repair
BIT Error A-C, G-I	Return Transmitter for Repair Return SEU for Repair
BIT Error a-c	Change Tuning Module Move Transmitter Away From Metal Replace Power Supply Brick Return SEU for Repair
BIT Error D-F, J-L	Turn Off CRT-Based Displays Separate Receivers Return Receiver for Repair Return SEU for Repair
BIT Error T,V,Y,Z	Return Receiver for Repair Return SEU for Repair
BIT Error U,W,X	Return Transmitter for Repair Return SEU for Repair
BIT Error d-g	Move Receivers Away From CRT-Based Displays Separate Receivers Return Receiver for Repair
BIT Error j,l	Return SEU for Repair
BIT Error k	Reduce Range Return Transmitter and/or Receiver for Repair
BIT Error m,x,y	Peform Following Command Sequence: 'W', '^K', '^Y' (Resets System Defaults)
BIT Error n,w	Return SEU for Repair
BIT Error s	Reduce Range Return SEU for Repair
BIT Error t,u	Test with Compensation Turned Off (Send 'd' Command)

APPENDIX C. Glossary

6DOF — The **6** **D**egrees **O**f **F**reedom (XYZAER) needed to define the position and orientation of an object in 3D space.

Alignment — Obtaining congruence between the axes of the tracker and the axes of the application. For active technologies, this is often the same as aligning the active element from which all measurements are referenced. Alignment in an active system is not the same as a boresight operation, which concerns only the receiver. Only in passive systems, alignment and boresight can be identical.

Alignment Frame — The reference frame in which the position and orientation of the receiver is measured. The default alignment frame is the transmitter frame.

ASCII — American national Standard Code for Information Interchange defines a certain 8-bit code for display and control characters.

Attitude Matrix — A three-by-three matrix containing the direction cosines of the receiver's x axis in column one, the direction cosines of the receiver's y axis in column two, and the direction cosines of the receiver's z axis in column three. The order of the 3SPACE Euler angle rotation sequence is azimuth, elevation, and roll.

X Direction Cosines	Y Direction Cosines	Z Direction Cosines
CA*CE	CA*SE*SR - SA*CR	CA*SE*CR + SA*SR
SA*CE	CA*CR + SA*SE*SR	SA*SE*CR – CA*SR
-SE	CE*SR	CE*CR

where:

CA = Cos (azimuth)
CE = Cos (elevation)
CR = Cos (roll)
SA = Sin (azimuth)
SE = Sin (elevation)
SR = Sin (roll)

Azimuth — The coordinate of orientation tracking in the horizontal plane where an increase in the angle is clockwise when viewed from above. Azimuth is a rotation around the 'Z' or vertical axis. The term "yaw" is often substituted for azimuth, especially in the context of flight.

Baud Rate The signaling rate on a serial line. For example, to convey an 8-bit byte normally requires at least two additional bit times, a start bit and a stop bit so that synchronization is possible without a separate clocking line. For example, such an arrangement implies for a 9600 baud rate conveyance of data at a 9600*8/10 = 7680 bit rate.

Benign Environment A tracking environment free of the need for special calibration or compensation brought on by the unique features of a particular installation and its environment (e.g. high light levels for optical tracking, high sound levels for sonic tracking, high metallic distortion for magnetic tracking). If not otherwise noted, all measurements and statements pertaining to tracker performance shall be regarded as occurring in such a benign environment.

BIT Built-In-Test features monitoring the status and health of the tracking system as well as flagging of certain preset conditions monitored by the tracking system software. Not to be confused with bit, a contraction of binary digit.

Boresight Any procedure that rotates the receiver frame so as to precisely align the receiver to the designated reference frame.

In a 3SPACE system context, the term usually refers to the system software routine that, on command, performs a coordinate rotation, which effectively aligns the receiver frame to a predefined boresight reference orientation.

Note that the boresight routine accomplishes the boresight orientation of the receiver regardless of the receiver's physical orientation at the instant of boresight initiation. So, for applications that require the orientation tracking of the body (or body member) to which the receiver is attached, a prerequisite to initiating the boresight function is a physical orientation of the body to be tracked to the boresight reference orientation.

bps Bits per second. Not to be confused with the signaling, or baud, rate, which is always equal to or higher than the bit rate. (See baud rate.)

Compensation Data A set of invariable data that allows the 3SPACE to compensate for fixed distortions of the magnetic field due to the surrounding environment. The compensation data generally results from an application-specific distortion mapping procedure.

Direction Cosines The cosines of the angles between the receiver's x, y, z-axes and the X, Y, Z axes of the measurement reference (alignment) frame.

EEPROM Electronically Erasable Programmable Read Only Memory. Memory that can be altered by the 3SPACE, but is not lost when the power is OFF. User default data is stored here, as well as the system identification data.

Elevation Coordinate of orientation tracking in the vertical plane where an increase in the angle is upward from the horizontal. A term often substituted for elevation, especially as it concerns flight, is pitch.

Factory Defaults The values assigned to certain system variables by the factory. Stored in PROM, they are used to reinitialize the variables if EEPROM is lost.

Format The interchange coding used to present data. The 3SPACE outputs either ASCII or BINARY data, but accepts only ASCII inputs from the host.

Hemisphere Because of the inversion symmetry of the magnetic fields generated by the transmitter, there are two possible mathematical solutions for the X, Y, Z, position coordinates for each set of receiver data processed, and the 3SPACE is unable to determine which solution is the correct one without additional information. Therefore, only half of the total spatial sphere surrounding the transmitter can be utilized at any one time for unambiguous position measurement.

The selected hemisphere is referred to as the "current hemisphere." It is defined by an LOS (line-of-sight) vector from the transmitter through a point at the zenith of the hemisphere, and is specified by the direction cosines of the chosen LOS vector.

The orientation coordinates do not have a two-solution spherical ambiguity and are therefore valid throughout the operating sphere centered at the transmitter.

Host Any device capable of supporting an RS-232C interface or the high speed USB interface when available and capable of bi-directional data transmission. Devices may range from a dumb terminal to a mainframe computer.

Increment The minimum movement necessary to cause the 3SPACE to transmit a record to the host.

I/O latency The interval of time needed by the host computer to transfer tracker data from the tracking system into the host application.

Lag The total time from motion data sample capture to host inputting where the data are ready for application use.

Line of Sight (LOS) 1) The orientation angle of the tracker receiver. 2) In active tracker systems, the angle between the source of stimulation and the tracker receiver. 3) Not obscured or blocked from view, such as a clear line of sight for optical uses.

LSB Least significant bit.

LSD Least significant digit.

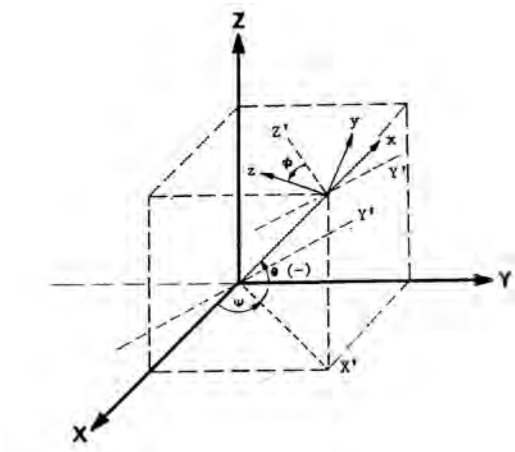
MSB Most significant bit.

Motion Box The volume in which motion tracking is guaranteed to perform as prescribed. Although this 3D volume usually is cubicle in nature, many of the tracking technologies known as active are dependent on a source of stimulation (e.g., magnetic field, light transmitter) which actually performs equally well at a constant radius from the source so that the "box" actually might be better described as spherical or hemispherical.

Orientation Angles The azimuth, elevation, and roll angles that define the current orientation of the receiver coordinate frame with respect to the designated reference frame.

The Euler angle coordinates that are output by the 3SPACE as one measure of receiver orientation are graphically defined in Figure C-1.

In Figure C-1, the x,y,z and X,Y,Z tri-axis arrays represent independent, three-dimensional orthogonal coordinate frames. The x,y,z triad represents the receiver frame in its current orientation state. The X,Y,Z triad represents the reference frame against which the relative orientation of the receiver frame is measured. By definition then, the X,Y,Z frame also represents the zero-orientation reference state of the receiver frame.



X, Y, Z = Alignment (Reference) Frame

x, y, z = Rotated Stylus or Sensor Coordinate Frame

Ψ = Azimuth

θ = Elevation

ϕ = Roll

Figure C-1 Euler Angles

The 3SPACE Euler angles, azimuth, elevation and roll, are designated ψ, θ, and ϕ in Figure C-1. These angles represent an azimuth-primary sequence of frame rotations that define the current orientation of the receiver with respect to its zero-orientation state. The defining rotation sequence is an azimuth rotation followed by an elevation rotation followed by a roll rotation.

The azimuth angle ψ is defined in Figure C-1 as a rotation of the X and Y reference axes about the Z reference axis. Note that the transition axes labeled X' and Y' represent the orientation of the X and Y axes after the azimuth rotation.

The elevation angle θ is defined as a rotation of the Z reference axis and the X' transition axis about the Y' transition axis. Note that the transition axis labeled Z' represents the orientation of the Z reference axis after the elevation rotation. Note also that the current x-axis of the current receiver frame represents the orientation of the X' transition axis after the elevation rotation.

Lastly, the roll angle ϕ is defined as a rotation of the Y' and Z' transition axes about the x-axis of the receiver frame. Note that the y and z-axes of the current receiver frame represent the orientation of the Y' and Z' transition axes after the roll rotation.

Note also that in the example of Figure C-1, the azimuth, elevation and roll rotations are positive, negative and positive respectively.

Output List A list of the data items included in a data record.

P&O Acronym for position and orientation, the six pieces of data needed to fully describe tracking of an object in 3D space. Some tracking devices, by virtue of their principle of operation, can produce only position or only orientation whereas others can produce both P&O (although the user usually can opt for only those parameters desired).

Pitch Same as elevation.

Quaternion A four-parameter quantity representing a vector and a scalar. The quaternion $q = q_0 + i\,q_1 + j\,q_2 + k\,q_3$ can be used to represent the receiver's orientation without the need for trigonometric functions. The attitude matrix output from the 3SPACE can be equivalently represented by the following matrix using quaternions:

X Directional Cosines | Y Directional Cosines | Z Directional Cosines

$$\begin{bmatrix} q_0^2 + q_1^2 - q_2^2 - q_3^2 & 2(q_1 q_2 - q_0 q_3) & 2(q_1 q_3 + q_0 q_2) \\ 2(q_3 q_0 + q_1 q_2) & q_0^2 - q_1^2 + q_2^2 - q_3^2 & 2(q_2 q_3 - q_0 q_1) \\ 2(q_1 q_3 - q_0 q_2) & 2(q_1 q_0 + q_3 q_2) & q_0^2 - q_1^2 - q_2^2 + q_3^2 \end{bmatrix}$$

Receiver The receiver measures the low-frequency magnetic field generated by the transmitter. The receiver is used to track both the position and orientation of the object to which it is attached, relative to the measurement reference frame.

Roll Coordinate of orientation tracking about the azimuth-elevation axis where an increase of the angle is clockwise as viewed from behind or in the same direction as the object is facing.

Sensor Same as Receiver.

Station The transmitter-receiver pair. Up to four receivers are permitted, yielding a possible four stations.

Stylus A pencil-shaped housing for the receiver with an integral switch and used by the operator to indicate and/or select points to be digitized.

Sync Shorthand for synchronization. For example, sync signal.

System ID Data Thirty-two characters of ASCII data (hardware serial number, etc.) stored in EEPROM containing information identifying the system. See 'X' command.

Tracker Alignment The process whereby the tracking system coordinate reference is brought into coincidence, either physically or mathematically, with other coordinates of the environment.

Tracker Calibration The process whereby the tracking system is made to operate accurately in the installed environment to produce tracking data throughout the motion box.

Tracker Latency The interval of time between when tracker measurement data were collected and when the P&O result is formatted ready for transfer to the host computer. In some systems, namely active trackers, there is a timer interval when the active element is illuminating the environment when the data are collected after which the P&O computation can be done. Hence, this definition is intended to correspond to the center point of data collection time so that tracker latency is straightforward and understandable as stated. Other tracking systems (e.g., inertial) may produce raw data continuously or nearly continuously. Tracker latency in this case reduces to the computation time for producing the answer ready for transfer to the host computer.

Tracker Response The interval of time between a request to the tracking system to collect a data point and when that data is available for input from the tracker.

Transmitter The transmitter generates the low-frequency magnetic field measured by the receiver. The transmitter's X, Y, and Z-axes are the default measurement reference frame.

Units The unit of assumed distance. The 3SPACE allows either inches or centimeters.

Update Rate The rate at which motion-tracking data can be made available from the tracking system.

Useful Range The maximum distance at which the resolution and noise performance of the tracking system can be realized.

User Defaults The values assigned to certain system variables by the user. Stored in EEPROM, the system receives these variable values at power-up.

XYZ or X,Y,Z The Cartesian coordinates of position tracking where normally +X is in the forward direction; +Y is in the right hand direction and +Z is upward.

XYZAER The output string of date reporting the position, XYZ, and orientation, AER - azimuth, elevation and roll, of the tracking receiver.

Yaw Same as azimuth.

<> Used in text to indicate the “Enter” key.

... An ellipsis indicates that you can repeat an item.

, A comma represents a delimiter in a list of optional parameters. The comma must be present for those parameters which are omitted except for the case of trailing commas. For example:

Qs,p1,,,p4<>

is the proper command format when omitting parameters p2 and p3. Commas following the parameter p4 are not required if parameters p5 and p6 are omitted.

| A vertical bar means either/or. Choose one of the separated items and type it as part of the command. For example,

ON|OFF

indicates that you should enter either ON or OFF, but not both. *Do not enter the vertical bar.*

^ Used in text to indicate the “Ctrl” key.

APPENDIX D. 'Accuracy and Resolution' White Paper

ACCURACY AND RESOLUTION IN ELECTROMAGNETIC 6 DEGREE-OF-FREEDOM (6DOF) MEASUREMENT SYSTEMS APB 8500-001A

INTRODUCTION

The classical definitions of resolution and accuracy as articulated by Cook and Rabinowicz in "Physical Measurement and Analysis," Addison-Wesley Publishing Company, 1963, are:

> Resolution: the smallest amount of the quantity being measured that the instrument will detect.
>
> Accuracy: the fractional error in making a measurement.

Clearly, confusion over these issues in light of the burgeoning need to measure both the position and orientation of a freely movable object in space with respect to a fixed reference, can lead to inconclusive results and lost effort in application measurements.

From the outset of electromagnetic 6 Degree-Of-Freedom (6DOF) measurement technology, regardless of the application, the subjects of accuracy and resolution have been confusing in light of claims by competing technologies and product manufacturers. This Application Note attempts to clarify accuracy and resolution and to illustrate their total applicability to the classical definitions.

THEORY OF OPERATION

The position of a point in space may be fully described by its relationship to any fixed and convenient three axis (x, y, z) coordinate system. Orientation means direction in relationship to that position and may be fully described by three parameters or angles known as azimuth (yaw), elevation (pitch), and roll.

A typical Polhemus system consists of a fixed magnetic-dipole transmitting antenna called a transmitter; a freely movable magnetic-dipole receiving antenna called a receiver; and associated electronics as shown in Figure D-1. Both the transmitter and receiver antennas consist of three mutually orthogonal loops (coils). The loop diameters are kept very small compared to the distance separating the transmitter and receiver so that each loop may be regarded as a point or infinitesimal dipole. Exciting a loop antenna produces a field consisting of a far-field component and a near or induction-field component. The far-field intensity is a function of loop size and excitation frequency and decreases with the inverse of the distance (1/r). The induction-field or "quasi-static" field component intensity is not frequency dependent and decreases by the inverse cube of the distance ($1/r^3$). The quasi-static field is not detectable at long distances; in fact, its strength dominates at short distances and the far-field is negligible.

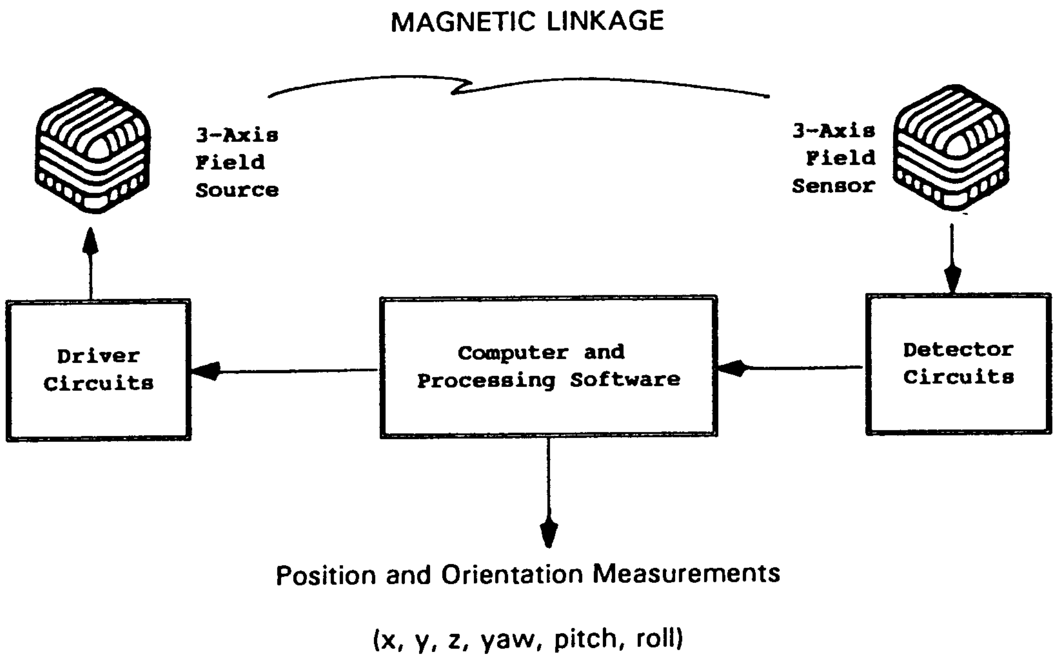


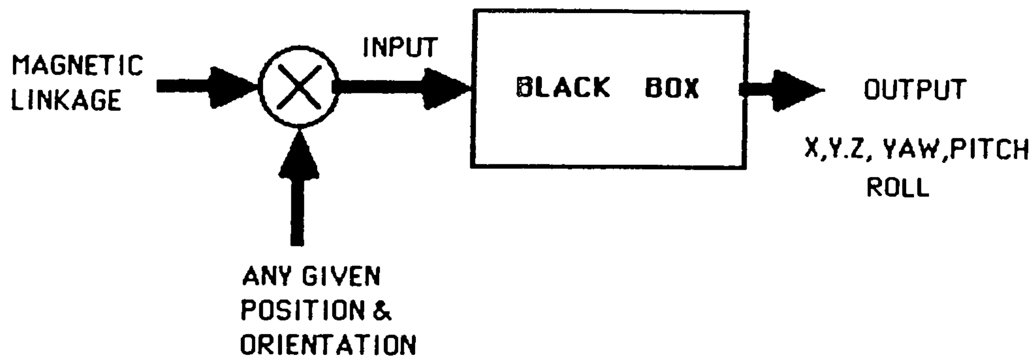
Figure D-1 Position and Orientation Measurements System Block Diagram

In the system shown in Figure D-1, each loop of the transmitter antenna is in turn excited with a driving signal identical in frequency and phase. Each excitation produces a single axis transmitter dipole. The transmitter excitation is a pattern of three states. Exciting the transmitter results in an output at the receiver of a set of three linearly independent vectors. The three output (receiver) vectors contain sufficient information to determine the position and orientation of the receiver relative to the transmitter. Essentially nine measurements are available to solve for the six unknowns of x,y,z for position and azimuth (yaw), elevation (pitch), and roll for orientation.

DEFINITIONS

For resolution and accuracy considerations, the electromagnetic instruments are treated as "black boxes" thereby focusing on the performance of the instruments and negating the process of solution from the definitions.

A key element for determining resolution and accuracy from a "black box" point of view is the system's signal-to-noise (S/N) ratio. First, consider the black box system shown in Figure D-1. The Magnetic Linkage is the magnetic field or B field which is a vector quantity derived from the vector sum of the radial and tangential field components for a magnetic dipole. It contains both the magnetic moment vector **m** and the inverse cube of the range factors given by the quantity K/r^3.



MAGNETIC LINKAGE = Magnetic Moment

POSITION & ORIENTATION = Sensor Loop triad receiving antenna for position and orientation

Figure D-2 Black Box System

There are three sensing coils and three magnetic moments with the resultant matrix = **M** expressed by **M** = [$\mathbf{m}_1 | \mathbf{m}_2 | \mathbf{m}_3$]. Position and orientation are described by the voltages induced in the three receiver loops according to their sensitivity and orientation and given by the matrix quantity **S** = [$\mathbf{s}_1 | \mathbf{s}_2 | \mathbf{s}_3$]. Coupling between the Magnetic Linkage and Position and Orientation sensitivity produces nine voltages giving rise to the input voltage matrix expressed as:

$$V = \frac{1}{r^3} S^t K M$$

Equation D-1

Coupled through the Magnetic Linkage is a noise quantity N_i, which is composed of incidental link noise plus atmospheric noise. Additionally, system noise, generated as a function of the black box electronics is given by N_b. System noise (N_b) is the sum of quantization, shot and thermal noise and is referred to the input of the black box. These noise quantities are algebraically added to the voltage equation for the input to the black box and expressed as:

$$V = \frac{1}{r^3} S^t K M + N_i + N_b$$

Equation D-2

SIGNAL-TO-NOISE (S/N) RATIO

At the output of the black box, the signal (S) portion of the S/N ratio is the value of any given position and orientation of the receiver. It could be considered as the input equation stated above, minus the noise components, times the transfer function of the “black box.” The noise portion (N) is the noise components of the input equation times the “black box” transfer function and is observed as the deviation in the output parameters about the given position and orientation. Therefore, determining the S/N ratio from a "black box" perspective involves the use of a precise mechanical positioning instrument with a precision gimbal. Using surveyed (precisely known) attitude coordinates (azimuth, elevation and roll), a statistically valid number of measurement samples are taken at each attitude. For each attitude the mean vector sum of these samples yields the signal (S) component and the vector sum of the one sigma values of the deviation yields the noise (N) component. The S/N ratio may be expressed as a unitless number or in db, that is, 20 $\log_{10}$ S/N.

RESOLUTION

Resolution for electromagnetic 6DOF measurement instruments is generally specified as angular resolution and translational resolution.

ANGULAR RESOLUTION

Considering that the receiver is an all-attitude (360 degree) device, the angular resolution is calculated by dividing 360 degrees by the S/N ratio thus yielding its value in degrees.

TRANSLATIONAL RESOLUTION

The translational or positional resolution is a function of the S/N ratio and range. Being a positional function, there are three orthogonal vectors whose vector sum multiplied by any given range number yields the required translational resolution as shown in Figure D-3. One vector is defined along the axis of the range and is therefore a function of the inverse cube of the range. The remaining two orthogonal vectors (a & b) are a function of the tangent of the angle derived by dividing 180 degrees by the S/N ratio. Unlike angular resolution which uses 360 degrees divided by the S/N ratio, 180 degrees is used for these translational resolution component vectors because with an electromagnetic system there are two possible solutions to the 6DOF measurement problem. This two solution possibility constitutes a potential system ambiguity. Obviously for a position measurement, only one solution is permitted and valid. The units for translational resolution are either English (inches) or metric (cm.).

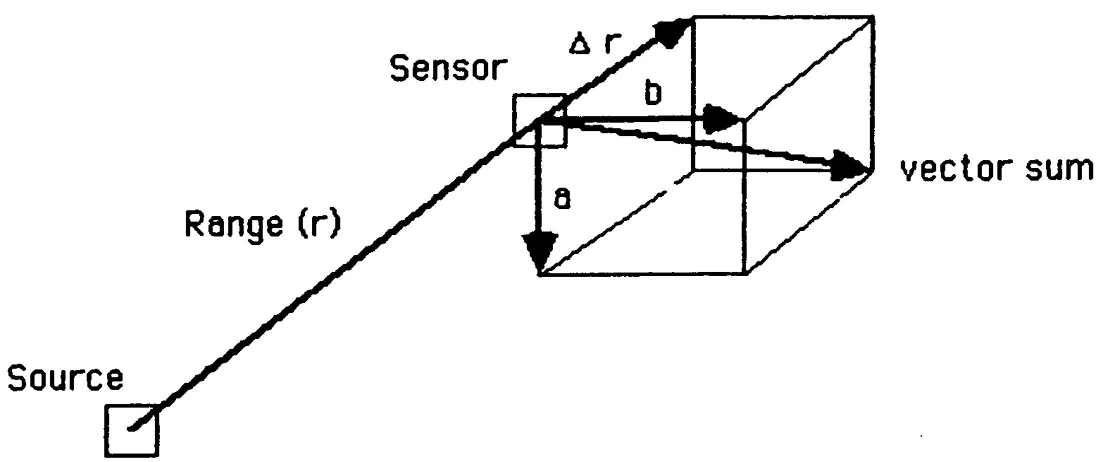


Figure D-3 Translational Resolution.

ACCURACY

The accuracy of electromagnetic 6DOF measurement instruments is a function of the error involved in making measurements and is therefore expressed in statistical error terminology. It should be noted here that the use of statistical error terminology is the reason the accuracy of such instruments is generally specified in degrees RMS for attitude (orientation) and in inches or centimeters RMS for position. As with resolution, accuracy will be considered here from the point of view of the instruments as “black boxes.” When treating the instruments as “black boxes,” all classic error terms such as linearity, repeatability, hysteresis and drift are included.

One factor to be considered with any of the electromagnetic instruments is range or field-of-regard. All instruments have a practical operating range for which accuracy is specified. Operation beyond that range will degrade accuracy as a function of the degradation of the system’s S/N ratio. Additionally, all electromagnetic 6DOF systems are affected somewhat by the metallic environment in which they operate. As this is clearly an uncontrollable function of the environment from the manufacturer’s viewpoint, accuracy is generally specified and/or should be determined in a metallically clean environment.

The accuracy specified by manufacturers of electromagnetic 6DOF instruments is called “Static Accuracy” as the measurements are made with both the transmitter and receiver in a fixed and surveyed attitude and position condition within a specified motion box or field-of-regard.

POSITIONAL STATIC ACCURACY

The positional Static Accuracy may be determined by measuring the vector positions (“X”, “Y”, “Z”) of a receiver positioned in a statistically valid number of fixed and known locations throughout a specified motion box using a precise mechanical positioning instrument with a precision gimbal. The X, Y, and Z error terms are recorded and the RMS values calculated for each term. These resulting error values (one of “X”, one for “Y”, and one for “Z”) are the system’s positional Static Accuracy at each given point within the specified motion box. Obviously, an overall positional Static Accuracy for “X”, “Y”, and “Z” may be obtained by calculating the RMS value for all positional Static Accuracy points taken within the specified field-of-regard.

ORIENTATIONAL STATIC ACCURACY

Whereas a similar exercise is required to determine the orientational Static Accuracy, a clear understanding of the orientation parameters is necessary to understand the meaning of the specification and how it is measured. The electromagnetic instruments all measure and output 6DOF data in different optional formats including Cartesian coordinates of position and Euler angles and/or direction cosines as orientation parameters. The azimuth, elevation, and roll (yaw, pitch, and roll) angles are the more intuitive of the orientation parameters of the receiver and are measured with respect to the alignment (or fixed transmitter) reference frame.

Euler angles are defined as the sequence of angles (azimuth, elevation, and roll) that define the orientation of the receiver with respect to the X, Y, Z alignment reference frame. Azimuth is a rotation of the receiver’s **x** axis projection in the X Y reference plane about the Z reference axis. Elevation is a rotation of the receiver's **x** axis about the Y reference axis. Roll is a rotation of the receiver's **y** (or **z**) axis about its **x** axis.

In order to measure the orientation Static Accuracy in the same manner that the positional accuracy was obtained, the aforementioned precise gimbal test fixture is required to allow input of precise and simultaneously different attitudes. As with the positional measurements, azimuth, elevation, and roll measurements of the receiver are taken in a statistically valid number of known attitudes in fixed and known locations throughout the same specified motion box as used for the positional measurements. The azimuth, elevation, and roll error terms are recorded and the RMS values calculated for each term. The resulting error values (one for azimuth, one for elevation, and one for roll) are the instrument's orientational Static Accuracy. As for the positional Static Accuracy, the overall orientational Static Accuracy for azimuth, elevation, and roll may be obtained by calculating the RMS value for all orientational Static Accuracy points taken within the specified field-of-regard.

CONCLUSION

It can be seen from the above discussions that accuracy and resolution for electromagnetic, 6DOF instruments conform to the classical definitions of these terms. Accuracy is indeed the fractional error obtained in making a measurement and Resolution is the granularity of the measurement or the smallest amount of the quantity being measured that the instrument will detect. It can also be seen that numerical values of accuracy and resolution may be obtained from careful and precise measurements of the system's output data with respect to surveyed and known receiver positions and orientations.

APPENDIX E. 'Latency' White Paper

TECHNICAL NOTE
Latency - 3SPACE™ FASTRAK®
H. R. Jones

INTRODUCTION

ANSI/IEEE Std 100-1977 defines latent period as "The time elapsing between the application of a stimulus and the first indication of a response". The definition excludes the time required to transmit the response. It is in this context that we define the latent periods (1) between the application of a synchronization pulse and a response, and (2) between the application of receiver motion and a response. The "response" for both cases occurs when the receiver coordinate solution is made ready for output, and, as noted above, does not include the time required to transmit the coordinates over the interface in use (e.g. RS-232, MIL-STD-1553, IEEE-488, etc).

Polhemus 3SPACE FASTRAK magnetic 6DOF measurement systems emanate low frequency magnetic fields from a stationary transmitting antenna and sense them with a movable receiving antenna. The received magnetic field samples are subjected to analog and digital processes, and are ultimately solved for the receiver's position and orientation coordinates. The solutions are formatted in varied ways according to user selections, then output over various types of interfaces depending on the product.

The FASTRAK system's latent period is due to the time required to sample the magnetic fields, solve for the receiver coordinates, and make the solutions available for output. However, from the user's point of view, the latent period may appear longer than this due to delays in the interface or in the user's computer, or due to (incorrectly) configured FASTRAK filters which can make the response appear to occur later. These topics are discussed in the following paragraphs.

SYNC-TO-OUTPUT LATENT PERIOD

Application of an external synchronization pulse[1] initiates magnetic field sampling, a period that lasts about 3.5 ms. It goes beyond the scope of this note to explain the sampling process in more detail, so let it suffice that nine magnetic field samples are taken per cycle time. The samples are then solved for receiver coordinates, a period that requires another 2 ms. The solution is then placed in an output buffer and is made ready for transmission over the interface in use. The total "sync-to-output" latent period is the sum of field sampling and coordinate solution periods, or 5.5 ms, and is independent of update rate.

EFFECTIVE LATENT PERIOD

"Sync-to-output" latency is important for reasons of interface timing; however, it does not quantify the effective latent period between receiver motion and output coordinate values.

[1] If external synchronization and continuous print are not implemented, the environment is being run asynchronously and the latent period cannot be defined precisely.

This period is important to helmet display or virtual reality applications since dynamic errors between the actual and computed coordinates can be very noticeable to the eye.

To discuss effective latent period let the beginning of the magnetic field sampling be at t=0; let the end of sampling be at t=τ; and let the time that the solution appears in the output buffer be t=T. The computed solution for a receiver moving at constant velocity will correspond to where the receiver was at t=τ/2, the midpoint of the sampling period; hence, the effective latency is T - τ/2, or 3.75 ms.

OTHER FACTORS

Although the time to transmit data is not included in the definition of latent period, a knowledge of how to compute these delays is needed to properly align in time the receipt of tracker solution with the actual event. For example, the factory default ASCII output record x-y-z-az-el-rl is composed of 47 bytes (3 status bytes, 6 data words each 7 bytes long, and a CR LF terminator) and at 115.2K Baud requires a transmission time of 4 ms (recall that there is one start bit and one stop bit per 8 bit data byte). The tracker’s sync-to-output latent period plus transmit time for this example is 9.5 ms, and the effective latent period plus transmit time is 5.8 ms.

It is very important to note that if the transmit time exceeds the tracker cycle time (8.33 ms), which could happen if the baud rate is too slow or if the record length is too long, it becomes necessary for the tracker to periodically discard solutions to prevent output buffer overflow. This would make it appear as though the tracker was not tracking continuously or was dropping data. This interface problem is most noticeable in multiple receiver operation as the tracker is designed to maintain constant order of receiver processing. If the interface just missed a given receiver in the list of multiple receivers, the tracker will output nothing until this receiver is again processed.

Another common problem is the RS232 communications XON/XOFF protocol. If the user’s computer cannot assimilate the tracker’s output fast enough, the computer can transmit an XOFF signal to the tracker commanding it to stop transmitting. When the user’s computer has finally assimilated the data it has accumulated, it transmits an XON command and the tracker once again begins transmitting coordinate data. During the XOFF period the tracker’s output buffer is continually discarding solutions to prevent buffer overflow, thus many data sets are never transmitted. Toggling of XON/XOFF in the user’s computer could be happening without the user’s knowledge and could again make it appear that tracker sync-to-output latent period was varying from 5.5 ms to many times this, and periodically dropping data. The RS232 lines should be monitored if this problem is suspected.

A third problem is asynchronous interfacing, and a particularly annoying example of such an interface is MIL-STD-1553 as this bus is not only asynchronous but often very slow (e.g. 25 Hz). Asynchronous interfaces guarantee that on the average the apparent latent period will be increased by one half the tracker cycle time. For a slow 25 Hz bus rate, the sync-to-output latent period would vary from 5.5 ms to 13.8 ms. Another example is a unsynchronized computer issuing single record print commands at random times in the tracker’s cycle.

FILTER RESPONSE (LAG)

FASTRAK has optional filters that are intended to smooth the receiver's calculated position and orientation in mechanically or magnetically noisy environments. The degree of filtering is user selectable from very heavy to none at all, or the degree of filtering can be automatically selected in real time by the tracker as it adapts to "noise". Filtering can introduce lag in response; the sync-to-output latent period remains unchanged (recall that latent period is defined as "a first indication" and not a final settled response), but the data that is output may not correspond to where the receiver was recently.

To help understand the response of the optional filters, the filter algorithm is described and analyzed in the following paragraphs.

FASTRAK coordinate filters are exponential filters as described by the following equation.

$$< x >_k = \alpha x + (1 - \alpha) < x >_{k-1}$$

Equation E-1

In this equation "x" is the unsmoothed receiver coordinate measured at time "k"; it may be a coordinate of position or orientation. The variable "$<x>_k$" is the filter output at discrete time "k" and "$<x>_{k-1}$" is the smoothed value at time "k-1". The filter parameter "α" controls the degree of filtering and must be within the range $0 < \alpha < 1$. Small values of α produce heavy filtering; large values produce light filtering; in the limit as $\alpha \to 0$ the filter output never changes; and in the limit as $\alpha \to 1$ the output exactly follows the input. The filter parameter α can be set to a specific value through system commands, or a range of values can be specified which allows the system to choose its own optimum value automatically adapting to environmental noise.

Equation E-2 expresses the steady state filter response for zero acceleration in receiver coordinates and for a constant filter parameter α. In the derivation of the equation, the coordinate "x" is assumed to be of the general form "x = vt", where "v" represents a constant velocity (in either position or orientation), "t" is time, and "Δt" is the tracker's cycle time (the inverse of update rate).

$$< x >_k = x - \left(\frac{1 - \alpha}{\alpha} \right) v \, \Delta t$$

Equation E-2

Equation E-2 can be reformulated to express the filter time delay for a constant rate of change ("v") in input.

$$\frac{x - < x >_k}{v} = \left(\frac{1 - \alpha}{\alpha} \right) \Delta t$$

Equation E-3

Equation E-3 may be interpreted as the error in degrees per "v" degrees/second in orientation input, or the error in inches per "v" inches/second of translation. Note that in either case the units are in seconds.

As an example, suppose that the update rate of the tracker is 120 Hz, thus $\Delta t = 1/120$ second. Suppose also that the receiver is slewing in azimuth at 90 degrees per second and that α is a constant 0.95, a value that can be attained by either fixing both the upper and lower limits of α to 0.95, or by setting just the upper limit to 0.95 and letting the adaptive filter push α to this maximum limit which is what would happen for slew rates of this magnitude. The filter lag for this example is calculated to be 0.44 ms. The correct interpretation of this figure is that the receiver coordinates output at t=5.5 ms correspond to where the receiver was at $t = \tau/2 - 0.44$ ms = 2.2 ms; this would increase apparent latency to $T - \tau/2 + 0.43$ ms = 4.2 ms.

The next example demonstrates what can happen when the filter constant is set too low producing extremely heavy filtering. Suppose α is set to 0.05 and all other conditions are the same as in the above example. In this case the filter lag calculates to 158 ms, and the interpretation is that the coordinates output at t=5.5 ms corresponds to where the receiver was at $t = \tau/2 - 158$ ms; this yields an apparent latent period of $T-\tau/2+158$ = 162 ms. Obviously, low filter settings must be avoided if any reasonable dynamic response is desired.

RECAPPING

This technical note has discussed the latency in the application of a Polhemus 3SPACE™ FASTRAK product. As pointed out, sync-to-output and effective latencies are measures of tracker throughput and cannot be changed, while apparent latency and filter response are controlled to a degree by the interface and application environment. To derive best performance the FASTRAK product should be synchronized and data records should be reduced to the minimum required. Also, use the fastest baud rates available, consider the use of binary formats, and use the continuous print mode.

APPENDIX F. Cable Diagrams

RS-232 Cable Diagram

- IBM (PC) Compatible Computer
- SGI O2, Onyx 2, or Octane

To PC D-Type Connector 9-Pin Female		To FASTRAK D-Type Conn. 9-Pin Female
Pin #	Identification	Pin #
1		
2	--Receive Data --Transmit Data---	3
3	--Transmit Data --Receive Data--	2
4		8
5	------------------------------------Signal Ground--	5
6		7
7		
8		
9		

RS-232 Cable Diagram

- IBM (PC) Compatible Computer

To PC D-Type Connector 25-Pin Female		To FASTRAK D-Type Conn. 9-Pin Female
Pin #	Identification	Pin #
1		
2	--Transmit Data --Receive Data--	2
3	--Receive Data --Transmit Data--	3
4		
5		
6		7
7	----------------------------------Signal Ground---------------------------------------	5
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		8
21		
22		
23		
24		
25		

RS-232 Cable Diagram

- SGI Indigo2, Indigo, Onyx, Iris

To PC Circular Connector DIN-8		To FASTRAK D-Type Conn. 9-Pin Female
Pin #	Identification	Pin #
1		8
2		
3	--Transmit Data --Receive Data--	2
4	-----------------------------------Signal Ground---------------------------------------	5
5	--Receive Data --Transmit Data--	3
6		
7		7
8		

RS-232 Cable Diagram

- SGI VTX, Onyx, Personal Iris

To PC Circular Connector DIN-8		To FASTRAK D-Type Conn. 9-Pin Female
Pin #	Identification	Pin #
2	--Transmit Data------Receive Data--	2
3	--Receive Data------Transmit Data-	3
4		
5		
6		
7	------Ground------	5
8		7
9		8

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