



**G-822A and G-823A & B  
CESIUM MAGNETOMETER  
27597-0M REV. B5**

*Operation Manual*

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# TABLE OF CONTENTS

<b>1.0 INTRODUCTION .....</b>	<b>1</b>
<b>2.0 SYSTEM COMPONENTS .....</b>	<b>2</b>
<b>3.0 PERFORMANCE.....</b>	<b>3</b>
<b>4.0 INSTALLATION .....</b>	<b>4</b>
4.1 Sensor orientation.....	5
4.2 Sensor attachment .....	10
4.3 Environmental Considerations .....	11
Vibration .....	11
Electronic/electromagnetic.....	11
Temperature .....	12
<b>5.0 OPERATION .....</b>	<b>12</b>
<b>6.0 TROUBLE SHOOTING .....</b>	<b>13</b>
<b>7.0 G-823A MAGNETOMETER .....</b>	<b>14</b>
7.1 CM-201 Output Format .....	16
7.2 Commands.....	18
7.3 Detailed command descriptions:.....	22
Cycle Time Set.....	22
A/D channel select/enable.....	22
Baud Rate Change.....	23
Output Format Select .....	23
Julian Time Set .....	27
Julian Time Enable .....	27
Julian Output format .....	28
Find Counters.....	28
Set Preamble character.....	29
Echo Error command .....	29
Interrogate Setup command .....	29
Analog channels .....	29
Reset command .....	30
Jump to debug.....	30
7.4 Power-up Initialization.....	31

<b>8.0 G-823B MAGNETOMETER .....</b>	<b>31</b>
<b>9.0 ACCESSORY SOFTWARE.....</b>	<b>32</b>
<b>9.1 CM-201 .....</b>	<b>32</b>
install.bat.....	33
cm201set.bat .....	33
cm201.bat.....	33
cm201go.exe.....	33
commflip.exe .....	34
batmenu.exe, drawbox.exe, gotoxy.exe, yymmdd.exe, foreach.exe, getkey.com.....	34
<b>9.2 Cesium Sensor Azimuth Program - CsAz.....</b>	<b>34</b>
<b>9.3 View201 .....</b>	<b>36</b>
Function Keys .....	37
Displaying Analog Channels.....	39
Display channel ON/OFF [0/1]:.....	39
Counter Number [0-2]: .....	40
Analog Channel Number [0-5]:.....	40
Unipolar/Bipolar [U/B].....	40
Clip/Wrap [C/W] .....	40
Full Scale Set .....	40
Label .....	41
Set trace color .....	41
<b>APPENDIX A1. MODEL G-822A SPECIFICATIONS.....</b>	<b>43</b>
<b>APPENDIX A2. MODEL G-823A SPECIFICATIONS.....</b>	<b>44</b>
<b>APPENDIX A3. SENSOR INSTALLATIONS .....</b>	<b>45</b>
<b>APPENDIX A4. CESIUM-VAPOR SENSOR THEORY .....</b>	<b>50</b>
<b>APPENDIX A5. G-822A GENERAL BLOCK DIAGRAM OF SYSTEM COMPONENTS .....</b>	<b>54</b>
<b>APPENDIX A6. G-823A GENERAL BLOCK DIAGRAM OF SYSTEM COMPONENTS .....</b>	<b>55</b>
<b>APPENDIX A7. G-823B GENERAL BLOCK DIAGRAM OF SYSTEM COMPONENTS .....</b>	<b>56</b>

## LIST OF FIGURES AND TABLES

FIGURE 1. G-822A SENSOR AND SENSOR DRIVER MODULE.....	1
FIGURE 2. G-822A SYSTEM COMPONENTS .....	2
FIGURE 3. ACTIVE ZONE FOR THE CESIUM-VAPOR SENSOR. ....	3
FIGURE 4. SURFACE INCLINATION OF THE EARTH'S MAGNETIC FIELD. ....	4
FIGURE 5. MAGNETIC FIELD INTENSITY AT THE EARTH'S SURFACE. ....	5

FIGURE 6. MID-LATITUDE ZONE. ....	6
FIGURE 7. POLAR LATITUDE ZONES. ....	7
FIGURE 8. EQUATORIAL LATITUDE ZONE - 1. ....	8
FIGURE 9. EQUATORIAL LATITUDE ZONE - 2.....	8
FIGURE 10 . SENSOR MOUNT THAT PROVIDES FOR TWO AXES OF ADJUSTMENT. ....	10
FIGURE 11. SIGNAL DECOUPLER CIRCUIT .....	12
FIGURE 12. SCHEMATIC OF CM-201, MAGNETOMETER, AND COMPUTER CONNECTIONS .....	16
FIGURE 13. SCHEMATIC DIAGRAM OF DAISY-CHAINED CM-201 COUNTER MODULES. ....	18
FIGURE 14. G-823B INSTALLED AS BASE-STATION MAGNETOMETER. ....	32

TABLE 1. G-822A STANDARD COMPONENT WEIGHTS AND DIMENSIONS .....	2
TABLE 2. TROUBLE SHOOTING .....	13
TABLE 3. G-823A STANDARD COMPONENT WEIGHTS AND DIMENSIONS .....	15
TABLE 4. G-823A INTERFACE CABLE PIN-OUT .....	15
TABLE 5. EXAMPLE OF CM-201 DEFAULT OUTPUT DATA STREAM.....	17



## 1.0 INTRODUCTION

Congratulations on your purchase or rental of one of the finest cesium vapor magnetometers ever produced. This manual will provide you with an understanding of alkali vapor magnetometer technology and will give you instructions for installing the system for airborne, land or marine use. It is not meant to be exhaustive for every case as there are many different situations and applications in which magnetometers can be used. Please contact the factory if you have specific questions relating to your special application.

The Geometrics G-822A and G-823A magnetometers employ an optically pumped Cesium-vapor atomic magnetic resonance system that functions as the frequency control element in an oscillator circuit. The G-823A is simply a G-822A containing additional counter circuitry that internally converts the magnetometer's analog signal into a digital RS-232 output. Because the G-822A is identical to the G-823A in all other respects, the installation instructions are provided referencing the G-822A only. However they apply to the G-823A as well. A description of the G-823A operation is presented in the last chapter.



**Figure 1. G-822A Sensor and Sensor driver module**

The frequency of the magnetometer electrical oscillator is known as the Larmor frequency and it varies directly with the ambient magnetic field at the sensor. When this frequency is accurately measured it provides a precise measurement of the total magnetic field. The design of the sensor optical package uses a split-beam design which eliminates the need to optimize sensor orientation to obtain precise measurements.

As shown in Figure 1, the G-822A magnetometer consists of two interconnected modules: a sensor module and sensor driver module.

The G-822A relies on counter circuitry that is external to the sensor driver module, that can be a Geometrics SuperCounter, an RMS Instruments AADC II, or other form of counting device. Some users elect to use their own counter circuitry with the G-822A. In these cases Geometrics can supply an

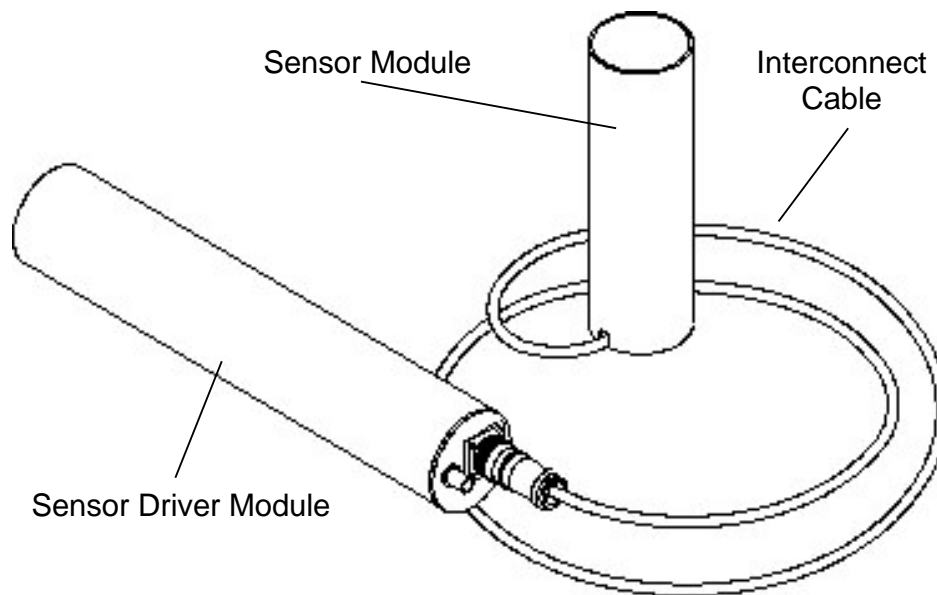
optional power/signal decoupler (P/N 27560-01) to interface the sensor driver module to both the power supply and an external counter.

A basic understanding of the physics employed in the G-822A, and optically pumped resonance magnetometers in general, is valuable for troubleshooting new installations and for achieving optimum results during field use, but is not essential for either. Such basic information can be found in the Appendix of this manual.

## 2.0 SYSTEM COMPONENTS

The basic system components of the G-822A consist of the sensor module, a sensor driver module, and an interconnect cable that is permanently attached to the sensor module and detachable from the sensor driver module. These components are identified in Figure 2. The weights, dimensions, and connector's specifications for these components and ancillary system components are listed in the Table 1.

**Figure 2. G-822A system components**



**Table 1. G-822A standard component weights and dimensions**

<i><b>Description</b></i>	<i><b>Weight</b></i>	<i><b>Dimensions</b></i>
Cesium sensor package P/N 27516-01	1lb. 8oz.	2'3/8"x5-1/2" cylindrical housing with 109 in. cable. Termination: Burndy 0119 G6JF12-88 PNE
G-822A Sensor driver module P/N 27512-01	2 lbs.	12-5/8" including connectors. 11-5/8" long x 2-1/2" cylindrical housing
Analog signal/power cable P/N 27565-02	14oz.	33' coaxial with BNC termination
Carrying Case P/N 27615-01	10 lbs.	18l" x 9.5w" x 15h"



A single coaxial cable connected to the BNC connector on the sensor driver module carries power to and signal from the module. This BNC connection is located next to the interconnect cable. This coaxial cable may be as long as 200ft (61m) for interconnection with a power/signal decoupler (e.g. Geometrics P/N 27560-01)

### 3.0 PERFORMANCE

Geometrics G-822A magnetometer produces a Cesium Larmor frequency output at 3.498572 Hz per nT. 'nT' refers to the magnetic field strength as measured in nanoTesla. 1nT equals one gamma or  $10^{-5}$  gauss. So, at the earth's surface, in a nominal 50,000nT field, the Larmor frequency is about 175 kHz. The output of the G-822A is a continuous sine wave at the Larmor frequency. The typical signal amplitude is from 1 to 2 volts peak-to-peak with the sensor in its optimal orientation.

The G-822A is intended for use in airborne, marine, land and base station applications, and operates over the earth's magnetic field range of 20,000 to 100,000nT. Absolute accuracy depends on sensor orientation, internal light shift and the accuracy of the external counter's time base. Error due to orientation of the G-822A does not exceed  $\pm 0.25$ nT or 0.5 nT peak-to-peak (p-p) throughout the active zones shown in Figure 3. Environmental conditions for proper operation are -35 to +50°C (-31 to +122° F), humidity to 99 percent non-condensing, over an altitude range of 0 to 30,000 feet.

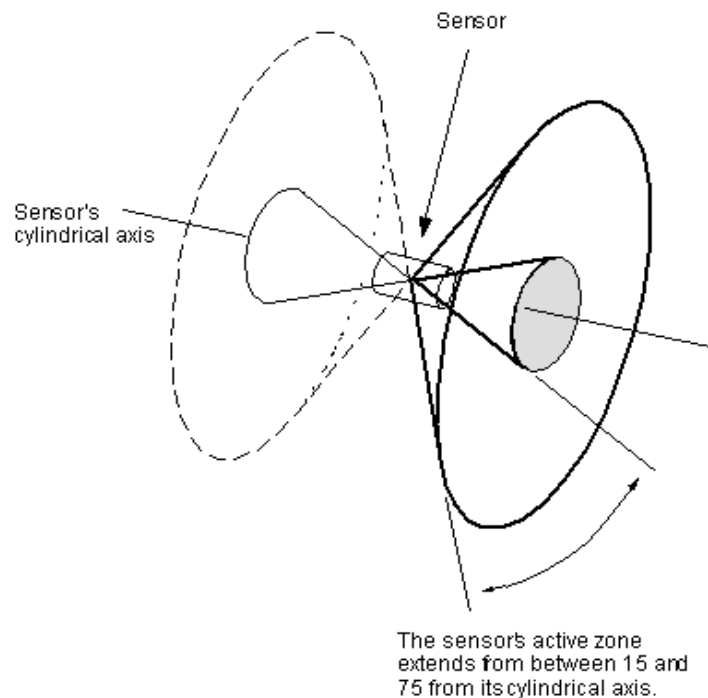


Figure 3. Active zone for the cesium-vapor sensor.

Like all magnetometers, performance of the G-822A is primarily dependent upon the counting circuitry employed and the quality of the installation procedures. Compensation and/or noise reduction techniques must normally be used to minimize the magnetic effect of the platform and its motion. Navigational and positional errors, radiated electromagnetic noise and heading errors from the aircraft's induced and remnant magnetic fields are typically the major contributors to noise in the survey results.

## 4.0 INSTALLATION

The particular installation requirements for each system component must be met in order to obtain the best performance from the system. It is important to remember that the sensor driver circuit receives a signal from the sensor whose amplitude is normally one milli-volt as it delivers both heater and lamp oscillator power to the sensor. Anything that increases the cross-talk between the power and signal circuits or introduces noise into the power circuit can degrade the sensor output signal and affect system performance. A BNC terminated coaxial cable is used to supply power to the matching connector on the G-822A sensor driver module.

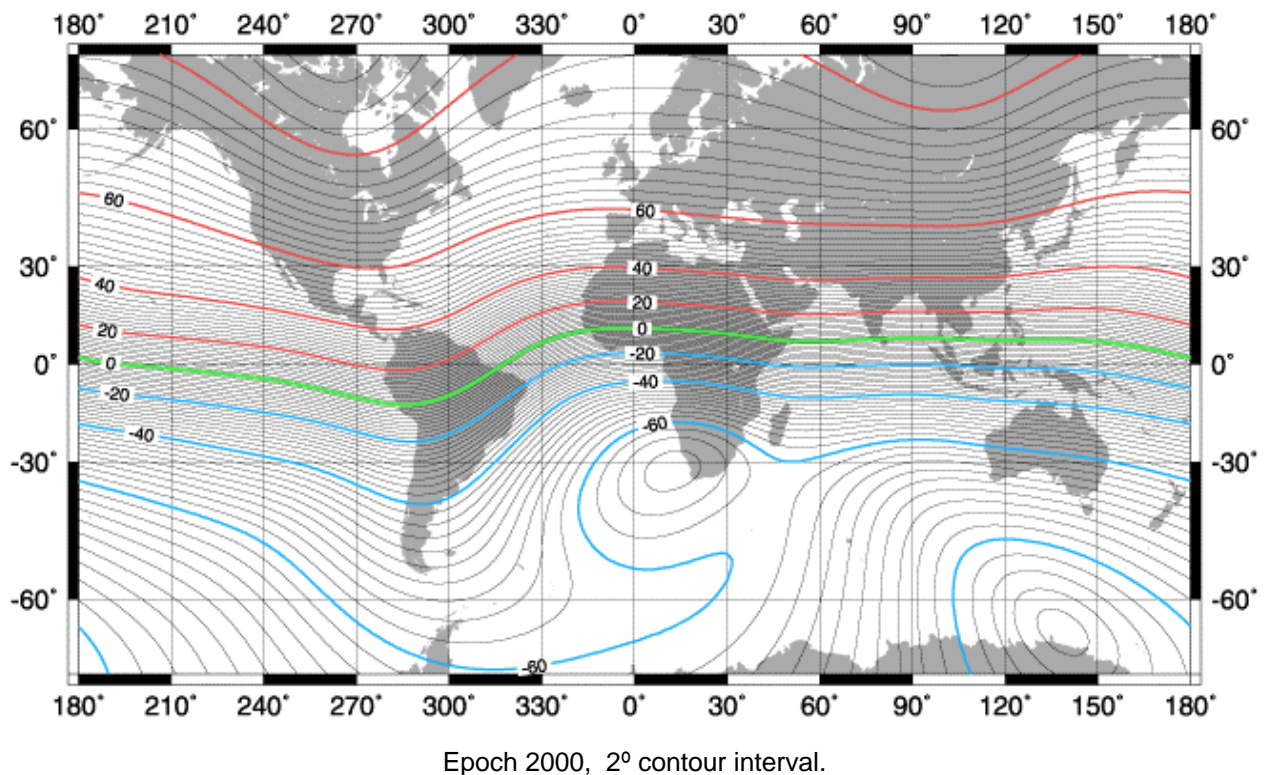
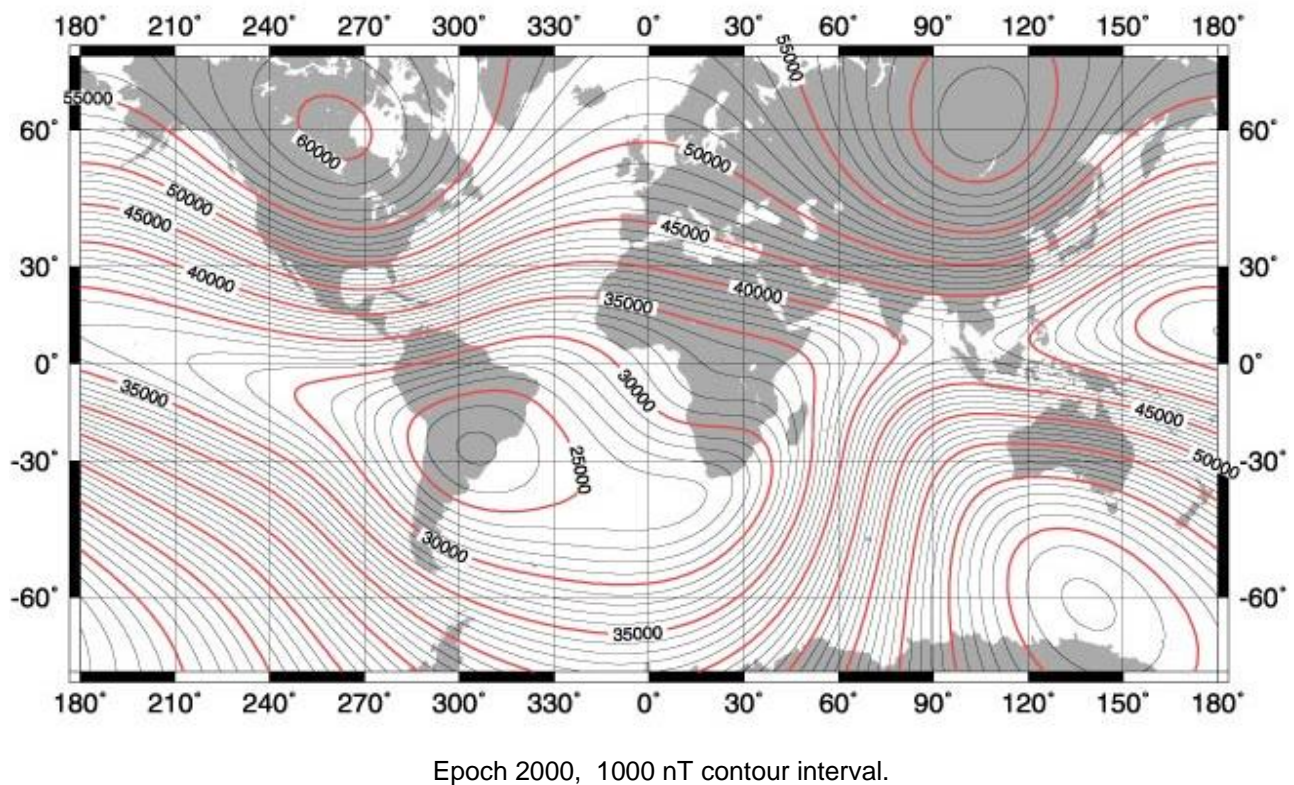


Figure 4. Surface inclination of the earth's magnetic field.

## 4.1 Sensor orientation

Magnetic fields are vector fields. At any point they are defined by their magnitude and direction. If the G-822A sensor is going to accurately measure the local magnetic field magnitude, it must be properly oriented relative to the local magnetic field direction.

The sensor head must be oriented so that the local field impinges at an angle of from  $30^\circ$  to  $60^\circ$  to the cylindrical axis of the sensor, for all platform attitudes. Alignments that produce a field/axis angle less than  $15^\circ$  place the magnetic field within the sensor's "polar dead zone". Similarly, alignments that produce a field/axis angle greater than  $75^\circ$  place the magnetic field within the sensor's "equatorial dead zone". The sensor will not



**Figure 5. Magnetic field intensity at the Earth's surface.**

produce usable data when the angle between the earth's field and the cylindrical axis falls within one of these two zones.

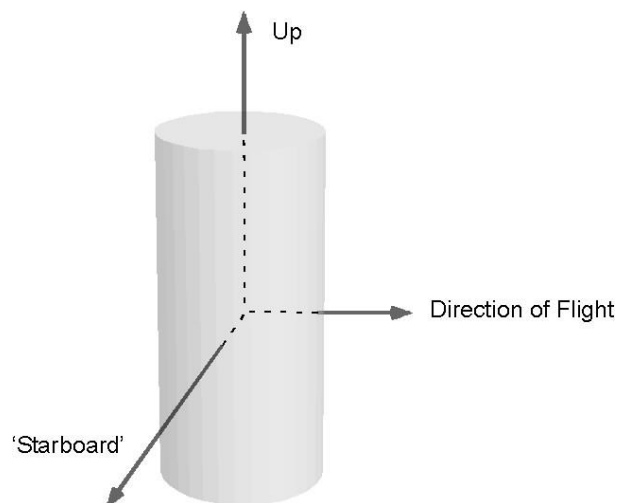
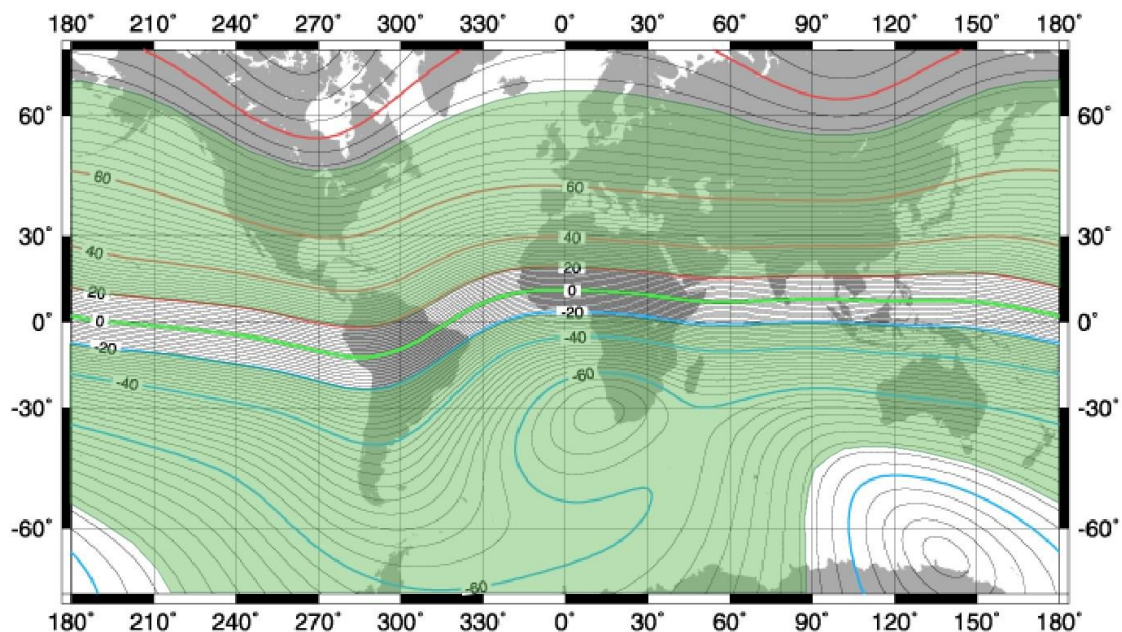
Unless the sensor is quite near very magnetic objects, the local magnetic field will be almost entirely due to the earth's magnetic field. So, in latitudes where the inclination of the earth's field vector is  $45^\circ$ , vertical orientation of the sensor's axis will allow operation in all practical flight attitudes. In equatorial regions it may be necessary to orient the

sensor horizontally and at an angle to the flight path. In polar regions the sensor may be mounted with its major axis tilted east or west to obtain the desired angle.

The maps in figures 4 and 5 may be used to determine the inclination and total intensity of the Earth's magnetic field in the intended area of survey. This inclination information should be used to adjust the sensor orientation for the best performance in the survey area. The intensity information may be used as a check of the system operation.

In regard to sensor orientation, the Earth's surface can be divided into three zones based upon magnetic field inclination: a mid-latitude, equatorial, and polar. Within each of these zones there is a particular sensor orientation that will yield adequate signal strength over the entire zone. These regions and the corresponding sensor orientations recommended for each region are shown in figures 6 through 9.

**Figure 6. Mid-latitude zone.**

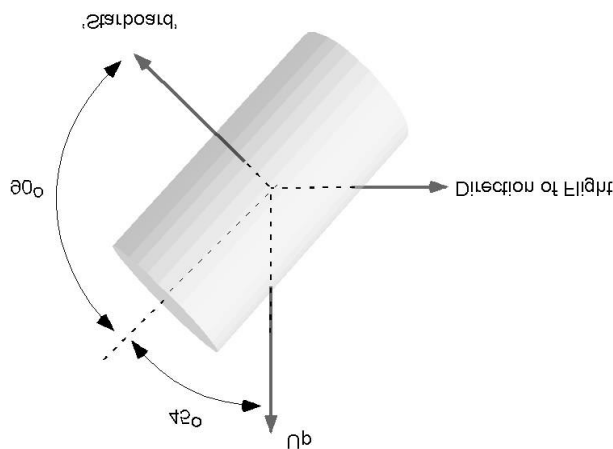
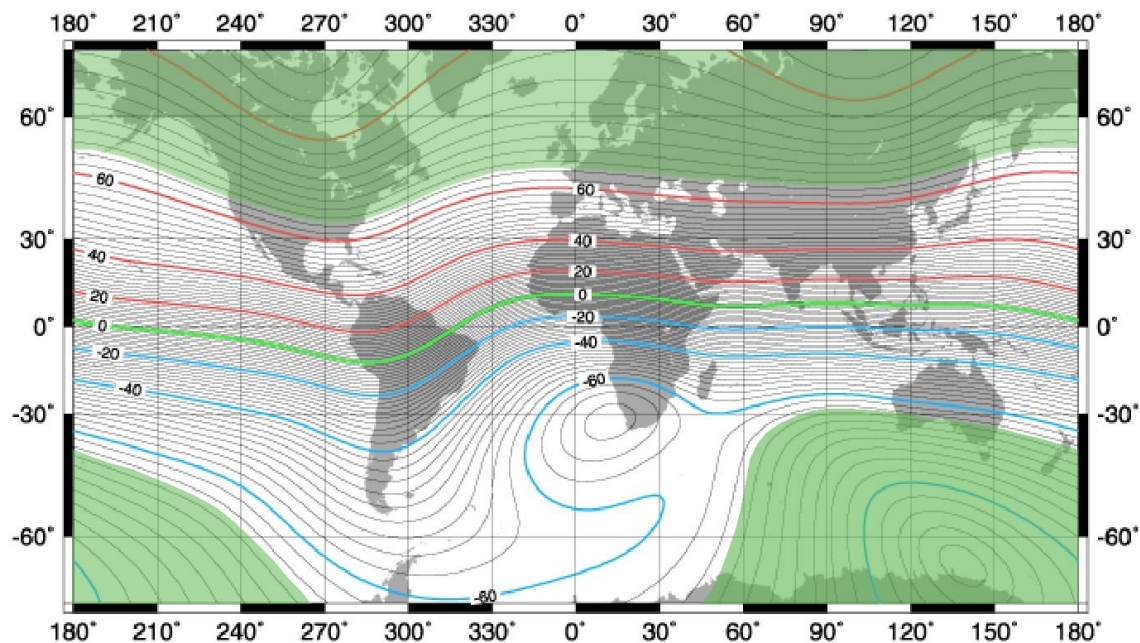


*The diagram to the left shows the recommended sensor orientation for operation in mid latitudes. This zone is shown as the shaded regions above and includes those areas where the absolute inclination of the Earth's magnetic field is greater or equal to 20° and less than or equal to 75°. There are no restrictions on the direction of travel when using this sensor orientation.*



Note that the orientation zones show in Figures 6 through 9 overlap one another by 10° of magnetic inclination. In these regions of overlap either of the recommended orientations may be used. Also, note that in the equatorial region there are two different recommended sensor orientations. In this region the magnetic field is nearly horizontal and there will be some restrictions on the direction of flight. Choosing one of the two recommended orientations will allow you to choose flight directions most suitable for your survey area.

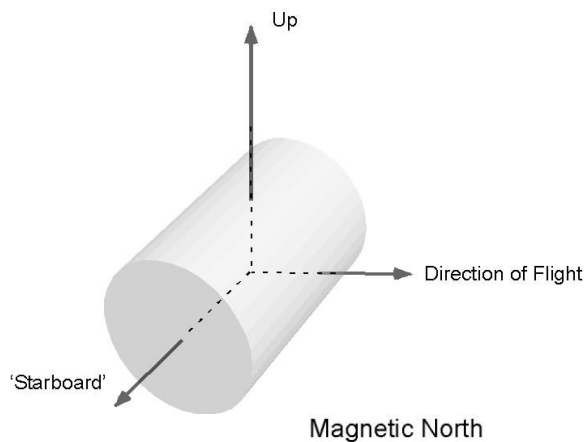
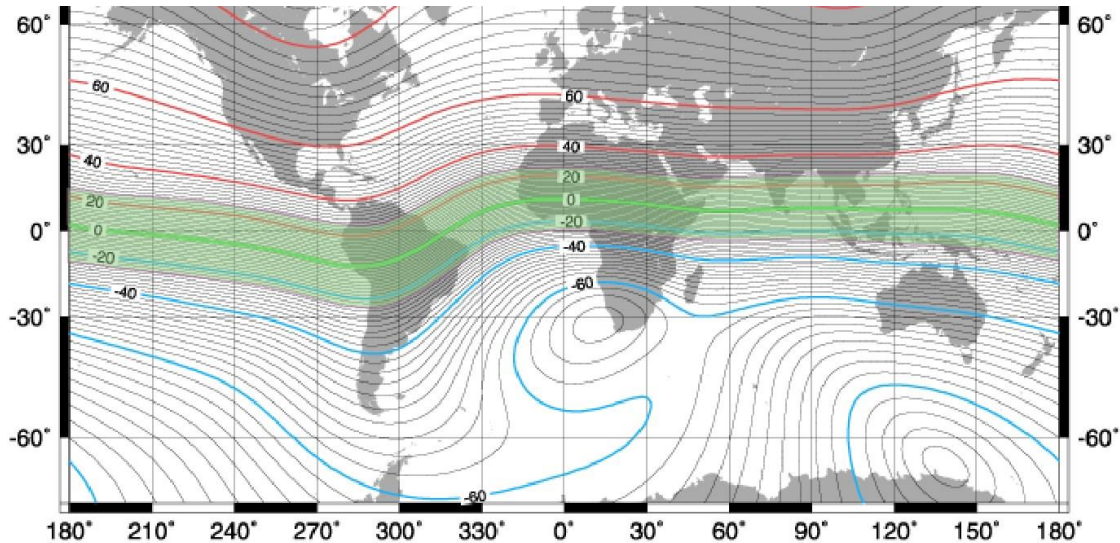
**Figure 7. Polar latitude zones.**



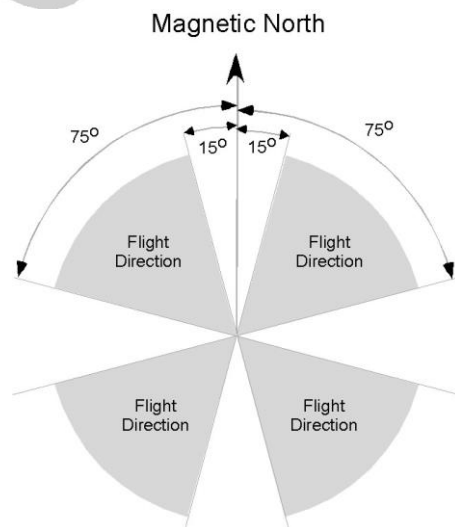
*The diagram to the left shows the recommended sensor orientation for operation in polar latitudes. This zone is shown as the shaded regions above and includes those areas where the absolute inclination of the Earth's magnetic field is greater or equal to 65°. There are no restrictions on the direction of travel when using this sensor orientation.*

Figure 8. Equatorial latitude zone - 1.

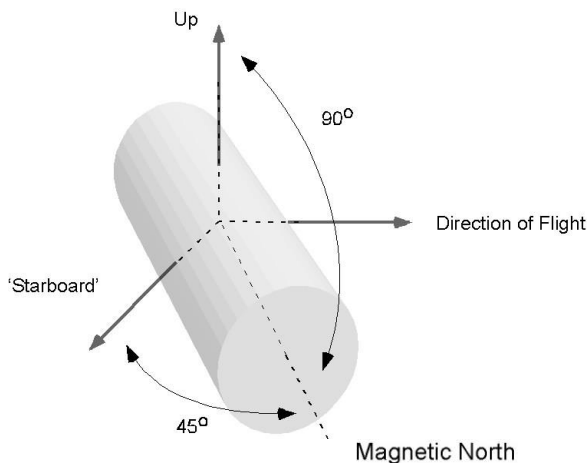
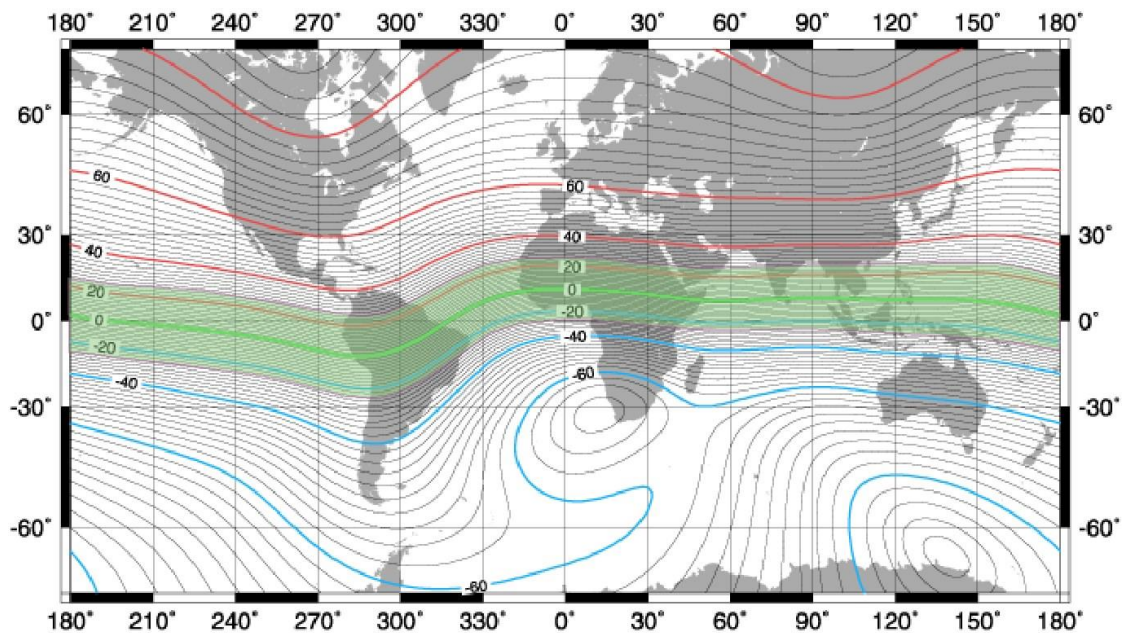
Figure 9. Equatorial latitude zone - 2



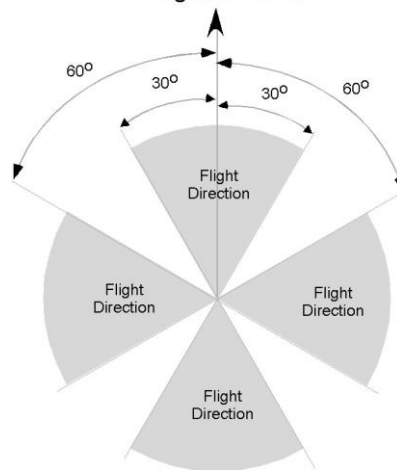
The diagram to the left shows the recommended sensor orientation for operation in equatorial latitudes. This zone is shown as the shaded region above and includes those areas where the absolute inclination of the Earth's magnetic field is less than or equal to 25°.



There are restrictions on the direction of flight when using this sensor orientation in this region. The bottom diagram to the left shows the flight directions where the sensor will produce good signal strength. These flight directions are 60° wide and are centered on 45°, 135°, 225°, and 315°.



The top diagram to the left shows an alternative sensor orientation for operation in equatorial latitudes. This zone is the same as that shown in figure 8 except that the sensor is rotated about its equator by  $45^\circ$  allowing N-S, E-W survey lines. It includes those areas where the absolute inclination of the Earth's magnetic field is less than or equal to  $25^\circ$ .



As with the sensor orientation shown in Figure 8, there are restrictions on the direction of travel when using this sensor orientation in this region. The bottom diagram to the left shows the flight directions where the sensor will produce adequate signal strength. These flight directions are  $60^\circ$  wide and are centered on the cardinal magnetic field directions  $0^\circ$ ,  $90^\circ$ ,  $180^\circ$ , and  $270^\circ$ .



In addition to the diagrams provided here, the program CsAz may be used to calculate the sensor's output for a particular orientation for the magnetic field attitude in your survey area. This is a DOS program and is provided on the Magnetometer Support CD supplied with your magnetometer.

## 4.2 Sensor attachment

An acceptable mount for the G-822A sensor will provide a stable, nonmagnetic attachment to the vehicle, provide vibration dampening and allow the sensor's orientation to be adjusted with minimal effort. One example of such a mounting solution is the sensor mount available from Geometrics (P/N 27530-01). This structure is shown in Figure 10 below and is designed for attachment inside of a towed bird, a wing pod, or inside a tail mounted stinger or any circular enclosure with an inside diameter of 7 inches.

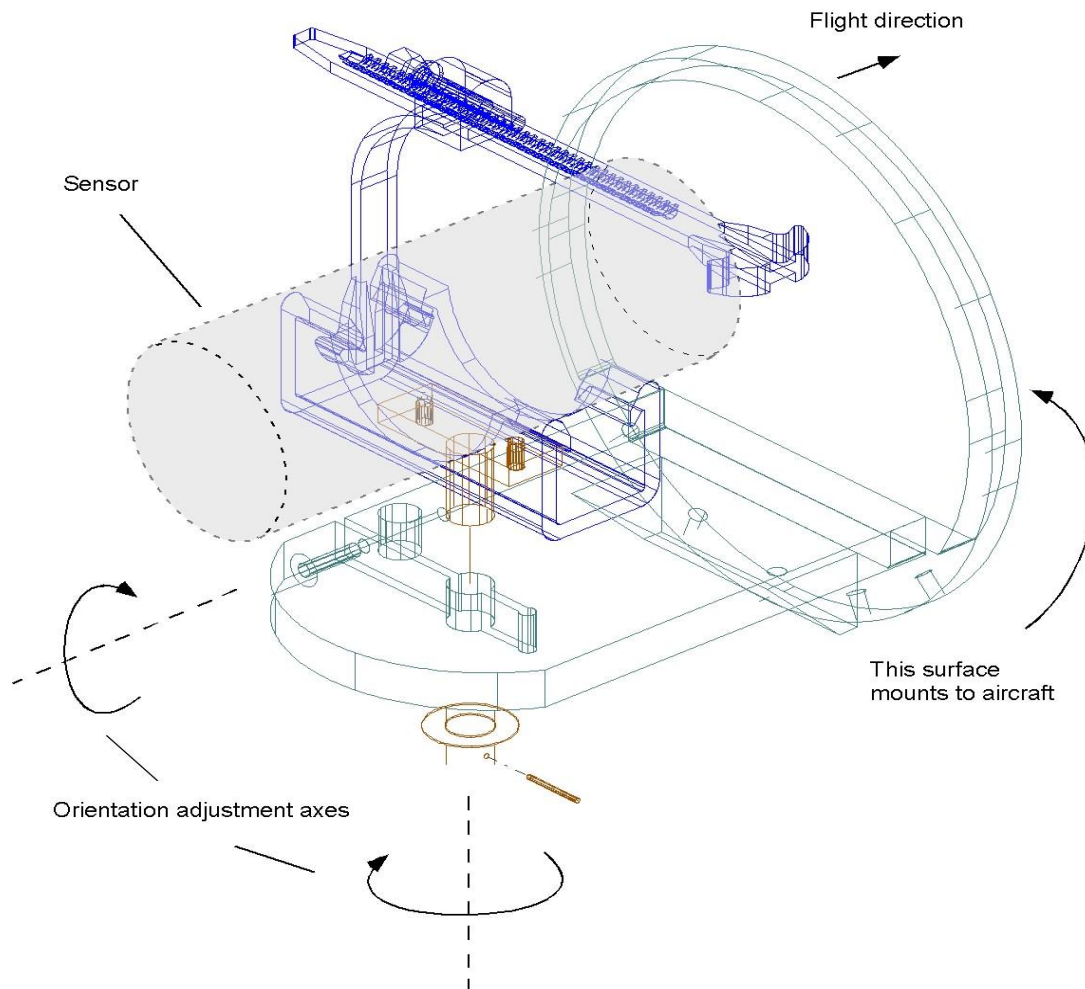


Figure 10 . Sensor mount that provides for two axes of adjustment.



### 4.3 Environmental Considerations

Optically pumped magnetometers are more sensitive to magnetic field variation than are proton and fluxgate types. To realize the full performance of the cesium-vapor technology, special precautions must be taken during planning and execution of the installation.

#### Vibration

The G-822A is usually installed in aircraft and this environment presents particular challenges. Intense vibration of system circuitry can induce microphonic noise and shorten the life of system components. For performance and safety considerations the sensor, sensor driver, and system cabling are normally hard mounted to the aircraft or are hard mounted in components that are themselves firmly attached to the aircraft in structures such as stinger and wingtip pods. Some attachments points may be prone to intense vibration and we recommend the use of good quality shock mounts that are designed to isolate the G-822A components from as much of the intense vibration as possible. Special care should be taken in securing or routing the cable so that it does not encounter hard or sharp objects that could damage the cable. Those components used to mount the G-822A sensor or any or any objects near this sensor should be non-magnetic in order to minimize the system heading error.

#### Electronic/electromagnetic

Sources of performance problems may arise in two areas: external electromagnetic noise and errors introduced from platform motion. Electrostatic and electromagnetic signals from aircraft systems, including other sensor instrumentation, can significantly lower the signal to noise ratio of the magnetometer. An example is the "hash" created by sparking brushes in certain aircraft generators. This can be seen as a rapidly changing field value causing excessive scatter in the readings. The permanent, induced and eddy-current magnetic fields of the airplane can cause significant errors that are dependent on attitude, motion and heading in the earth's magnetic field. The use of a device such as the RMS Instruments' Automatic Aeromagnetic Digital Compensator, Geometrics software program MagComp or fixed aero-magnetic compensation techniques will help reduce these types of errors (See Geometrics technical report TR-15). Variations in electrical currents in aircraft systems will also cause shifts, bias or increased heading error in the readings. Consult with Geometrics about the compensation and noise reduction processes before installation if you are unfamiliar with the procedures used to minimize noise and platform errors.

G-822A DC power and impressed signal pass through a common, non-magnetic, coaxial cable. The shield of this cable should not be connected to aircraft/ship ground at any place other than the decoupler or the G-822A counter. In installations where the counting electronics are customer supplied, we recommend keeping the DC voltage applied to the Sensor Electronics between 24 and 33volts DC for proper operation. Although the signal

on this cable is greater than 1 V p-p, coupling noise onto this cable by running it near an electric motor may still reduce performance.

### Temperature

The G-822A is designed to operate over an ambient temperature range of -35 to +50°C. In an enclosed region it may be necessary to providing adequate cooling by free flowing air. If the sensor and electronics are in an unconfined region, convection cooling is generally adequate. The cesium lamp only needs to dissipate 3 to 4 watts of heat and when operating in cold regions providing some insulation or baffling will help reduce the sensor's power consumption.

The G-822A requires a minimum warm up period of 15 minutes. In cold regions the warm up period will be longer and, to avoid delay, we recommend that the sensor power be left on overnight when ambient temperatures are expected to fall below -10°C.

## 5.0 OPERATION

The G-822A produces an analog output signal on the BNC connector of its sensor driver module. Because this BNC connection also serves as the power input connection it is necessary to decouple the power from the output signal. The circuit shown in Figure 11 shows a simple decoupling circuit. The output is the Larmor signal and it is a sinusoidal wave with a peak-to-peak amplitude of approximately 2.0 volts and a frequency that will vary from 70kHz to 350kHz in accordance with the local magnetic field (Cesium oscillator frequency is 3.498572 Hz per nT). This signal can be observed by attaching the output of the signal decoupler to an oscilloscope. To be useful as a survey instrument the G-822A's Larmor signal must be converted into a digital data stream and this is done by attaching a counter to the output of a the decoupler circuit.

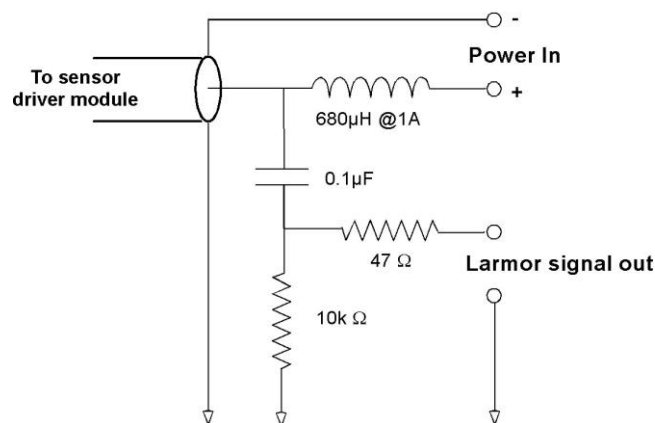


Figure 11. Signal decoupler circuit

## 6.0 TROUBLE SHOOTING

Operation of the G-822A is relatively simple and when trouble arises it is usually easy to recognize and correct. Table 2. is a trouble shooting guide provided to help in quickly locating the probable cause of the most common system problems.

**Table 2. Trouble shooting**

Symptom	Probable Causes	Corrective Actions
Long warm-up time.	Low voltage.	Increase voltage (minimum 24 VDC at the electronics) or repair the Coax cable.
	Low ambient temperature.	Insulate sensor housing.
	Faulty sensor cable connection.	Disconnect sensor from electronics and carefully clean the pins and sockets.
	Low heater setting.	Adjust heater to 34.5 K-ohms: contact factory for details.
	Defective internal sensor or electronic components.	Return sensor and electronics to Geometrics for repair.
Noisy magnetic field readings.	Local field is noisy.	Locate and eliminate source of noise or relocate sensor.
	Sensor not oriented correctly.	Refer to Sensor Orientation section of this manual, or use MagPick IGRF and CsAz software to model magnetic field and sensor behavior, and correct orientation if necessary.
	Heater setting incorrect.	Adjust heater to 34.5 K-ohms: contact factory for details.
	Signal amplitude too low with correct orientation.	Adjust signal amplitude or return sensor and electronics to Geometrics for repair.
	Sensor cable or connector worn or damaged.	Replace sensor cable and connector assembly. Check connector on electronics bottle for wear and replace if required.
Sensor cable kinked or cut.	Handling or mechanical problem.	Change handling or mechanical mount. Then replace sensor cable and connector.
Sensor connector damaged or worn	Handling, mechanical problem, accident, or normal wear.	Correct handling or mechanical problem. Then replace sensor cable and connector.
Excessive current consumption.	Damaged Coax cable.	Replace Coax cable.
	Defective sensor or electronics.	Return sensor and electronics to Geometrics for repair.

Preventing a problem is almost always less costly than correcting the problem. We recommend checking the follow items as part of any new installation or whenever an

existing installation is altered. It is also recommended that these items are checked periodically as part of a scheduled platform or system safety check.

1. Power check
  - a. Minimum 24 Volts DC at electronics bottle. 28VDC recommended
  - b. Maximum 33 Volts DC at electronics bottle
  - c. Starting current 1 Ampere at 28 Volts
  - d. Running current 0.3 to 0.6 Ampere at 28 Volts depending upon ambient temperature
2. Connector checks
  - a. Dirt or corrosion
  - b. Bent pins
  - c. Back-shell tight
3. Cable jacket check
  - a. Kinks
  - b. Abrasions
  - c. Cuts
4. Sensor orientation
  - a. Use MagPick IGRF and CsAz to model sensor behavior
  - b. Adjust sensor orientation and observe dead zones
  - c. Return sensor to correct orientation for the survey area
5. Field readings
  - a. Reasonably close to MagPick IGRF model estimate
  - b. Sample to sample noise less than 0.1 nT @ 10 Hz when not moving
6. Larmor amplitude check and adjustment (Authorized Repair Facility only)
  - a. Potentiometer on GSN board adjusted for 2.0 Volts Peak to Peak at 50,000 nT after 20 minute warm up
7. Heater check and adjustment (Authorized Repair Facility only)

## **7.0 G-823A MAGNETOMETER**

The addition of Geometrics CM-201 counter assembly board to the G-822A's sensor driver module transforms the instrument's analog output signal into RS-232 digital data. With the addition of the CM-201, the instrument is designated as the G-823A. The CM-201 counter module is an integrated circuit that converts the cesium Larmor signal (70 kHz to 350 kHz) into a numeric value indicating the magnetic field strength in nanotesla (20,000 nT to 100,000 nT). In addition there are 5 external 12 bit A/D channels and 1 internal A/D channel that can be digitized and appended to the output data. This can be useful, for instance, in digitizing an analog altimeter signal and incorporating it into the magnetometer data stream. A Julian clock string can be enabled and added to the output data stream as well. Finally there is an External Event pin that can be used for external trigger or event marking.

**Table 3. G-823A standard component weights and dimensions**

<b>Description</b>	<b>Weight</b>	<b>Dimensions</b>
Cesium sensor package P/N 27516-01	1lb. 8oz.	2'3/8"x5-1/2" cylindrical housing with 109 in. cable. Termination: Burndy 0119 G6JF12-88 PNE
Electronics W/counter P/N 27512-04	2lb. 5oz.	12-5/8" including connectors. 11-5/8" long x 2-1/2" cylindrical housing
Carrying Case P/N 27615-01	10 lbs.	18l" x 9.5w" x 15h"
Analog signal/power cable P/N 27565-02	14oz.	33' coaxial with BNC termination
Digital signal/power cable P/N 27611-02	2lb, 2oz.	25' multi-conductor: Belden # 8418. Termination: SP06A14-19S-SR and SP06A14-19P-SR
Power/data junction box P/N 24870-20	9oz.	L 4-3/4", W 3-1/4", H 3-1/4"
Serial data cable P/N 60-230-237	5oz.	6' DB9
Optional AC/DC Power Supply P/N 24810-02	2lbs. (typical)	Input: 100v-240v @ 50-60 hz; output 30v, 1.9A 7" x 4" x 2.5" (typical) with 4' output cord.

The G-823A is shipped with a 25ft external signal/power interface cable, a power/data junction box, and an RS-232 data cable. The signal/power interface cable attaches to a mating connector on the sensor driver module. These components are used to connect the magnetometer to the user's 30VDC power source and logging computer. The signal/power cable also carries analog signal but the junction box does not break these channels out to its DB9 connector. If the user wishes to observe or record analog signal they may use the interface cable for this purpose. To do so we recommend that electrical connection is made using a mating connector (e.g. Amphenol SP02A-14-19S) although the connectors used on the interface cable are of the solder type and they may be removed and reused to suit the application. Table 4 describes the pin-out of the 19 pin connector on the G-823B magnetometer. The interface cable is wired straight through, pin-to-pin. **Note that when the interface cable is used there is still Larmor signal on the BNC and that the power supply voltage is also present. Take care to avoid a short circuit at his connector. We recommend that you cap this BNC connection when it is not in use.**

**Table 4. G-823A interface cable pin-out**

Circuit description of the external signal/power interface cable Connector type <u>SP02A-14 -19P</u>		
<b>Pin #</b>	<b>Function</b>	<b>Description</b>
A	30V power	Magnetometer power; 24 – 32VDC
B	GND	Power ground
C	TxD	From logging computer, connects to RxD of G-823B
D	Rxd	To logging computer, connects to TxD of G-823B
E	COMM	RS-232
F	RESET	Contact closure to GND
G	EVENT	External Trigger Input

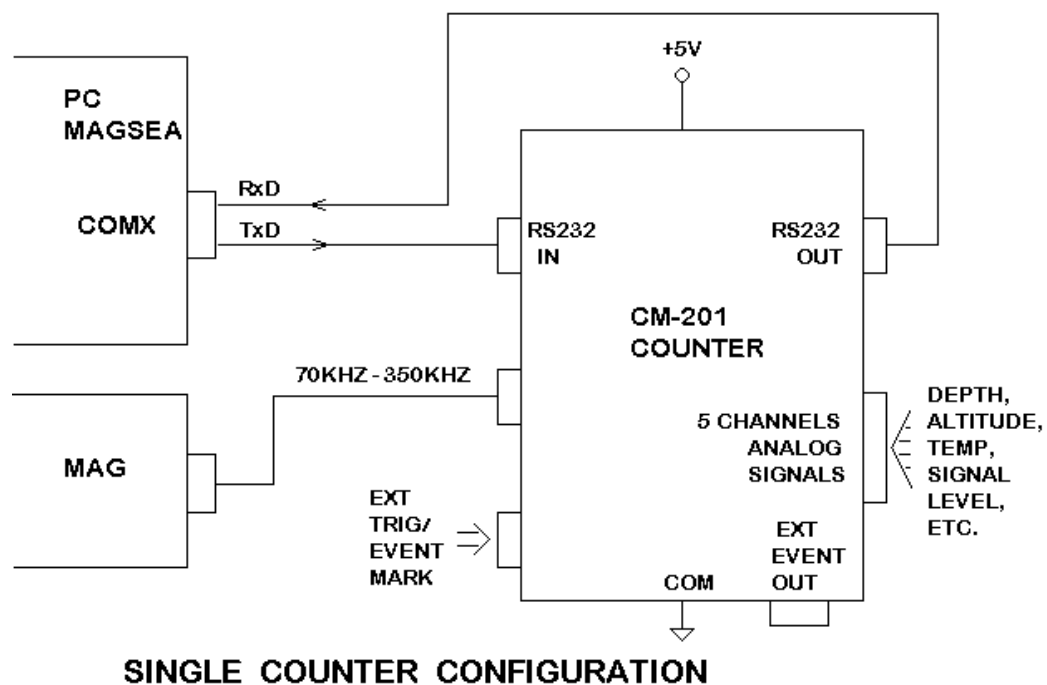
H	CHANNEL 1 +	Analog channel #1 – differential input, 5v full scale, 2K $\Omega$ input impedance.
J	CHANNEL 1 -	
K	CHANNEL 2 +	Analog channel #2 – differential input, 5v full scale, 2K $\Omega$ input impedance
L	CHANNEL 2 -	
M	CHANNEL 3 +	Analog channel #3 – differential input, 5v full scale, 2K $\Omega$ input impedance
N	CHANNEL 3 -	
P	CHANNEL 4 +	Analog channel #4 – single ended $\pm 2.048$ v full scale, >10K $\Omega$ input impedance
R	CHANNEL 4 -	
S	CHANNEL 5 +	Analog channel #4 – single ended $\pm 2.048$ v full scale, >10K $\Omega$ input impedance
T	CHANNEL 5 -	
U,V	<i>Not used</i>	

Note: 1) All analog channels have 12 bit resolution  $\pm 1\%$ ; 2) Differential channels 1, 2 and 3 may be able accept other full-scale voltages if original order called for custom input specification - consult the factory if you suspect that your system has non-standard input ranges; 3) If the single ended channels 4 or 5 are used, the signal source must be operated from a power source that is isolated from power ground.

## 7.1 CM-201 Output Format

The output data format of the G-823A is programmable. For example each of the A/D channels can be added or removed from the output data stream by sending the appropriate commands to the CM-201. There are several other commands that are discussed in detail below.

Figure 12 shows the standard single counter configuration. Commands from the PC are sent out the computer RS-232 transmit pin (TxD) to the counter. Magnetometer and other data are read on the computer receive pin (RxD).



Upon power on the counter module defaults to the following setup:

- Baud rate: 9600 baud, 8 data bits, no parity, 1 stop bit
- Cycle rate: 10 Hz
- Analog channels: Channel 0 (Larmor signal level) enabled, channels 1-5 disabled
- Julian Clock: Disabled
- Output Format: ASCII

The default output data stream contains all printable ASCII characters with each sample terminated with a carriage return/ line feed sequence. Table 5 illustrates an example of this format.

**Table 5. Example of CM-201 default output data stream.**

<b>Character #</b>	<b>Description</b>
1	An ASCII '\$' (marks first character of data stream)
2	an ASCII 'I' or a blank (depending on whether Mag reading is above or below 99999.999nT).
3-7	5 digits of Mag data
8	an ASCII decimal point ['.']
9-11	3 more digits of Mag data
12	an ASCII comma [',']
13-16	4 digits of A/D channel 0 (9999 full scale, 0 to +5 volts in). This channel is internal and contains the signal level of the magnetometer.
17	an ASCII carriage return
18	an ASCII line feed

If the data were captured to a file and then copied to a line printer the printout would look something like this:

```
$ 99778.131,3749
$ 99890.376,3687
$ 99955.517,3545
$ 99998.293,3472
$100078.835,3329
$100032.071,3381
$ 99979.159,3498
$ 86778.508,3514
$ 78778.216,3645
```

Counter modules can be daisy chained to form multiple sensor arrays as shown in Figure 13. Note that the output data from counter 0 goes into the input port of counter 1, and so on. This allows each counter module to append its output data onto the end of the data stream coming from the previous counter(s). As each counter receives data characters from previous counters they get echoed to the next. An exception to this is the carriage return/line feed sequence. Here, the carriage return is replaced by a comma and the line feed is ignored. Thus one long concatenated string from all counters is output from/through the last counter, and is terminated by a carriage return/line feed sequence by the last counter only. Note that only the first counter outputs a preamble character (the default character is '\$').

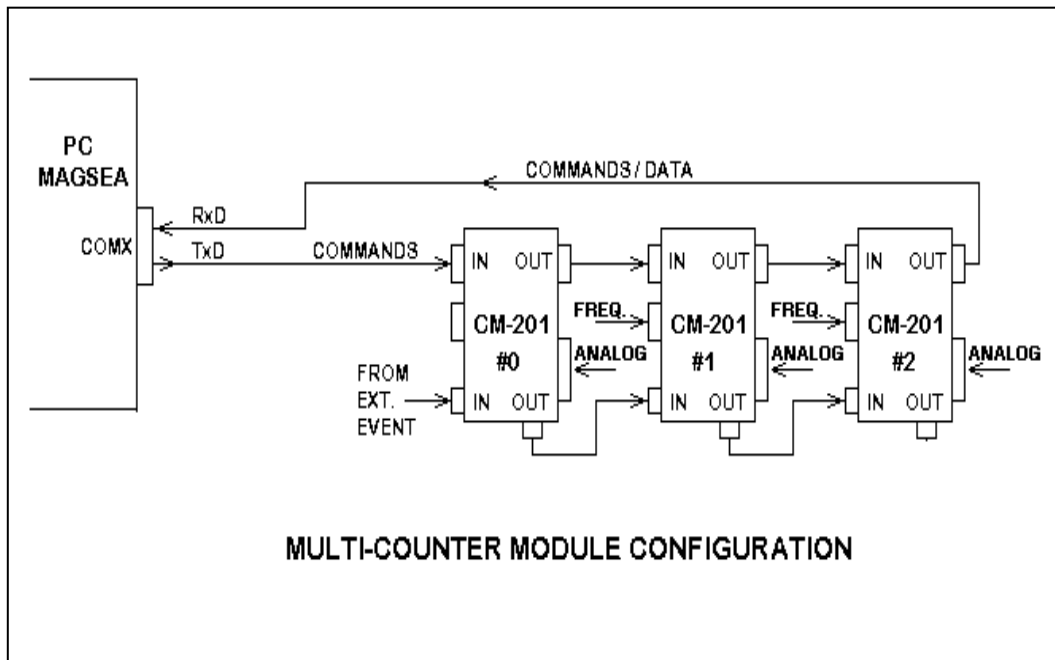


Figure 13. Schematic diagram of daisy-chained CM-201 counter modules.

## 7.2 Commands

Commands are sent into the input port of the first counter. Note that commands are the only characters that enter the first counter. A command string is stored in an incoming buffer until terminated by a carriage return. The command will then be executed at the end of the current sample, immediately after the last 'data' byte has been sent out the output port. Then the command will be echoed to the next counter (or back to the logging computer if it is the last/only counter in the chain).

Subsequent counter modules in multiple counter arrays differentiate between output data and commands by assuming that all characters between the data preamble character ('\$') is



the default) and the next line feed are Data bytes from the previous counter(s). Commands only arrive at subsequent counters after the data transmission is complete. Each command is identified by the first character, followed by some number of operand characters and a carriage return.

Only one command can be sent at a time. After each command, you must wait for the command echo before sending another.

All commands are terminated with a carriage return. A line feed may be sent as well, but it will be ignored by each counter module. However, at the end of every output data string there will be a carriage return and a line feed sent. This method insures that the final counter will have a carriage return/line feed sequence so that if the file is printed it will look correct on paper. By using the carriage return as the command terminator and stripping input line feeds insures that dumb terminals (and dumb terminal emulation software) can be used to control the counter output. (Dumb terminals do not normally transmit line feeds when <Enter> is pressed).

Here are the current list of commands and the format of each:

Command	Format:	Description:
-----	-----	-----
Set Cycle time	Byte 1: 'C' 2: x 3: x 4: x 5: x x: x 6/7: CR	Set time in 0.01 sec increments MS digit of number ('0'-'9') 3S digit of number 2S digit of number LS digit of number 5 MS optional char ('0' or '5') carriage return
[Note: the 5 MS char is optional. It was added to allow setting the cycle time to more precision after the initial software release]		
Set A/D ch's	Byte 1: 'A' 2: x 3: x 4: x 5: x 6: CR	Enable/disable A/D channels '0' = turn off channel; '1' = turn on select channel # ('0'-'5') MS digit of counter # ('0' or '1') LS digit of counter # ('0' - '9') carriage return

[Note: characters 4 and 5 can be omitted. If this is done the command will default to counter 0.]

Change Baud Rate	Byte	1: 'B'	Baud rate change command
		2: x	MS char (1,0,0,0,0,0,0)
		3: x	S char (9,9,4,2,1,0,0)
		4: x	3S char (2,6,8,4,2,6,3)
		5: x	2S char (0,0,0,0,0,0,0)
		6: x	LS char (0,0,0,0,0,0,0)
		7: CR	carriage return

Output Format	Byte	1: 'O'	select output format
		2: x	format select: 'A'= ASCII (default) 'E'= excess 3 'P'= packed BCD 'S'= Sandia G-822A fmt
		x: x	'0' = Sandia single Mag '1' = Sandia dual Mag
		3: CR	carriage return

[Note: the '0' and '1' 3rd characters are valid only when selecting the Sandia format. This format was developed for an earlier logging software program and is now obsolete. Excess3 is used for high speed multi-sensor array data transmissions.]

Julian Clock Format:	Byte	1: 'O'	select output format
		2: J	format select:
		3: x	Day field: '1' = on ; '0' = off
		4: x	Hour field: '1' = on ; '0' = off
		5: x	Min field: '1' = on ; '0' = off
		6: x	Sec field: '1' = on ; '0' = off
		7: x	10mS field: '1' = on ; '0' = off
		8: x	MSB of counter # ('0' or '1')
		9: x	LSB of counter # ('0' thru '9')
		10: CR	carriage return

[Note: characters 8 and 9 can be omitted. If this is done the command will default to counter 0.]

Julian Time Enable:	Byte	1: 'J'	Enable/Disable Julian time output
		2: x	'0' = turn off; '1' = turn on
		3: x	MS digit of which counter ('0','1')
		4: x	LS digit of counter # ('0' - '9')
		5: CR	carriage return

[Note: characters 3 and 4 can be omitted. If this is done the command will affect all counters in the chain.]

Set Julian Day:	Byte	1: 'D' 2: x 3: x 4: x 5: CR	Set the Julian day number MS digit of number ('0'-'3') 2S digit of number ('0'-'9') LS digit of number ('0'-'9') carriage return
Set Hour:	Byte	1: 'H' 2: x 3: x 4: CR	Set the hour MS digit of number ('0'-'2') LS digit of number ('0'-'9') carriage return
Set Minute:	Byte	1: 'M' 2: x 3: x 4: CR	Set the minute MS digit of number ('0'-'5') LS digit of number ('0'-'9') carriage return
Set Second:	Byte	1: 'S' 2: x 3: x 4: CR	Set the second MS digit of number ('0'-'5') LS digit of number ('0'-'9') carriage return
Find counters:	Byte	1: 'F' 2: '0' 3: '0' 4: CR	Find and assign counter numbers assign first counter as # 0 (MSB) LSB carriage return
Set Preamble	Byte	1: 'P' 2: x 3: CR	Set the preamble char ('\$') The desired character carriage return
Jump to debug	Byte	1: 'X' 2: 'B' 3: 'U' 4: 'G' 5: CR	first char of 'XBUG' string 2'nd char 3'rd char 4'rth char carriage return
Error echo	Byte	1: 'E' 2: 'R' 3: 'R' 4: x 5: x 6: ':'	Syntax err - echo 'ERR' + counter # 2'nd char 3'rd char MS digit of counter number ('0'-'1') LS digit of counter number ('0'-'9') colon delimits error message cmd

[Note: xxx: bad command string is echoed in the following characters, followed by a ...  
x: CR carriage return]

Reset	Byte	1: 'R'	Reset the microprocessor
		2: 'E'	2'nd char
		3: 'S'	3'rd char
		4: 'E'	4'th char
		5: 'T'	5'th char
		6: CR	carriage return
Interrogate Setup:	Byte	1: 'I'	Interrogate command
		2: x	item select: 'A'= Analog output fields selected 'J'= Julian Clock fields selected 'V'= software version number.
		3: x	MS digit of counter number ('0'-'1')
		4: x	LS digit of counter number ('0'-'9')
		5: CR	carriage return

[Note: Characters 3 and 4 are optional. If they are omitted the command will return the output from counter 0. The addressed counter will insert characters into the command string just before the carriage return before echoing to subsequent counters. See detailed command description for format and definition of these added characters.]

### 7.3 Detailed command descriptions:

#### Cycle Time Set

Cycle time is set by transmitting the number of 0.01 second increments needed to make the desired output rate. The default rate is 10 hertz (C0010). To set the output rate to 1.2 seconds the command string would be "C0120".

After the initial software release another character was added to allow the cycle time to be set to 5 ms resolution. To maintain compatibility with older versions this character is optional. For an example on using this extra precision, the command "C00125" would set the cycle time to 8 hertz (125 ms).

#### A/D channel select/enable

Three pieces of information are needed to select and turn on/off an A/D channel: The counter #, the channel number, and a flag indicating whether to enable or disable that channel. The enable/disable flag is sent first (after the 'A' command identifier). A '0' character will turn off the channel, a '1' turns it on. The next character specifies the channel number (0-7), followed by 2 characters indicating the counter number (00-19). If the counter number is not sent then it defaults to counter 0.

### Baud Rate Change

The baud rate can be commanded to change by giving a 'B' command character followed by 5 more number characters specifying the desired baud rate. Valid baud rate commands are: 'B19200', 'B09600', 'B04800', 'B02400', 'B01200', 'B00600', and 'B00300'. This command will not execute until the entire command has finished echoing out to the next counter/logging device. This allows the command to propagate through all counters and be implemented before output data arrives at a different rate.

### Output Format Select

The default (ASCII) output format is described in detail at the beginning of this document. This is the easiest format to view and import into various processing utilities. It is also very inefficient in terms of disk storage space and time required to transmit each cycle. There are three other output formats that can be used as well:

#### *Packed BCD*

Packed BCD format throws away all commas, decimals, spaces, and the magnetometer most significant byte ('1' if more than 100,000 nT, or a blank is less than 100,000nT). The Preamble character is left alone. In addition all numeral characters (ASCII codes 30 hex through 39 hex) have the upper nibble (always a 3) discarded and two lower nibbles combined to form one byte. Finally, the carriage return, line feed sequence is replaced with a single terminating character '\*' (2A hex).

It is very difficult to show what these files would look like if displayed on a computer screen since each type of computer would display these binary characters differently. Many of these binary characters would be interpreted as screen commands which might ring the bell or clear the screen. Therefore it is necessary to convert ASCII printouts to hexadecimal numbers to show the Packed BCD format.

An ASCII counter output of:

'\$ 54369.127,1234,5678,0000' (plus carriage return line feed)

converted to hexadecimal numbers would be:

24 20 35 34 33 36 39 2E 31 32 37 2C 31 32 33 34

2C 35 36 37 38 2C 30 30 30 30 0D 0A

[ '\$' = 24, ' ' = 20, '.' = 2E, ',' = 2C, CR/LF = 0D 0A,  
'0'-'9' = 3x (where x = number 0-9)]

Using the above definition the same data in packed BCD output format would be:

24 54 36 91 27 12 34 56 78 00 00 2A  
  \          \          \          \          \          \\_\_\_\_Terminating character ('\*')  
  \          \          \          \          \          \\_\_\_\_analog channel #3 ('0000')  
  \          \          \          \          \          \\_\_\_\_analog channel #2 ('5678')  
  \          \          \          \          \          \\_\_\_\_analog channel #1 ('1234')  
  \          \          \          \          \          \\_\_\_\_Mag reading ('54369.127')  
  \          \          \          \          \          \\_\_\_\_Preamble Character ('\$')

Note how easy it is to see the numbers if viewing a hex dump of the data. Remember though that it must be translated to printable characters before copying the raw data to printers or a CRT screen.

Commands that are echoed through the counter chain are received and sent as unmodified ASCII strings. Thus all commands will appear in the binary data set after the next '\*' data terminating character and will be terminated itself by a carriage return line feed sequence. Binary transmission then resumes with the next sample.

### ***Excess 3 format***

Excess three format is very similar to packed BCD. In fact the only difference is that each byte has 33 hex added to it after converting to Packed BCD. The reason for adding 33 hex to each packed BCD number is to avoid some difficult pitfalls with Packed BCD:

Packed BCD is a very common format but has potential problems that can arise. ASCII digits are combined to form bytes with hexadecimal values in the control character range (less than 20 hex) which must be handled very carefully by the logging program. Examples of these characters include the Cntl-S and Cntl-Q software handshake controls (11 hex and 13 hex), the bell character (Cntl-G, 07 hex), and the ASCII null (Cntl-shift-@, 00H). Most terminal emulation programs can be configured to handle these characters as data instead of commands, but this is not the way the typical default configuration is set up. Note that MagLog and MagLogLite Logging software from Geometrics is designed to receive and decode the Excess 3 data transmission. This is typically used for multiple sensor array systems such as MTADS employed for UXO or archaeological surveys.

Packed BCD eliminates this by shifting all numbers up by 33 hex. This moves all possible output values out of the control character range. It also makes them printable to a screen or

printer without bells, beeps, screen clears, form feeds, etc. However they will still look like gibberish without translation.

### ***Sandia/Super-Counter format***

This is a printable ASCII format that mimics the output from a one or two channel G-823A magnetometer. Its output is limited to one counter module, with the Mag and signal level values as the only data being sent out. The Mag reading is preceded with an 'A' followed by 10 characters of ASCII Mag data. The G-823A format sometimes has a second Mag reading following the first which is preceded with an ASCII 'B'. If selected the CM-201 counter places the signal level in the first 4 significant characters of the second Mag data slot. The sample is terminated by a carriage return line feed sequence.

The purpose of this format is to allow customer with existing G-823A Sandia logging software to be able to use the CM-201 without upgrading to new logging software. Note that Geometrics no longer supports the Sandia logging software.

The single channel Sandia format is selected with the command string "OS" or "OS0". The dual channel output is selected by the command string "OS1".

### ***Example output:***

This is the ASCII output example from earlier, but with 3 A/D channels:

-----

```
$ 99778.131,3749,0004,0005
$ 99890.376,3687,0003,0007
$ 99955.517,3545,0003,0006
$ 99998.293,3472,0005,0006
$100078.835,3329,0004,0005
$100032.071,3381,0006,0006
$ 99979.159,3498,0003,0007
$ 86778.508,3514,0004,0007
$ 78778.216,3645,0004,0004
$ 69978.347,3797,0003,0005
```

The same data displayed in hexadecimal:

-----

```
24 20 39 39 37 37 38 2E 31 33 31 2C 33 37 34 39
2C 30 30 30 34 2C 30 30 30 35 0D 0A 24 20 39 39
38 39 30 2E 33 37 36 2C 33 36 38 37 2C 30 30 30
33 2C 30 30 30 37 0D 0A 24 20 39 39 39 35 35 2E
35 31 37 2C 33 35 34 35 2C 30 30 30 33 2C 30 30
30 36 0D 0A 24 20 39 39 39 39 38 2E 32 39 33 2C
```

```

33 34 37 32 2C 30 30 30 35 2C 30 30 30 36 0D 0A
24 31 30 30 30 37 38 2E 38 33 35 2C 33 33 32 39
2C 30 30 30 34 2C 30 30 30 35 0D 0A 24 31 30 30
30 33 32 2E 30 37 31 2C 33 33 38 31 2C 30 30 30
36 2C 30 30 30 36 0D 0A 24 20 39 39 39 37 39 2E
31 35 39 2C 33 34 39 38 2C 30 30 30 33 2C 30 30
30 37 0D 0A 24 20 38 36 37 37 38 2E 35 30 38 2C
33 35 31 34 2C 30 30 30 34 2C 30 30 30 37 0D 0A
24 20 37 38 37 37 38 2E 32 31 36 2C 33 36 34 35
2C 30 30 30 34 2C 30 30 30 34 0D 0A 24 20 36 39
39 37 38 2E 33 34 37 2C 33 37 39 37 2C 30 30 30
33 2C 30 30 30 35 0D 0A

```

The same data in Packed BCD format:

-----

```

24 99 77 81 31 37 49 00 04 00 05 2A 24 99 89 03
76 36 87 00 03 00 07 2A 24 99 95 55 17 35 45 00
03 00 06 2A 24 99 99 82 93 34 72 00 05 00 06 2A
24 00 07 88 35 33 29 00 04 00 05 2A 24 00 03 20
71 33 81 00 06 00 06 2A 24 99 97 91 59 34 98 00
03 00 07 2A 24 86 77 85 08 35 14 00 04 00 07 2A
24 78 77 82 16 36 45 00 04 00 04 2A 24 69 97 83
47 37 97 00 03 00 05 2A

```

The same data in Excess 3 format:

-----

```

57 CC AA B4 64 6A 7C 33 37 33 38 5D 57 CC BC 36
A9 69 BA 33 36 33 3A 5D 57 CC C8 88 4A 68 78 33
36 33 39 5D 57 CC CC B5 C6 67 A5 33 38 33 39 5A
57 33 3A BB 68 66 5C 33 37 33 38 5D 57 33 36 53
A4 66 B4 33 39 33 39 5D 57 CC CA C4 8C 67 CB 33
36 33 3A 5D 57 B9 AA B8 3B 68 47 33 37 33 3A 5A
57 AB AA B5 49 69 78 33 37 33 37 5D 57 9C CA B6
7A 6A CA 33 36 33 38 5D

```

The same data displayed in dual channel Sandia/G-823A ASCII format:

-----

```

A9977813100B3749000000
A9989037600B3687000000
A9995551700B3545000000
A9999829300B3472000000
A0007883500B3329000000 (Note how the most significant '1'
A0003207100B3381000000 is truncated for readings greater

```



A9997915900B3498000000    than 100,000 nT).  
A8677850800B3514000000  
A7877821600B3645000000  
A6997834700B3797000000

The same data in single channel Sandia format (ASCII):

A9977813100  
A9989037600  
A9995551700  
A9999829300  
A0007883500  
A0003207100  
A9997915900  
A8677850800  
A7877821600  
A6997834700

### Julian Time Set

The Set Time commands (D,H,M,S) will initialize the time in all counter modules. If a particular counter has all Julian clock fields enabled the output string will have the following inserted after the last A/D channel and before the CR/LF:

,DxxxHxxMxxSxx\_xx

The x's would be ASCII characters (0-9) as required. The time registers are not incremented until enabled with the 'J1xx' command, so they can be set up then synchronized by sending the enable command at the correct time.

In Packed BCD and excess format the letters D,H,M,S, and \_ are stripped and the data encoded as per the Mag data above. The Day info is put into 2 bytes with the most significant nibble of the most significant byte set to zero.

### Julian Time Enable

This command starts/stops the Julian clock. To start the clock on counter 0 the command would be "J100". "1" turns on the clock, while the "00" selects counter 0. To turn off the clock update on counter 2 the command would be "J002".

If the counter number information is omitted the command will affect all counter in the chain. Thus the command "J0" will turn off the update for every counter.

Note that the "Jxxx" command only affects whether the clock increments with time. It has no effect on whether or which of the clock fields are output. The "OJxxxxxyy" commands selects which field is output.

### Julian Output format

There are five clock output fields that can be turned on or off. These are the Julian Day, Hour, Minutes, Seconds, and Fractional seconds (to .01 seconds). These are selected with the "OJxxxxxyy" command. Each of the five x's corresponds to an output field, and can either be a '0' or a '1'. '1' turns the field on, '0' turns the field off. The yy characters is the counter number. Following is a diagram showing which character corresponds which each display field:

command: "OJ0111103"

```

|||||_ Counter number LSB
|||||_ Counter number MSB
||||_ 10 ms field
|||_ Seconds field
||_ Minutes field
\_ Hours field
\_ Days field
```

In this example counter three would have all clock fields output except the Julian Day.

The counter number characters are optional. If not present the command would affect only counter 0 in the chain.

### Find Counters

This command is used to figure out how many counters there are in the daisy chain. An 'F00' is sent to the first counter which assigns it as counter 0. Before the command is echoed to the next counter the command is modified to 'F01'. The next counter modifies it to 'F02', and so on until the logging PC gets the command echo of 'Fxx' where xx is the number of counters in the chain.

Continuous data output can be inhibited by sending the command 'F01' to the first counter. In this mode there is no first counter (#00) which normally starts data transmission. Data output can be resumed by sending a new 'F00' command.

### Set Preamble character

By default the first character of each data stream is a '\$'. If another character is desired the 'Px' command is used to change it to the character sent following the 'P'. All characters are allowed except control characters, digits (0-9), spaces, commas, decimal points, and the termination char (\*).

### Echo Error command

This is not really a command but a message. If a command string is incorrectly sent or garbled the counter receiving it will change it to 'ERRxx' before echoing it to the next counter. 'xx' specifies the counter number where the syntax error first occurred. This error message is interpreted as a command by subsequent counters which echoes the string unchanged.

### Interrogate Setup command

This command allows the operator or logging software to identify which analog channels and Julian clock fields are being output via the serial port. This information is used to verify output fields with their hardware channels, and to allow automated calculation of data field position within each sample being sent out. In addition the software revision number can be interrogated.

The first character 'I' designates the interrogate command, the second letter designates which item to interrogate. 'A' specifies interrogating the analog channels, 'J' specifies the Julian clock, and 'V' specifies the software revision number.

The next two characters specify the counter number '00' through '19'. If the counter number is omitted, counter 0 will respond.

The addressed counter will insert a response into the command string before sending echoing it out the serial port to the display terminal or subsequent counter modules. Subsequent counter modules will ignore these extra response characters and pass them unmodified down the chain. The response format for each of the three interrogate items are detailed in the examples below:

### Analog channels

The command "IA01" will command counter number one to output characters indicating which of the six analog channels have been selected for output. Counter 1 will modify the command string to "IA01:abcdef" where the letters a-f are either an ASCII '0' (channel off) or '1' (channel on) corresponding to channels 0-5 respectively. If analog channel 0,3, and 4

were selected on counter 1 the echoed command string would be "AI01:100110" followed with a carriage return line feed.

#### *Julian Clock:*

The command "IJ" will command counter 0 to output which Julian clock fields have been selected for output (note that the two digit counter number was not specified, so counter 0 responds by default). Counter 0 will modify the command string to "IJ:abcde" where the letters a-e would be replaced with an ASCII '0' (field off) or '1' (field on). The five output fields are:

- a: Julian day
- b: Hour
- c: Minute
- d: Second
- e: Fractional Seconds (to 10 milliseconds)

If counter 0 had all clock fields selected for output except the Julian Day it would modify the command string to "IJ:01111" followed with a carriage return line feed.

#### *Software Version Number*

The command "IV02" will command counter 2 to send its two character software version number. Counter 2 would change the command string to "IV02:xx" where xx is the version number of the software. If Counter 2 was software version "A4" then the echoed command string would be "IV02:A4" followed by a carriage return line feed.

#### Reset command

If the command 'RESET' is sent to the counter a power up reset will occur initializing all parameters to default. The reset sequence will not start until the reset command has finished echoing out the RS232 port to the next counter/logging device. This allows each device down the chain to reset in sequence.

#### Jump to debug

If the command string 'XBUG' is received the counter will do a one way jump to factory debug mode where a rudimentary operating system allows probing of registers, ports and memory for debugging purposes. It will only function properly with a single counter module (no daisy chained counters).

## 7.4 Power-up Initialization

By default all counters will wake up thinking that they are counter #0 and begin to output data at the default 10 hertz rate. This data will appear as commands to any subsequent counters and will cause a brief period of chaos until each counter figures out where they stand in the daisy chain. Thus there will be some garbled transmissions to the logging PC upon power-up or reset.

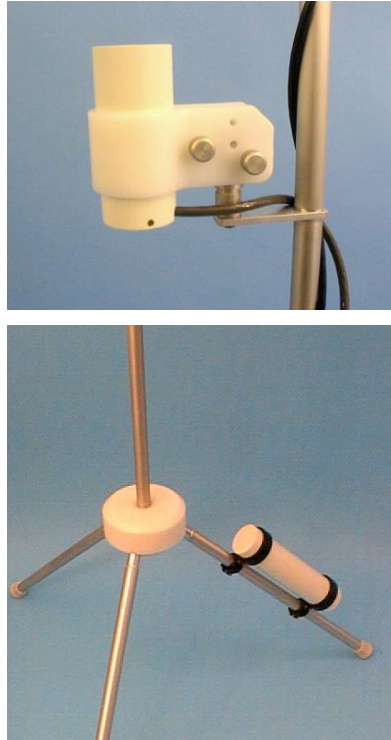
## 8.0 G-823B MAGNETOMETER

The model G-823B magnetometer is a variant of the G-823A intended for use as a high-performance base-station instrument. This model has the same dimensions and performance as the G-823A with the exception of its heading error. G-823B heading error is typically in the range of from 2nT to 3nT. Heading errors specifications are not normally supplied with the G-823B. As with the G-823A, the G-823B is shipped with a 25ft external signal/power interface cable, a power/data junction box, and an RS-232 data cable. These components are used to connect the magnetometer to the user's 30VDC power source and logging computer.

When used as a base station, Julian date/time are available for recording and the standard sensitivities and measurement rates of the CM-201 counter apply. In this application the D/A converters installed in the CM-201 can be used to convert such other parameter (e.g. barometric altitude) and include these values in the data stream. Recording rates from once each 10 seconds to 100 times per second may be selected.

The 25ft power/data cable included with G-823B will permit the logging computer to be located far enough from the sensor to avoid interference. Base-station data will also be more noise free if the sensor is positioned in a spot where the gradients are relative low. Such a spot may be located by casual surveying of the area selected for the base station site and identifying the spot with the most uniform field. Selecting this spot will also make a reoccupation of the spot easier (e.g. for base-station recordings used for block-leveling regional survey data).

We recommend a base-station installation that places the sensor approximately 5ft (1.5m) above the ground in order to reduce motion-induced noise. Motion noise will be proportional to both the amount of sensor motion and the size of the local gradient. Positioning the sensor off the ground will reduce the strength of short wave-length gradients arising for the soil or from disturbed outcrop. It is also important to provide a ridged support structure so as to keep wind induced motion to a minimum. Figure 14 shows a base station installation that uses a kit supplied by Geometrics for this purpose.



G-823B magnetometer installed using sensor staff sections and tripod base. This installation provides a ridged, non-ferrous support for the sensor that presents minimal wind resistance. Photo on left shows installation combined with a GPS receiver.

**Figure 14. G-823B Installed as base-station magnetometer.**

## **9.0 ACCESSORY SOFTWARE**

### **9.1 CM-201**

CM-201 is a program that facilitates sending a command start-up file to the G-823A counter(s) and initiating system operation. The program is executed by typing “cm201” at the DOS prompt and pressing return. CM-201 expects a counter command file that must be called cm-201go.cnf. This file is a list of counter commands, each followed by a carriage return that may be required to configure the counter to your application.

This software and all its necessary files may be installed on your system by placing the Install disk in either your a: or b: floppy drive, switching to that drive, typing “install” at the DOS prompt and pressing return. Install will ask a number of questions to which you should respond to configure the CM-201 counter to your system and create the cm-201go.cnf file.

If, after installing CM-201, further commands are required (such as CLOCK) to configure CM-201 operation to your application, they may be added to the cm201go.cnf file by editing this file with any suitable text editor.

The following describes CM-201 and the files that will be installed on your C: drive:

install.bat

This is a batch file used to copy the contents of the floppy onto your hard disk. A directory called "GeoUtil" is created on the "C" drive, then all of the files are copied into that directory. After the files are copied, this batch file then runs Cm201set.bat

cm201set.bat

This batch asks the user questions and based on the answers to these questions creates a batch file called "cm201.bat". The questions include such things as, to which COM port the CM-201 counter is connected.

cm201.bat

This batch file is created by Cm201set.bat. It invokes cm201go.exe to send any command lines necessary to correctly configure the CM-201 counter(s) for the users application.

cm201go.exe

This program is intended to send any commands to correctly configure the CM-201 counter module(s). Normally the commands are taken from the file cm201go.cnf, but this can be overridden if needed.

The calling syntax for this program is:

Cm201go FileName.cnf /b:BBBBB /p:P /i:I /d:D

Where:

BBBBB	Is the baud rate that the CM-201 starts at. Normally this is 9600.
P	The port number /p:1 would mean use COM1. This parameter is optional. If it not specified COM1 will be used.
I	The interrupt number to use. This parameter is optional. If it is not specified the normal interrupt for the COM port is used.

- D Any value other than zero will turn on the debugging display. This parameter is optional. If it is omitted the debugging display is disabled.

The contents of the cm201go.cnf file are sent line by line to the CM-201 counter module(s). After each line is sent the cm201go program waits for the confirmation that the command was received correctly. If the confirmation is not received the line is repeated. For lines that change the CM-201's baud rate the cm201go program changes its baud rate as required. If the input line has the special code "[CLOCK]" on it, the CM-201's clock will be set to match that of the PC.

A typical cm201go.cnf would be:

```
[CLOCK]
c0010
oj11111
```

commflip.exe

Given the port numbers of two COM ports this program will exchange their addresses. On some note book computers this is needed to be able to use some software.

batmenu.exe, drawbox.exe, gotoxy.exe, yymmdd.exe, foreach.exe, getkey.com

These programs are utility programs that allow the batch files to interact with the user.

## **9.2 Cesium Sensor Azimuth Program - CsAz**

CsAz is a DOS program written by Geometrics for users of Cesium magnetometers. The purpose of the program is to determine the proper orientation of the Cesium sensor at various field dip angles of the Earth's field. (Cs is for cesium and Az is for azimuth.)

We note here that a firm grasp of the orientation section of this manual (section 4.1) makes the use of this program optional. There is no additional information imparted by running CsAz.

The program is easy to operate. Begin by typing CsAz at the prompt followed by the Enter key. You will see a towed bird with the sensor mounted vertically. A lower graphic image displays the bird from a vertical perspective. If you are using the program for land or marine applications, the orientation of the bird can be taken to be the orientation of the wand or fish.



Note: It is helpful to have CsAz running on a computer while studying the following material.

The first piece of information required is the earth's magnetic field inclination (dip angle) in your survey area. Refer to Figure 4 and obtain this angle from the map. For instance, the dip angle in San Francisco is 62 degrees North, Chicago is 72 degrees North, Sao Paulo is 30 degrees South and Singapore is 18 degrees South.

Next enter a N or S for the hemisphere (no enter key required here).

The first time, we recommend that you just press enter twice for no tilt and no rotation. After a few moments you will hear a beep when the computations are completed. Press any key to see the graphical display of the signal to noise ratio of the sensor in that orientation at that dip angle.

The circumference of the graphic represents the compass directions in degrees, i.e. the survey direction. The white portion of the graphic emanating from the center is the proportional signal-to-noise ratio that would be obtained if the survey were run in that direction. The black regions represent survey directions (approximately a 30 degree cone) in which the earth's magnetic field vector would be in the dead zone of the sensor. The region of the display that is white and outside of the 15 degree circle represents survey directions in which the earth's magnetic field vector would be in the sensor's active zone and provide good data. The longer the white line, the better the response of the Mag in that direction.

If the white line terminates inside the 15 degree circle, then you will get no signal traveling in that direction. If it terminates just outside the 15 degree circle, then the installation will tolerate very little in the way of yaw, pitch or roll (depending on orientation, but most likely yaw) of the sensor before the earth's field vector goes into the sensor dead zone. Longer lines are better.

Next, press escape and reenter the dip angle and hemisphere information. Now you can tilt and rotate the sensor to see the effect on the signal versus survey direction. We have found that tilt angles of 0, 45 and 90 cover all realistic installations and dip angles. Rotating the sensor often has the effect of changing the optimum direction of survey.

Try a dip angle of 0 degrees with a tilt of 90 degrees. Try rotating 45 degrees. Even in a horizontal field, one can survey in both north-south and east-west directions. Geometrics sensors are fully automatic hemispheric switching allowing this versatility.

Try a dip angle of 70 degrees (Indiana) with a tilt of 45 degrees and a rotation of 90 degrees. In some areas, maximum signal cannot be achieved in all survey directions, but any signal-to-noise lines extending out to 20 and beyond will produce excellent data in those survey directions even in turbulent air.

With each entry of an angle of tilt and angle of rotation the sensor is depicted in the bird (fish) in the position that would be obtained if the sensor is first tilted aft from the depicted vertical axis by the specified angle and then rotated by the specified angle about the depicted vertical axis to its final position. Note the position of the sensor depicted in CsAz and make the appropriate mechanical adjustments to put the sensor in this same position as depicted by CsAz.

If you press F1 the program will identify your first available printer port and print out a laser printer compatible graphic of the screen. F2 is for Epson compatible printers. If you have both LPT1 and LPT2 operational and you want to go to LPT2, then add the following to the command line:

```
c:\csaz.exe /L=2          or /L=3   for LPT3
```

### 9.3 View201

View201 is a DOS program that enables programming and viewing the magnetometer and analog data from one to three CM-201 counter modules. It was written primarily as a factory debug/test utility and is provided as a tool to help installation and testing of the counter(s) in the field. The output can be viewed in both raw text and in graphics mode. In addition the output data can be logged to disk if desired. The program defaults to using Com port #1, although Com port #2 can be used by adding " /COM2" to the command line after "View201".

Upon startup the program listens to the output data stream from the counter(s) and synchronizes to the output baud rate. The raw output data is then displayed in a data text window. Along the top is a status bar showing the condition of the serial port and the serial input buffer.

View201 defaults to using COM port #1. COM port #2 can be selected by typing "View201 /COM2" and <ENTER> at the DOS prompt.

After the magnetometer has warmed up the first comma delimited field should be showing a stable magnetometer reading. The default counter output format includes the 4 character signal level in the next field (9999 full scale). Other data may be present as well depending on output configuration. If more than one magnetometer is daisy chained together there will be other magnetometer data fields embedded in the output stream.

Commands can be sent to the counter module(s) at anytime. There are many commands that control the CM-201 which are detailed in the Section 7.2. As an example, the command "A0000" followed by a carriage return turns off analog channel 0 (signal level) in counter 00: Each character is sent as it is typed and stored by the counter. When a carriage return is received by the counter the command is executed and then echoed down the daisy chain of counters until it is received back by the View201 program and

displayed in the data window. A correctly echoed command string is a confirmation that the command was received and executed properly. Mis-typed or invalid commands will be turned into an error message and echoed through to the View201 display window. (Type A1000<return> to turn the signal level channel back on).

The magnetometer data can be viewed in graphics mode by pressing the <F5> function key. View201 defaults into displaying the magnetometer data from counter #0 at 10 nT full scale. Data from the second and third magnetometer can be displayed by pressing <F2> and <F3> respectively. If magnetometer 2 or 3 are not present the data fields are set to zero.

Data can be logged to disk at any time by pressing <F10>. A filename is created based on date and time and logged to disk. A logging message is displayed and a low frequency beeper plays to indicate that logging is taking place. Pressing <F10> again stops the logging process.

Currently, View201 only recognizes the ASCII output format. This is the default output format, but there is nothing preventing a change format command from being sent to the counter module. If the output format is changed the View201 program will cease to function correctly.

A list of function keys and their use can be viewed at anytime by typing a question mark '?'.

The following is a description of each View201 function key. These are functions that control the operation of the View201 program and should not be confused with commands that affect the counter module:

### Function Keys

- <F1> = Toggle graphics display of Mag1 on/off. Default setting is on. This key has effect in graphics mode only.
- <F2> = Toggle graphics display of Mag2 on/off. Default setting is off. If turned on and no magnetometer#2 is present the magnetometer 2 data value is forced to zero. This key has effect in graphics mode only.
- <F3> = Toggle graphics display of Mag3 on/off. Default setting is off. If turned on and no magnetometer#3 is present the Mag3 data value is forced to zero. This key has effect in graphics mode only.
- <Alt F1> = Toggle graphics display of Grad1 on/off. Gradient channel 1 is the difference between Mag1 and Mag2. This key has effect in graphics mode only.

- <Alt F2> = Same as <Alt F1> except it applies to Grad2 channel.
- <Alt F3> = Same as <Alt F1> except it applies to Grad3 channel.
- <Shft F1>= Change graphics display color for Mag1. Press this key several times to cycle through the 16 colors available for displaying mag1. Note that the display indicator for Mag1 in the lower left hand corner of the graphics display changes as well, aiding in identifying which trace belongs to which variable. This key only has effect in graphics mode.
- <Shft F2>= Same as <Shft F1> except it applies to Mag2 channel.
- <Shft F3> = Same as <Shft F1> except it applies to Mag3 channel.
- <Ctl F1> = Change graphics display color for Grad1 trace. Press this key several times to cycle through the 16 colors available for displaying Grad1. Note that the display indicator for Grad1 in the lower right hand corner of the graphics display changes as well, aiding in identifying which trace belongs to which variable. This key only has effect in graphics mode.
- <Ctl F2> = Same as <Ctl F1> except it applies to Grad2 channel.
- <Ctl F3> = Same as <Ctl F1> except it applies to Grad3 channel.
- <F4> = Toggle between true and normalized gradient display. When measuring gradients it is often desirable to center the display trace so that small variations do not cause screen wrapping. Pressing F4 will calculate and add an offset value to force the gradient display traces to the center. Pressing F4 again will toggle back to absolute display mode. Note that the Grad display indicators in the lower right hand corner of the graphics display screen change from "Gradx" to "GradZx" indicating the current mode. Note that this normalizing only takes place on gradient channels.
- <Alt F4> = Toggle true and normalized w. offset grad display. When measuring gradients with all three gradient channels turned on it is often desirable to move the three gradient traces close to the center of the display - but not place them right on top of each other. This key works the same as F4 above but leaves the traces slightly offset from one another.
- <F5> = Toggle between graphics and text display mode.
- <F6> = Lower the magnetometer full scale coefficient in the graphics display window. This key only affects the Mag channels (not gradient).

- <F7> = Raise the magnetometer full scale coefficient in the graphics display window. This key only affects the Mag channels (not gradient).
- <Alt F6> = Lower the Grad full scale coefficient in the graphics display window. This key only affects the Grad channels (not magnetometer).
- <Alt F7> = Raise the Grad full scale coefficient in the graphics display window. This key only affects the Grad channels (not magnetometer).
- <F8> = Clear next graphics screen and jump to it.
- <F9> = Clear Break, Frame, and Parity errors in the Com port status bar (text display screen only).
- <ALT F9>= Auto adjust to incoming baud rate and clear errors.
- <F10> = Toggle logging to disk.
- <Esc> = Exit to text mode (if in graphics display mode). Exit to DOS (if text mode and not logging to disk).

### Displaying Analog Channels

When in graphics display mode [F5] up to six analog channels may be enabled by typing <CTRL A>. This will activate a series of questions to format the analog data for display:

#### ***Display Channel Number [0-5]:***

Selects one of six display channels. Any channel can be selected. The default number is the first unused display channel. If a channel currently in use is selected all subsequent menu items will have their default values set to the current values. This makes it easy to modify the format of a channel currently being plotted by simply pressing <enter> until the parameter to modify is reached.

#### Display channel ON/OFF [0/1]:

Type '0' to turn a channel off. No further menu parameters will follow and the channel will stop plotting. Type '1' to turn the display channel on or just <ENTER>, which defaults to on.

### Counter Number [0-2]:

Selects which counter the analog data will come from. Up to three daisy chained counters may be logged by this program. The default is always counter 0 (the first [or only] counter).

### Analog Channel Number [0-5]:

Selects which A/D channel of the above counter is to be displayed. Do not confuse "analog channel number" with "display channel number" above. They are not related in any way. Think of the display channels as 6 separate input channels to a 6 channel analog strip chart recorder. The counter channel numbers (along with counter number information) specify a particular analog information channel. With three counters there could be 18 separate information channels – any one of which could be configured to any display channel. For instance, one analog channel could be assigned to two display channels with differing full scale coefficients - allowing a course and fine graphics display of the same channel.

The program does not 'know' which analog channels are actually coming out of the counter. It is possible, for example, for the counter to be commanded to output channels 0, 4, and 5 only. This program sees only three analog channels in the counter's data stream and will refer to them as channels 0,1, and 2.

### Unipolar/Bipolar [U/B]

As described in the magnetometer/counter manual there are 4 unipolar (including the signal level) [0 to +4.096 volts], and 2 bipolar channels [ $\pm 2.048$  volts]. This parameter is used to signify which type of analog channel this is.

### Clip/Wrap [C/W]

This parameter specifies what to do when the analog data exceeds the full scale setting (see Full Scale Set below). Clip mode causes the data to be clipped at full scale so that the channel traces the top of the display screen (or possibly the bottom of screen in bipolar mode). Wrap allows the trace to over-scale and wrap back around to the bottom or top of the screen.

### Full Scale Set

Set the full-scale value of the display using the "+" and "-" keys. Note that a value of 10000 nT full-scale display as "0000" full scale. All other values display correctly in the allocated 4 digits.

## Label

This allows a 10-character label to be associated with the analog channel. These labels make it easy to identify each trace by looking at the label. The labels are written at the top of the screen and color coded to match the associated trace. To erase the default label of "channel n" use the backspace key and then enter a new one.

## Set trace color

Use the "+" and "-" keys to cycle through all the possible trace colors using the label name entered above as a guide.

After the above data have been entered, the display channel will be plotting. At the top of the screen all of the activated display channels are documented in the same color as their associated trace color as in the following example:

Pitch  
A13±1000C

The display channel in this case was labeled "Pitch". Underneath it is a shorthand display of all the setup parameters:

"A" : signifies this is an analog channel.  
"1" : the counter number [0-2]  
"3" : the counter channel number [0-5]  
"±" : Bipolar mode, would have been set to "-" for unipolar  
"1000" : Full scale value. If "0000" is displayed it mean "10000" full scale.  
"C" : Clipped display, would be a "W" for wrap mode.





## APPENDIX A1. MODEL G-822A SPECIFICATIONS

<b>OPERATING PRINCIPLE:</b>	Self-oscillating split-beam Cesium Vapor (non-radioactive)
<b>OPERATING RANGE:</b>	20,000 to 100,000 nT
<b>OPERATING ZONES:</b>	The earth's field vector should be at an angle greater than 6° from the sensor's equator and greater than 6° away from the sensor's long axis. Automatic hemisphere switching
<b>SENSITIVITY:</b>	<0.0005 nT/√Hz rms. Typically 0.002 nT P-P at a 0.1 second sample rate (90% of all readings falling within the P-P envelope) using 822A Super-counter
<b>HEADING ERROR:</b>	<0.15 nT over entire 360° polar and equatorial spin
<b>ABSOLUTE ACCURACY:</b>	Better than 3 nT throughout range
<b>OUTPUT:</b>	Cycle of Larmor frequency = 3.498572 Hz/nT, RS-232 data at 9600 baud, concatenated data streams from up to 6 sensors
<b>MECHANICAL:</b>	
SENSOR:	2.375" (60.32 mm) dia., 6.25" (158.75 mm) long, 12 oz (339 g) without cable, 24 oz (680 g) with cable
SENSOR ELECTRONICS:	2.5" (63.5 mm) dia., 11" (279.4 mm) long, 24 oz (680g)
CABLES:	
Sensor to electronics:	109" (2.77 m) standard. Cable length can be increased by 43" (1.10 m) for a total length of 152" (3.87m).
Sensor Electronics to Counter:	33' (10m) standard. Cable length can be increased up to 164' (50 m)
<b>OPERATING TEMPERATURE:</b>	-30°F to +122°F (-35°C to +50°C)
<b>STORAGE TEMPERATURE:</b>	-48°F to +158°F (-45°C to +70°C)
<b>ALTITUDE:</b>	Up to 30,000 ft (9,000 m)
<b>WATER TIGHT:</b>	Sealed for up to 2 ft (0.9 m) water depth
<b>POWER:</b>	24 to 32 VDC, 0.75 amp at turn-on and 0.5 amp thereafter
<b>ACCESSORIES:</b>	
Standard:	Power/RS-232 multi-conductor cable (electronics to power/data junction box with 9 pin RS-232 connector and power lugs), lengths to be specified, spare O rings, operation manual and carrying case
Optional:	
Logging Software	MagLog (Logs GPS and Mag, shows track-plot, mag profile )
Accessories	Birds, Stingers, Wingtips, Avionics, GPS receivers

*SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE*

## APPENDIX A2. MODEL G-823A SPECIFICATIONS

<b>OPERATING PRINCIPLE:</b>	Self-oscillating split-beam Cesium Vapor (non-radioactive)
<b>OPERATING RANGE:</b>	20,000 to 100,000 nT
<b>OPERATING ZONES:</b>	The earth's field vector should be at an angle greater than 6° from the sensor's equator and greater than 6° away from the sensor's long axis. Automatic hemisphere switching.
<b>SENSITIVITY</b>	<0.004 nT/√Hz rms. Typically 0.02 nT P-P at a 0.1 second sample rate (90% of all readings falling within the P-P envelope) using CM-201 Mini-Counter
<b>HEADING ERROR:</b>	<0.15 nT over entire 360° polar and equatorial spin. Not specified on 823B
<b>ABSOLUTE ACCURACY:</b>	Better than 3 nT throughout range
<b>OUTPUT:</b>	Cycle of Larmor frequency = 3.498572 Hz/nT, RS-232 data at 9600 baud, concatenated data streams from up to 6 sensors
<b>MECHANICAL:</b>	
SENSOR:	2.375" (60.32 mm) dia., 6.25" (158.75 mm) long, 12 oz (339g) without cable, 24 oz (680 g) with cable
SENSOR ELECTRONICS:	2.5" (63.5 mm) dia., 11" (279.4 mm) long, 29oz 822g)
CABLES:	
Sensor to sensor driver / counter:	109" (2.77 m) standard. Cable length can be increased by 43" (1.10 m) for a total length of 152" (3.87m).
Sensor driver to external counter:	33' (10m) standard. Cable length can be increased up to 164' (50 m)
Sensor driver / counter to Power/data junction	25' (7.6m) standard. Cable length can be increased up to 200' (61 m)
<b>OPERATING TEMPERATURE:</b>	-30°F to +122°F (-35°C to +50°C)
<b>STORAGE TEMPERATURE:</b>	-48°F to +158°F (-45°C to +70°C)
<b>ALTITUDE:</b>	Up to 30,000 ft (9,000 m)
<b>WATER TIGHT:</b>	Sealed for up to 2 ft (0.9 m) water depth
<b>POWER:</b>	24 to 32 VDC, 0.75 amp at turn-on and 0.5 amp thereafter
<b>ACCESSORIES:</b>	
Standard:	Power/RS-232 multi-conductor cable (electronics to power/data junction box with 9 pin RS-232 connector and power lugs), lengths to be specified, spare O rings, operation manual and carrying case
Optional:	Birds, Stingers, Wingtips, Avionics, GPS receivers

*SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE*

## APPENDIX A3. SENSOR INSTALLATIONS



Figure A1. G-822A sensor and G-822A Bird components



Figure A2. Airborne Stinger showing sensor mount.



Figure A3. Aircraft fitted with stinger assembly



Figure A4. Aircraft fitted with horizontal transverse and longitudinal gradiometer using faired wingtips and stinger.



**Figure A5. G-822A Boom installation on Ultra-lite autogyro.**



**Figure A6. Single sensor boom installation on Helicopter.**





Figure A7. Multi-sensor (7) MTADS Helicopter installation for UXO survey.



Figure A8. Rack mount for airborne geophysical survey system



Figure A9. MTADS multi-sensor array for UXO survey applications.

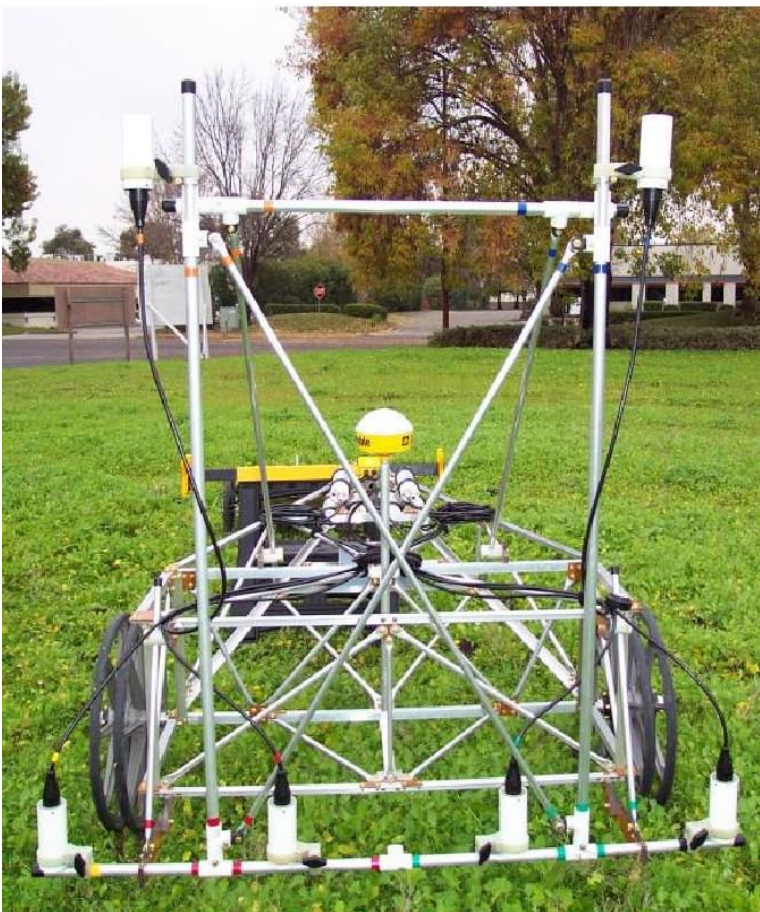


Figure A10. Multi-sensor array on cart for archaeological surveying.

## APPENDIX A4. CESIUM-VAPOR SENSOR THEORY

*Note: The following section is provided for information purposes only. Understanding this theoretical discussion is not required for proper operation of the magnetometer.*

For purposes of this discussion, the ambient magnetic field or earth's magnetic field is called  $H_0$ . A separate magnetic field generated by an AC signal applied to a coil inside the sensor is called  $H_1$ . This coil is shown cross-section along with the other sensor components in Figure A11.

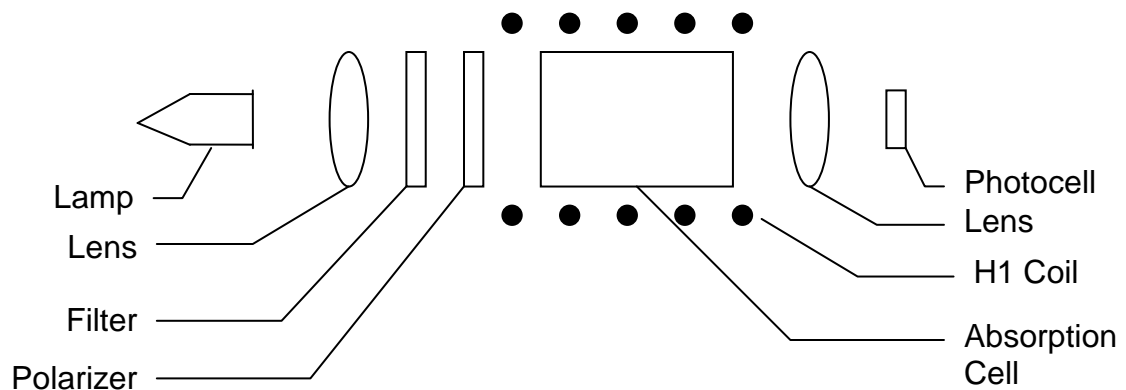


Figure A11. G-822A cesium-vapor



To initiate operation of the sensor, the lamp oscillator's RF power increases until the lamp strikes (plasma ignites and fluoresces). The lamp oscillator then reduces its power to produce the regulated amount of light. The heater warms the absorption cell until a Cesium vapor is formed. A lens bends the light from the lamp to parallel rays. The lamp produces many spectral lines but only one line in the infrared region is employed. All of the other light is blocked by a high grade optical filter.

The infrared line of interest is then passed through a split-circular polarizer. On one side of the polarizer the transmitted light has an electrostatic vector that advances with a right-handed rotation. For conceptual purposes, it can be said that all of the photons in this light have the same right-hand spin direction. The light transmitted through the other side of the split-circular polarizer produces light in which the vector advances with a left-handed rotation, therefore having the opposite spin. Both circular polarized light beams pass through the absorption cell. Because there is a buffer gas in the cell, the single cell can be considered as two separate cells, each having the opposite sense polarized light passed through it. Both light beams exit the cell and pass to a second lens. This lens focuses the light onto an infrared photo detector.

Because Cesium is an alkali metal, the outer most electron shell (orbit) has only one electron. It is the presence of this single electron that makes the Cesium atom well-suited for optical pumping and therefore magnetometry.

The Cesium atom has a **net magnetic dipole moment**. This net dipole moment, termed **F**, is the sum of the **nuclear dipole moment**, called **I**, and the **electron's angular momentum**, called **J**. In a Cesium atom:

$$\mathbf{I} = 7/2$$

$$\mathbf{J} = 1/2$$

and thus **F** can have two values depending on whether the electron's angular momentum adds to or subtracts from the nuclear dipole moment. Therefore, **F** can have the value of **3** or **4**. These values are called the hyperfine energy levels of the ground state of Cesium.

Normally the net dipole moments are randomly distributed about the direction (vector sum of the 3 axial components) of the ambient magnetic field ( $H_0$ ). Any **misalignment** between the net atomic dipole moment and the ambient field vector causes the Cesium atom be at a higher energy level than if the vectors were aligned. These small differences are called **Zeeman splitting** of the base energy level.

The laws of quantum electrodynamics limit the inhabitable atomic magnetic dipole orientations and therefore the atomic excitation energy to several discreet levels: 9 levels for the **F=4** state and 7 levels for the **F=3** state. *It is this variation in electron energy level state that is measured to compute the ambient magnetic field strength.*

When a photon of the infrared light strikes a Cesium atom in the absorption cell, it may be captured and drive the atom from its present energy level to a higher energy level. To be absorbed the photon must not only have the exact energy of the Cesium band gap (therefore the narrow IR line) but must also have the correct spin orientation for that atom.

There is a high probability that the atom will immediately decay back to the initial energy level but its original orientation to the ambient field is lost and it assumes a random orientation. An atom that returns to the base level aligned such that it can absorb another photon, will be driven back to the higher state. Alternately, if the atom returns to the base level with an orientation that does not allow it to absorb an incoming photon, then it will remain at that level and in that orientation. Atoms will be repeatedly driven to the higher state until they happen to fall into the orientation that cannot absorb a photon. Consequently, the circularly polarized light will depopulate either the aligned or inverse aligned energy states depending on the orientation (spin) of light polarization. Remember that one side of the cell is right-hand polarized and the other left-hand polarized to minimize sensor rotational light shifts and subsequent heading errors.

Once most of the Cesium atoms have absorbed photons and are in a state that does not allow them to absorb another photon, the light absorption of the cell is greatly reduced, i.e., more light hits the photo detector. If an oscillating electromagnetic field of the correct radio frequency is introduced into the cell, the atoms will be driven back (depopulating the energy level) into an orientation that will allow them to absorb photons again. This frequency is called the Larmor frequency and is exactly proportional to the energy difference caused by the Zeeman splitting mentioned previously. This energy splitting is in turn directly proportional to the ambient magnetic field strength. The relationship between frequency and energy is given by:

$$E = f\hbar$$

Where:

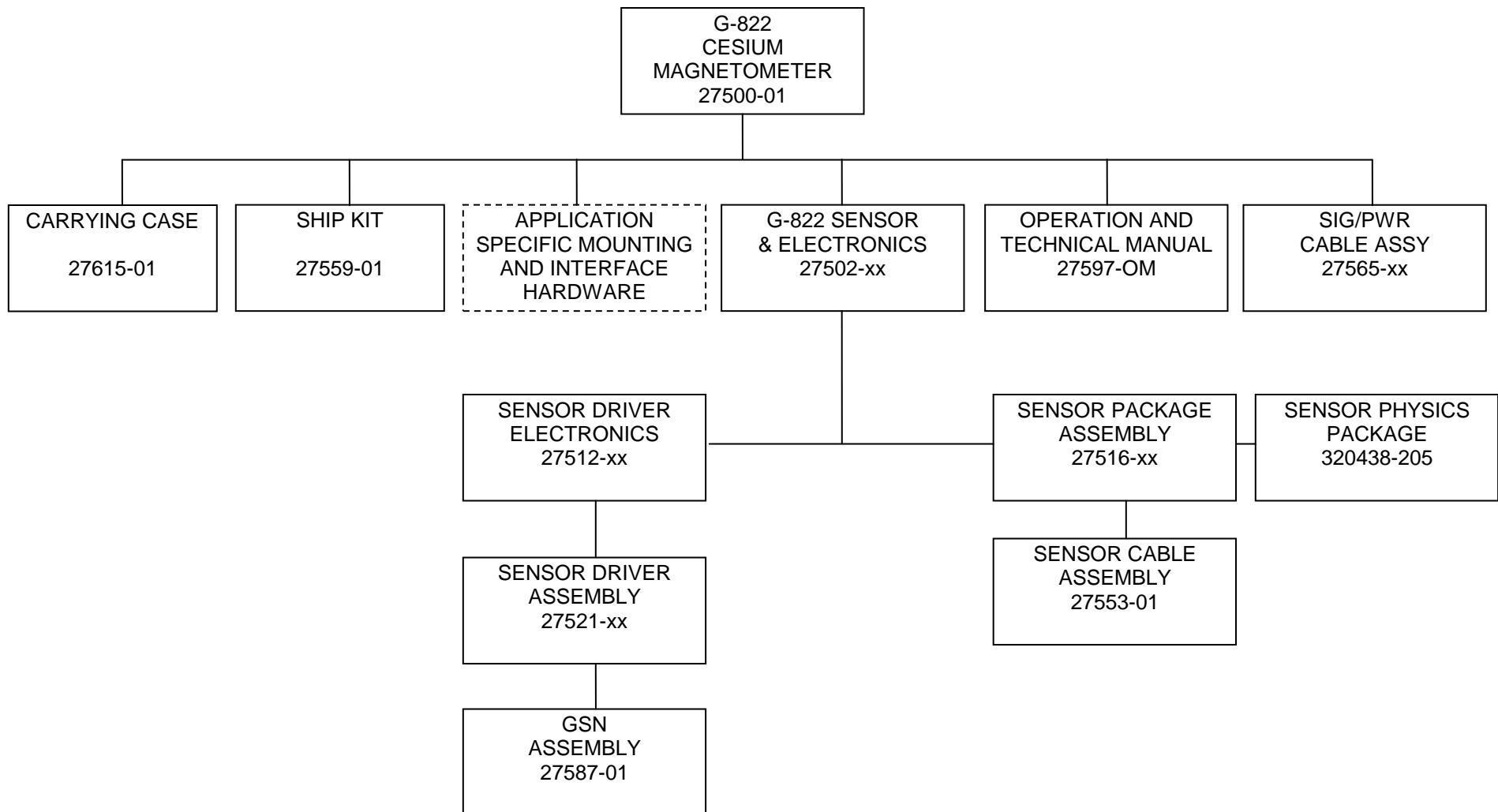
- E is the Zeeman energy difference
- f is the frequency of the Larmor
- $\hbar$  is Planck's constant

In Cesium this Larmor frequency is exactly 3.498572 times the ambient field measured in nano-teslas (gammas). In the G-822A this radio frequency field is generated by a coil, called the H1 coil that is wound around the tube holding the optical components. When the R.F. field is present the total light passing through the cell is reduced because atoms are in an energy state in which they can again absorb the infrared light.

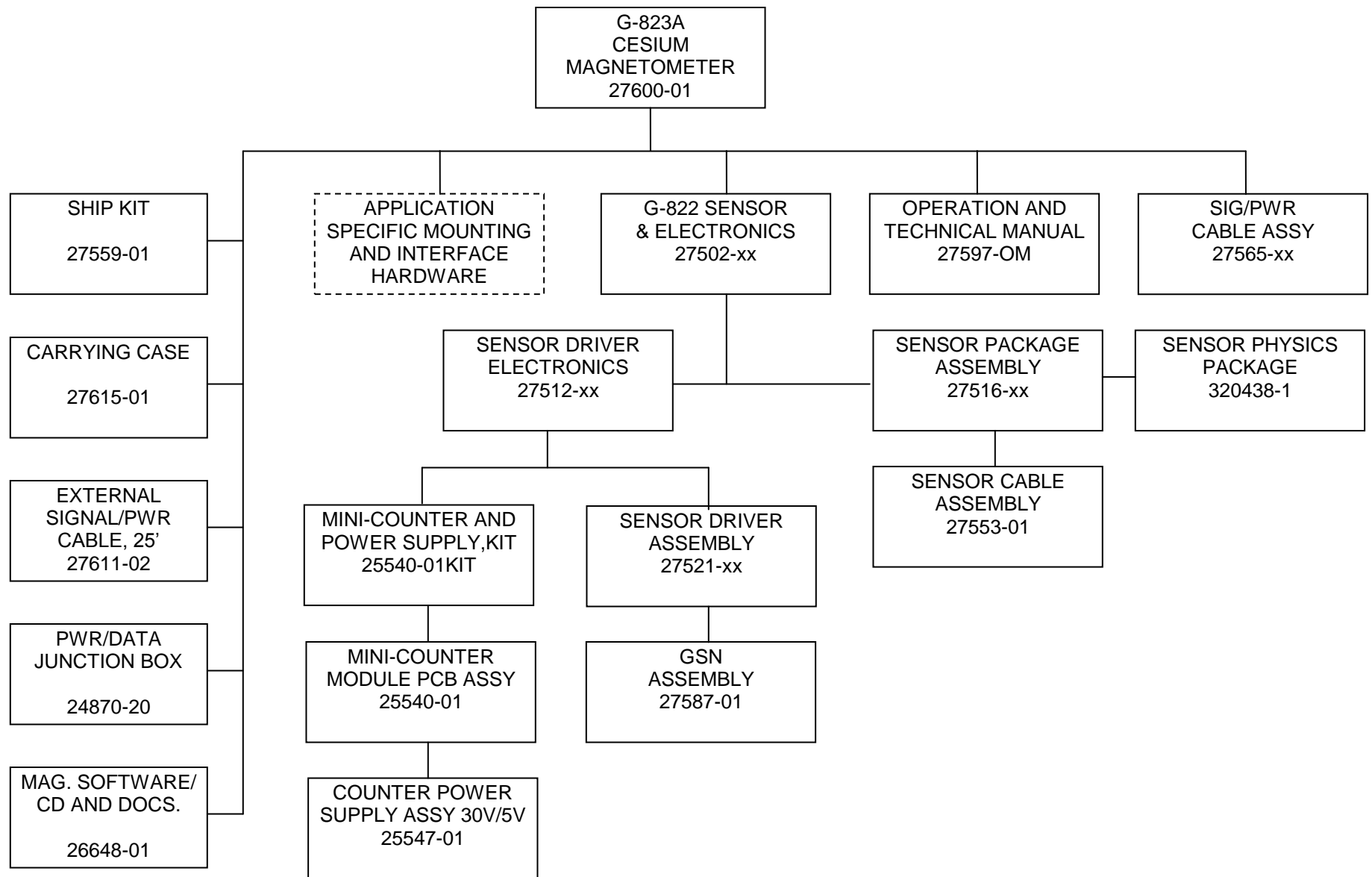
There is a small variation in the atomic light absorption at the frequency of the applied H1 depopulation signal. This variation in light intensity appears on the photo-detector as a small AC signal (micro-volts). If this AC signal is amplified and shifted to the correct phase, it can be fed back to the H1 coil to produce a self sustaining oscillation. In

practice simply connecting the 90° phase shifted and amplified signal to the H1 coil will cause the oscillation to spontaneously start. Reversing the direction of the earth field vector ( $H_0$ ) through the sensor requires the drive to the H1 coil to be inverted to obtain oscillation. (See Automatic Hemisphere Switching, section 2.4.3).

## APPENDIX A5. G-822A GENERAL BLOCK DIAGRAM OF SYSTEM COMPONENTS



## APPENDIX A6. G-823A GENERAL BLOCK DIAGRAM OF SYSTEM COMPONENTS



## APPENDIX A7. G-823B GENERAL BLOCK DIAGRAM OF SYSTEM COMPONENTS

