OPM01PI021
April 2001

3SPACE®

ISOTRAK II®

USER'S MANUAL

2001 Edition, Rev. A

OPM01PI021
April 2001

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 his own expense.

EC-Declaration of Incorporation

This product conforms to the following European Community Directives:

89/336/EEC AS AMENDED BY 92/31/EEC, 73/23/EEC LOW VOLTAGE AS AMENDED BY 93/68/EEC

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

EN50081-2, EN50082-1, EN60950, *EN55022

* NOTE: This product complies with the Class A requirements of EN55022.

Table of Contents

1.0 Getting Started

Congratulations on buying the finest low-cost 3D tracker system available! 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 ISOTRAK II 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 RS-232 serial port at 9600 Baud communicating with a Windows 95/98/NT PC, and use of the Microsoft Windows program HYPERTERMINAL.EXE.

1. Unpack the ISOTRAK II SEU, transmitter, receiver(s), and power supply.

Complete ISOTRAK II System

2. 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.

3. Identify the transmitter (the two-inch gray 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.

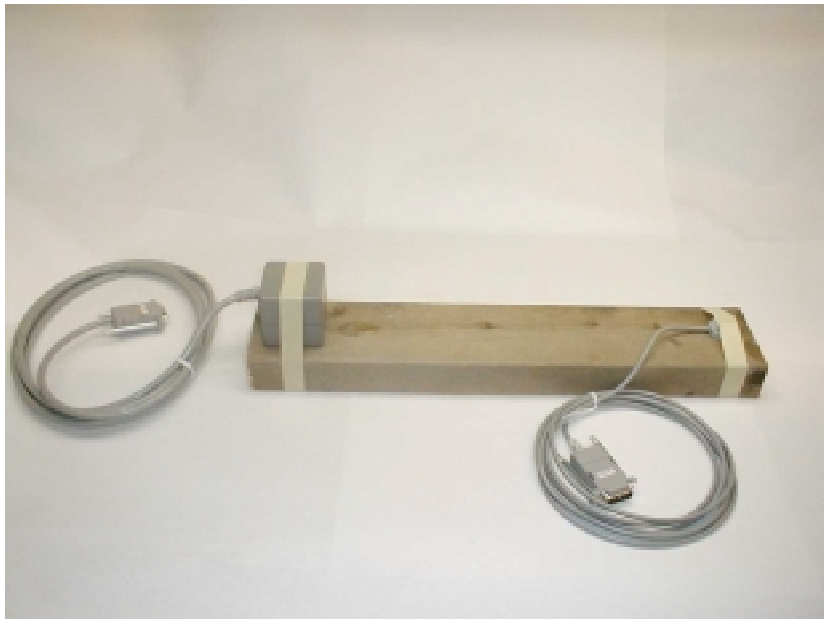
Transmitter Connection

4. 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 3.

Receiver Connection

5. 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 not routed together and they come off opposite ends of the 2X4.



Mounting Transmitter and Receiver on 2x4

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

Power Connector

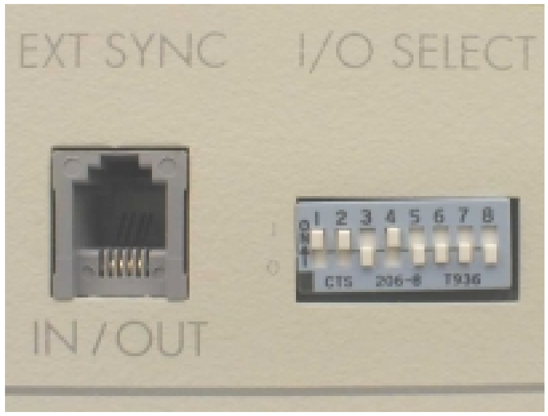
With the separate Power supply ("brick") **UNPLUGGED** from the outlet of the wall, plug the "brick's" DIN connector into the power-input connector on the rear panel of the electronics unit and firmly seat.

DC Power Cable Insertion

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

7. Identify the I/O Select Switch located on the rear panel of the electronics unit. Set the switches to the following positions:

Switch	Position
1	UP
2	UP
3	DOWN
4	UP
5	DOWN
6	DOWN
7	DON’T CARE
8	DON’T CARE



Default I/O Select Dip Switch Settings

As set, these switches provide for RS-232 serial operation at 9600 baud (Switches 1, 2 & 3), Internal synchronization (Switch 4), sync generator off (Switches 6 & 7). (Switches 7 & 8 are not used.)

8. **NOTE: THE ISOTRAK II SYSTEM BEHAVES AS A TRANSMITTER ON THE RS-232 AND THEREFORE A NULL MODEM CABLE IS REQUIRED.** Obtain a <u>NULL MODEM</u> RS-232 serial interconnection cable with a 9 pin, <u>female</u> "D" connector on the tracker end of the cable. Plug one 9 pin, female "D" connector into the I/O connector located on the rear panel of the electronics unit. Engage and lock this connection in the same manner as the receiver and transmitter connections as indicated in steps 3 & 4.

RS-232 Cable Connection

9. Most PC hosts have a 9 pin, male "D" type connector for Com 1. If you are using Com 1, plug the remaining end of the cable into the Com 1 port of the host PC, engage, and lock as before. If your host computer has a 25 pin "D" connector for the RS-232 port, you will need a 9 to 25 pin "D" connector adapter with the proper genders. **Note that this adapter must not compromise the NULL MODEM sense of your cable.**

10. Open a serial connection using the Windows program HyperTerminal. The steps are as follows:

- Click Start, point to Programs, Accessories, and click HyperTerminal
- Double-click the Hyperterminal.exe icon
- Enter a session name, choose an icon, and click OK
- In the “Connect using” field, select Com 1 or Com 2 (depending on the tracker connection) and click OK
- In the “Bits per second” field, select 9600
- In the “Data bits” field, select 8 (default)
- In the “Parity” field, select None (default)
- In the “Stop bits” field, select 1 (default)
- In the “Flow control” field, select None and click OK

11. At this point, you may turn on the ISOTRAK II 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 immediately turn on (without flashing) to a steady-on state thereby indicating that the system is ready to operate.

12. You may now use the HyperTerminal Program to exercise the system. After sending an upper case “P” command to the system, the six-degree-of-freedom output data will be sent to the host. The data consists of a header (0s, 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

ISOTRAK II 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 5), the data output will not change regardless of the number of data samples you take.

13. 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.

14. 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 pressing “P”. The first four columns will be approximately as they were in Step 13, but the Azimuth data in column 5 will have changed by approximately 45 degrees.

15. Experiment with the system as shown in Step 14 to demonstrate that it measures the position and orientation (six-degrees-of-freedom) of the receiver with respect to the transmitter.

16. If the system fails to produce six-degree-of-freedom data, carefully go over the above procedure in a systematic fashion, checking connections and switch settings especially. When all else fails, call us.

Contacting Polhemus Customer Service

If problems are encountered with the ISOTRAK II 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" 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 click 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 the warranty section of this document. The proper return address is:

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

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

ISOTRAK II Commands Index

2.0 TECHNICAL OVERVIEW

The ISOTRAK II 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 ISOTRAK II consists of a System Electronics Unit (SEU), one or two receivers, a single transmitter, a power supply and a power cord. The system operates at a carrier frequency of 8.013 kHz. The ISOTRAK II interfaces to the host computer via RS-232 serial communication. A single receiver may be operated at the fastest update rate (60 Hz), or two receivers at one half this rate (30 Hz). Of course, the unit must be set to output at a high enough baud rate to receive data at these update rates. Mixed rates are not permitted meaning that all active receivers operate at the same update rate, i.e. one cannot be operated faster than the other. Active receivers are selected by physical receiver cable connections and software configuration commands.

Additionally, the ISOTRAK II may be used with a stylus or a 3BALL device 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 both the stylus and 3BALL device. The stylus and 3BALL must be used in the Receiver Port labeled "one."

3.0 SPECIFICATION

Position Coverage

The system will provide the specified accuracy when the receivers are located within 30" (76 cm.) of the transmitter. Operation with separations up to 60" (152.4 cm) is possible with reduced accuracy.

Angular Coverage

The receivers are all-attitude.

Static Accuracy

0.10" (0.24 cm) RMS for the X,Y,or Z receiver position, and 0.75° RMS for azimuth, elevation, or roll receiver orientation.

Resolution

0.0015 inches/inch of range (0.0038 cms/cm of range), and .1°.

Latency

20 milliseconds unfiltered and 40 milliseconds filtered, from center of receiver measurement period to beginning of transfer from output port.

Output

Software selectable. Cartesian coordinates of position and Euler orientation angles are standard. English or metric units and ASCII or binary outputs also are selectable.

Update Rate

One receiver: 60 updates/second
Two receivers: 30 updates/second

Carrier Frequency

The ISOTRAK II carrier frequencies is 8013 Hz

Interface

RS-232C serial port with software selectable baud rates of 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200, ASCII or Binary formats. The factory default setting is 9600 baud, ASCII format.

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 11.38" (28.91 cm.), length 11.06" (28.90 cm.), height 3.63" (9.22 cm.), weight 5.0 lb. (2.26 Kg.).

Transmitter: Width 2.15" (5.5 cm.), length 2.15" (5.5 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.

3BALL: A standard receiver mounted in an official #3 billiard ball fitted with an integral switch. The 3BALL has a standard 10' cable.

Power Requirements

International Power Sources Supply: Input power is 85-264 VAC, 47-440 Hz, and single phase at 30 watts.

4.0 COMPONENT DESCRIPTION

4.1 SEU

The 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 output port. 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 4.1A and Figure 4.1B.

Figure 4.1A ISOTRAK II SEU, Front View

Figure 4.1B ISOTRAK II SEU, Rear View

4.2 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 4.1A. 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 ISOTRAK II 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.

4.3 Receiver Ports (2)

The two Receiver receptacle ports are 15 pin, female “D” type connectors located on the front of the SEU as shown in Figure 4.1A. 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 Ctrl Y reset command after doing so. This will allow the receiver’s precise characterization matrix to be loaded into the ISOTRAK II memory. Again, rout the receiver cables separately from the transmitter cable.

4.4 Power Indicator

A green LED power on indicator is located on the front of the SEU as shown in Figure 4.1A. Upon power up, the indicator will immediately turn to a steady-on mode indicating that the system is ready for operation.

4.5 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 4.1B, Rear View and is only read on power up or system re-initialization (Ctrl Y command). The purpose of these switches is to select the I/O baud rate and the synchronization mode to be used. The 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	Sync Mode: Internal = “1” Up External = “0” Down

5	Sync Generator Select
6	Sync Generator Select
7	Not Used
8	Not Used

The Baud rate select logic for switches 1, 2 and 3 is as follows:

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

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 Ctrl Y command.

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 Sync Mode (switch 4) is to allow the selection of either Internal Sync or External Sync. The switch is read only on power-up or after sending the Ctrl Y command. The Sync Generator is a “built in” 30 Hz square wave generator having a differential driver.

The sync generator select logic for switches 5 and 6 is as follows:

Sync Gen	5	6
Off	0	0
On	1	1
Not Used	1	0
Not Used	0	1

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

4.6 External Sync I/O

The Sync I/O connector is located on the rear panel of the SEU as shown in Figure 4.6A. The connector is a single modular telephone socket. All input and output signals must be differential TTL compatible. If the output is employed in the user's system, it must be interfaced with the same differential TTL circuitry. The Sync In and Sync Out signals are also compatible with RS-422 specifications. The pin assignments are as follows and their numbering is shown in Figure 4.6A:

Figure 4.6A. Sync Connector Identification (Input & Output)

Pin #	Function
4	Ground
3	Sync /
2	Sync
1	Ground

4.7 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 4.1B. The pinout identification for this connector is as follows:

Pin #	Function
1	Not used
2	RxD (Receive Data)
3	TxD (Transmit Data)
4	Not used
5	GND
6	Not used
7	RTS* (Not Used)
8	CTS* (Not Used)
9	Not used

Pin 7 is electrically shorted to Pin 8 on the circuit board. ISOTRAK II does not use RTS and CTS. If possible, electrically shorting these pins (functions) in your interface cable is recommended.

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 D 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 D, call Polhemus 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 ISOTRAK II and your host computer. (Our Telephone and FAX numbers and email address can be found in Section 1.)

4.8 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 4.1B. 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.)

4.9 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 4.13A including the position of the electrical center. There are 4, 1/4" - 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.

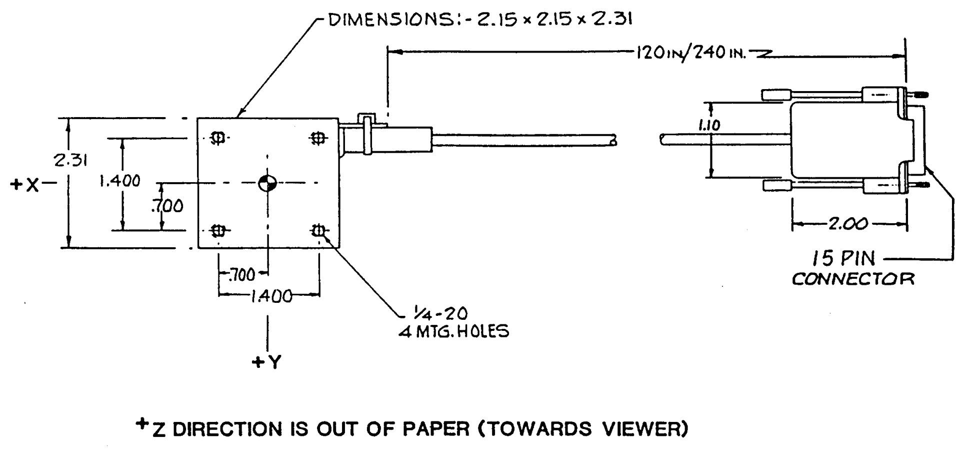


Figure 4.13A Transmitter Dimensions (In Inches)

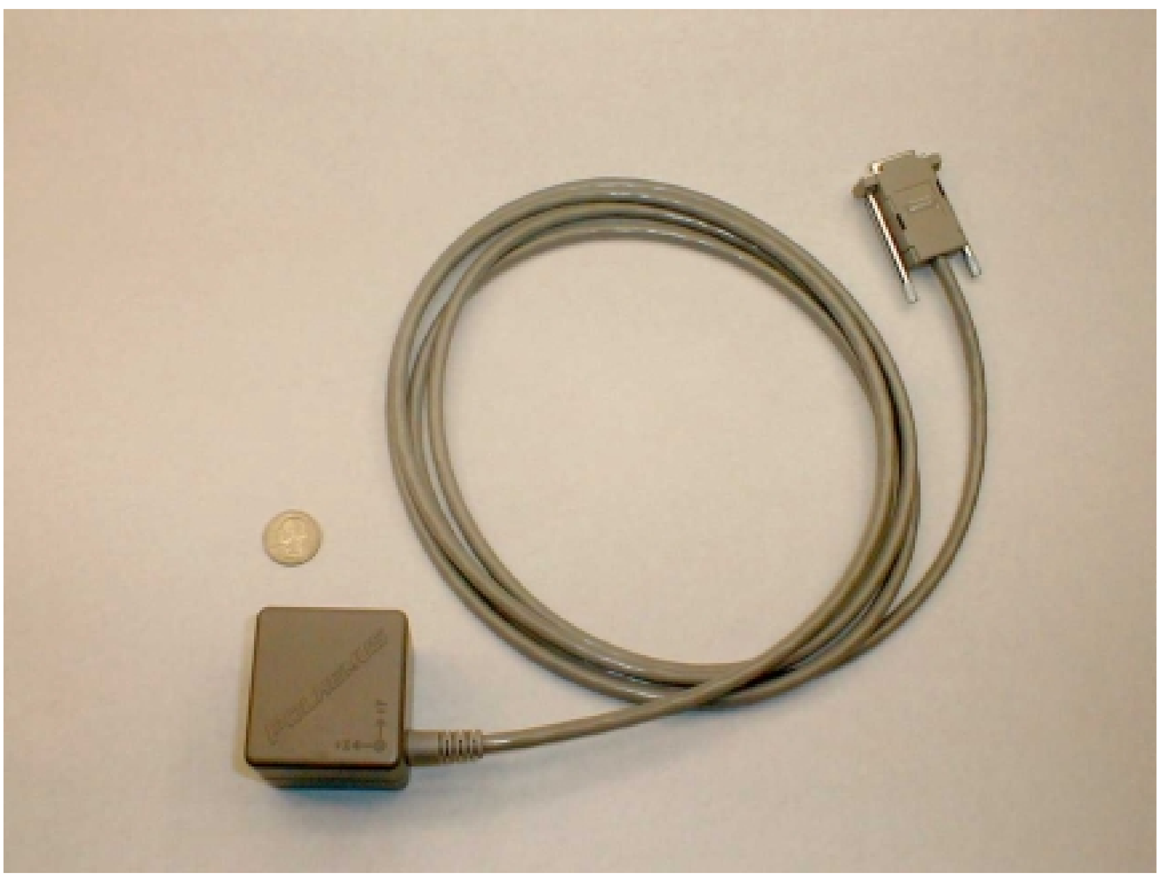


Figure 4.13B Transmitter

4.10 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 4.14A including the position of the electrical center. The Receiver package provides 2 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.

4.11 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 4.15A and may be used in any of the receiver ports. 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 Section 6.5 for operation with a stylus.

4.12 3BALL

The 3BALL is a #3 billiard ball with a receiver coil assembly built inside and an integral push button switch to effect data output. The 3BALL is shown in Figure 4.16A. It may be used in the same manner as a stylus where single or continuous data output records may be obtained as a function of the switch. The data are referenced to the center of the ball. Like the stylus, the 3BALL may be used in any of the receiver ports. See section 6.5 for operation with the 3BALL device.

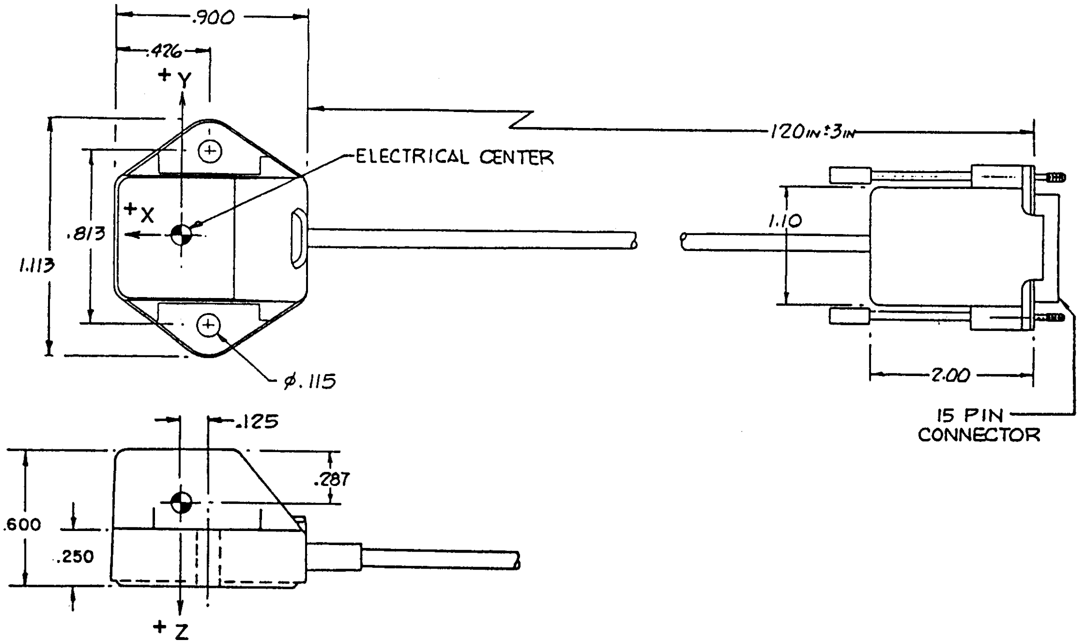


Figure 4.14A Receiver Dimensions (In Inches)

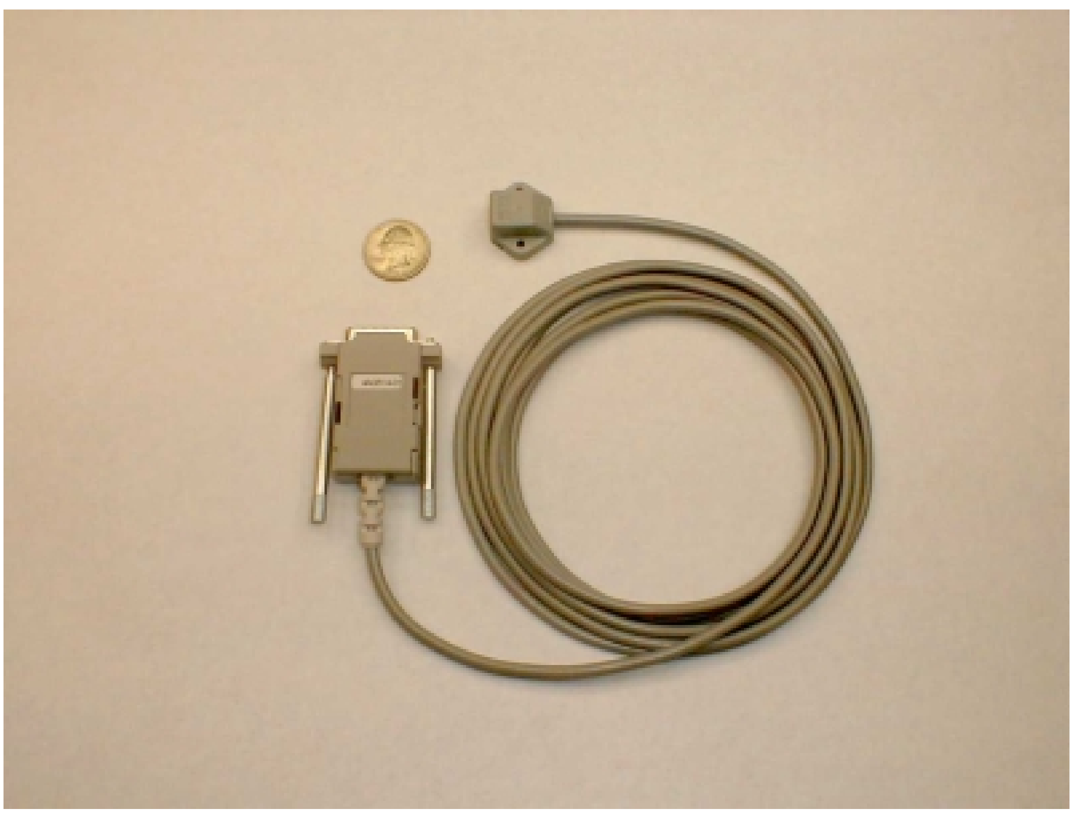


Figure 4.14B Receiver

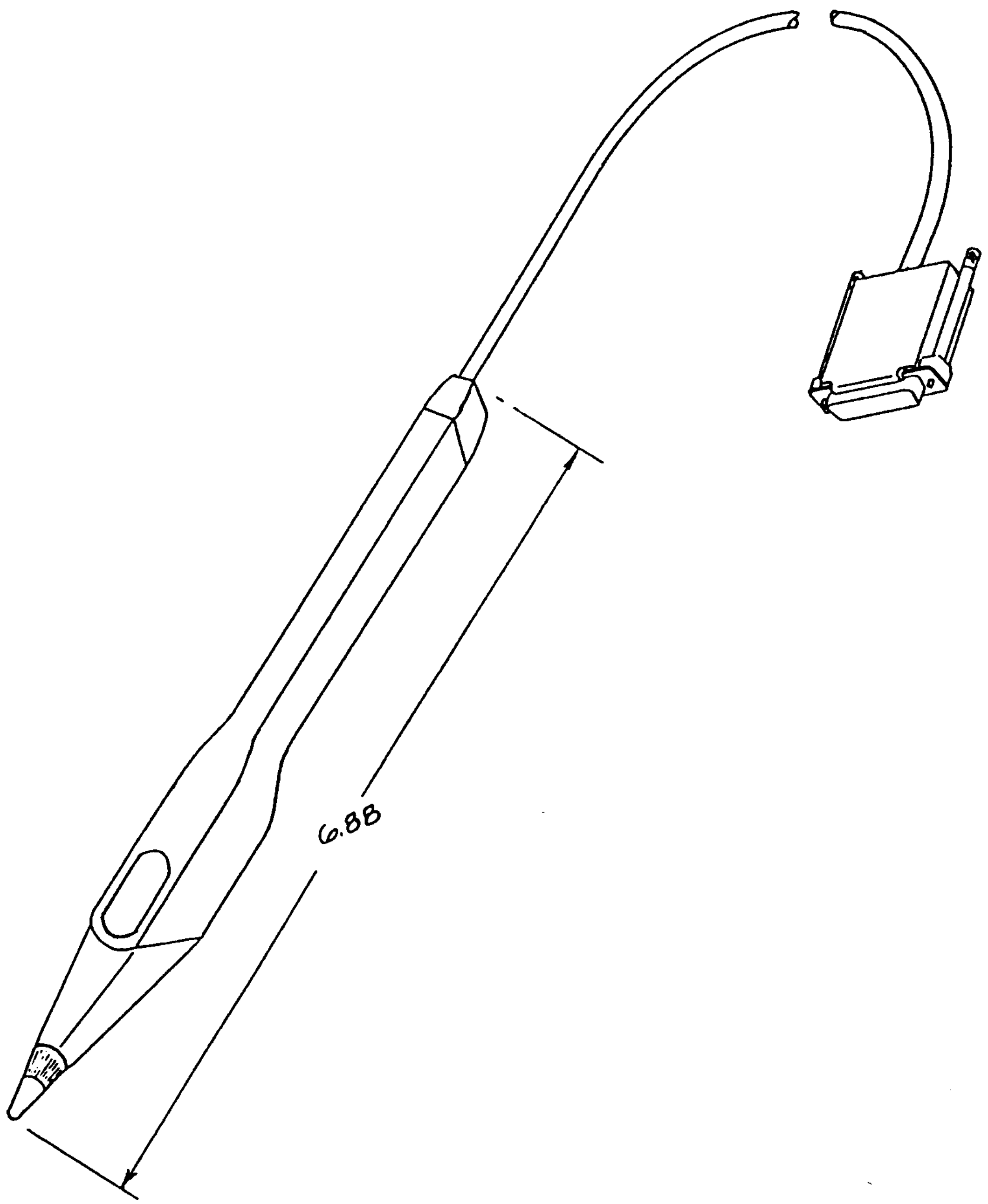


Figure 4.15A Stylus Dimensions (In Inches)

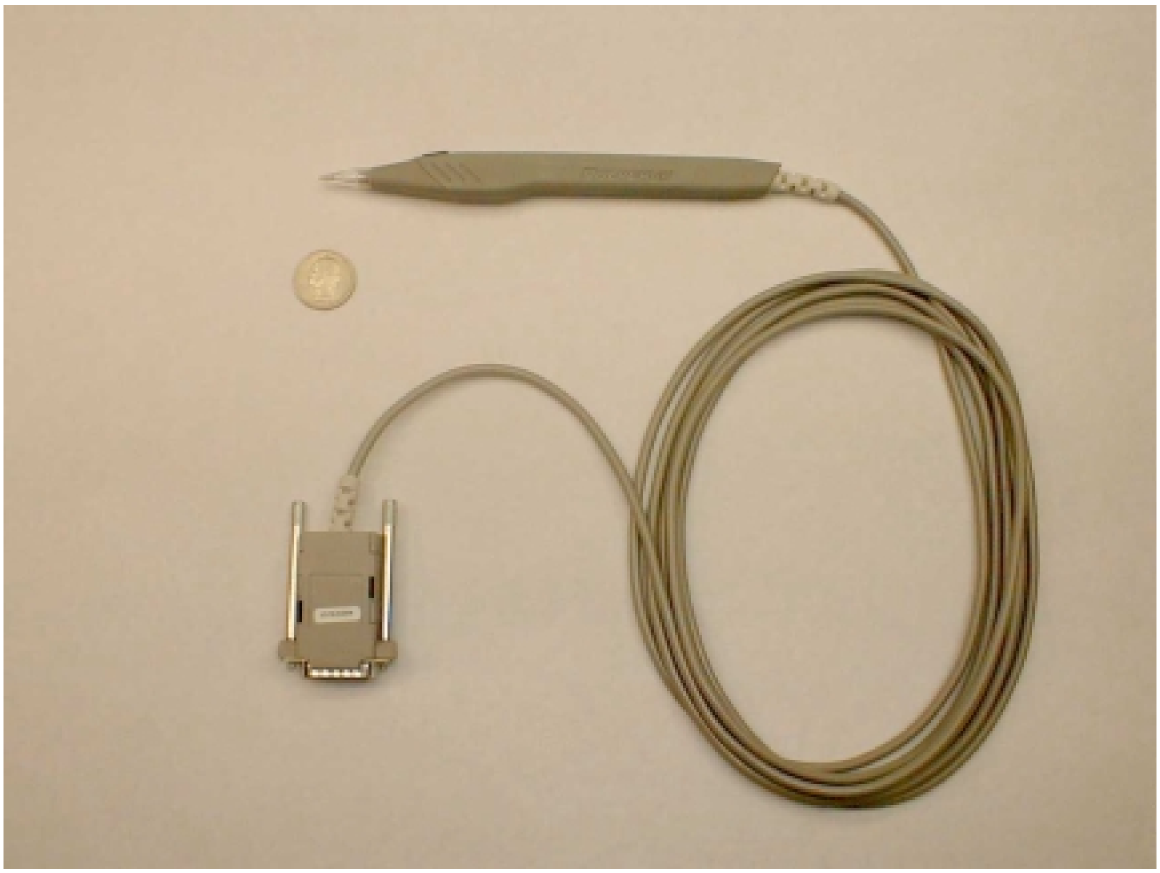


Figure 4.15B Stylus

Figure 4.16A. 3BALL

4.20 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.

5.0 SYSTEM OPERATION

5.1 I/O Considerations

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 ISOTRAK II 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.) There are two modes of operation with the RS-232; with Hardware Handshake (HH) and without HH.

Ensure that your RS-232 cable connects the **ISOTRAK II TRANSMIT** data pin (pin 3) to the **HOST'S RECEIVE** data pin and that the **ISOTRAK II RECEIVE** data pin (pin 2) is connected to the **HOST'S TRANSMIT** data pin. Also ensure that the RS-232 cable connects the **ISOTRAK II 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. In addition to proper cable connections, the I/O select switch must be set correctly, according to the host communication software. See diagram below for RS-232 cable connections without hardware handshaking:

RS-232 Cable Connections

ISOTRAK II		HOST
Transmit (pin 3)	--	Receive
Receive (pin 2)	--	Transmit
Ground (pin 5)	--	Ground

Note: The EIA standard RS-232C recommends that the maximum length of the interface cable should be less than 50 feet. Shielded cable is also recommended, in order to avoid possible interference.

The RS-232 interface of the ISOTRAK II uses the following protocols:

- Start Bits: 1
- Data Bits: 8
- Parity: None
- Stop Bits: 1
- Baud Rate: Selectable

5.2 Powering Up ISOTRAK II

To power-up your ISOTRAK II system, first ensure that the power switch on the back panel of the ISOTRAK II 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 ISOTRAK II. 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 immediately turn to a "steady-on" state, which indicates that the system is operational.

Important Note: Do not connect or disconnect the power cable to the ISOTRAK II electronics unit while it is powered on or while the power supply brick is energized. Internal component damage could result.

Initial Power Up Procedure

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

5.3 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 Ctrl 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 ISOTRAK II system is powered on.

5.4 Synchronization

Synchronization defines and controls the precise time that an ISOTRAK II system measurement cycle will start and thereby controls the tracking output from an application system point of view. The ISOTRAK II system has two distinct synchronization modes that are controlled by switch 4 of the I/O select switches: Internal sync and External sync.

5.5 Internal Sync

Internal synchronization is the normal operating mode for the ISOTRAK II system. Switch 4 of the I/O select switches should always be set to on (logic “1”or “up” position) unless an external sync pulse is provided. In the Internal Sync mode, each measurement cycle of the ISOTRAK II system starts immediately after the previous cycle ends. In internal sync mode, the system performs one measurement cycle every 16.67 milliseconds and any external sync signal is ignored.

5.6 External Sync

The external sync mode is invoked by turning switch 4 of the I/O select switches off (logic “0” or “down” position). The External Sync mode allows the user to define when the ISOTRAK II 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 ISOTRAK II data collection cycle or to slow the ISOTRAK II to a known and desired rate. To initiate the External Sync mode an external signal must be input to the SYNC IN port. In the external sync mode, the ISOTRAK II waits for an external sync signal in order to perform a single measurement cycle.

Note: Perform this function with the position and attitude filters off until the sync condition is established.

In external sync mode, the ISOTRAK II system will perform one and only one measurement cycle for each external sync input that transitions from the inactive state to the active state. The external sync signal requirements are as follows:

- Driver – Differential, from a 26LS31 or similar.
- Input – To ISOTRAK II sync I/O connector that has an LM339 differential receiver.
- Minimum Pulse Width – 100 microseconds
- Maximum Rep Rate – 16.67 milliseconds.
- Inactive State – Between 0 and 0.4 volts.
- Active State – Between 2.4 and 5.0 volts.

5.7 Multiple Systems Synchronization

When using more than one ISOTRAK II in the same area, it is important to sync the units together so that they will not interfere with each other and produce noisy data. When they are synced together, the ISOTRAK II systems are operated on a time-shared basis where the maximum update rate is 30 Hz per system when each system has a single receiver connected. Follow the procedure below to establish this condition:

- The I/O select switches of the first ISOTRAK II system should be set as follows: Switch 4 in the “down” position (to select external sync), switches 5 and 6 in the “up” position (to **enable** the 30 Hz square wave sync generator, the external sync signal that will be supplied to the second unit.)

- The I/O select switches of the second ISOTRAK II system should be set as follows: Switch 4 in the “down” position (to select external sync), switches 5 and 6 in the “down” position (to **disable** the 30 Hz square wave sync generator on that unit).

- Connect the two units together using a standard, four conductor modular telephone cable. (The cable plugs into each unit’s Sync I/O connector.)

5.8 Output Considerations

Most applications of the ISOTRAK II 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 the lag are as follows:

- Baud Rate
- Output Record Length
- Filtering
- Data Format (binary is more efficient than ASCII)

The ISOTRAK II baud rate should be set to the highest setting that is compatible with the host computer and the communication software. Although the ISOTRAK II system runs at 60 Hz, it may appear that it is running slower if the output is constrained by a slow baud rate. The ISOTRAK II is capable of running at speeds of up to 115,200 as selected by the I/O Select Switches on the back panel.

The ISOTRAK II default output record contains measurements for X, Y, Z in inches and Azimuth, Elevation, and Roll in degrees. This output format can be changed to Direction Cosines with “O” command (see section 6). Although the ISOTRAK II offers different combinations 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 ISOTRAK II 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.

When using the ISOTRAK II binary format, there are two import factors that should be considered: Serial encoding and byte swapping.

Continuous Binary Serial Encoding

This section describes the encoding scheme used to ensure synchronization when outputting binary data in the “continuous” mode. This information only applies to this combination of options. If either “non-continuous” transmit mode or ASCII format is used, this section can be ignored.

When receiving data serially, the host needs a way to recognize the beginning of each data record. This recognition is accomplished by insuring that the high order bit of each 8 bit byte is zero except in the first byte of each record as shown in Figure 5.8A.

When binary data is output continuously, the host must decode all of the records transmitted by the ISOTRAK II. This decoding must simply reverse the encoding performed by the ISOTRAK II. Figure 5.8A illustrates the encoding of a 14-byte record to produce a 16-byte record to be transmitted. (The overflow makes up the two extra bytes.) The number of encoded bytes transmitted is computed from the number of actual bytes as follows:

> Let LD = the length of the decoded record.
>
> Let LE = the length of the encoded record.
>
> Then LE = LD + Integer((LD-1) / 7) + 1.

Note: LE must be less than or equal to 125 bytes.

```
          +----------------------------------------------------------------------------+
          |         +-----------------------------------------------------------------+|
          |         |         +------------------------------------------------------+||
          |         |         |         +-------------------------------------------+|||
          |         |         |         |         +--------------------------------+||||
          |         |         |         |         |         +---------------------+|||||
          |         |         |         |         |         |         +----------+||||||
          |         |         |         |         |         |         |          |||||||
Decoded:  bbbbbbbb  bbbbbbbb  bbbbbbbb  bbbbbbbb  bbbbbbbb  bbbbbbbb  bbbbbbbb   |||||||
           |||||||   |||||||   |||||||   |||||||   |||||||   |||||||   |||||||   |||||||
Encoded:  1bbbbbbb  0bbbbbbb  0bbbbbbb  0bbbbbbb  0bbbbbbb  0bbbbbbb  0bbbbbbb  0bbbbbbb
           BYTE 1    BYTE 2    BYTE 3    BYTE 4    BYTE 5    BYTE 6    BYTE 7   OVERFLOW
          |      Header       |        X          |        Y          |    Z

          +----------------------------------------------------------------------------+
          |         +-----------------------------------------------------------------+|
          |         |         +------------------------------------------------------+||
          |         |         |         +-------------------------------------------+|||
          |         |         |         |         +--------------------------------+||||
          |         |         |         |         |         +---------------------+|||||
          |         |         |         |         |         |         +----------+||||||
          |         |         |         |         |         |         |          |||||||
Decoded:  bbbbbbbb  bbbbbbbb  bbbbbbbb  bbbbbbbb  bbbbbbbb  bbbbbbbb  bbbbbbbb   |||||||
           |||||||   |||||||   |||||||   |||||||   |||||||   |||||||   |||||||   |||||||
Encoded:  1bbbbbbb  0bbbbbbb  0bbbbbbb  0bbbbbbb  0bbbbbbb  0bbbbbbb  0bbbbbbb  0bbbbbbb
           BYTE 8    BYTE 9    BYTE 10   BYTE 11   BYTE 12   BYTE 13   BYTE 14  OVERFLOW
               Z    |        Az         |        El         |        Rl       |
```

Figure 5.8A – Binary Serial Encoding

Byte Swapping

Byte swapping refers to the manner in which the microprocessor chips handle the 16-bit integer values when transferring between their internal memory and main memory. Many common microprocessors “swap” the two bytes of a 16-bit integer when transferring it. In other words, when sending it to main memory, the low order byte is stored first, then the high order byte. This order is expected when the processor reads back a 16-bit integer from main memory to its internal memory.

Therefore, if the host utilizes a processor that employs this byte swapping technique, binary data received from the ISOTRAK II is immediately usable as 16-bit integers (after decoding as described in Serial Encoding.) However, if the host processor does not swap the high and low bytes automatically, the binary data must be swapped by the host to match the expectations of the ISOTRAK II as follows:

16-Bit Integer	**As Transmitted**
High Byte Low Byte	Low Byte High Byte

6.0 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.

6.1 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.

6.2 Command Format Notes

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

(2) 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.

(3) The RELATIVES field contains a list of those commands which provide related information to the system. For example, the unboresight command “b” is a relative to the boresight command “B”.

(4) The term station is a transmitter-receiver pair. The two receivers paired with the one available transmitter are assigned station numbers one and two.

(5) A numeric floating point value will be accepted by the machine if any of the following formats are used. <u>For example</u>: 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.

(6) 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

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

6.3 Command/Output Listing

See pages that follow.

ALIGNMENT REFERENCE FRAME A1

Syntax: A1,[Ox],[Oy],[Oz],[Xx],[Xy],[Xz],[Yx],[Yy],[Yz]<>

or

A1<> 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 6.3A. 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 ISOTRAK II and the axes of the sloped surface.

NOTE: This command operates incrementally. If the command is entered and the user then changes his/her mind, the 'R' command 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:

Ox,Oy,Oz	the Cartesian coordinates of the origin of the new reference frame.
Xx,Xy,Xz	the coordinates of the second 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. (0,0,0,166.32,0,0,0,166.32,0) in centimeters

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

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<>

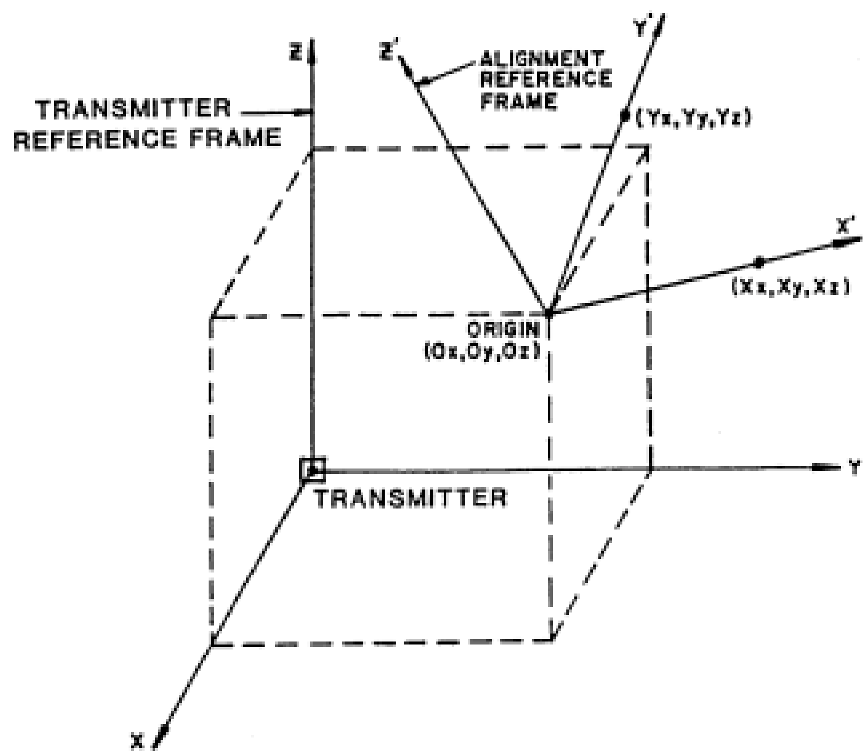


Figure 6.3A System Alignment

ALIGNMENT REFERENCE FRAME

SUB-RECORD IDENTIFIER .... A
INITIATING COMMAND .... A

---

byte(s)	Identification	Format
1	Record type, "2"	A1
1	“1”	A1
1	"A"	A1
21	Origin coordinates	3(Sxxx.xx)
21	Positive X-axis coordinates	3(Sxxx.xx)
21	Positive Y-axis coordinates	3(Sxxx.xx)
2	Carriage return, line feed	
68		

RESET ALIGNMENT REFERENCE FRAME R

Syntax: R1<>

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 or the transmitter's own reference frame.

Relatives: A

Example: Any time the alignment command (A1...) 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 Standard Alignment Procedure listed under Alignment Reference Frame.

BORESIGHT **B**

Syntax: Bstation<>

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 0,0,0 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

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 user's head is looking at a given object, he 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 user'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.

Note: **Do not use this command when using a stylus with the ISOTRAK II. The boresight command will nullify the tip calculations and induce errors in the X, Y, Z measurements.**

UNBORESIGHT **b**

Syntax: bstation<>

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

Example: If the user issued the Boresight command 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.)

CONTINUOUS PRINT OUTPUT C

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.)

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, like an animated character for example) then the continuous output configuration should be enabled. To enable continuous output mode, send the command as follows:

C

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

DISABLE CONTINUOUS PRINTING c

Syntax: c

Purpose: This command disables the continuous print output mode. After sending this command, the continuous data stream from the ISOTRAK II 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.

ENABLE DIGITIZER MODE Y

Syntax: Y

Purpose: This command converts the ISOTRAK II from “tracker” mode of operation to “digitizer” mode when a stylus is being used in lieu of a receiver. Digitized data from the receiver coil assembly in the stylus is then translated to the stylus tip. This command is a toggle, so repetition of the command converts the system back to tracker mode of operation.

Default: System default is “tracker” mode

Relatives: C, e, E, i

Example: If the user wanted to receive data every time the stylus button was activated, the following commands must be sent:

1. Send the Y command to enable “digitizer” mode. (Assuming the system was previously in “tracker” mode.)
2. Send the E command to enable “point” mode.
3. Send the Ctrl D command to enable “compatibility” mode.
4. Send the C command to set continuous output mode.

The system will now output a data record each time the stylus button is pressed.

ENABLE "RUN" DIGITIZER MODE e

Syntax: e

Purpose: This command allows the user to put the ISOTRAK II into "run" digitizer mode. Before sending the command, the system must first be in the digitizer mode.

Default: System default is "tracker" mode

Relatives: C, E, i, Y

Example: The user may wish to configure the system to digitizer mode, but begin receiving continuous data as soon as the C command is sent. To do this, the following commands must be sent:

1. Send the Y command to enable "digitizer" mode. (Assuming the system was previously in "tracker" mode.)
2. Send the e command to enable "run digitizer" mode.
3. Send the C command to enable continuous output mode.

The system will now automatically begin transmitting data records to the host, without having to press the stylus button.

ENABLE "POINT" DIGITIZER MODE E

Syntax: E

Purpose: This command allows the user to put the ISOTRAK II into "point" digitizer mode. In this mode, the system will send data to the host each time the stylus button is pressed.

Default: System default is "tracker" mode

Relatives: C, e, i, Y

Example: If the user wanted to receive data every time the stylus button was activated, the following commands must be sent:

1. Send the Y command to enable "digitizer" mode. (Assuming the system was previously in "tracker" mode.)
2. Send the E command to enable "point" mode.
3. Send the Ctrl D command to enable "compatibility" mode.
4. Send the C command to set continuous output mode.

The system will now output a data record each time the stylus button is pressed.

SET TRACK DIGITIZER MODE i

Syntax: i

Purpose: This command allows the user to put the ISOTRAK II into “track” digitizer mode. The track mode is identical to the run mode except that the stylus or 3Ball switch must be pressed once to initiate data transmission (track on). Thereafter, any activation of the stylus or 3Ball switch may be used to alternately suspend (track off) and resume (track on) data collection.

Default: System default is “tracker” mode

Relatives: C, e, E, Ctrl E, Y

Example: The user may wish to be able to start and stop a continuous stream of data by pressing the stylus button. To do so, the following commands should be sent:

1. Send the Y command to enable “digitizer” mode. (Assuming the system was previously in “tracker” mode.)
2. Send the i command to enable “track digitizer” mode.
3. Send the Ctrl D command to enable compatibility mode.
4. Send the C command to enable continuous output mode.

The user will now be able to press the stylus button once to start the continuous data stream and press the stylus button again to stop the continuous data stream and so on.

ENABLE ASCII OUTPUT FORMAT F

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 ISOTRAK II 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 ISOTRAK II system and there was a requirement to take it off line temporarily to do visual checks, the user would enable the ASCII output data format in order to be able to easily read the ISOTRAK II 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.

ENABLE BINARY OUTPUT FORMAT f

Syntax: f

Purpose: This command enables the binary output data format. Binary format is generally computer readable while ASCII format is human readable.

Relatives: F

Default: The default output data format is ASCII.

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

f

The ISOTRAK II will now output binary data.

HEMISPHERE OF OPERATION H

Syntax: Hstation,[p1],[p2],[p3]<>

or

H<> 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 ISOTRAK II system which side of the transmitter they will be on, for each station. 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.

p2 — the y-component of a vector pointing in the direction of the operational hemisphere.

p3 — the z-component of a vector pointing in the direction of the operational hemisphere.

Relatives: None

Default: The default hemisphere value is: 1,0,0 which is positive X or “forward” hemisphere.

Example: 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 one of the ISOTRAK II 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<>

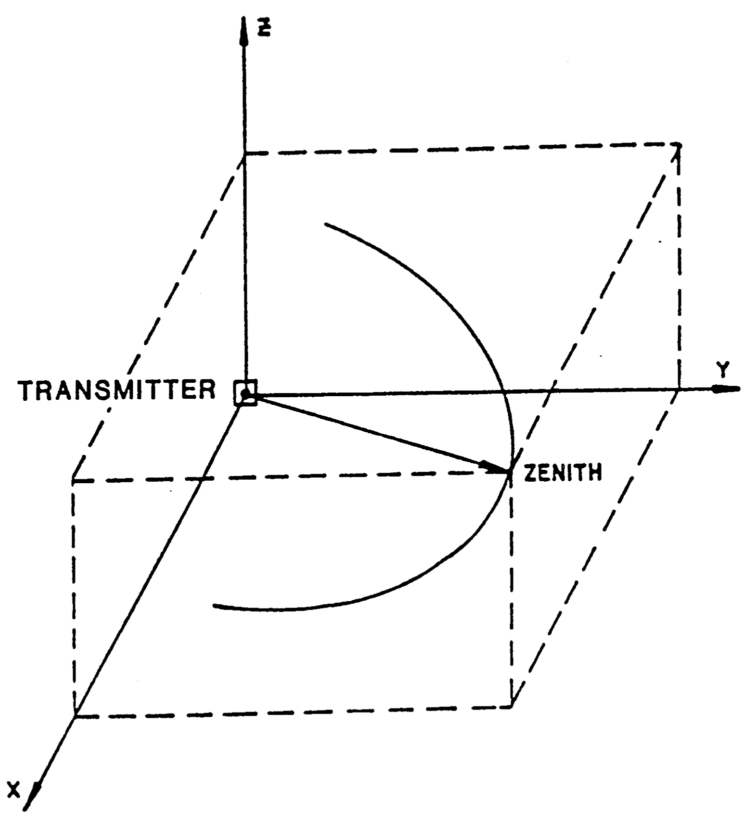


Figure 6.3B Hemisphere Vector
(Zenith represents the hemisphere vector)

HEMISPHERE OF OPERATION

RECORD IDENTIFIER .... H
INITIATING COMMAND .... H

byte(s)	Identification	Format
1	Record type, "2"	A1
1	Station number	A1
1	"H"	A1
7	Vector x-component	Sxx.xxx
7	Vector y-component	Sxx.xxx
7	Vector z-component	Sxx.xxx
2	Carriage return, line feed	
26		

DEFINE INCREMENT I

Syntax: I[distance]<>

or

I<> to read back the current increment distance selection.

Purpose: This command allows the user to define the increment and 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 ‘l<>’, 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:

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 one moves 2 inches in any axis, the following command should be entered:

I2<>

C

The system will now output a data record each time station one receiver moves two inches in any axis.

INCREMENT DEFINITION

RECORD IDENTIFIER I
INITIATING COMMAND I

byte(s)	Identification	Format
1	Record type, "2"	A1
1	“1”	A1
1	Sub-record type "I"	A1
7	Distance required to move	Sxxx.xx
2	Carriage return, line feed	
12		

ENABLE QUIET MODE **K**

Syntax: K

Purpose: This command allows the user to enable input signal averaging called "quiet mode."

Relatives: m

Default: Quiet mode is disabled

Example: The user can initiate data averaging on all input signals so the system will output position and orientation information based on averaged input data. The following command would be sent:

K

The system will now be in "quiet mode."

ACTIVE STATION STATE l

Syntax: lstation<>

or

l<> to retrieve the current station status

Description: A station is defined as a transmitter-receiver pair. The two receivers paired with the one transmitter are assigned station numbers one and two. Although stations are enabled simply by plugging the receivers into the ports on the ISOTRAK II SEU, the stations can then be disabled (or enabled again) by using a software toggle 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 toggle a station “on” or “off” in software, depending on the current state of that station. The command parameters are identified as follows:

Station	1 or 2

Relatives: none

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

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

1. Send the command l2<> to toggle station 2 off.
2. Press P to collect data from station 1 only.
3. Send the command l2<> to toggle station 2 on.
4. Send the command l1<> to toggle station 1 off.
5. Press P to collect data from station 2 only.
6. Send the command l1<> to toggle station 1 on.
7. Send the command l2<> to toggle station 2 off.
8. Press P to collect data from station 1 only.
9. Go to step 3 to continue collecting more data.

At any time, the user could send the command l<> to retrieve the current station status from the ISOTRAK II to find out which station or stations are active.

- If both stations were active, sending l<> would yield 11000000
- If only station one was active, sending l<> would yield 10000000
- If only station two was active, sending l<> would yield 01000000

DISABLE QUIET MODE m

Syntax: m

Purpose: This command allows the user to disable input signal averaging (quiet mode) and return the system to “normal mode.”

Relatives: K

Default: Quiet mode is disabled

Example: If the system is in quiet mode, the user can deactivate data averaging on all input signals so the system will be in “normal mode.” The following command would be sent:

m

The system will now be in normal mode.

DEFINE TIP OFFSETS N

Syntax: N,xoff,yoff,zoff<>

or

N<> 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. In order for this command to work, the system must first be in “Digitizer” mode (see Y command.) Although changing the tip offsets is not recommended, the ability to do so is available. The command parameters are listed below:

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. Set the ISOTRAK II to Digitizer mode by sending the command “Y”.
2. Verify that the ISOTRAK II system is in “inches” units by sending the “U” command.
3. Read the factory tip offsets from the PROM in the connector by sending the command N<>. (A typical factory tip offset might be 2.523, 0.004, 0.03.)
4. To add one inch to the factory calibration, type N,3.523,0.004,0.03<>
5. To verify that the tip offset was entered correctly, type N<> to read it back.

OUTPUT DATA LIST **O**

Syntax: O[code#],[code#],...,[code#]<>

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:

Code#	Data Item
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" command.
4	azimuth, elevation, roll Euler orientation angles
5	x-axis direction cosines
6	y-axis direction cosines
7	z-axis direction cosines
8	x-axis receiver data (factory use only)
9	y-axis receiver data (factory use only)
10	z-axis receiver data (factory use only)
11	orientation quaternion

Relatives: none

Default: 02,4,1<>; i.e., the three Cartesian coordinates, the three Euler orientation angles, carriage return, and line feed for stations 1 and 2.

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:

O5,6,7,1<>

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

OUTPUT ITEM LIST

RECORD IDENTIFIER .... O
INITIATING COMMAND .... O

byte(s)	Identification	Format
1	Record type, "2"	A1
1	Station number	A1
1	Sub-record type "O"	A1
1	Output item 1	A2
1	Output item 2	A2
1	Output item 3	A2
1	Output item 4	A2
.	.	
.	.	
.	.	
1	Output item N	A2
2	Carriage return, line feed	A2

SYSTEM DATA RECORD, ASCII FORMAT

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

Item	Identification	Format
1	Record type, “0” or System Error Code	A1
2	Station Number	A1
3	Blank	A1

Data Items:

0	ASCII space character	A1
1	Carriage return, line feed	A2
2	X,Y,Z position Cartesian Coordinates	3(Sxxx.xx)
3	Relative X,Y,Z Cartesian Coordinates	3(Sxxx.xx)
4	Az, El, Roll Euler orientation angles	3(Sxxx.xx)
5	X-axis Direction Cosines	3(Sx.xxxx)
6	Y-axis Direction Cosines	3(Sx.xxxx)
7	Z-axis Direction Cosine	3(Sx.xxxx)
11	Orientation Quaternion (Q0-Q3)	4(Sx.xxxx)

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.

SYSTEM DATA RECORD, BINARY FORMAT

RECORD IDENTIFIER .... none
INITIATING COMMANDS ..... P or in continuous mode

Data Items	Identification	Length
0	ASCII space character	A1
1	Carriage return, line feed	A2
2	X,Y,Z position Cartesian Coordinates	6
3	Relative X,Y,Z Cartesian Coordinates	6
4	Az, El, Roll Euler orientation angles	6
5	X-axis Direction Cosines	6
6	Y-axis Direction Cosines	6
7	Z-axis Direction Cosine	6
11	Orientation Quaternion (Q0-Q3)	6

SINGLE DATA RECORD OUTPUT P

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 two stations are enabled, then data from each active station will be displayed in numerical order (station 1 first, station 2 second) 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 ISOTRAK II system will be sent across the serial port to the host computer.

TRANSMITTER MOUNTING FRAME **r**

Syntax: r1,r,[A],[E],[R]<>

or

r1,r<> 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 the receivers. It is basically a non-physical rotation of the transmitter and becomes the new orientation reference for the receiver's measurements. The command parameters are as follows:

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:

t (to enable extended configuration mode)
r1,r,0,0,180<> (to apply a 180 degree rotation in roll)

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

SYSTEM STATUS RECORD S

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 ISOTRAK II system.

Relatives: None

Default: N/A

Example: Sending the "S" command to the system will yield an output similar to the following:

21S208 0 0 4 0

- The fact that the status record was received verifies communication
- **2** is the record type
- **1** is the station number
- **S** is the command to retrieve a status record
- **208** is the hex code for system configuration (see following page for explanation)
- **0 0** are the BIT error codes (it would be a number other than 0 if there was a system error to report)
- **4.0** is the firmware version number

Note: The station listed is chosen by the ISOTRAK II, 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.

SYSTEM STATUS

RECORD IDENTIFIER .... S
INITIATING COMMAND .... S

Length	Identification	Format
1 byte	Record type, "2"	A1
1	Station number	A1
1	"S"	A1
3	System flags (config. code)	H3
3	Bit Error	I3
6	Bit Error	I6
6	Software Version Number	I6
32	Blank	A32
2	Carriage Return, Line Feed	A2
55		

Bit #	Meaning of System Flags (configuration code)	
0	Output Format	0=ASCII,1=Binary
1	Units	0=Inches, 1=Centimeters
2	Compensation	0=Off, 1=On
3	Transmit Mode	0=Non-Continuous, 1=Continuous
4	Configuration	1=Tracker
5	Extended Config.	0=Off, 1=On
7,6	Digitizer Mode	11=Off 00=Point 01=Run 10=Track

Example 1: Send the “S” command to the ISOTRAK II
The system responds with 21S208 0 0 4 0
Convert to 208 to binary format: =11010000
Read the number from right to left and convert it using the table above:
Bit 0=0 (ASCII)
Bit 1=0 (Inches)
Bit 2=0 (Compensation is off)
Bit 3=0 (Non-continuous)
Bit 4=1 (Tracker mode)
Bit 5=0 (Extended configuration is off)
Bit 6=1
Bit 7=1 (Digitizer mode is off)

Example 2: Send the “Y” command to the ISOTRAK II
Send the “i” command to the ISOTRAK II
Send the “S” command to the ISOTRAK II
The system responds with 21S128 0 0 4 0
Convert 128 to binary format: = 10000000
Read the number from right to left and convert it using the table
Bit 0=0 (ASCII)
Bit 1=0 (Inches)
Bit 2=0 (Compensation is off)
Bit 3=0 (Non-continuous)
Bit 4=0 (Digitizer mode)
Bit 5=0 (Extended configuration is off)
Bit 6=0
Bit 7=1 (“Track” Digitizer mode is enabled)

EXTENDED CONFIGURATON t

Syntax: t

Purpose: This command allows the user to toggle extended configuration on or off. With the ISOTRAK II system, certain commands are accessible only with the extended configuration enabled. Extended commands include filter settings (“x” and “v” commands) and transmitter mounting frame (“r” command).

Relatives: None

Default: Extended configuration off

Example: If the user wanted to adjust the filter settings, extended configuration would have to be enabled first by sending the following command:

t
(See “x” and “v” commands for information on adjusting filter settings.)

Extended configuration is now enabled. Because it is a toggle command, sending the “t” command again would disable extended configuration.

Syntax: T

Purpose: This command allows the user to turn tracker configuration on (if the system was previously in “digitizer” mode). In “tracker” mode, the tip calibration offset for the stylus are no longer activated

Relatives: Y

Default: Tracker mode on

Example: If the system was in “digitizer mode”, the user could send the following command to switch to “tracker mode”:

T

The system is now in tracker mode

ENGLISH CONVERSION UNITS U

Syntax: U

Description: Input/output units 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 units 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.

METRIC CONVERSION UNITS u

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 units 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.

POSITION OPERATIONAL ENVELOPE V

Syntax: Vs,[xmax],[ymax],[zmax],[xmin],[ymin],[zmin]<>

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.

xmax the maximum x-coordinate for the position operational envelope.

ymax the maximum y-coordinate for the position operational envelope.

zmax the maximum z-coordinate for the position operational envelope.

xmin the minimum x-coordinate for the position operational envelope.

ymin the minimum y-coordinate for the position operational envelope.

zmin the minimum z-coordinate for the position operational envelope.

Relatives: Q

Default: 65.48 65.48 65.48 –65.48 –65.48 –65.48

166.32 166.32 166.32 –166.32 –166.32 –166.32 (in centimeters)

Example: A user could reduce the position operation envelope to specific dimensions by sending the following command:

V1,10,20,30,0,-20,-15<>

This would yield the following operation envelope:

X = 0 to +10
Y = -20 to +20
Z = -15 to + 30

POSITION OPERATIONAL ENVELOPE

RECORD IDENTIFIER V
INITIATING COMMAND V

byte(s)	Identification	Format
1	Record type, "2"	A1
1	Station number	A1
1	"V"	A1
7	Maximum X-coordinate value	Sxxx.xx
7	Maximum Y-coordinate value	Sxxx.xx
7	Maximum Z-coordinate value	Sxxx.xx
7	Minimum X-coordinate value	Sxxx.xx
7	Minimum Y-coordinate value	Sxxx.xx
7	Minimum Z-coordinate value	Sxxx.xx
2	Carriage return, line feed	

ATTITUDE FILTER PARAMETERS v

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. **Note:** It is an extended command, so the user must enable extended commands before using this command. (See "t" command.)

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.

Relatives: none

Default: The default mode for all filter parameters is ON. Although these parameters are a function of the user's particular environment, the following default settings are a good starting point for determining optimum filtering in your particular environment.

F	Set to 0.2
FLOW	Set to 0.2
FHIGH	Set to 0.96
FACTOR	Set to 0.96

Example: The settings listed above are the default settings. To turn off filtering, send the following commands to the system:

t (to enable extended commands)
v0,1,0,0<> (to turn off filtering)

To turn the filters back on to the default value, cycle the power or send the following command:

v.2,.2,.95,.95<> (to select medium filtering)

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

ATTITUDE FILTER PARAMETERS

RECORD IDENTIFIER v
INITIATING COMMAND v

byte(s)	Identification	Format
1	Record type, "2"	A1
1	Station number	A1
1	"v"	A1
7	Filter sensitivity	bSx.xxx
7	Floating filter low value	bSx.xxx
7	Floating filter high value	bSx.xxx
7	Transition rate maximum	bSx.xxx
2	Carriage return, line feed	

POSITION FILTER PARAMETERS x

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. **Note:** It is an extended command, so the user must enable extended commands before using this command. (See “t” command.)

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.

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 ON. Although these parameters are a function of the user's particular environment, the following default settings are a good starting point for determining optimum filtering in your particular environment.

F	Set to 0.2
FLOW	Set to 0.2
FHIGH	Set to 0.96
FACTOR	Set to 0.96

Example: The settings listed above are the default settings. To turn off filtering, send the following commands to the system:

t (to turn on extended commands)
x0,1,0,0<> (to turn off filtering)

To turn the filters back on to the default value, cycle the power or send the following command:

x.2,.2,.95,.95<> (to turn on medium filtering)

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

POSITION FILTER PARAMETERS

RECORD IDENTIFIER x
INITIATING COMMAND x

byte(s)	Identification	Format
1	Record type, "2"	A1
1	Station number	A1
1	"v"	A1
7	Filter sensitivity	bSx.xxx
7	Floating filter low value	bSx.xxx
7	Floating filter high value	bSx.xxx
7	Transition rate maximum	bSx.xxx
2	Carriage return, line feed	

REINITIALIZE SYSTEM **Ctrl Y**

Syntax: Ctrl 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: None

Default: N/A

Example: If the user had changed several configuration parameters and wanted to get the system back to its original, factory default condition, the following command should be sent:

Ctrl Y

The system will now be in its original factory default condition. The Ctrl Y simulates turning the system power off, then back on again.

COMPATIBILITY MODE **Ctrl D**

Syntax: Ctrl D

Purpose: Compatibility mode refers to compatibility with the previous ISOTRAK design. It allows the user to enable specific uses of the digitizer “point” mode and digitizer “track” mode.

Relatives: E, i

Default: Disabled

Example: See examples for “E” and “i” command sets using the Ctrl D command.

END TRACK MODE **Ctrl E**

Syntax: Ctrl E

Purpose: This command allows the user to disable digitizer “track” mode.

Relatives: i

Default: N/A

Example: If the user had previously enabled digitizer track mode (see example for “i” command) the system would be in a mode where pressing the stylus button would start the continuous stream of data. The user could then **stop** the continuous stream of data by pressing the stylus button again, or by sending the following command:

Ctrl E

Restarting the continuous stream of data would be accomplished by pressing the stylus button again.

SUSPEND DATA TRANSMISSION **Ctrl S**

Syntax: Ctrl S

Purpose: This command suspends data transmission to the host device until a subsequent Ctrl Q is received. If a previous Ctrl S command has been issued, without an intervening Ctrl Q, this command will have no effect.

Relatives: Ctrl Q

Default: N/A

Example: If the ISOTRAK II system had been issued the "C" command to output data continuously the following command could be used to suspend or temporarily stop the data transmission:

Ctrl S

The data stream will stop scrolling and will not begin again until a Ctrl Q is issued.

RESUME DATA TRANSMISSION **Ctrl Q**

Syntax: Ctrl Q

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

Relatives: Ctrl S

Default: N/A

Example: If the ISOTRAK II system had been issued the “C” command to output data continuously and then the Ctrl S command had been used to suspend or temporarily stop the data transmission, the following command could be used to start the data again:

Ctrl Q

The continuous data stream will now resume.

6.4 Error Codes and Trouble Shooting

- Error codes A-Z are generally hardware failures
- Error codes a-z are generally software failures (with the exception of “d”)

Symptom	Possible Solution
ISOTRAK II Won't Communicate	Check Dipswitch Settings Check RS-232 Cable Check Communication Program Settings Check PC COM Port Return SEU for Repair
BIT Error A – EPROM Checksum Error	Firmware may need Replacing, Return SEU for Repair
BIT Error C – RAM Test Error	Return SEU for Repair
BIT Error S – Self-Calibration Error	Return SEU for Repair
BIT Error U – Transmitter or Receiver Error	PROM Failure or Broken Wire, Return Transmitter or Receiver for Repair
BIT Error V – Transmitter or Receiver Error	Bad Connection to SEU, or Broken Wire, Return Transmitter or Receiver for Repair
BIT Error d – Receiver Error	Broken Wire, Return Receiver for Repair
BIT Error e – Out of Envelope Error	Move Receiver Closer to Transmitter or Specify a Larger Envelope (See “V” Command)

7.0 LIMITED WARRANTY AND LIMITATION OF LIABILITY

7.1

Polhemus Incorporated warrants that the Systems shall be free from defects in material and workmanship for a period of one year from the date ownership of the System passed from PI to Buyer. PI shall, upon notification within the warranty period, correct such defects by repair or replacement with a like serviceable item at PI's option. This warranty shall be considered void if the System is operated other than in accordance with the instructions in PI's User Manual or is damaged by accident or mishandling. Parts or material, which are clearly expendable or subject to normal wear beyond usefulness within the warranty period such as lamps, fuses, etc., are not covered by this warranty.

7.2

In the event any System or portion thereof is defective, Buyer shall, within the warranty period, notify PI in writing of the nature of the defect, remove the defective parts and, at the direction of PI, ship such parts to PI. Upon determination by PI that the parts or Systems are defective and covered by the warranty set forth above, PI, at its option shall repair or replace the same without cost to Buyer. Buyer shall pay all charges for transportation and delivery costs to PI's factory for defective parts where directed to be sent to PI, and PI shall pay for transportation costs to Buyer's facility only for warranty replacement parts and Systems. Removed parts covered by claims under this warranty shall become the property of PI.

7.3

In the event that allegedly defective parts are found not to be defective, or not covered by warranty, Buyer agrees that PI may invoice Buyer for all reasonable expenses incurred in inspecting, testing, repairing and returning the Systems 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.

7.4

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

7.5

Warranties shall not apply to any Systems which have been:

(a) repaired or altered other than by PI, except when so authorized in writing by PI.
(b) used in an unauthorized or improper manner, or without following normal operating procedures; or
(c) improperly maintained and where such activities in PI's sole judgement, have adversely affected the Systems. Neither shall warranties apply in the case of damage through accidents or acts of nature such as flood, earthquake, lightning, tornado, typhoon, power surge or failure, environmental extremes or other external causes.

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GLOSSARY

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 SA*CE -SE	CA*SE*SR - SA*CR CA*CR + SA*SE*SR CE*SR	CA*SE*CR + SA*SR SA*SE*CR – CA*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 A1.

In Figure A1, 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.

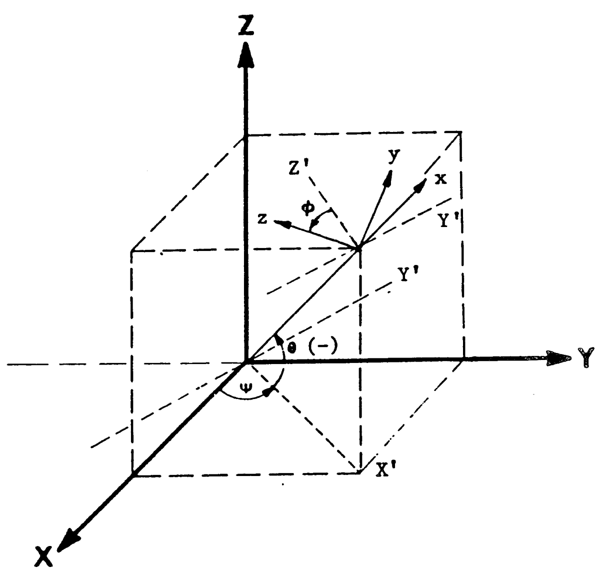
The 3SPACE Euler angles, azimuth, elevation and roll, are designated ψ, θ, and ϕ in Figure A1. These angles represent an azimuth-primary sequence of frame rotations that define the current orientation of the receiver with respect to its zero-orientation state. The defining rotation sequence is an azimuth rotation followed by an elevation rotation followed by a roll rotation.

The azimuth angle ψ is defined in Figure A1 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 A1, the azimuth, elevation and roll rotations are positive, negative and positive respectively.



X, Y, Z = Alignment (Reference) Frame
X, Y, Z = Rotated Stylus or Receiver Coordinate Frame

Ψ = Azimuth
Θ = Elevation
ϕ = Roll

Figure A1. 3Space Euler Angles

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.

APPENDIX A: STANDARD/OPTIONAL ITEMS

ISOTRAK II HARDWARE

The ISOTRAK II system consists of the following standard and optional items:

Standard Items

1. System Electronics Unit (SEU)	4A0323-03
2. Power Supply Brick	1C0034
3. 110V Power Cord	17500B-BLK
4. Standard Transmitter w/ 10' cable	3A0369-07
5. Standard Receiver w/ 10' cable	4A0314-01
6. ISOTRAK II User Manual Kit	OPM00PI003

Optional Items

1. Mini Receiver w/ 20' cable	4A0394-06
2. Stylus w/ 10' or 20' cable	4A0318-01/-02
3. Short Handle Stylus w/ 10' or 20' cable	4A0318-03/-04
4. Round Tip Stylus w/ 10' or 20' cable	4A0318-06/-05
5. 3Ball w/ 10' cable	4A0314-05
6. 220V Power Cord	17850
7. Synchronization cable	xxx

Note: Because the ISOTRAK II is a diverse system and is used in many different types of applications, special options are often created for specific applications. Please contact Polhemus for more information.

APPENDIX B: 'ACCURACY AND RESOLUTION' WHITE PAPER

ACCURACY AND RESOLUTION IN ELECTROMAGNETIC
SIX-DEGREE-OF-FREEDOM 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 six degree-of-freedom 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 B1. 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.

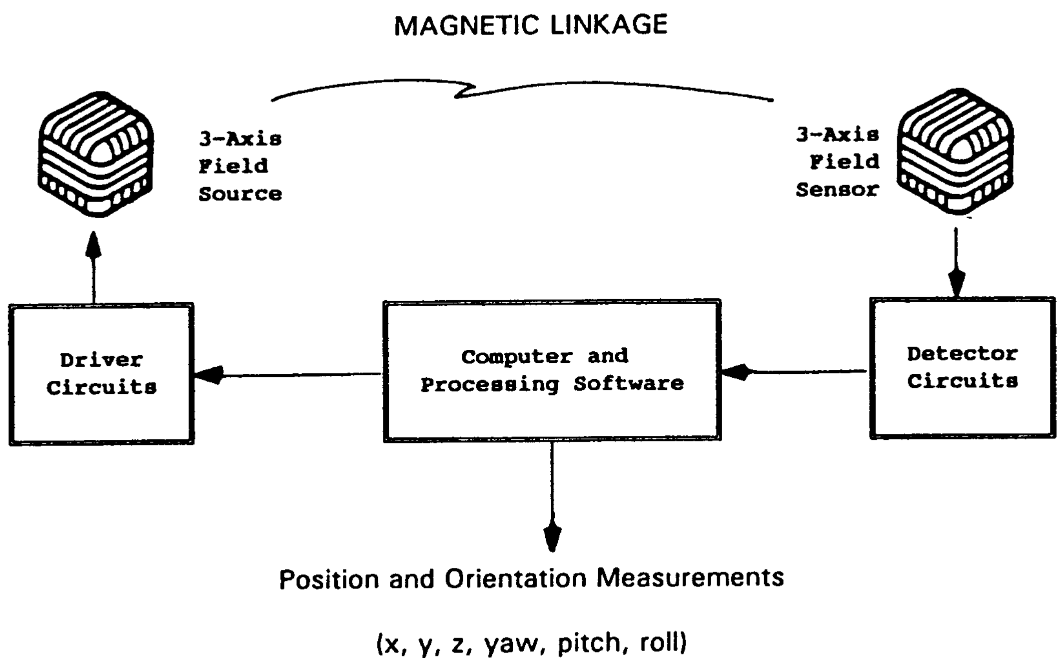


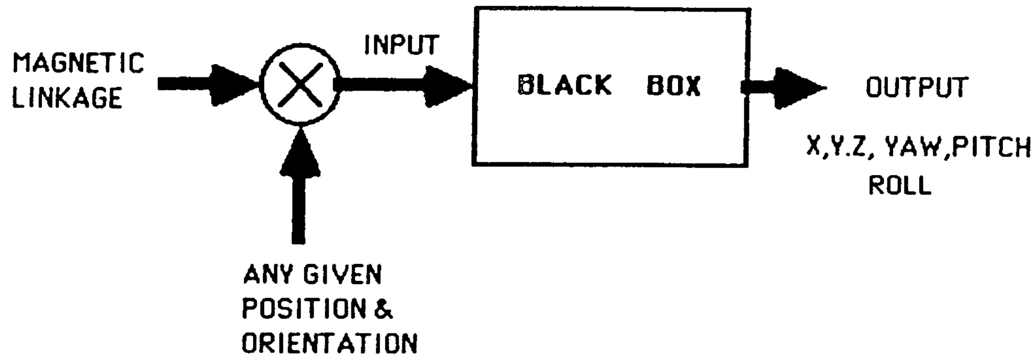
Figure B1. Position and Orientation Measurement
System Block Diagram.

In the system shown in Figure B1, 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 B2. 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 B2. 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:

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

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:

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

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 six degree-of-freedom 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 B3. 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 six degree-of-freedom 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.).

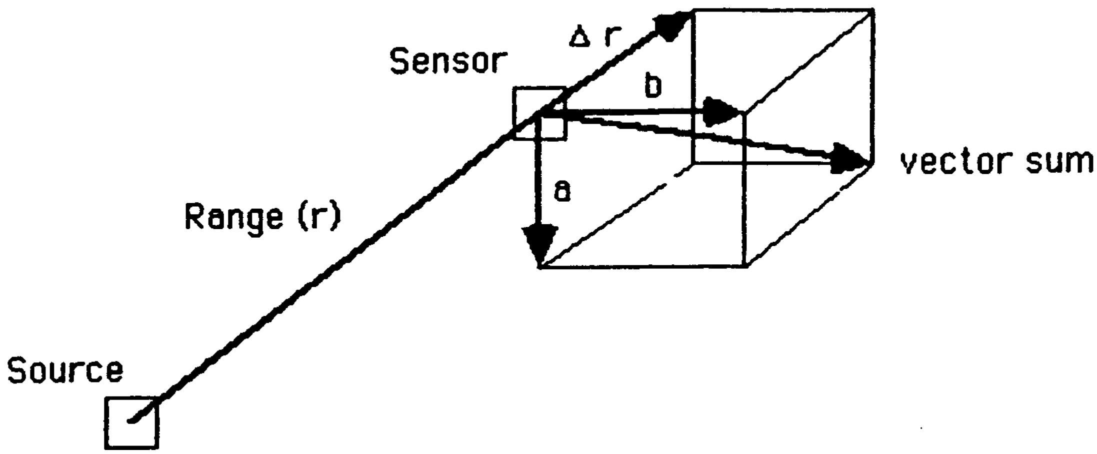


Figure B3. Translational Resolution.

ACCURACY

The accuracy of electromagnetic six degree-of-freedom 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 six degree-of-freedom 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 six degree-of-freedom 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 <u>positional</u> Static Accuracy at each given point within the specified motion box. Obviously, an <u>overall</u> 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 <u>orientational</u> 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 six degree-of-freedom 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 <u>sequence</u> 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 <u>orientational</u> Static Accuracy. As for the positional Static Accuracy, the <u>overall</u> <u>orientational</u> 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, six-degree-of-freedom 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 C: 'LATENCY' WHITE PAPER

TECHNICAL NOTE

Latency - 3SPACE® ISOTRAK II®

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 ISOTRAK II magnetic six-degree-of-freedom 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 ISOTRAK II 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 ISOTRAK II 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

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

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. 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 $t=\tau$; 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 $t=\tau/2$, the midpoint of the sampling period; hence, the effective latency is $T - \tau/2$, 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 115.2 kBaud 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)

ISOTRAK II 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.

ISOTRAK II coordinate filters are exponential filters as described by the following equation.

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

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 $\alpha \rightarrow 0$ the filter output never changes; and in the limit as $\alpha \rightarrow 1$ 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 (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).

$$< x >_k = x - \left(\frac{1 - \alpha}{\alpha} \right) v \, \Delta t \qquad \textbf{(2)}$$

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

$$\frac{x - \langle x \rangle_k}{v} = \left(\frac{1-\alpha}{\alpha} \right) \Delta t \qquad \textbf{(3)}$$

Equation (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 Δt = 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 = τ/2 - 0.44 ms = 2.2 ms; this would increase apparent latency to T - τ/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 = τ/2 - 158 ms; this yields an apparent latent period of T-τ/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 PI 3SPACE® ISOTRAK II 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 ISOTRAK II 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 D: CABLE DIAGRAMS

RS-232 Cable Diagram

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

```
To PC                                                          To ISOTRAK II
D-Type Connector                                               D-Type Conn.
9-Pin Female                                                   9-Pin Female

Pin #                       Identification                     Pin #

1                           DCD (Signal Detector)
2 --Receive Data ---------------------------------Transmit Data---  3
3 --Transmit Data --------------------------------Receive Data--    2
4                           DTR (DTE Ready)                    8
5 ------------------------  Signal Ground-----------------------    5
6                           DSR (DCE Ready)                    7
7                           RTS (Request to Send)
8                           CTS (Clear to Send)
9                           RI (Ring Indicator)
```

RS-232 Cable Diagram

- IBM (PC) Compatible Computer

To PC D-Type Connector 25-Pin Female		To ISOTRAK II D-Type Conn. 9-Pin Female
Pin #	Identification	Pin #
1	Shield	
2 --Transmit Data -----	-----Receive Data--	2
3 --Receive Data -----	-----Transmit Data--	3
4	RTS (Request to Send)	
5	CTS (Clear to Send)	
6	DSR (DCE Ready)	7
7 -----	Signal Ground-----	5
8	DCD (Received Line Signal Detector)	
9	Reserved	
10	Reserved	
11	Not Used	
12	SCF/CI	
13	Secondary CTS	
14	Secondary TD	
15	Transmitter Signal Element Timing	
16	Secondary RD	
17	Receiver Signal Element Timing	
18	Local Loopback	
19	Secondary RTS	
20	DTR (DTE Ready)	8
21	Remote Loopback/Signal Quality	
22	Detector RI (Ring Indicator)	
23	Data Signal Rate Selector	
24	Transmit Signal Element Timing	
25	Test Mode	

RS-232 Cable Diagram

- SGI Indigo2, Indigo, Onyx, Iris

To PC Circular Connector DIN-8		To ISOTRAK II D-Type Conn. 9-Pin Female
Pin #	Identification	Pin #
1	DTR (DTE Ready)	
2	CTS (Clear to Send)	
3 --Transmit Data ----------	----------Receive Data--	2
4 ----------	Signal Ground----------	5
5 --Receive Data ----------	----------Transmit Data--	3
6	RTS (Request to Send)	
7	DCD (Received Line Signal Detector)	
8	Ground	

RS-232 Cable Diagram

- SGI VTX, Onyx, Personal Iris

To PC Circular Connector DIN-8		To ISOTRAK II D-Type Conn. 9-Pin Female
Pin #	Identification	Pin #
2	--Transmit Data--Receive Data--	2
3	--Receive Data---Transmit Data-	3
4	RTS (Request to Send)	
5	CTS (Clear to Send)	
6	Not Used	
7	------------------------------------ Ground---	5
8	DCD (Received Line Signal Detector)	
9	DTR (DTE Ready)	

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