GEOMETRICS
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G-862RBS
High Performance Base Station

Operation Manual

P/N 27922-OM

Rev. B

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CE March 14, 2003 **03**

Sunnyvale, California, USA

EC DECLARATION OF CONFORMITY

We, Geometrics, Inc.
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declare under our sole responsibility that our marine magnetometers, models G-862 and G-862RBS to which this declaration relates are in conformity with the following standards:

EN 55022: 1995, EN50082-2 : 1995, ENV 50140: 1994, ENV 50141 : 1994, EN 61000-4-2: 1995, EN 61000-4-4: 1995

per the provisions of the **Electromagnetic Compatibility Directive** ***89/336/EEC*** of May 1989 as Amended by ***92131/EEC*** of 28 April 1992 and ***93/68-EEC, Article 5*** of 22 July 1993.

The Technical documentation required by Annex IV(3) of the Low Voltage Directive is maintained by Christopher Leech of Geometrics Europe (address below).

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Warning

This is a Class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

Table of Contents

Chapter 1: Introduction

Overview

The model G-862RBS is a quality professional magnetic base station tool offering the highest performance base station recordings on the market today. This system provides extremely accurate magnetic readings at a high sample rate, stored on a USB thumb drive recorder and sent to a computer or external device for display through Bluetooth or RS-232 connections. A GPS message is integrated into the magnetic data to provide accurate time stamps that are synced to a high degree of precision with a mobile magnetometer using a GPS as well. This reduces the need to sync the clocks on the base station and mobile magnetometer instrument, and ensures a high degree of accuracy when removing the diurnal variations in the magnetic field during your survey.

Data is stored as a .TXT file on the USB thumb drive or external device for quick entry into the MagMap2000 data software for applying diurnal corrections to the survey data. The rate of data recording is fixed at 10 Hz sample rate. Geometrics provide a 1 Gbyte USB thumb drive to store this base station data. A 1 Gbyte thumb drive will allow for 22 days of continuous data at 10 Hz before needing to exchange thumb drives.

The increased accuracy in synchronization between the mobile magnetometer system and the base station will remove any phase differences in the data. This allows for a more robust removal of time variations prominent in the surveying data, providing a more exact data set to examine and process for publication.

Applications

The G-862RBS has two potential purposes. The first purpose is to provide highly precise and accurate magnetic readings for diurnal corrections to mobile magnetometers. A larger storage space allows the magnetometer to record data at 10 Hz for weeks at a time without needing to download. Synchronizing data streams of two instruments produces a more accurate removal of the time variation seen in both instruments without introducing a phase shift exhibited in poorly coordinated instrument clocks.

The second potential purpose is to act as a magnetic screening bench to test the magnetic cleanliness of materials prior to survey. It is important to test any object that is located close to the sensor during the survey for any magnetic properties so that it can be removed from the area. If a screw or common instrument part is lost or missing it is possible to replace this piece. Any part that is not supplied by Geometrics should be properly screened before use. Geometrics screens each component separately to make sure only magnetically clean parts are used in the sensor to ensure the highest quality data is possible.

Features

The G-862RBS is designed to greatly improve the quality and application of base station data in all survey applications. Each feature is intended to more accurately record the magnetic field strength at a single location as well as more precisely remove the time variations in the data from a surveying magnetometer by synchronized time stamps using a GPS.

- Continuous base station readings, where the unit automatically records data at a preset rate, up to 10 magnetometer readings per second.
- Integrated GPS data for accurate time stamps and exact coordination with a mobile magnetometer also using a GPS device.
- Storage capacity for more than 22 days of readings and positions at 10 Hz, each recorded with the time of the event.

Open Source:

This is something new for Geometrics. We have made the G-862 data logger box an open source project. It uses an open source hardware platform (an Arduino Mega 2560 with a RISC 32 bit processor), the Arduino open source development system, and open source libraries. The schematics of the data logger and the source code (written in C) are available on our ftp site at ftp:\\geom.geometrics.com/pub/mag/G862RBS. The schematic of the Arduino Mega 2560, libraries, and development software are all available at (or through) www.arduino.cc.

Important Note Concerning Memory Sticks:

All memory sticks are not created equal. In fact many are marginal at best even at room temperature. They often fail completely at temperature extremes. It is imperative that you do not use consumer grade memory sticks. Instead use industrial grade memory sticks that are guaranteed over the full temperature range of -40 to +85 degrees C such as ATP NANODURA. P/N AF1GUFNDNC(I)-AABXX Available at www.avnet.com. They are more expensive than consumer grade memory sticks – a 1 gigabyte memory stick is about $30 USD, but this is minor compared to the cost of a corrupted/lost survey data file. 1 gigabyte is a lot of memory – about 22 days when recording continuously 24 hours a day.

Chapter 2: Instrument Assembly

G-862RBS Assembly

This section details unpacking and assembling the instrument. Later sections will describe steps to configure, operate and download the data.

Unpacking the G-862RBS

The G-862RBS is shipped in a rugged, hard plastic shipping container, with each element carefully packed (Figure 1). Unlock the case by unbuckling the clasps and lifting the lid.

Figure 1: Shipping case with instrument enclosed

Carefully remove all instrument pieces and lay on a flat surface for assembly (Figure 2). A list of all the required assembly pieces can be found in Table 1 below.

Figure 2: Assembly pieces

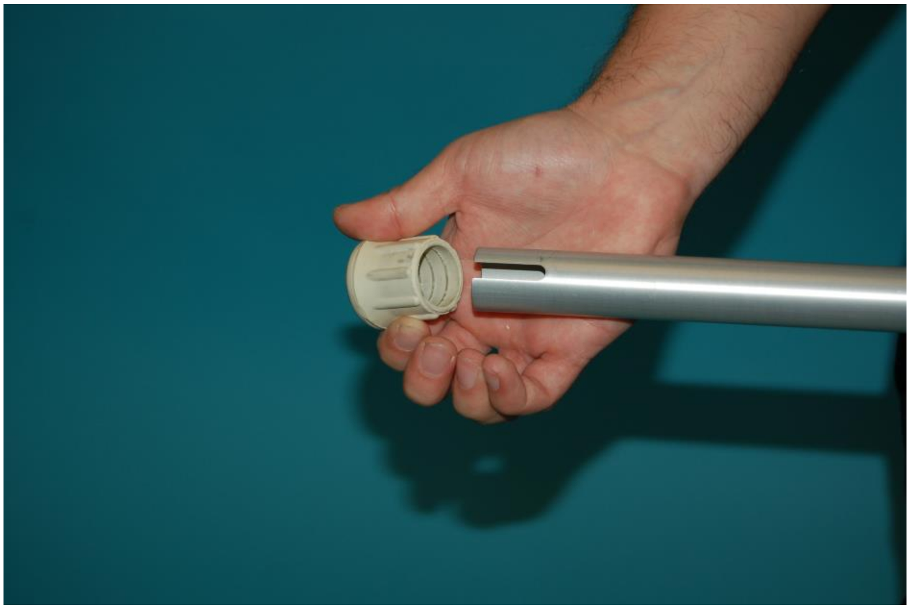
Table 1: Parts list for G-862RBS

Part Number	Name	Description
27921-32	G-862 Sensor with cable	Main instrument sensor with electronics boards attached by 3 foot long cable
56145-01	Base Station Data Logger	Dogcatcher Data logger console to record data on USB thumb drive
24810-59	AC/DC 24V Supply	Power box to supply the instrument with an outlet plug
20-650-239	USB Thumb Drive	2 ea 1GB Industrial USB thumb drives
65631-01	Tallysman TW5310	Tallysman TW5310 non-magnetic GPS with power supply and 1PPS interface.
65602-03	Carrying case	Heavy plastic carrying/shipping case
65544-02	Padded instrument bag	Padded green tote bag to protect sensor through transit
16708-16	Base Station Tripod Kit	5 ea aluminum staff sections, sensor holder and pyramid staff section
27611-33	G-860 Power/Data cable	Power and communications between the magnetometer and the data logger.
25379-03	Battery Jumper Cable	Cable to allow instrument to be powered from 12VDC battery
27922-OM	Operation Manual	This document
26648-01	MagMap2000 PC Software	Used to open and manipulate base station data

Attaching Sensor Bottle

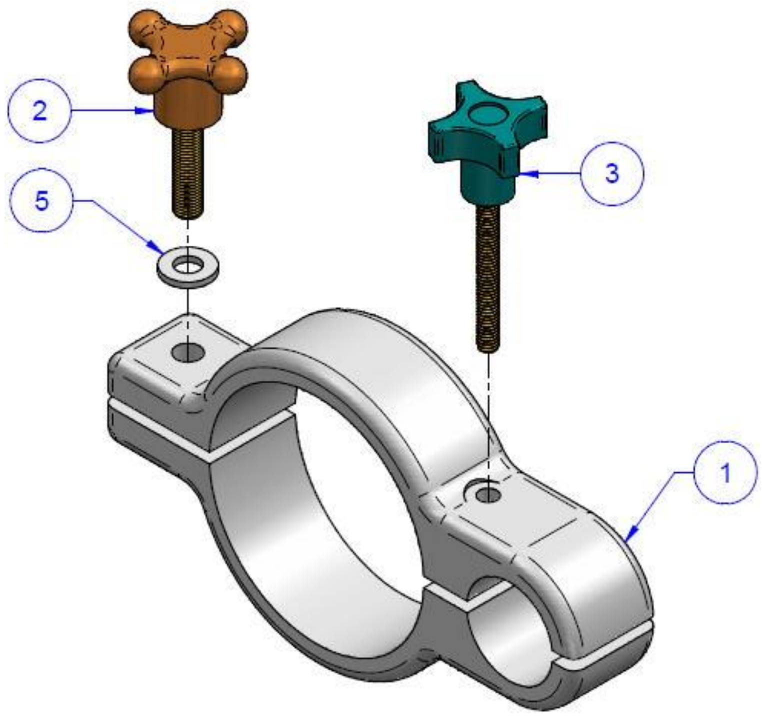
The sensor bottle attaches to one of the three tripod legs which removes the electronics and magnetic materials used in the sensor bottle far enough away from the magnetic sensor that they will not interfere with the base station readings. When attaching the bottle assembly to the leg of the tripod stand make sure that the sensor cable is pointed up so that you have more cable for a greater distance between the sensor and electronics.

Attach the sensor bottle to the leg by first removing the rubber crutch tip on one of the leg pieces.



3 Remove crutch tip on base station tripod leg to attach the sensor electronics bottle and data storage box

Loosen the knobs on the two black plastic bottle clamps to allow the aluminum rod to slide through the smaller hole more easily. Slide the aluminum rod into the hole and tighten the knobs to secure the sensor bottle in place.



4 Diagram of sensor electronics bottle clamp. The staff section fits through the small hole and is clamped tight by the two black knobs.

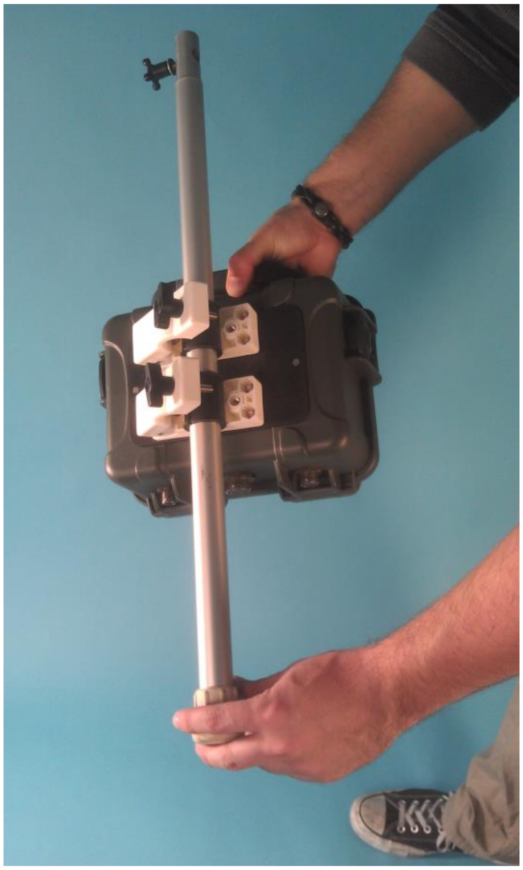
It might be necessary to alternate tightening each knob since tightening one sensor bottle clamp will cause a looser fit at the other knob. Ensure that the electronics bottle is not able to swing around freely. This instrument is sensitive enough that it could detect the motion of the electronics, and contaminate the base station readings. When the electronics bottle is secured place the rubber crutch tip back on the staff section. Slide the end with the black knob through one of the bottom three slits on the base station tripod kit and tighten the staff section in place.

5 Attaching the tripod leg to the base station tripod kit.

Attaching Data Storage Box

To attach the data storage box to the staff section, first completely loosen the latch on the back of the box by unscrewing the two bolt locks. Place the rubber jackets around the staff section and align them with the two latches. Close and tighten the latches by screwing the two bolts back down.

Again you may need to alternate tightening each knob for a firm connection so the box is not able to move freely. When the box is secured place the rubber crutch tip back on the staff section. Slide the end with the black knob through one of the bottom three slits on the base station tripod kit and tighten the staff section in place.

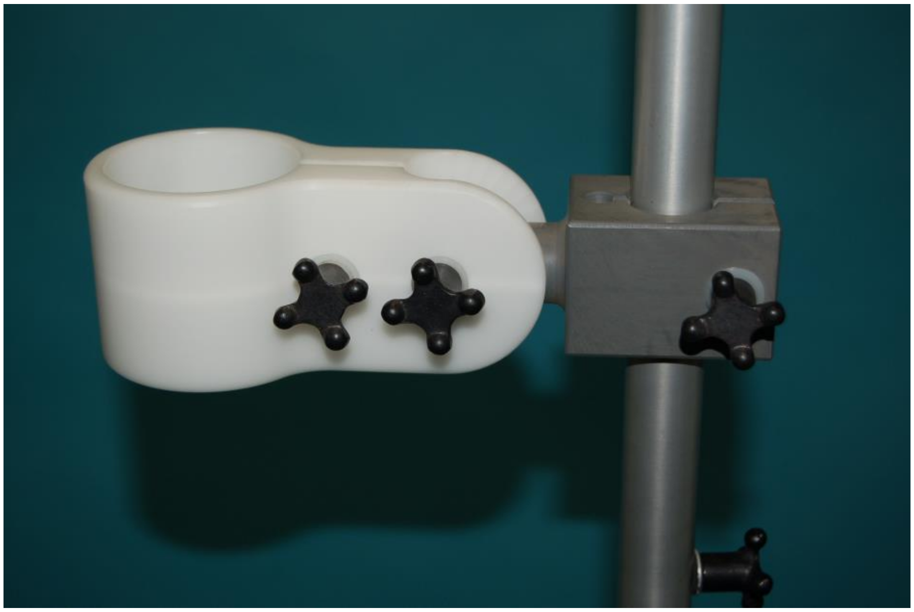


6 Attaching the data storage box to a second base station leg piece.

Attach the remaining staff section with the crutch tip attached to the last bottom slit of the base station tripod kit and tighten the staff section in place.

Sensor Clamp

The sensor clamp is designed to allow the operator to adjust the vertical location of the sensor on the base station to sufficiently remove it from the influences of the GPS above and the electronics and battery below. Loosen the knob on the sensor clamp to allow the aluminum staff section to fit through the hole.



7 Sensor clamp. A) Clamps to secure the sensor in place. B) Rotates the sensor for different orientations. C) Fixes the sensor clamp assembly on the base station tripod.

Sensor Orientation

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 Bendix connector terminated multi-conductor cable is used to supply power to, and data connections to, the matching connector on the G-862 sensor driver module.

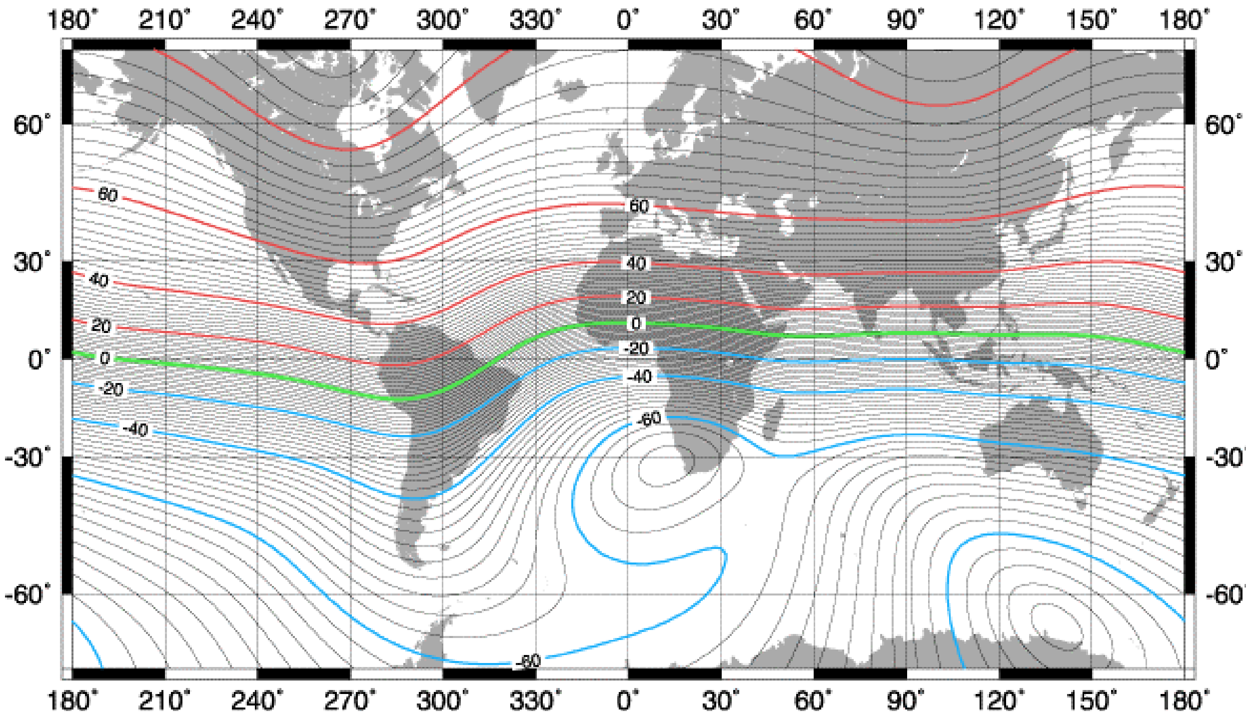


Figure 8: Epoch 2000, 2 degree contour interval

Magnetic fields are vector fields. At any point they are defined by their magnitude and direction. If the G-862 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 30º to 60º to the cylindrical axis of the sensor, for all platform attitudes. Alignments that produce a field/axis angle less than 15º place the magnetic field within the sensor’s “polar dead zone". Similarly, alignments that produce a field/axis angle greater than 75º place the magnetic field within the sensor’s “equatorial dead zone". The sensor will not produce usable data when the angle between

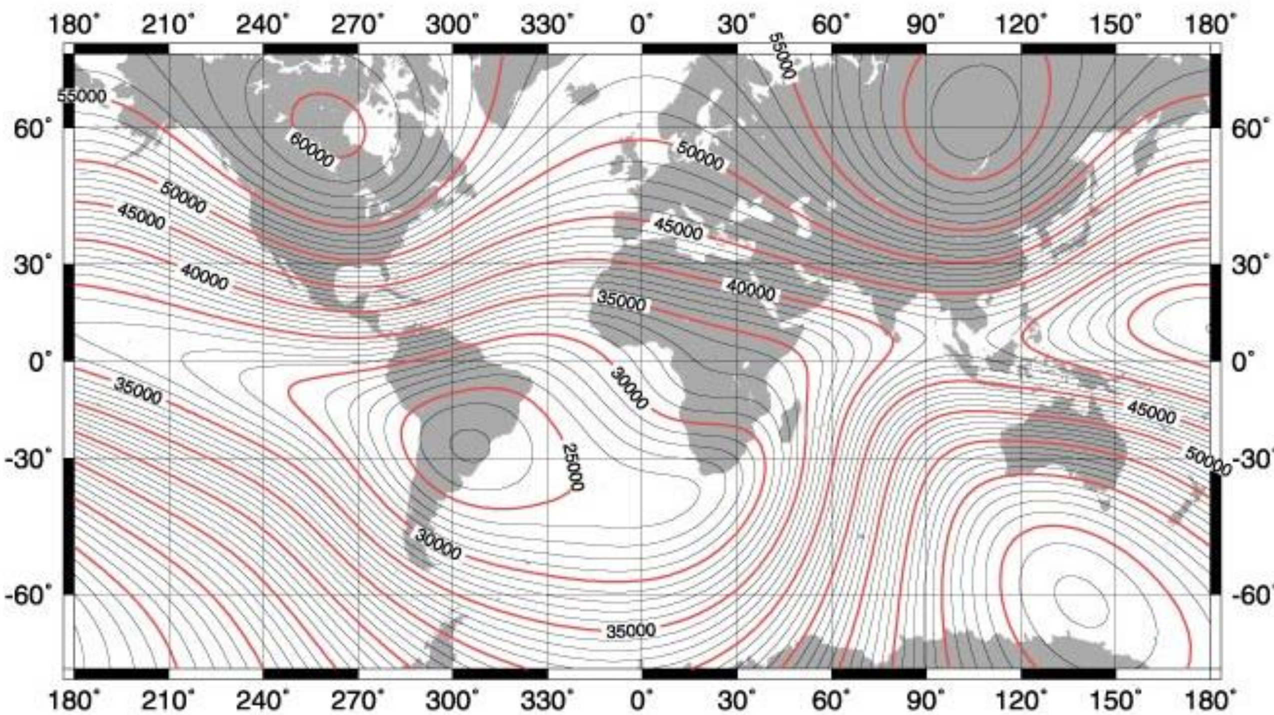


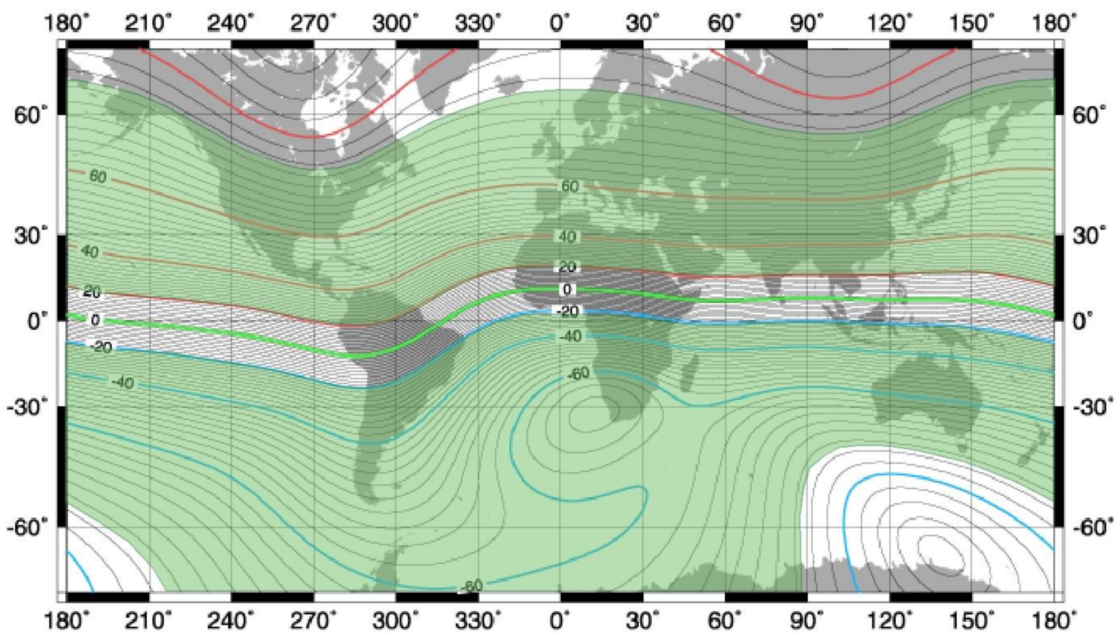
Figure 10: Epoch 2000, 1000 nT contour interval

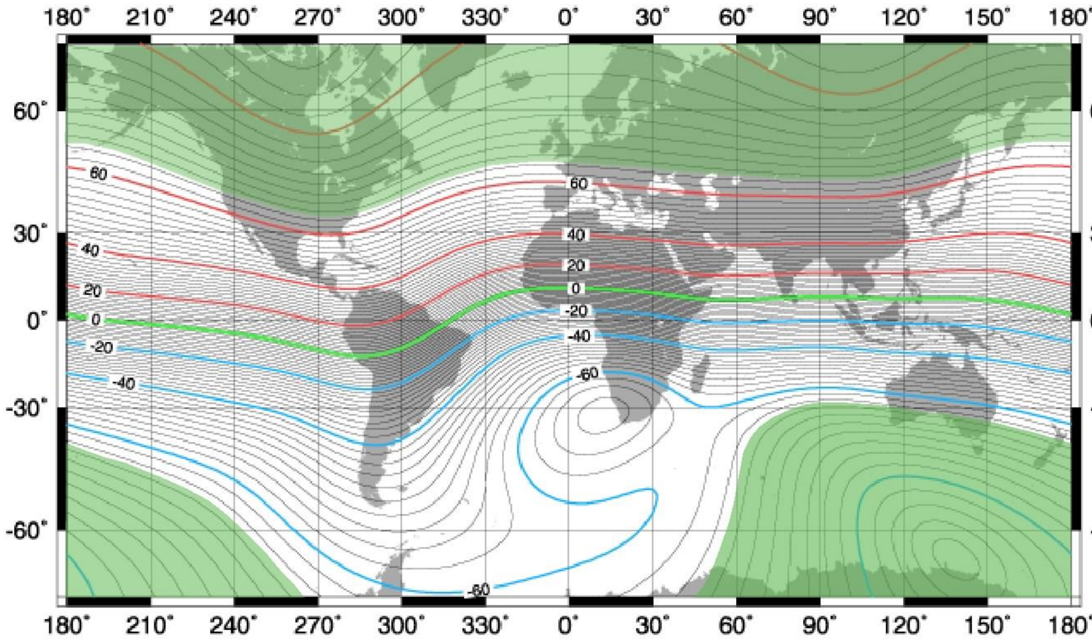
the earth's field and the cylindrical axis falls within one of these two zones.

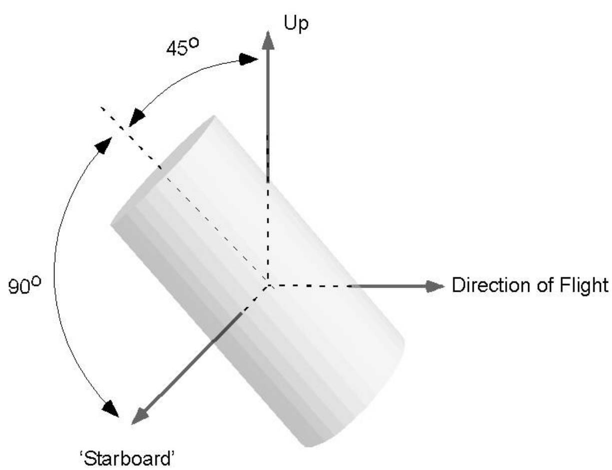
Unless the sensor is quite near very magnetic objects, the local magnetic field will be almost entirely due to the earth’s magnetic field. So, in latitudes where the inclination of the earth's field vector is 45º, vertical orientation of the sensor’s axis will allow operation in all practical flight 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.

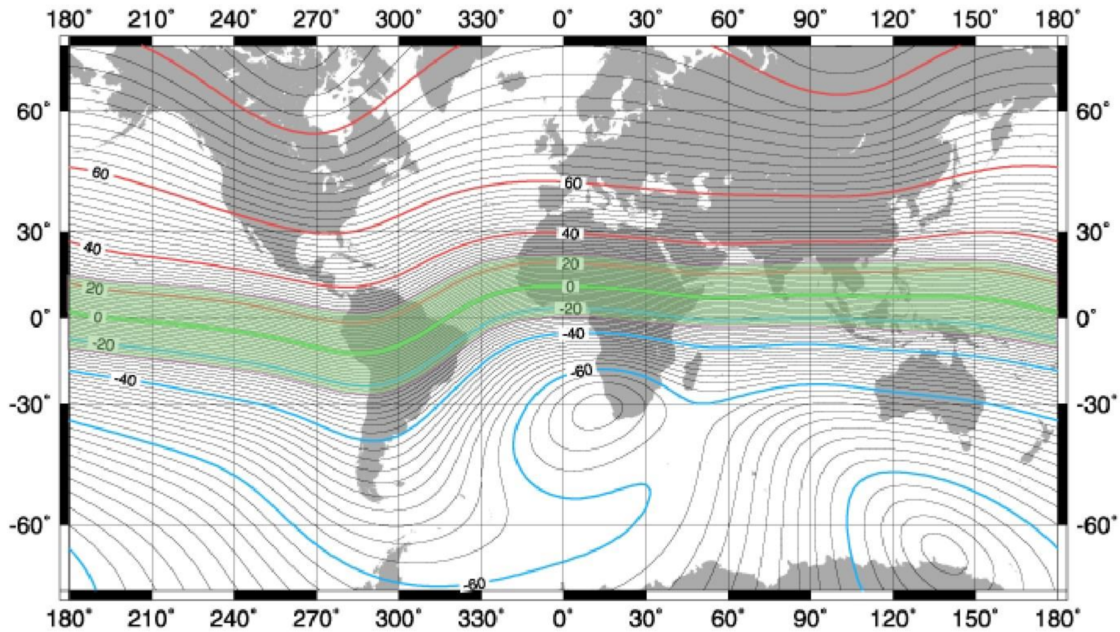
In regards to sensor orientation, the Earth's surface can be divided into three zones based upon magnetic field inclination: mid-latitude, equatorial, and polar. Within each of these zones there is a particular sensor orientation that will yield adequate signal strength over the entire zone. These regions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

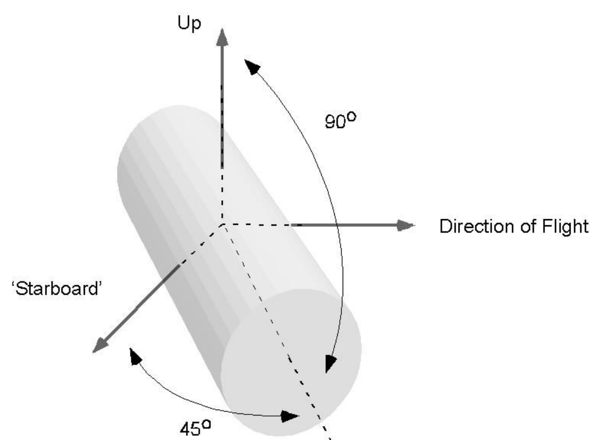




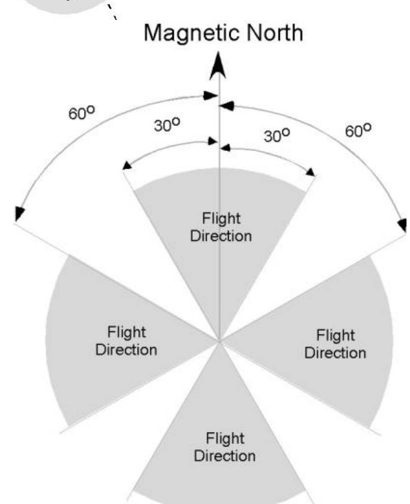


The diagram to the left shows the recommended sensor orientation for operation in polar latitudes. This zone is shown as the shaded regions above and includes those areas where the absolute inclination of the Earth's magnetic field is greater or equal to 65º. There are no restrictions on the direction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





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 45º 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 25º.

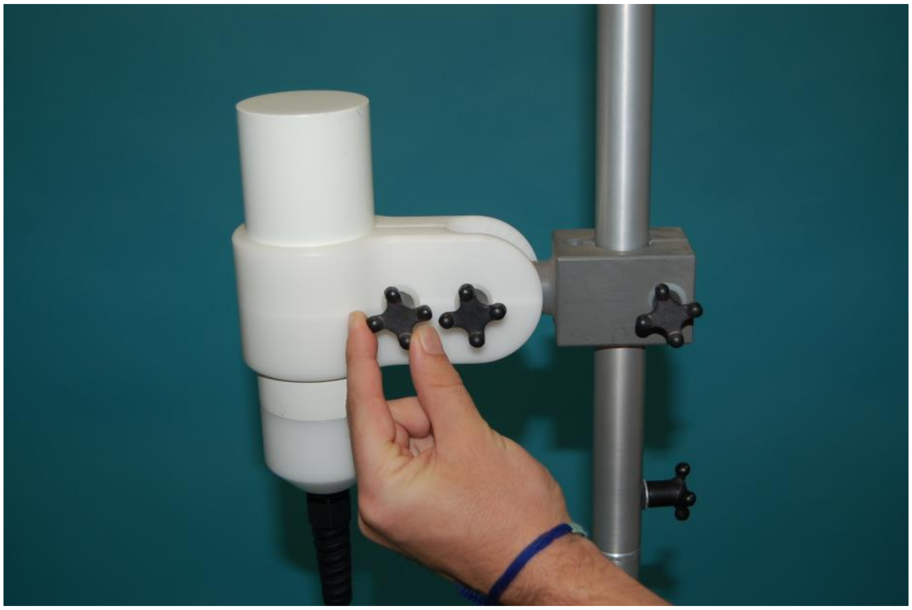


As with the sensor orientation shown in Figure 8, there are restrictions on the direction of travel when using this sensor orientation in this region. The bottom diagram to the left shows the flight directions where the sensor will produce adequate signal strength. These flight directions are 60^0 wide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

Note that the orientation zones show in Figures 6 through 9 overlap one another by 10º of

magnetic inclination. In these regions of overlap either of the recommend 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.
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.

The G-862RBS allows the user to position the sensor in any orientation needed to produce a strong signal for magnetic measurement. First, loosen the black knob closest to the sensor to allow for enough space to slide the sensor through the plastic sensor holder.



11 Sensor clamp knob that secures the sensor.

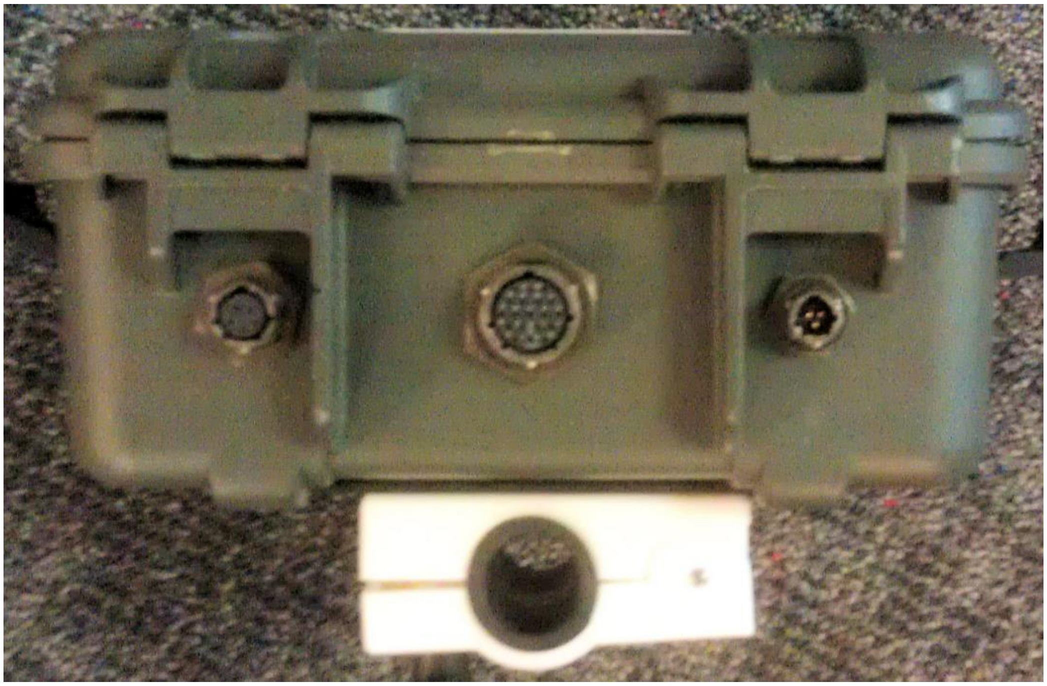
After the sensor is in place tighten the black knob back down to secure the magnetometer sensor in place. The sensor will need to be oriented vertically, horizontally, or at a 45° angle to the ground. Tilt the sensor to the appropriate orientation by loosening the pivot bolt. When the plastic sensor holder is free to move, tilt the sensor to the appropriate orientation and tighten the bolt back so the sensor is not free to move.

If you need to rotate the sensor, simply completely unscrew the pivot bolt and rotate the sensor holder to the appropriate position. Line up the holes of the sensor holder with the holes on the grey attachment piece and screw the pivot bolt back down until the sensor is not free to rotate.

Once the sensor is in the correct position attach the GPS piece on top of the base station staff sections by sliding the black knob through the slit and tightening down so it is fixed in place. It is advised to wrap the GPS cable around the aluminum staff so the cable is not able to move around, and for a cleaner looking instrument.

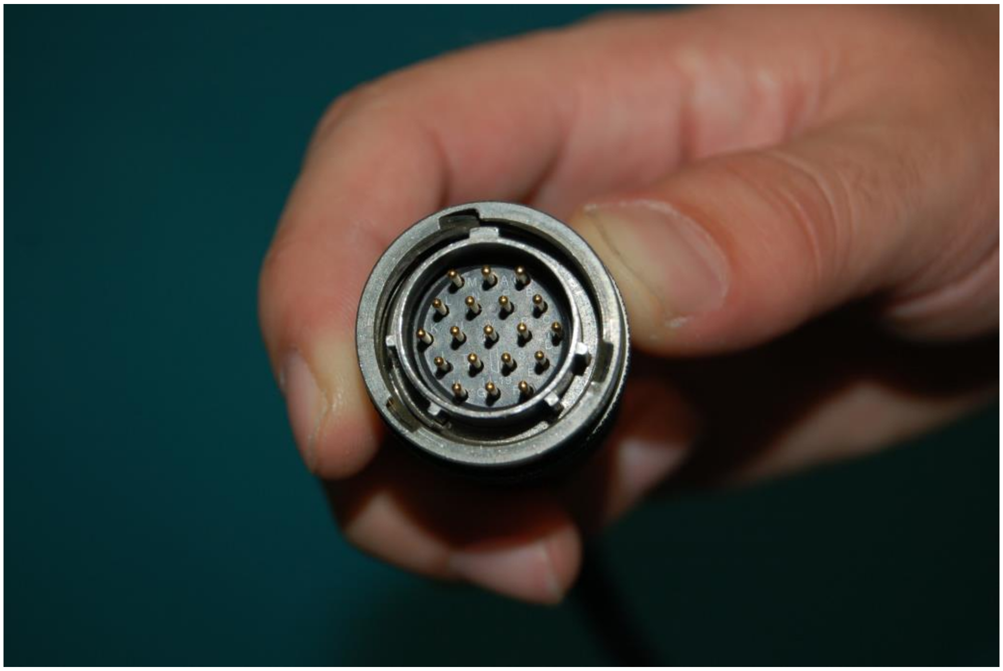
Cable Connections

Each cable has a different connector which limits the ability of someone connecting an instrument into the wrong port. Looking down on the connectors, from left to right, is the port for the cesium magnetometer electronics bottle, the GPS cable, and then the battery.
Each port connection has a locking ring with keys to make sure the connector is in the right orientation. The connector will not be allowed to insert if the keys are not correctly aligned.



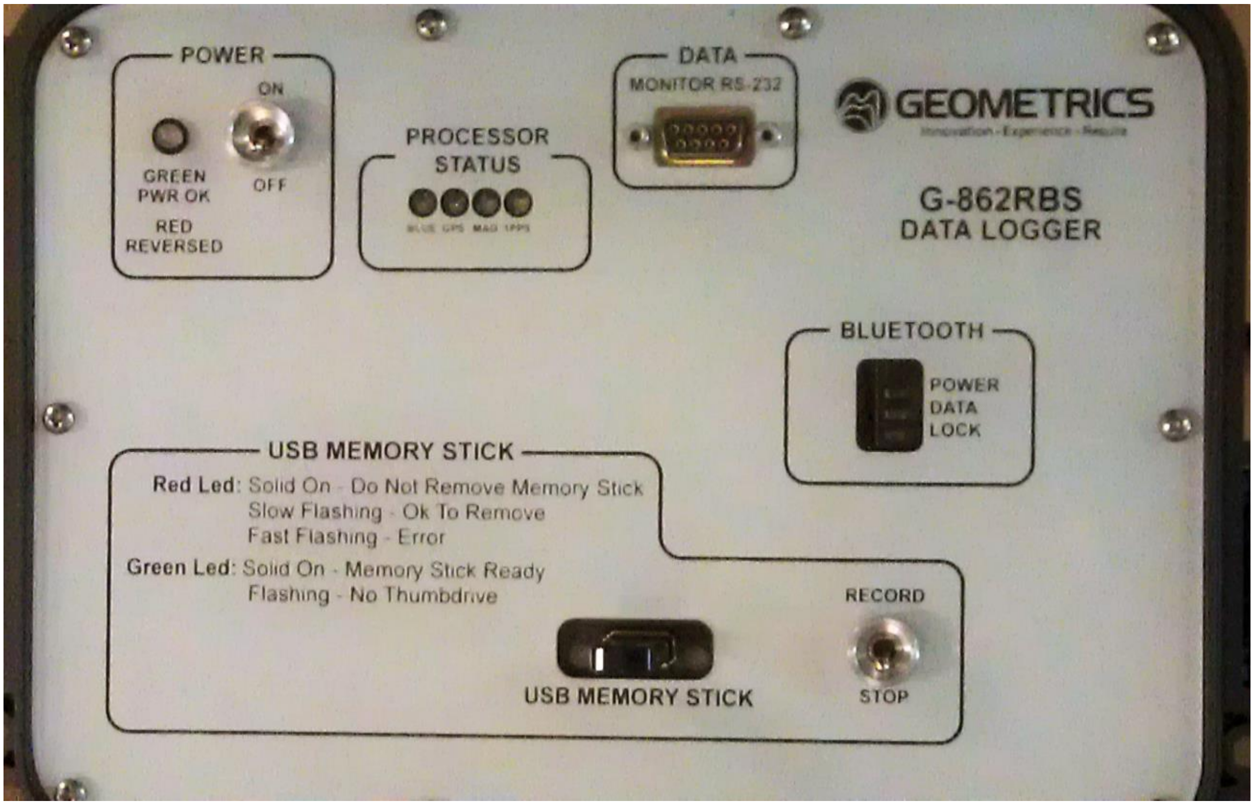
12 Data Logger box with connectors facing up. The connections, from left to right, are the magnetometer sensor cable, GPS cable and battery cable.

This is to ensure that the pins are not bent or damaged. If a pin is bent or snapped, the instrument will need to be returned to Geometrics for repair. When the keys are aligned, rotate the locking ring to make a firm connection. Forcing the connector into the port could result in a bent or snapped pin.



13 GPS cable connector. The keys around the inside must be lined up with the cable connector on the data storage box. Use the outer locking ring to make the connection.

Once the magnetometer, GPS and battery are connected, turn the power on the box to the on position. This is done by first pulling the switch out and then moving it to the on position. The green light next to the switch will turn on if the battery is charged and properly connected.



14 Power switch is located on the upper left hand side of the front panel. Open the cover and flip the switch up to turn on the box. The light to the left of the power switch will glow green when correct polarity power is applied, or will glow red if reverse polarity power is applied.

Chapter 3: G-862RBS Operation

The G-862RBS has two toggle switches, several LED status lights, a USB port, and a RS 232 port on its front panel.

Turning on the System

Open the data logger cover. Make sure the Record/Stop switch in the USB MEMORY STICK section is in the STOP position. Insert a USB Thumb Drive into the USB port. Then turn on the system by flipping the POWER switch towards ON.

Wait for the GPS to find satellites and for the magnetometer to warm up. This should take no more than 15 minutes in cold weather and could be as short as 5 minutes when the magnetometer is at room temperature or warmer.

When the system is ready to record, the PROCESSOR STATUS lights should have the following conditions.

The Processor Status Lights on the Front Panel:

Blue LED:

This Status LED presently does not indicate anything. It may be used for something in the future.

Yellow LED: The GPS Status Indicator:

1) One flash: Indicates that recognizable GPS serial data characters are being received (i.e. serial data is recognized and valid carriage returns and line feed are seen). In other words the baud rate is correct. But no 1PPS pulse is being received.
2) Two flashes: Indicates that 1PPS pulses are being received, but no recognizable GPS serial data is being received (in other words the baud rate is probably not correct).
3) Three flashes: Indicates that both the GPS serial stream and the 1PPS pulse are being received, but the GPS stream is not outputting valid location and/or time info. This

indicates a GPS reception problem, or insufficient time has elapsed to allow the GPS to lock onto its position.

4) LED on solid: GPS data is reporting valid location/time info and the 1PPS pulse is being received. The GPS is working correctly.

Green LED: The Mag Data Monitor:

This LED shows that mag data is being received, and flashes at the mag output data rate (10 hertz).

White LED: Phase Lock Indicator:

This LED, when lit, indicates that the magnetometer is being triggered precisely synced to the GPS 1PPS pulse. This means that the time stamps on the magnetometer data can be treated with confidence as long as we occasionally get good GPS time info from the $GPRMC string. The 1PPS tells us the edge of each second transition, but only the GPS serial data stream tells us which second (of many) that particular one is.

Logging Data with the Dogcatcher logging Module:

Insert a memory stock into the Dog Catcher memory stick slot. The green LED on the logging module will go from flashing to solid on. This indicates that the memory stick is recognized and ready to record data.

To log data to Dog Catcher logging module turn the logging switch on the front panel from the "Stop" position to the "Record" position. Logging to the Dog Catcher will commence at the start of the next one second rollover (where GPS data is transmitted followed by 10 magnetometer readings). This allows the recorded data to always start cleanly at the beginning of a 1 second sample set, as compared to starting in the middle of a sample. As data is written to the memory stick the red LED on the Dog Catcher logging module will flash on and off. The data is buffered inside the logging module into 64 byte packets, and is then written in chunks to the memory stick. The red LED is lit while the writing is taking place.

The data is logged to a file named "capture.txt". If this file is already present on the memory stick then all incoming data will be appended to the existing file.

At the start of the logged data will be a short header segment consisting of a few lines of ASCII text. These lines of text will specify the Serial Number of the unit, the software version number and build date, and configuration info. This will be followed by the logged data. If data is appended to an existing “capture.txt” file, the header will be written again. This allows a simple ASCII search in a large data file to find and differentiate different logging time segments.

To stop logging data set the logging switch on the front panel from “Record” to “Stop”. Logging will stop cleanly at the end of a 1 second sample set rollover period. Because there is probably data in logging module buffer, wait a few seconds for the logging module to time out and write the buffer contents to the logging module. At this time the red LED on the logging module will go out (unless there is an error as outlined below).

Always stop logging data, and wait for the red LED to go out before removing memory sticks. This will ensure that data is not lost, and also prevent rare (but possibly catastrophic) file corruption. If there is an error detected in the logging module the red LED will not go out, but continue to flash at a regular and repeating pattern as outlined below. The regular and repeating pattern is the thing that separates an error from the random and varying write operations while logging.

Exchanging USB Thumb Drive

Open the data logger cover. Flip the RECORD/STOP switch to the Stop position. Wait until the red lamp by the USB MEMORY STICK goes off. Remove the USB thumb drive and replace it with another one.

Flip the RECORD/STOP switch to the RECORD position. Logging will begin at the start of the next one second rollover from the GPS. The USB MEMORY STICK green light should be on and not flashing. Close and latch the data logger cover.

Turning off the System

Flip the RECORD/STOP switch to the STOP position. Wait until the red light in the USB MEMORY STICK section goes out before removing the USB thumb drive or turning off power.

The Dogcatcher Logging Module Error Status Lights:

If the Dog Catcher logging module detects an error it will set a red LED flash pattern which will be displayed after the logging has stopped. This flashing pattern will be regular and repeating as compared to the random and varying flash pattern as data is being logged and written to the memory stick. These are the error codes:

> ***Rapidly Blinking Data:*** Data has been received and buffered inside the logging module, but memory stick is recognized. Data will continue to be buffered until a memory stick is inserted. If the 13K byte buffer overflows, the oldest data is discarded in favor of new data.
>
> ***One Blink and a Pause:*** Buffer has been overrun. This could happen if something is wrong with the flash drive, or the flash drive is badly fragmented. Try starting off with a blank flash drive.
>
> ***Two Blinks and a Pause:*** The memory stick is full.
>
> ***Three Blinks and a Pause:*** The memory stick, or the "capture.txt" file is set to 'read only'.
>
> ***Five Blinks and a Pause:*** Communications error: If a byte is received with a framing error this error gets set. Check the data. If it is only one byte then it isn't so serious. If it is every byte then the baud rate to the logging module nay not be right. Lots of data errors indicate a hardware problem.

Seven Blinks and a Pause: Hardware within the logging module: Try cycling the power. If the problem persists the logging module will have to be replaced.

The Logged Data Format:

Standard Format:

This is an example of the standard format of the logged data (minus the header information which is described below):

```
$GPRMC,015738.000,A,3724.00107,N,12153.35969,W,0.0,0.0,110314,0.0,W*66
$ 30530.813,0068,01:57:39.055,03/11/14,00
$ 30530.634,0071,01:57:39.155,03/11/14,00
$ 30530.690,0071,01:57:39.255,03/11/14,00
$ 30530.925,0068,01:57:39.355,03/11/14,00
$ 30530.772,0071,01:57:39.455,03/11/14,00
$ 30530.787,0071,01:57:39.555,03/11/14,00
$ 30530.689,0068,01:57:39.655,03/11/14,00
$ 30530.607,0071,01:57:39.755,03/11/14,00
$ 30530.773,0071,01:57:39.855,03/11/14,00
$ 30530.578,0068,01:57:39.955,03/11/14,00
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$ 30530.621,0071,01:57:40.355,03/11/14,00
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$ 30530.676,0071,01:57:40.555,03/11/14,00
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$ 30530.483,0071,01:57:40.855,03/11/14,00
$ 30530.358,0071,01:57:40.955,03/11/14,00
$GPRMC,015740.000,A,3724.00107,N,12153.35969,W,0.0,0.0,110314,0.0,W*69
```

The data sentence begins with the GPRMC message from the GPS. The parts of the GPRMC message are as follows:

$GPRMC,015738.000,A,3724.00107,N,12153.35969,W,0.0,0.0,110314,0.0,W*66

015738.000	Time of fix 22:54:46 UTC
A	Navigation receiver warning A = OK, V = warning
3724.00107,N	Latitude 37 deg. 24.00107 min North
12153.35969,W	Longitude 121 deg. 53.35969 min West
0.0	Speed over ground, Knots
0.0	Course Made Good, True
110314	Date of fix 11 March 2014
0.0, W	Magnetic variation 0.0 West
*68	Mandatory checksum

The magnetometer sentence is as follows:

$ 30530.813,0068,0112,1904,01:57:39.055,03/11/14,00

30530.813	Magnetic Field Reading
0068	Signal Level
01:57:39.155	UTC Time
03/11/14	Date in US Format
00	Status Byte

Magnetometer Only Data Format:

$ 30530.744,0071,01:57:40.055,03/11/14,00
$ 30530.703,0071,01:57:40.155,03/11/14,00
$ 30530.635,0068,01:57:40.255,03/11/14,00
$ 30530.621,0071,01:57:40.355,03/11/14,00
$ 30530.413,0071,01:57:40.455,03/11/14,00
$ 30530.676,0071,01:57:40.555,03/11/14,00
$ 30530.772,0071,01:57:40.655,03/11/14,00
$ 30530.662,0071,01:57:40.755,03/11/14,00

$ 30530.483,0071,0112,1904,01:57:40.855,03/11/14,00

$ 30530.358,0071,0112,1902,01:57:40.955,03/11/14,00

The Status Byte:

Each magnetometer sample in the output data stream includes the contents of the status byte. The status byte is an 8 bit number and is output as a two character hexadecimal number. Currently only the upper 4 bits of the 8 bit number are being used.

The same information in the status byte is also encodes into a flash sequence for the front panel Status LEDs.

If there are no errors the status byte will be "00". Anything other than that indicates and error. There may be more than one error. Each bit of the 8 bit number has a meaning that is defined below:

80 [hex] or 10000000 [binary]:

This bit is set whenever the G-862 RBS CPU board does not receive a recognizable serial data stream from the GPS within a 1 second time frame. "Recognizable" means it received a carriage return and line feed. This error could indicate that there is no GPS data arriving at the G-862 RBS GPS serial port, or it could indicate that the GPS baud rate and the G-862 serial port baud rate are not set to the same value. In the absence of GPS data, the G-862 RBS will make up a GPS RMC string as a token place holder. All the data fields within this made up string will be nulls.

40 [hex] or 01000000 [binary]:

This bit is set whenever the GPS data does not contain a valid fix and is therefore suspect. This can be due to not enough satellites, no clear view of the sky, GPS hasn't acquired the satellites yet, no GPS serial data being received (which would also set the 0x80 bit), or a defective GPS.

20 [hex] or 00100000 [binary]:

This bit is set whenever the 1 PPS pulse is not received. This could be due to a GPS reception problem, the GPS hasn't acquired the satellites yet, or a defective GPS.

10 [hex] or 00010000 [binary]:

This bit is set whenever the 1 PPS phase locked loop has not closed. It means that the magnetometer trigger is not phase locked to the 1 PPS pulse. This will always be the case upon power up. Once the 1 PPS pulses start to arrive from the GPS, it takes about 15-20 seconds for the phase locked loop to synchronize with the 1PPS pulses. At that time this bit will be cleared.

If more than one error is occurring then the individual bits will add in a hexadecimal fashion. For example, if no GPS serial data stream is received both the 80 [hex] and the 40 [hex] bits will be set. The status byte in the log file would be the sum of those two, or C0 [hex].

The Logging Header:

Each data logging is started a block of header information is written such as follows:

Software Version: 01.00.00
Build Date: Mar 10 2014 15:22:00
Output Baud Rate = 19200
Mag Baud Rate = 19200
GPS Baud Rate = 19200
Debug Port Baud Rate = 19200
1 PPS Edge = positive edge
Auto 1 PPS Edge Detect = true
Log GPS Data with Mag Data = true

Each line of the header block is described below:

 # Software Version: 01.00.00

This is the G-862 RBS CPU software version number.

 # Build Date: Mar 10 2014 15:22:00

This is the time and date that the software was compiled and loaded into the G-862 RBS CPU board.

 # Output Baud Rate = 19200

This is the serial output port baud rate from the Arduino CPU. It feeds the Monitor port, the Bluetooth port, and the Dogcatcher Logger port.

 # Mag Baud Rate = 19200

This is the baud rate of the Arduino serial port that is connected with the magnetometer.

 # GPS Baud Rate = 19200

This is the baud rate of the Arduino serial port that is connected with the GPS.

 # Debug Port Baud Rate = 19200

This is the baud rate of the Arduino serial port that is connected to the Arduino USB connector. This serial to USB port is used to download and debug the software via the development software running on a Windows PC.

 # 1 PPS Edge = positive edge

This defines which edge of the 1 PPS pulse is being used for the one second rollover. It is either “positive edge” or “negative edge”. If “Auto 1 PPS Edge Detect” = true, this is the edge that the Auto detect routine chose after analyzing the 1 PPS waveform. If the “Auto 1 PPS Edge Detect” = false, this was set directly by firmware.

 # Auto 1 PPS Edge Detect = true

When true, the 1PPS rollover edge is selected by analyzing the 1 PPS waveform on start up. It works by assuming that a positive edge 1 PPS pulse will have a duty cycle that is mostly low, with a with a relatively narrow positive pulse at the 1 PPS time. In contrast, a negative edge 1 PPS waveform will have a duty cycle that is mostly high, with a relatively narrow negative going pulse at the 1 PPS time.

 # Log GPS Data with Mag Data = true

If true then both magnetometer and GPS data are logged together. If false, only the magnetometer data is logged (along with GPS functionality and health info in the Status Byte).

GPS/Magnetometer Timing:

It is not necessary to understand this section to use the G-862 RBS. If you accept the time stamps on the data in the logged data file as being absolutely correct then you do not need to read further into this section. But if you study the format of the logged data questions may arise, like: "Why is the GPS data at time hh:mm:22 seconds appear after the magnetometer data time stamped at hh:mm:23.xxx seconds? Shouldn't data in a logged file be time sequential?"

Or

"Why is the magnetometer data have funny time stamps such as hh:mm:23.155 seconds? Why not even 100 mS time stamp values?"

Or

"What does the time stamp signify? "

The timing of the data synchronization and collection is a little tricky. The following diagram and description will hopefully make it clearer:

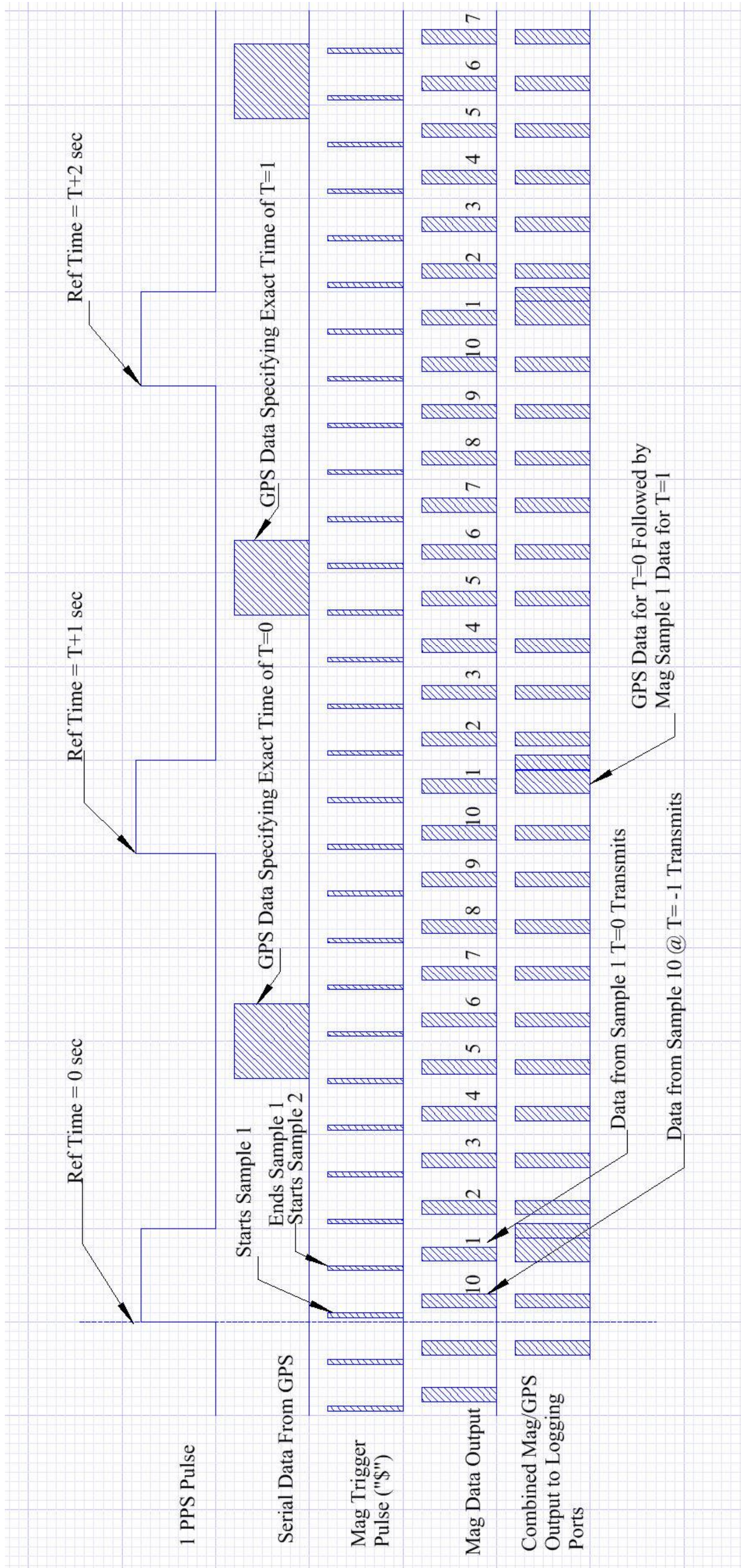


Figure 15: GPS and Magnetometer Timing Diagram

Everything is synchronized to the 1PPS leading edge. The 1PPS pulse is used to generate a phase locked 10 hertz signal to externally trigger the magnetometer such that its cycling is also phase locked to the 1PPS pulse. The 1PPS pulse from the GPS precisely defines that a 1 second rollover has happened, but *which* second that happens to be is not transmitted for many hundreds of milliseconds later. Worse, the exact timing of that transmitted time information varies from sample to sample, with the number of satellites, and with location. In the previous timing diagram note the 1PPS pulse on the top waveform. The 1PPS critical time in this case is on positive going edge of the pulse. The left side of the diagram is arbitrarily defined as second [T = 0]. The second waveform from the top shows the outline of the serial transmission from the GPS to the G-862 (and to the Arduino CPU serial port 2). Inside this data packet is the exact time of the 1PPS edge that happened a few hundred milliseconds ago. Because the timing of this serial data is not defined and highly variable, and because we want to have a regular defined output format, the GPS data is buffered inside the G-862 Arduino CPU and is always output between the last magnetometer sample (of a batch of ten) and the first sample of the next batch of ten. Thus the GPS data gets recorded later about one second behind the magnetometer data which is time stamped ahead of the delayed GPS.

The magnetometer is triggered by sending a “$” trigger command via the serial port. There is more detail on this in the “Block Diagram Section” section. This trigger waveform is seen in the third waveform down in the diagram below. This trigger is generated by the Arduino CPU on serial port 1from a software phase locked loop driven by the 1PPS edge. Both the 1PPS PLL and the 10 hertz trigger routines are interrupt driven. To keep the timing as accurate as possible we make the interrupts happen at different times so they can never be simultaneous. The time offset in this case is 5 mS. Thus the timing of the magnetometer trigger for sample one and (of a batch of ten) [T=0], happens at [T=0.005] seconds. The end of magnetometer sample one happens when the next trigger to start sample two arrives at [T=0.105] seconds. The magnetometer value for sample one is the average of the magnetic field from [T=0.005] seconds to [T=0.105]. The average of that time span is [T=0.055] seconds. Sample two would be [T=0.155] seconds, sample three would be [T=0.255] seconds and so on. The time stamp reflects the exact center of each magnetometer cycle period. This is why the time stamps for the magnetometer data appear in the data file as they do.

Even though the time stamp information in the data file is logged with a 1 mS resolution, the actual accuracy of that time stamp is much better at about 10 µS. Thus a time stamp of 23:10:45.055 seconds in the log is more like 23:10:45.05500 seconds accuracy.

As mentioned above the delayed GPS data is always inserted between magnetometer sample ten (of the previous batch of ten), and the first sample of the next batch of ten. The data for magnetometer sample one is calculated after the sample period is over and sample two has been started. At this time the GPS data is written out to the logger/monitor/Bluetooth serial port following directly be the data for magnetometer sample one. In waveforms 4 and 5 on the timing diagram you can see the transmitted magnetometer data going into the Arduino CPU serial port 1 (the GPS data comes in on serial port 2) and the combined data (GPS and magnetometer) goes out on serial port 3 – and on to the data logger/monitor ports Because the GPS and Magnetometer data are all buffered on the Arduino CPU, if the magnetometer data has to be delayed by a bit to allow the GPS data to insert itself beforehand it won't cause a problem. You may also note that the GPS transmission time going out the Arduino CPU is much shorter than the time it took coming into the Arduino CPU. In this particular example, the input baud rate on serial port 2 is 4800 baud, while the outgoing baud rate is 19200 baud. This may or may not be the case in a particular G-862 RBS system – the GPS, Magnetometer, and output baud rates are configurable. All that is required is that the Arduino CPU baud rates match the baud rates of the devices feed them. This is covered in more detail in the "G-862 RBS Commands Via the Monitor Port" in Appendix 1.

Block Diagram:

The CPU:

The heart of the G-862 RBS data logger is the Arduino Mega 2560 CPU board. It contains a RISC based 32 bit microprocessor running at 16 Megahertz. The CPU has four independent serial ports. The first serial port (#0) is used for downloading the software from the development system running on a PC (via a USB port). It also allow for software debugging. Serial port 1 is used to trigger and receive data from the magnetometer. Serial port #2 is used to send commands to and receive data from the GPS. Serial port #3 is used to output the synchronized and combined GPS and mag data to the Data Monitor connector on the front panel, to the Bluetooth port, and to the Dog Catcher data logging module (if logging is enabled via the logging on/off switch). In addition, commands can be sent to the Arduino CPU, to the GPS, or to the Magnetometer. See the section on "G-862 RBS Commands via the Monitor Port" in Appendix 1 for more details.

In addition to the four serial ports there are several digital input/output pins. These are used for various functions such as driving the LEDs, reading the four factory test configuration jumpers, reading the logging on/off switch position, and sensing the GPS 1 PPS signal. The serial and digital ports at the Arduino board are buffered on a Geometrics designed "shield" board which sits between the vulnerable Arduino pins and the outside world. In addition to buffering and protecting the CPU, the four serial ports are level shifted to make full plus and minus RS-232 serial data voltage swings.

The 1 PPS Phase Locked Loop:

In order to keep the magnetometer synchronized to the GPS one PPS pulse it must be externally triggered by a ten hertz clock that is phase locked to the one PPS pulse. This is done using a software digital phase lock loop in the Arduino microprocessor. The one PPS pulse comes in through a digital I/O line and interrupts the CPU. The timing of this pulse is compared to a timer count inside the microprocessor, and that timer period is adjusted up/down as needed to keep the two in lock step with one another. That same timer is used to generate the trigger timing to the magnetometer.

In actual fact, the phase locked loop generates a 100 hertz phase locked output. This gets divided by ten to make the 10 hertz mag cycle rate. The reason for this is that it allows for better resolution for controlling the PLL timer and increases the phase accuracy of the PLL. In addition it should be noted that the 100 hertz phase locked timer is offset from the 1 PPS edge by a constant 5 milliseconds (half of the 10 millisecond period of 100 hertz). The reason for this is that both the 1 PPS detect and 100 hertz timer rollover routines are interrupt driven. By having them offset it guarantees that they can never happen on top of one another. This removes any timing variation caused by one interrupt happening before or after the other. This 5 mS offset can be seen in the time stamped magnetometer data. When power is first applied the 1 PPS pulse from the GPS and the timer that triggers the magnetometer are asynchronous. About 15 seconds or so after the G-862 RBS starts receiving the 1 PPS pulse from the GPS the digital phase locked loop adjusts the timer into synch with the 1 PPS pulse. When this happens the PLL LED on the front panel is lit up solid indicating that the two are phase locked. This phase locked status is also reflected in the status byte which is logged with the mag data.

The phase lock loop keeps the mag triggered in synch with the 1 PPS pulse to a within +/- 5 microseconds. The time stamp in the data is only printed out to a 1 millisecond resolution, but you could safely add another couple zeroes to the time stamp after the one mS digit.

Magnetometer Trigger:

Geometrics' cesium magnetometers are designed such that they can be wired together such that you get one data stream with the mag data concatenated one after the other. Thus if you wired three magnetometers together this way you would get a serial data stream with data from magnetometer 1, a comma delimiter, followed by magnetometer 2 data, a comma, and then magnetometer 3 data. In this mode the magnetometers are wired such that the serial output of the first is connected to the serial command input of the second, and so on. The serial output for the last magnetometer in the chain will contain all the magnetometers data concatenated together. When a "$" character is received by a magnetometer in the chain it knows it is receiving magnetometer data. The incoming "$" character is passed through to the next magnetometer immediately (and so on down the chain), while the rest of the incoming magnetometer data follows thereafter. When the current magnetometer sees the incoming carriage return / line feed it strips it off and replaces it with a comma, then appends its own magnetometer data behind it (adding a carriage return / line feed at the end.
The Arduino uses this concatenation feature of Geometrics cesium magnetometers to externally trigger (and synchronize) the magnetometer to the 1PPS pulse of the GPS. At

trigger time, the Arduino CPU sends a “$” out serial port #1 triggering the magnetometer. The magnetometer has actually already been triggered by its own internal free running cycle time counter. What the “$” trigger actually does is cram into the cycle time counter what the timer count should be based on a cycle time that began one serial character transmission time ago. Remember is takes a fixed (and predictable) amount of time to transmit the “$” character at the current baud rate, and this method of cramming in the proper count compensates for this character transmission time and keeps the mag trigger phase locked to the trigger time – not when the “$” character is received. This “$” character is followed by a carriage return and line feed sent from the Arduino to the magnetometer.

The “$” and carriage line feed gets converted by the magnetometer as though it is previous magnetometer data in a chain of magnetometers. Thus the “$” gets passed through, and the carriage return / line feed is stripped and replaced with a comma. Then the magnetometer appends its own data and sends it out the magnetometer serial port back to serial port #1 on the Arduino board. Thus the Arduino CPU board receives from the magnetometer a data string like:

$,$ 50123.445,0867

The Arduino is expecting the extra “$,” at the beginning of the data stream and strips it off before sending a now normal looking single magnetometer data stream out serial port 3 to the Logging/Monitor/Bluetooth ports.

Chapter 4: MagMonitor Smartphone App

Geometrics has designed and implemented an installable application for Android smartphones and tablets to monitor the data streams as they are being recorded in the Dogcatcher data logger. This allows the operator to have a visual representation of the data at a safe distance from the base station so the base station data is not contaminated. This application is found on Geometrics' website and can be uploaded to your Android device through USB connection, email or internet download. This application is not found in the Android marketplace.

Installation

The installation process of the MagMonitor App is very simple through two methods: direct download from E-mail or file transfer over the micro-USB cable. Before transferring or downloading the file make sure that your Android device allows applications that do not appear on the Google Market to be installed. This is not a default feature of the Android tablets or smartphones, so to do this you must go to Settings and then select Applications. In this screen there will be a check box or setting to allow installation of non-Market applications. Make sure that this is checked or turned on, or else you will not be able to install and run the MagMonitor application.

Email

On your Android device, open the E-mail with the attached application file, format is .APK. Select the attachment for download and a security screen will appear to make sure you want to install this program. Select yes and the application will be installed. Go to your applications and select MagMonitor to start the application.

USB transfer

Connect your Android device to the computer through the micro-USB cable. When the device is found select the option to mount the device as a Disk Drive on the “Connect to PC” screen. This will allow you to transfer the MagMonitor Application file onto your Android device. Open a Windows explorer window and navigate to the Disk Drive associated with the Android device. Select yes and the application will be installed. Go to your applications and select MagMonitor to start the application. Upon start-up the application will see if the Bluetooth is turned on, and if not will ask you if you want to turn the Bluetooth on. Once the Bluetooth is turned on select the Menu button (the triple bar) and select Connect. You can now “Scan for Devices” to find the Bluetooth transmitter from the G-862RBS. Once the G-862RBS is found select this Bluetooth device to pair the base station with your Android device and ready to use.

Bluetooth connection

The Bluetooth provided by Geometrics has a working range of about 10 meters. Stand a reasonable distance away from the base station such that the presence of the phone or tablet is not detected in the magnetic data but can still communicate with the Bluetooth transmitter. Each device has different magnetic signatures so it is good practice to first determine the magnetic cleanliness of the Android device prior to surveying. This is done by slowly moving the Android device to see if there is a magnetic response from the magnetometer. If there is, move farther away before you start recording.

Upon start-up the application will see if the Bluetooth is turned on, and if not will ask you if you want to turn the Bluetooth on.

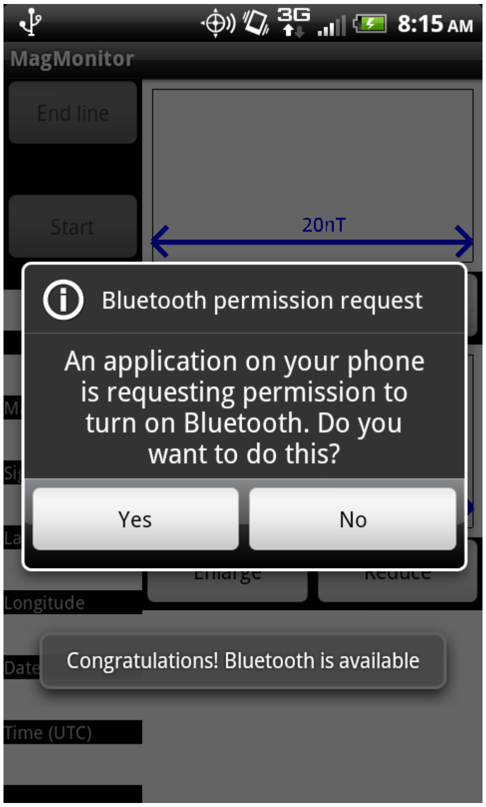


Figure 16: Initial screen to indicate Bluetooth usage

Once the Bluetooth is turned on select the Menu button (the triple bar) and select Connect. You can now “Scan for Devices” to find the Bluetooth transmitter from the G-862RBS.

Figure 17: Scan for devices page

Once the G-862RBS is found select this Bluetooth device to pair the base station with your Android device and ready to use.

Magnetometer Trace

The first screen shown when the MagMonitor Application is running is the Magnetometer Trace window that shows an analog trace of the magnetometer data, see Figure 17.

Figure 18: Magnetometer Trace Screen

A multiple line header displays a digital output of the magnetometer data readings as well as signal level. The signal level is a gauge of the quality of the magnetic readings, with values lower than 500 being questionable. This is a good check that the instrument is working properly and that the sensor is not operating in a dead zone. At initial start up the signal level will be in the first decades, but after the sensor has warmed up the readings should range from 600-2000, eventually stabilizing at a near constant number.

GPS Latitude/ Longitude

The second line shows the GPS Latitude and Longitude readings in decimal form. These fields use positive or negative numbers to show the correct hemisphere you are working in. In Figure 18 it shows a positive number for the Latitude which corresponds to the Northern Hemisphere, and a negative Longitude which corresponds to the Western Hemisphere.

Date and Time

The date is displayed in the mm/dd/yy format standard in the United States. This is currently the only date format available, but future versions of this program will allow for the European convention of dd/mm/yy.

Time is displayed in UTC time, the standard for GPS units. The time format is hh:mm:ss.(ms). It is important to note what the difference between the local time and UTC time for downloading the data. This is discussed in greater detail in the following chapter.

Scale

The scale bar for the analog trace is shown in the bottom left-hand corner of the screen. You can increase and decrease the scale by selecting the Enlarge and Reduce buttons at the bottom of the screen.

GPS Track Plot

The GPS track plot screen is shown in Figure 19. This screen was added as a way to visually show the accuracy of the GPS. This screen also helps show if the GPS loses satellites such that it cannot generate a 3-D fix. This will be shown by a drastic change in the GPS location accuracy on the track plot. Select the enlarge or reduce button to zoom in or out on the track plot to see the overall accuracy of the instrument. The red dot is the location of the latest GPS message received, with the black and grey dots representing past locations.

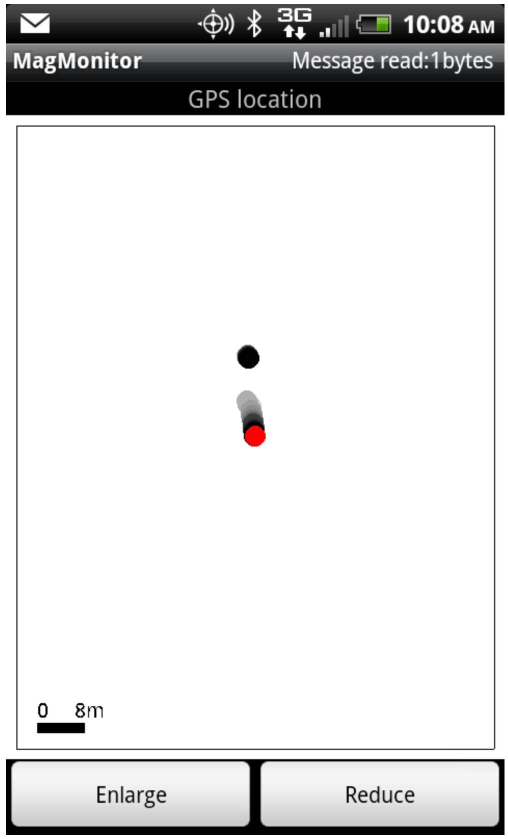
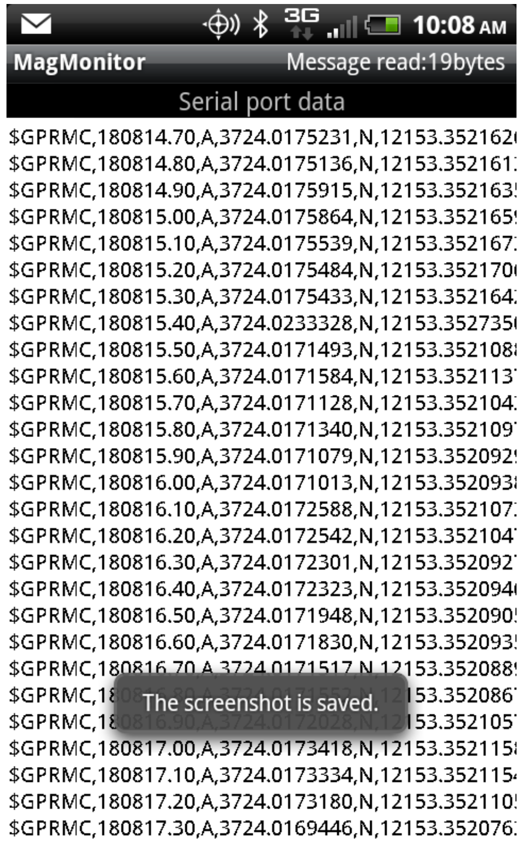


Figure 19: GPS track plot

GPS Serial Data Screen

The GPS data screen is a terminal emulation screen that shows the full GPS messages as they are logged by the DogCatcher.



The GPS is programmed to send $GPRMC data which has the following form:

$GPRMC,225446,A,4916.45,N,12311.12,W,000.5,054.7,191194,020.3,E*68

225446	Time of fix 22:54:46 UTC
A	Navigation receiver warning A = OK, V = warning
4916.45,N	Latitude 49 deg. 16.45 min North
12311.12,W	Longitude 123 deg. 11.12 min West
000.5	Speed over ground, Knots
054.7	Course Made Good, True
191194	Date of fix 19 November 1994
020.3,E	Magnetic variation 20.3 deg East
*68	mandatory checksum

Currently the entire string might not fit on the screen depending on the orientation and screen size. Further efforts are being made to adjust for the screen size so that the entire string can be examined for quality control purposes.

Composite Screen

The MagMonitor App also has the ability to show all three screens (magnetometer trace, GPS position, and serial data) on a single screen. Select the menu button (triple bar) and select settings.

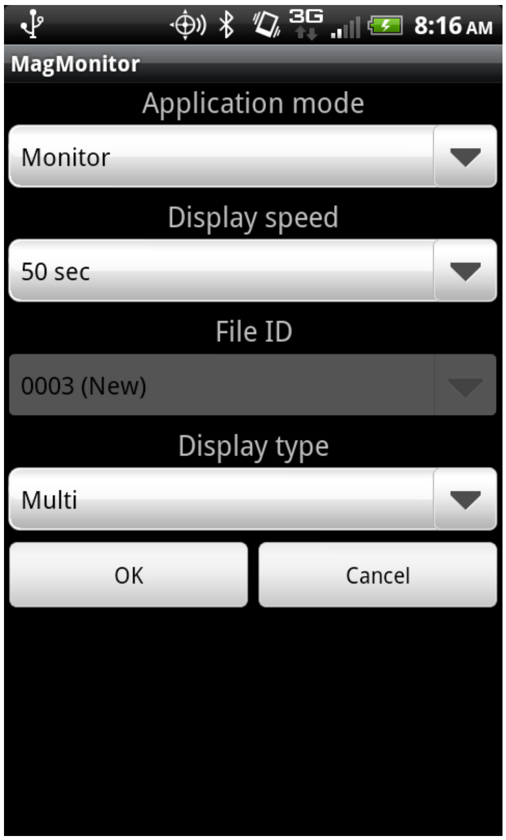


Figure 20: Settings screen

Here you are able to choose the display type (single or Multi). Single corresponds to a composite with three windows on the same screen showing the magnetometer trace, GPS position and data stream all in one. Multi is for a single screen for each data window.

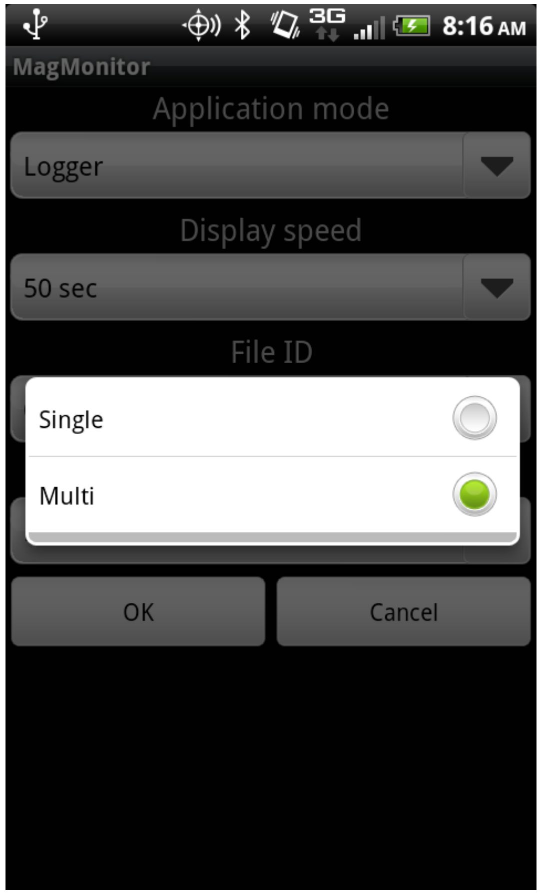


Figure 21: Selection between Single or Multi screen types

An example of the Single screen is shown below:

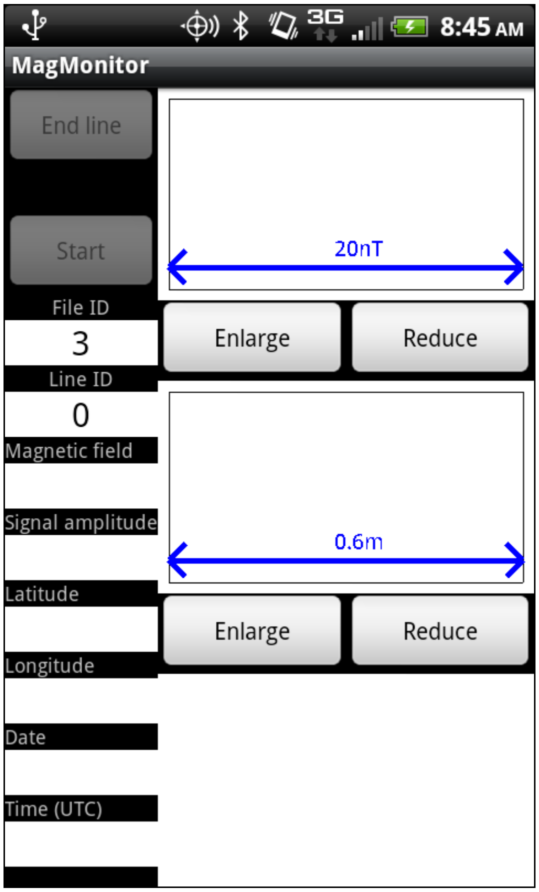


Figure 22: Single screen layout

The text data is shown on the left edge of the screen. The Magnetometer waterfall trace is at the top with the ability to change the full scale of the window. The GPS position plot is in the middle screen, again with the ability to change the full scale of the window. The bottom screen is where the full data stream is displayed.

Settings

The MagMonitor App also has the capability of logging the data into the smartphone or tablet's memory for data redundancy. This is helpful if there is an issue with the data being stored on the memory of the USB drive. To log data on the tablet, go to the settings screen and change the application mode from Monitor to Logger. Here you can save data to different files with predefined ID numbers (incrementing each time the application is closed. You can also append to past data files by selecting an older file and continuing to collect data.

Display speed dictates how quickly the magnetometer waterfall trace goes down its window. A 50 s display speed means that 50 seconds worth of data will be displayed on the screen.

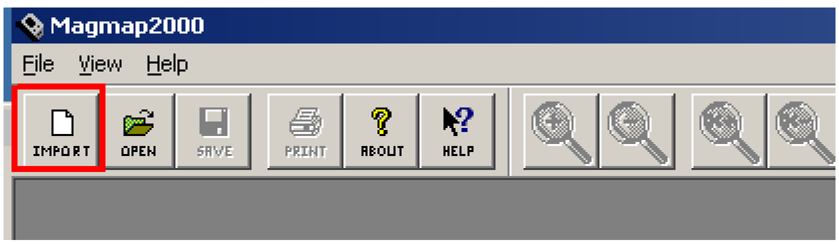
Chapter 5: Data Download

Uploading G-862RBS into MagMap2000

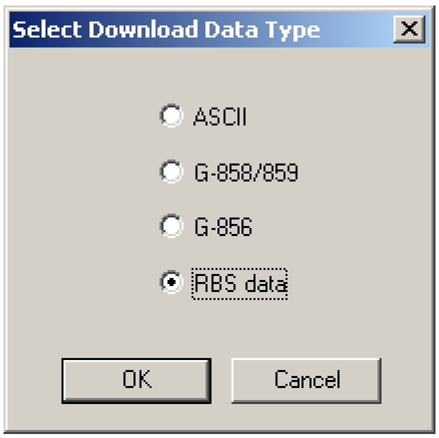
To use the data recorded by the G-862RBS to diurnally correct the magnetic readings of a mobile magnetometer system the files must be reconfigured to the necessary time stamp form for the MagMap2000 software to properly read the information.

MagMap2000 software provides RBS data download interface consistent with G-856 / G-858 / G-859 data download. The difference is that in case of RBS data is simply copied from the RBS USB stick onto host computer, and new file name is assigned based on UTC data of RBS data set.

To download RBS data make sure that RBS data stick is plugged in the available USB port and recognized by the PC, and press "Import" button from MagMap2000 tool bar.



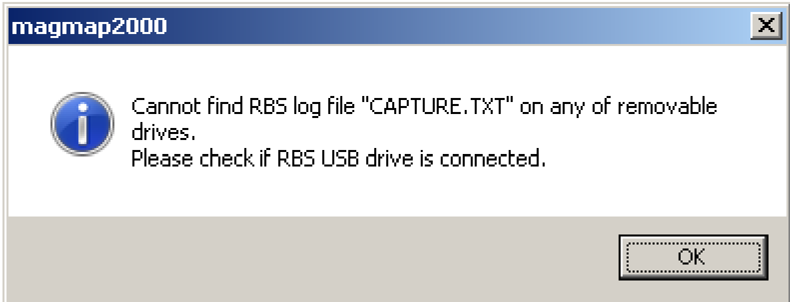
Program display import dialog with RBS data selection at the bottom:



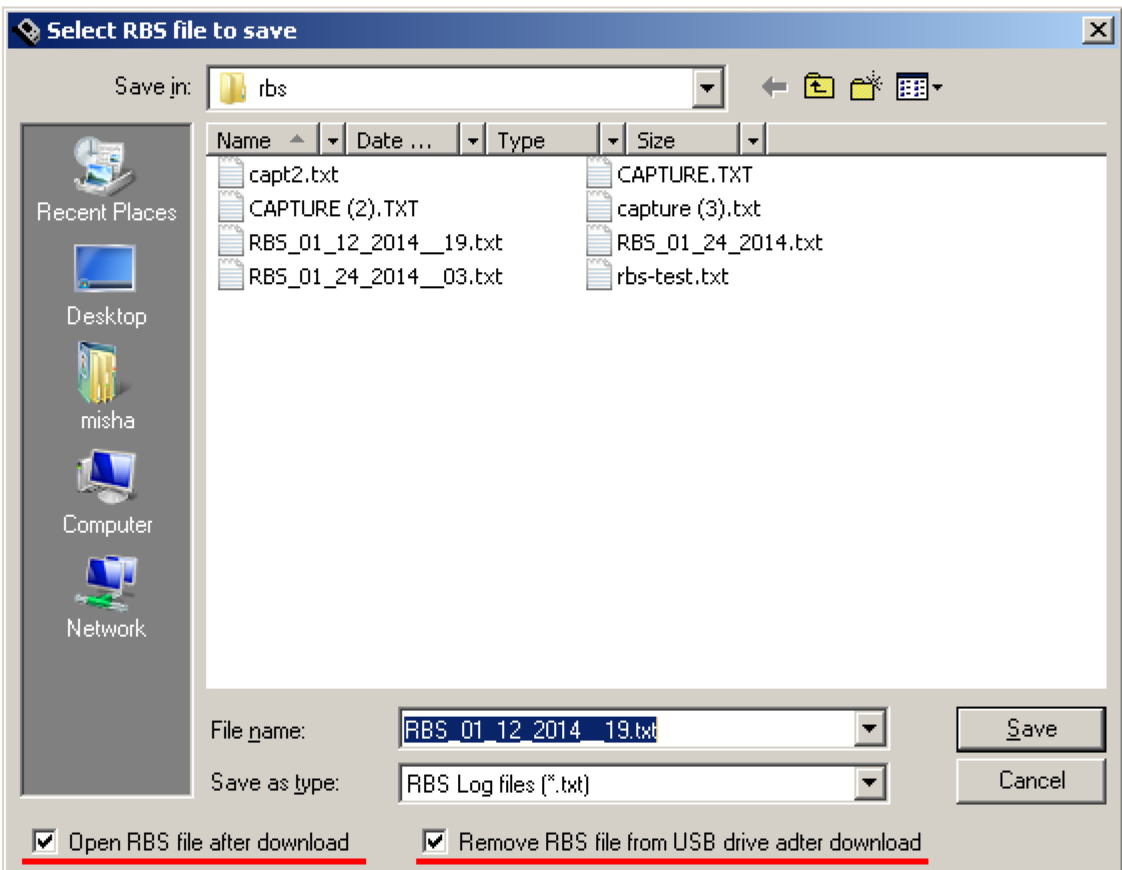
Select "RBS data" from dialog above.

Alternatively user can select "File / Import RBS data" from the main menu.

After selection is made, MagMag2000 searches removable media for RBS field log file. If file is not found the error message is displayed:



If MagMap2000 detects RBS log file, it suggests new name based of log UTC time and opens "Save file" dialog:



Note two check boxes at the bottom of the dialog:

1. **Open RBS file after download.** If this box is checked MagMap2000 will try to open RBS field data file after it is saved to the host computer. If box is not checked file will be simply copied to the host PC.

2. **Remove RBS file from USB drive after download.** If this box is checked MagMag2000 removes RBS field file from the USB drive after it is copied into PC, to free space for new data. Additional confirmation dialog is displayed before file is actually removed.
   After user presses “Save” button MagMap2000 copies field from USB stick to host PC under selected name, opens it if requested and removes from USB storage. The next section explains in detail how the RBS file is loaded.
   To read already saved RBS files use “File / Open” dialog as explained below.

Read RBS data into MagMap2000.

Geometrics Remote Base Station data is presented with file with extension .txt. The file holds mixture of raw GPS messages, such as RMC and magnetometer readings, accurately time stamped with the UTC time using GPS serial and PPS (pulse per second) output. Thus data is already has UTC time stamp. The typical example of RBS data is presented below:

```
$ 42204.989,1277,03:07:16.955,01/16/14,00
$GPRMC,030716,A,3724.0098,N,12153.3513,W,000.0,000.0,160114,013.7,E*62
$ 42205.009,1277,03:07:17.055,01/16/14,00
$ 42204.947,1274,03:07:17.155,01/16/14,00
$ 42205.028,1277,03:07:17.255,01/16/14,00
$ 42204.894,1274,03:07:17.355,01/16/14,00
$ 42204.894,1274,03:07:17.455,01/16/14,00
$ 42205.161,1274,03:07:17.555,01/16/14,00
$ 42204.932,1277,03:07:17.655,01/16/14,00
$ 42204.627,1274,03:07:17.755,01/16/14,00
$ 42204.970,1277,03:07:17.855,01/16/14,00
$ 42204.928,1277,03:07:17.955,01/16/14,00
$GPRMC,030717,A,3724.0098,N,12153.3514,W,000.0,000.0,160114,013.7,E*64
$ 42204.970,1277,03:07:18.055,01/16/14,00
```

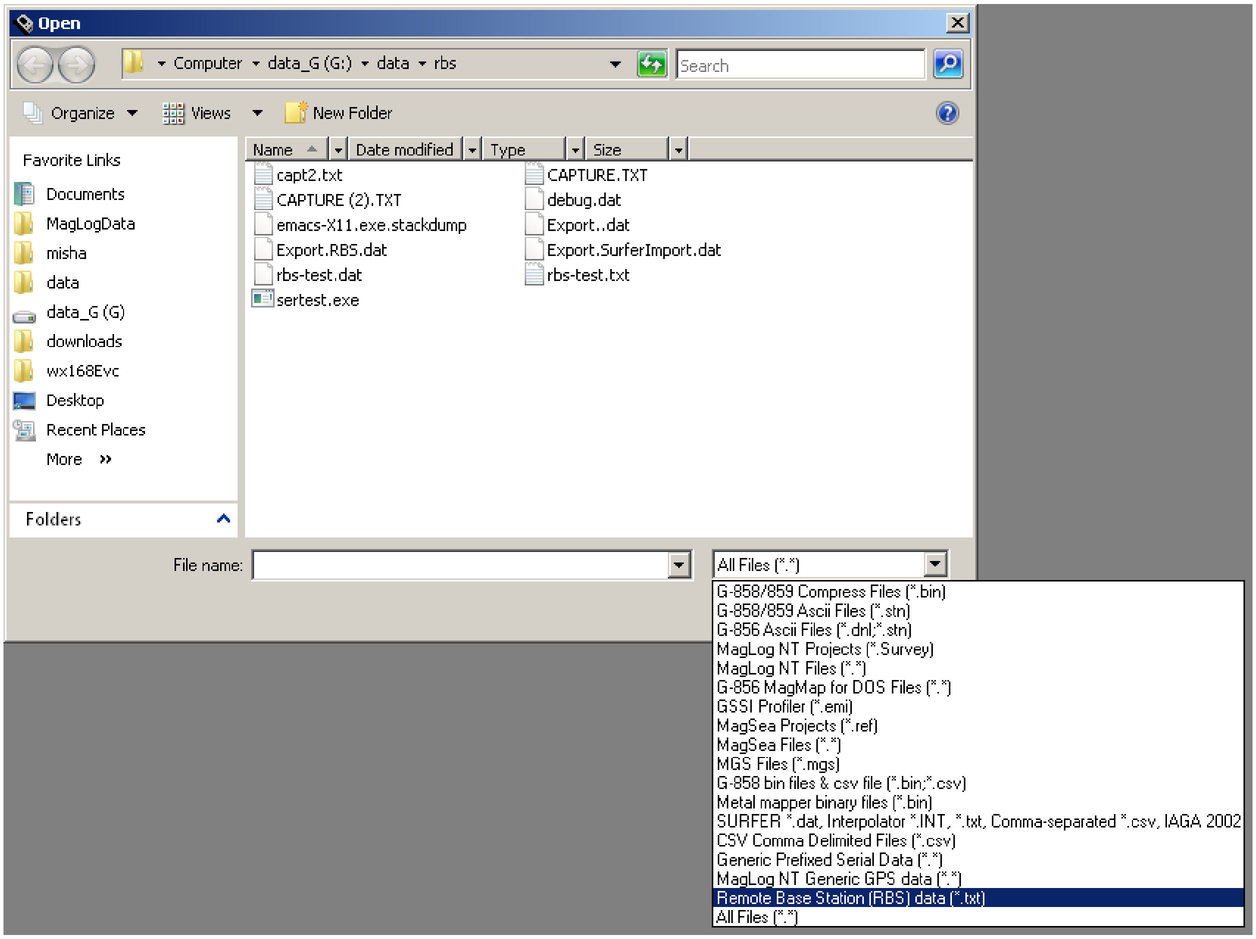
The magnetometer readings start with “$” and consist of total magnetic field, signal strength, UTC time and date, and hexadecimal status flag. All fields are comma separated. The status flag is zero if no errors were detected.

RBS file can be treated as Base Station data; in this case GPS raw messages are not used, and MagMap2000 opens one standard base station data. Data can be also treated as rover; in this case MagMap2000 parses raw GPS messages to extract positions. In latter case it opens two windows: readings view and GPS view, similar to data loaded as SURFER or airborne magnetometer. Please do not close any of these windows while working on the data. MagMap2000 does not allow opening of multiple RBS or GPS data in rover mode, but data from another RBS file from stationary magnetometer could be open as base station.

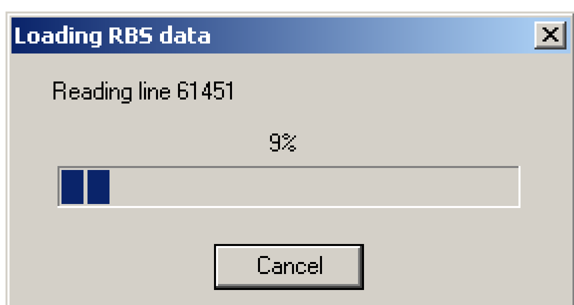
Note that RBS data is complementary in case of Base Station mode. Other rover data such as airborne, marine or land should be loaded before or after RBS base data is loaded.

RBS rover mode is self-sufficient, assuming RBS was moved to perform magnetometer survey. In this case data can be exported into SURFER or Geosoft formats for further processing.

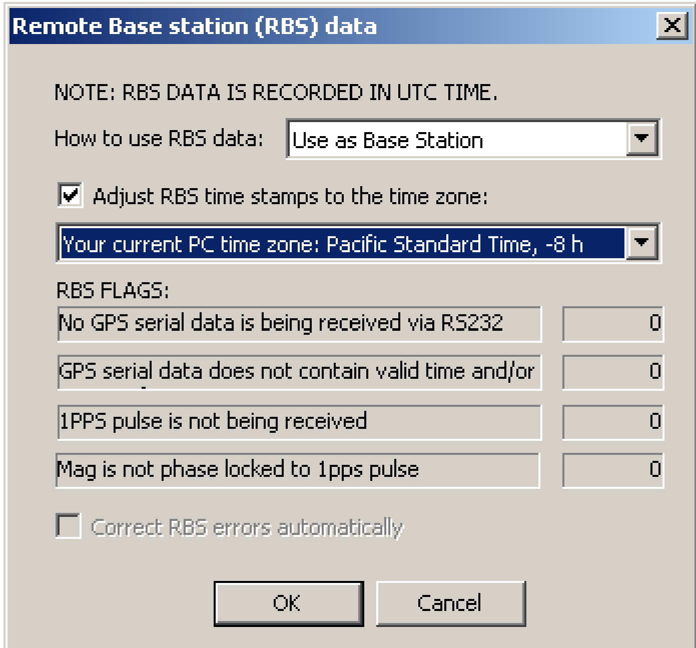
To open RBS file select File / Open from MagMap2000 main menu and select filter settings as Remote Base Station (RBS) data as it is shown on the picture below, and select file to open.



Program starts reading RBS file as shown below:



After reading is completed, RBS status dialog is displayed:



The following controls are available:

1. **How to use RBS data**. Possible selections are "Use as Base Station" or "Use as Rover (GPS+data)" In first case program opens base station window, in second case two windows (similar to airborne or SURFER data) with magnetometer readings and positions.
2. **Adjust RBS time stamps to the time zone**: RBS data always recorded in UTC time. Therefore it could be desirable to adjust then to the local time zone. Checking this box enables time zone selection below. In case of rover mode both magnetometer and GPS positions times are adjusted to local time zone.
3. **RBS flags**. Reports number of readings with specific flags set. These indicate problems with RBS and/or GPS. For the normal operation all flags should be 0.
4. **Correct RBS errors automatically**. This check box is enabled only if some of the RBS flags is not zero. Program will try to restore missing time stamps in this case.

After the "Ok" button is clicked program creates one or two windows, depending on the mode selection.

Appendix 1: G-862RBS Configuration

The G-862RBS is made up from a Geometrics G-862 magnetometer, a Tallysman TW5310 GPS receiver, a Dogcatcher USB thumb drive recorder in a weatherproof enclosure with power supplies and Bluetooth transmitter, a non-magnetic tripod, and cable set.

In operation data from the GPS is used to trigger the magnetometer, which is synchronized to the GPS 1PPS output. The GPS is configured to transmit NMEA $GPRMC messages at 1 Hz. This GPS message setting was chosen because it contains the date with the time stamping. The system Baud rate is set to 19,200. Each magnetometer sample is time stamped with GPS UTC date and time.

Data Collection Set Up

After the G-862RBS is completely assembled and power is running connect the data logger DATA Monitor port to your computer using an RS-232 extension cable. You may need to use the USB-RS232 adapter provided by Geometrics to successfully connect to your computer.

You can download the most recent version of Tera Term for the operating system you are using here:

http://logmett.com/

After installing Tera Term you can run the executable file and a command window appears:

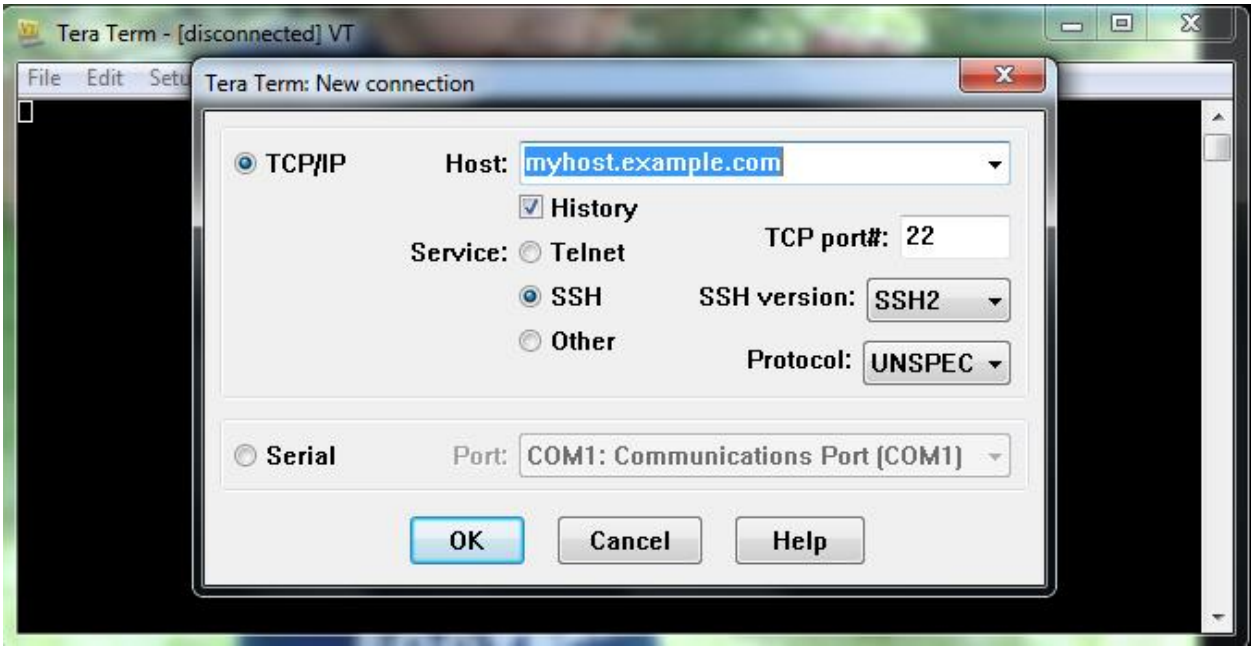


Figure 23: Serial connection screen in Tera Term

The data logger DATA Monitor port connects and streams the data to the computer through an RS-232 serial port. So we must select the radio button Serial at the bottom of the window.

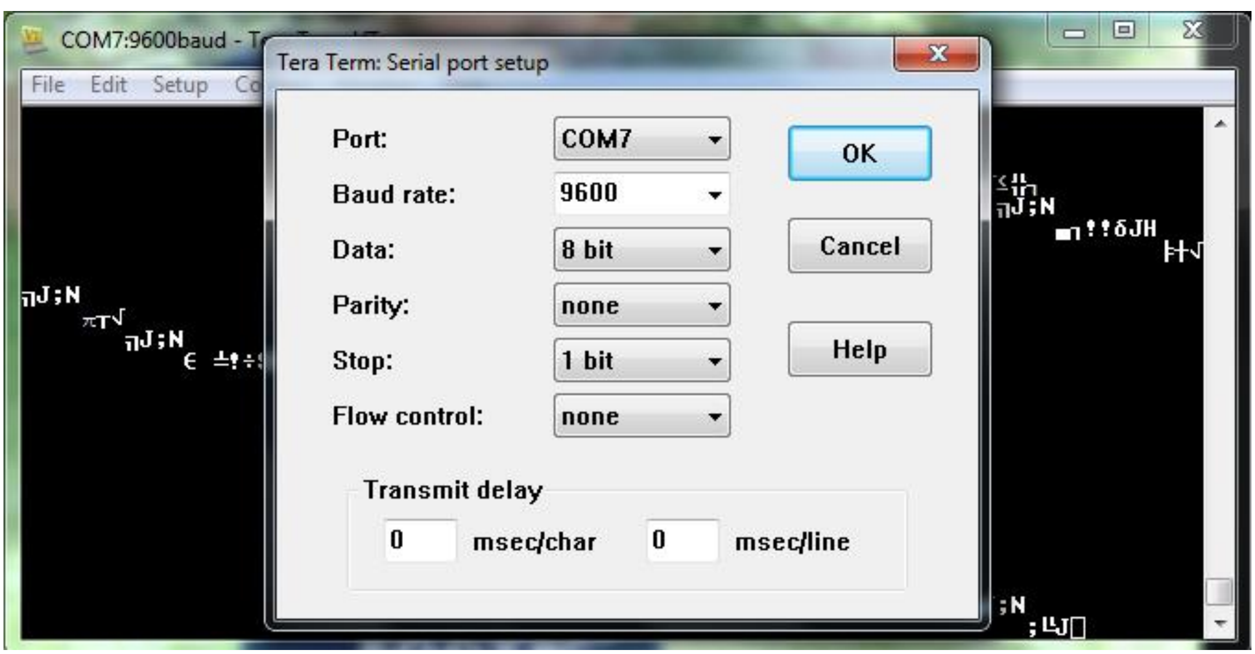


Figure 24: Serial Port Setup

Upon initial startup Tera Term will assume a baud rate of 9600. However, each piece of equipment in the G-862RBS is preset at the factory to send out data at 19,200 baud. With the computer and the data box operating at different baud rates you will see random characters populating the screen, which can be seen in the background of Figure 22. To change the baud rate go to Setup/Serial Port… and the window shown above will appear. Choose the 19,200 baud rate in the list in the drop down menu. The other options should remain the same, with Data at 8 bit, Parity at none, Stop is 1 bit and Flow control is none. Make sure that the correct COM port is selected and then click OK.

G-862RBS Commands Via the Front Panel Monitor Port:

The G-862 can be configured into many different operating modes by sending commands to it using a terminal emulation program via the Monitor port on the front panel. The commands fall into three groups. There are commands that configure the Arduino CPU, commands that get routed through to configure the GPS, and commands that get routed through to the Magnetometer.

Note that these commands are used to set up the G-862 RBS, GPS, and Magnetometer, but once the system is set up and the configuration saved you probably never need to use these commands. If you bring in a different GPS, or swap to another magnetometer then these commands will be useful to get the new components set up.

All the commands are sent by typing them into a terminal emulation program which in turn sends those typed characters into the Monitor port on the G-862. Each command string is followed by pressing the <enter> key. Note that all commands are lower case letters, and there are no spaces.

Arduino Commands:

Most of the commands are used to set up the Arduino CPU board. They all have the command preamble of "*ard:" signifying that the command will be received and acted on by the Arduino CPU itself. Below is a list of those commands and their functions:

*ard:saveconfig

This command takes the current setup and store it to EEPROM (non-volatile memory) so that the G-862 RBS will record this configuration on power up.

*ard:loadconfig

This command will reload the configuration from EEPROM. This allows you to undo any changes made to the configuration since the last power up (assuming you have not saved them). The same thing could be accomplished by cycling the power, but this command allows the configuration to be restored without powering down the GPS and magnetometer.

*ard:gpsbaud=4800
*ard:gpsbaud=9600
*ard:gpsbaud=19200
*ard:gpsbaud=38400
*ard:gpsbaud=57600
*ard:gpsbaud=115200

These commands set the baud rate of the GPS serial port on the Arduino CPU board. The Arduino board baud rate must match the GPS baud rate. The baud rates denoted in the above command list are all the possible baud rates for the Arduino GPS serial port.

*ard:magbaud=19200

Currently 19200 is the only baud rate available for the magnetometer. It is the fastest baud rate that the magnetometer can output. In future releases of the software we will be adding a command to be able to set the Arduino magnetometer serial port to 9600 baud.

*ard:loggps=true
*ard:loggps=false

When loggps=true the output data stream has both magnetometer and GPS data combined together. When false the GPS data is stripped off and just magnetometer data is logged. However the functionality and health of the GPS data is reflected in the status byte at the end of every magnetometer sample.

*ard:gpsdirect
This invokes a special operation mode that forms a direct pathway between the GPS and a computer through the G-862 RBS console. Once invoked the only way to exit this mode is by powering down and then powering back up.

In this mode every character that is sent by the computer to the monitor port on the G-862 RBS is echoed directly to the GPS. Every character sent out the GPS is echoed through to the monitor port (and on to the computer). Some GPS units are not configured via command line instructions – but rather use graphical user interface programs to set them up (like the Tallysman). This mode allows the GUI configuration program to set up the GPS as though the computer was directly wired into the GPS serial port.

Even though all characters out of the computer and/or out of the GPS are echoed on through, keep in mind that inside the G-862 RBS they are entirely separate serial ports and may be running at different baud rates. Any baud rate translation is done by the Arduino as required.

In the gpsdirect mode everything other than the special data pathway works normally. The interrupt routines still function, the magnetometer gets triggered, etc.

See Appendix 2 on “Configuring the GPS via the Monitor Port of the G=862RBS” for an example on configuring a Tallysman GPS using this mode.

*ard:magdirect
This mode is identical to the gpsdirect mode above except it opens a direct pathway to the magnetometer instead of the GPS. This is a handy way to configure the magnetometer directly.

In this mode, all characters entered at the computer are echoed directly to the magnetometer, and all character sent by the magnetometer are sent out the Monitor port and on to the computer.

For a list of the magnetometer commands please refer to the G-862 magnetometer manual.

There is one non-obvious caveat when sending commands directly to the magnetometer. The method used to trigger the magnetometer puts it from master mode into slave mode and changes its magnetometer number from “0” to “1”. Usually when setting up a single magnetometer there is no need to specify the magnetometer number in the magnetometer commands since it assumes it is magnetometer zero when a number isn’t specified. But in this case the all commands must be entered with a magnetometer number of “01” added. For example, to turn on the magnetometer signal level channel you need the command “A1001” instead of “A10” or “A1000”. This is covered in detail in the G-862 magnetometer manual.

Once entered the only way out of the magdirect mode is to power down, then power back up.

Appendix 2: GPS and Magnetometer Programming

Overview

The G-862RBS is designed to simultaneously acquire GPS positions while it is acquiring magnetic data. The Tallysman TW5310 GPS is preset at the Geometrics factory to send the $GPRMC position and time string in order to provide automatic date and time stamps. The G-862RBS uses the integrated GPS data to produce a highly accurate and precise time stamp which will be able to synchronize the data of both the base station and a mobile magnetometer for more accurate diurnal corrections.

All communication with the GPS takes place through the RS-232 extension on the data cable provided.

Collecting GPS Data

The G-862RBS is equipped with either a Tallysman TW5310 GPS mounted on the top of the base station assembly. These GPS units are cabled to the G-862RBS data logging box. All necessary wiring connections are in the power cable supplied with the battery box. The GPS is pre-configured by Geometrics to provide the $GPRMC NMEA sentence only at 1 Hz, and to output 1PPS timing pulse.

There is no need to program the Tallysman TW5310 GPS unless the GPS memory has become corrupted and it has lost its programming. If that were to occur it could start sending improper GPS serial data. If so, we recommend the following procedure:

Tallysman TW5310 GPS Setup

Required Equipment:

1. Windows XP - 8 PC with RS 232 Serial port
2. Tera Term or HyperTerminal software
3. Tallysman TW5X10Configurator.exe software installed on the Windows computer
4. P/N 60-230-237 RS 232 Extension Cable

Procedure:

1. Open the data logger cover and turn off the G-862RBS power switch.
2. Connect the 60-230-237 cable between the G-862RBS datalogger DATA Monitor RS-232 connector on the front panel, and a serial port on the computer.
3. Turn on the G-862RBS power switch
4. Start the Tera Term or HyperTerminal software.
5. Set communications to 8 data bits, No parity, 1 stop bit, and 19,200 baud.

The Tallysman GPS uses a special Windows configuration program called "TW5X10Configurator.exe" to setup the GPS. In order to use this program the Windows computer has to interface directly to the GPS via a serial port. In the normal operating mode the GPS get combined with magnetometer data and sent to the logger. To allow the configuration mode to work we must first invoke a special mode in the G-862 which forms a direct path between the computer and the GPS. To invoke this special mode we start up a terminal emulation program such as TeraTerm and monitor the serial output from the G-862. If logging is enabled turn it off. Then type the following command to the G-862 using TeraTerm:

*ard:gpsdirect

Followed by the <enter> key. Note that the characters are all lower case and there are no spaces in the command (see the section on G-862 Commands for details on all the possible commands that can be sent to the G-862 RBS).

The “*ard:” preamble tells the G-862 RBS that the command is for the Arduino board, and the rest of the command tells the Arduino to make a direct pathway between the monitor port on the G-862 and the GPS. In other words, every character that comes into the monitor port is echoed to the GPS, and every character that comes from the GPS is echoed directly to the monitor port. Keep in mind though that monitor serial port and the GPS serial ports are completely separate and may be running at different baud rates. The Arduino CPU takes care of baud rate translation if required.

In the following example we are going to use the TW5X10 configurator program to change the GPS output format from 9600 baud to 19200 baud, and change the GPS output sentence from GPGGA to GPRMC. Although both GPGGA and GPRMC strings will work for setting magnetometer time stamps, the GPRMC format is better in that it includes data as well as time.

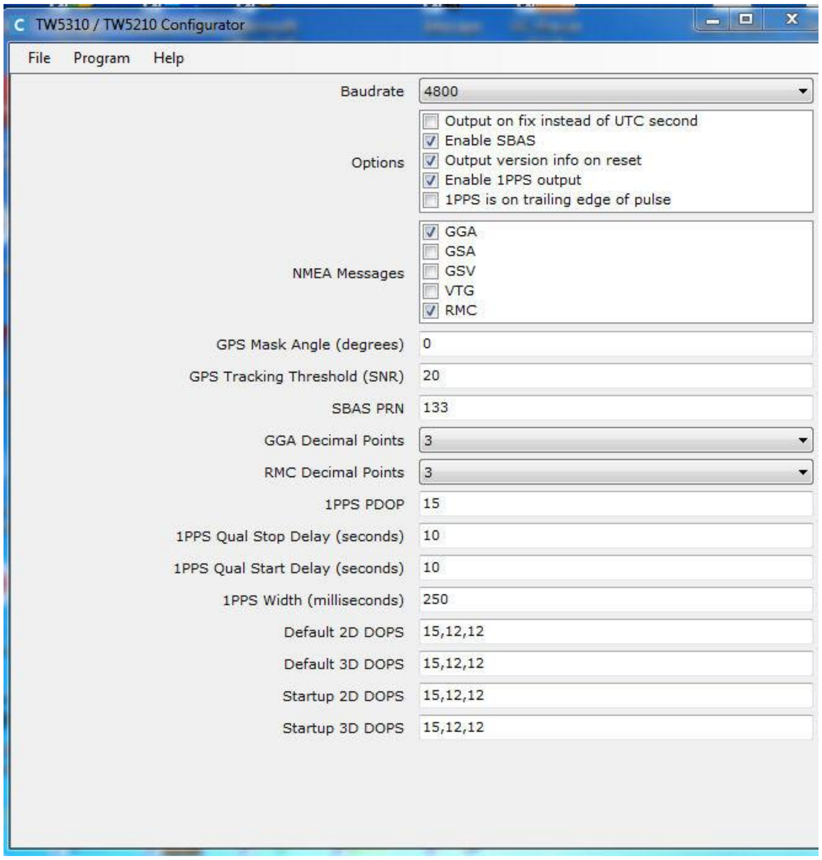
Below is a data stream coming in from the GPS at 9600 baud and being received by the terminal emulation program (via the monitor port) at 19200 baud. Note that the GPS format is GPGGA, and the magnetometer time stamps have zeroes in the date portion.

About midway through the example data set below the “*ard:gpsdirect” is sent (note there are no echoed characters). The output suddenly changes and only GPS data is coming through the monitor. Note that everything else in the G-862 RBS is still working. The interrupts are still functioning; the magnetometers are still being triggered, etc. Only the data routing to/from the GPS and Monitor port has changed.

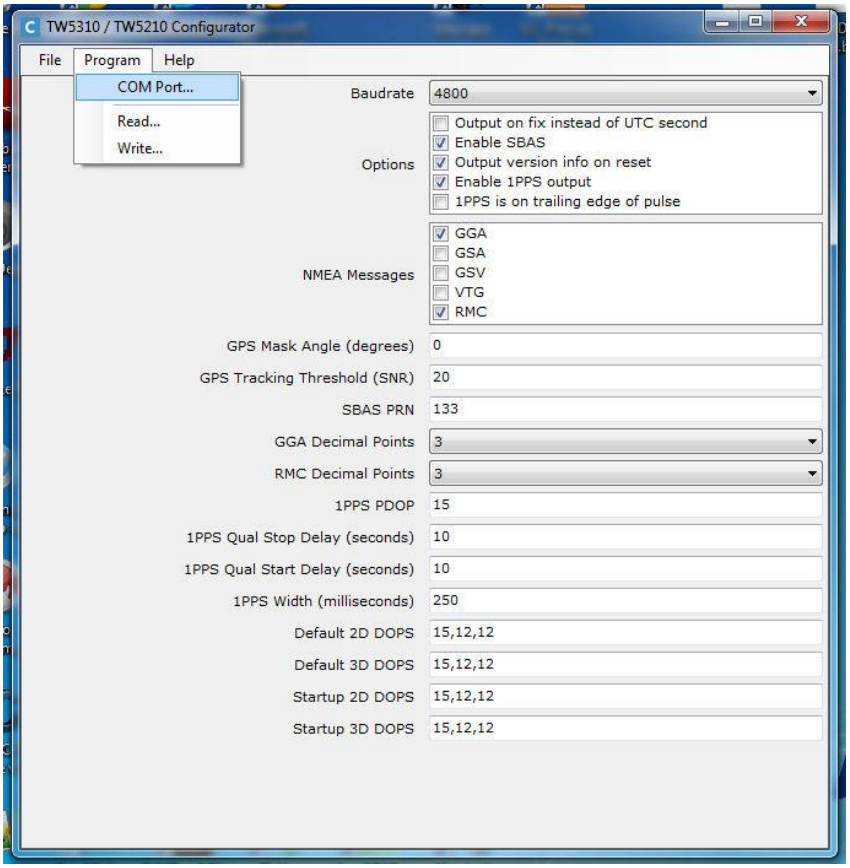
```
$ 34877.071,0244,20:53:16.455,00/00/00,00
$ 34876.866,0247,20:53:16.555,00/00/00,00
$ 34877.244,0249,20:53:16.655,00/00/00,00
$ 34877.055,0247,20:53:16.755,00/00/00,00
$ 34876.807,0247,20:53:16.855,00/00/00,00
$ 34876.593,0249,20:53:16.955,00/00/00,00
$GPGGA,205316.000,3723.99953,N,12153.35729,W,1,06,1.3,031.08,M,-25.5,M,,*58
$ 34876.724,0249,20:53:17.055,00/00/00,00
```

$ 34876.775,0247,20:53:17.155,00/00/00,00
$ 34876.629,0247,20:53:17.255,00/00/00,00
$ 34876.613,0247,20:53:17.355,00/00/00,00
$ 34876.641,0249,20:53:17.455,00/00/00,00
$ 34876.838,0249,20:53:17.555,00/00/00,00
$ 34876.661,0249,20:53:17.655,00/00/00,00
$GPGGA,205318.000,3723.99953,N,12153.35729,W,1,06,1.3,031.08,M,-25.5,M,,*56
$GPGGA,205319.000,3723.99953,N,12153.35729,W,1,06,1.3,031.08,M,-25.5,M,,*57
$GPGGA,205320.000,3723.99953,N,12153.35729,W,1,06,1.3,031.08,M,-25.5,M,,*5D
$GPGGA,205321.000,3723.99953,N,12153.35729,W,1,07,1.0,031.08,M,-25.5,M,,*5E
$GPGGA,205322.000,3723.99953,N,12153.35729,W,1,07,1.0,031.08,M,-25.5,M,,*5D
$GPGGA,205323.000,3723.99953,N,12153.35729,W,1,07,1.0,031.08,M,-25.5,M,,*5C
$GPGGA,205324.000,3723.99953,N,12153.35729,W,1,07,1.0,031.08,M,-25.5,M,,*5B
$GPGGA,205325.000,3723.99953,N,12153.35729,W,1,07,1.0,031.08,M,-25.5,M,,*5A
$GPGGA,205326.000,3723.99953,N,12153.35729,W,1,07,1.0,031.08,M,-25.5,M,,*59

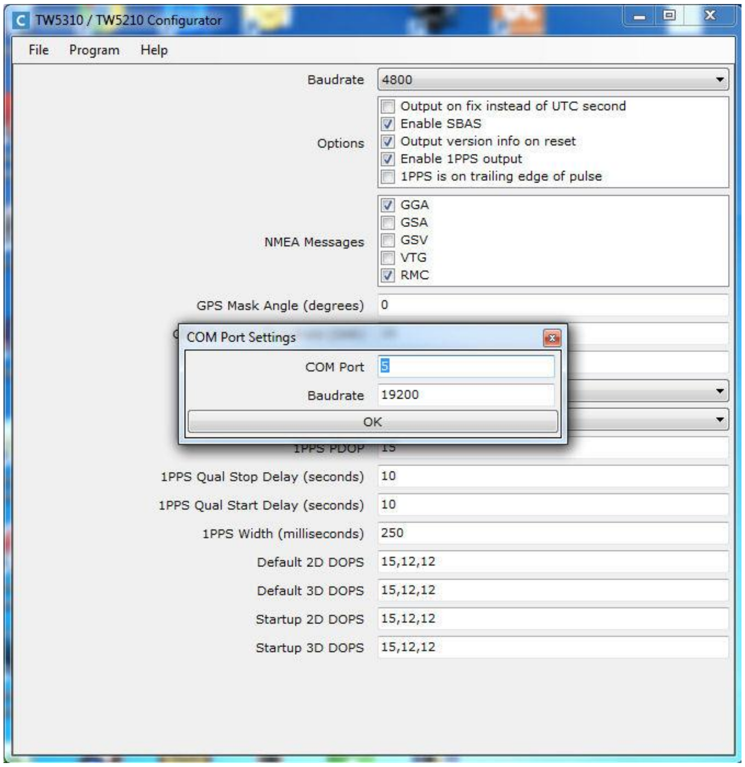
Now exit the terminal emulation program and start the TW5X10 Configurator program. This is the start up screen you will get:



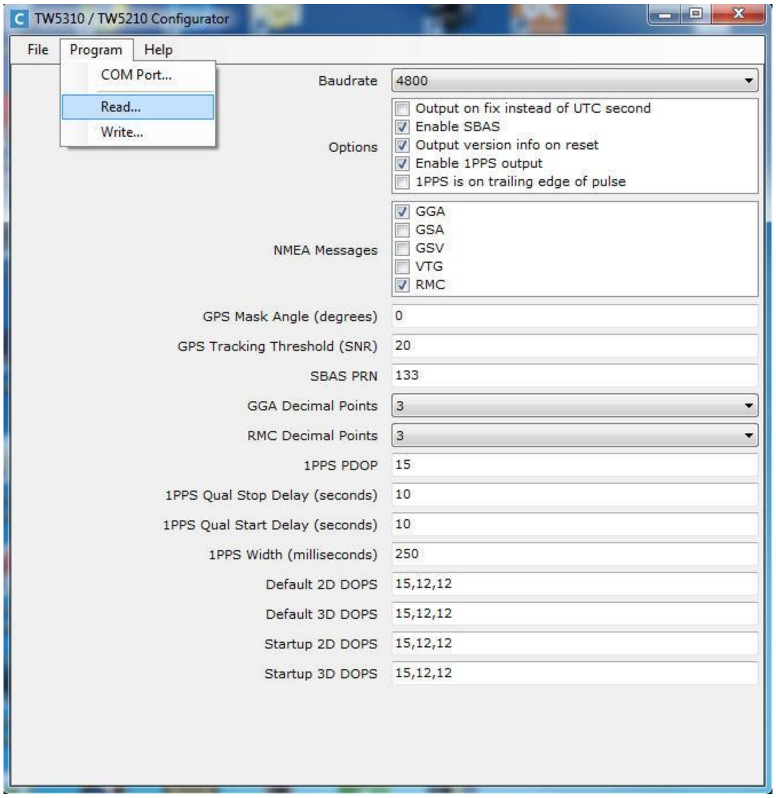
The first thing we want to do is set up the computer serial port to be at the same baud rate as the monitor port (which is 19200 baud). To do that click on the "Program" drop down menu, and then "Com Port":



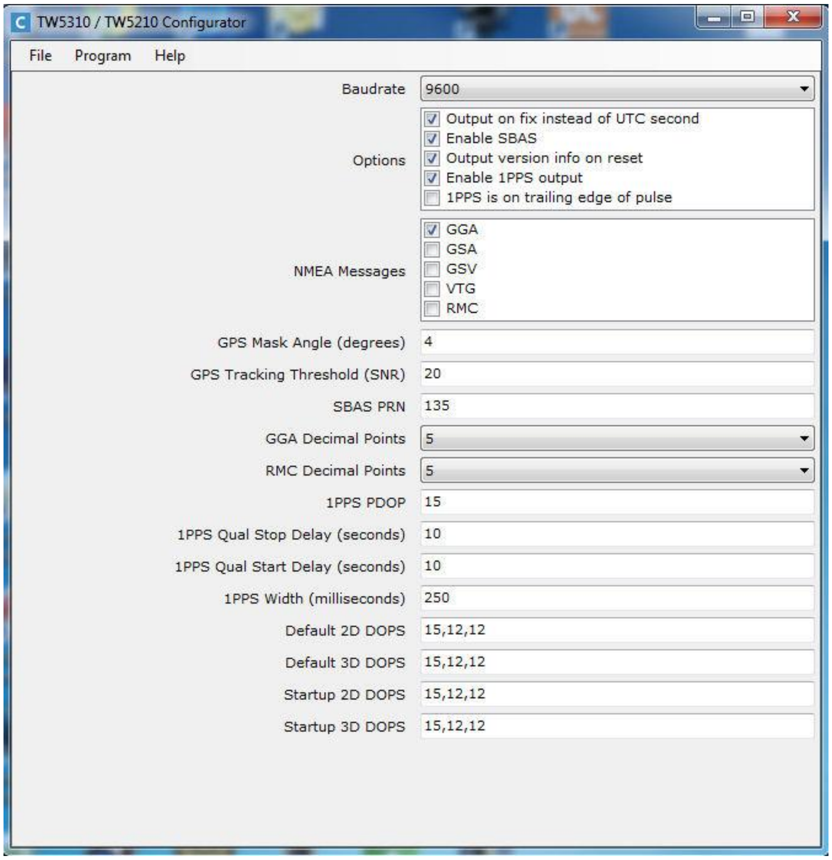
As shown below a menu box will appear asking which Com Port on your computer you will be using, and what the baud rate is. In this case it is Com 5 and 19200 baud. Click the "OK" button when finished entering the data. Note that this is the baud rate of the monitor port – not the GPS port.



Then go back to the “Program” drop down menu and click on “Read” as shown below:



The configuration contents of the GPS will be read in. The screen capture below shows the configuration as it was read from the GPS. Note that many of the check boxes and configuration values have changed. Also note that the output sentence is GGA instead of RMC, and that the GPS baud rate (uppermost right hand pull down menu) is 9600 baud.



Now we want to change the GPS baud rate (upper right pull down menu) to 19200 baud, and change the NMEA message from GGA to RMC. In the screen capture below this has been performed:

G-862 Magnetometer Setup

Magnetometer cycle rate is fixed at 10 Hz. Magnetometer timing should not be changed, but it is possible to change magnetometer Baud Rate and enable or disable internal analog channels so that diagnostic information can be recorded. Enabling internal analog channels will reduce maximum recording time.

Required Equipment:

1. Windows XP - 8 PC with RS 232 Serial port
2. Tera Term or HyperTerminal software
3. Optional CM201CFG software (installs automatically with MagLog)

4. P/N 60-230-237 RS 232 Extension Cable

Procedure

1. Open the data logger cover and turn off the G-862RBS power switch.

2. Connect the 60-230-237 cable between the G-862RBS datalogger DATA Monitor RS-232 connector on the front panel, and a serial port on the computer.

3. Turn on the G-862RBS power switch

4. Start the Tera Term or HyperTerminal software. Then select the appropriate computer COM port.

5. Set communications to 8 data bits, No parity, 1 stop bit, and 19,200 baud.

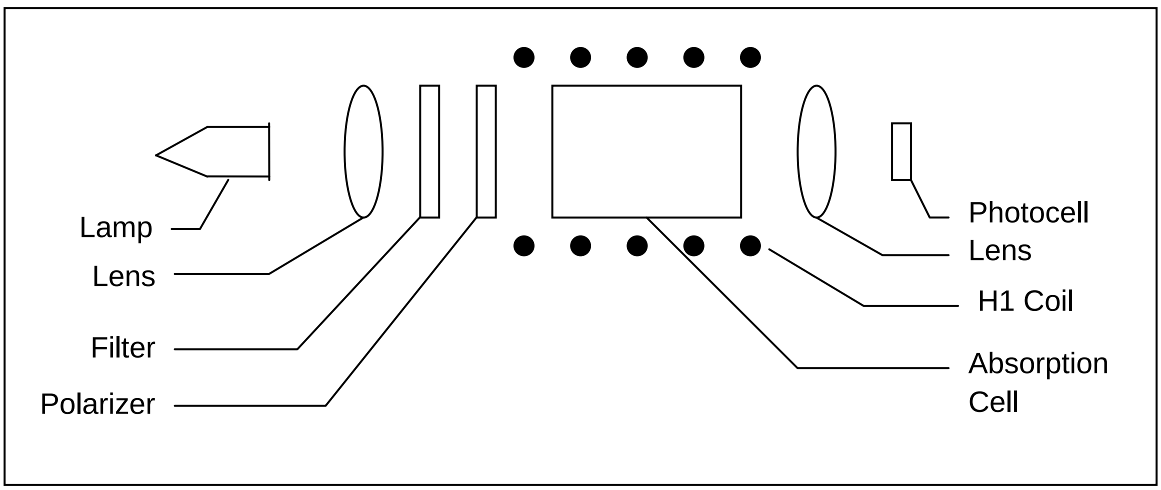
6. Type *ard:magdirect to form a direct pathway between the magnetometer and your computer.

7. When using terminal software set the magnetometer cycle rate, type the command, *C001001*, to set the time to 0.1 second (10 Hz). Analog channels 0 through 7 can be enabled by typing *A1x01* followed by the <enter> key (where x is the analog channel number). Analog channels 0 through 7 can be disabled by typing *A0x01* followed by the <enter> key (where x is the analog channel number). You should always enable analog channel 0, which is magnetometer sensor signal amplitude. Finally type the command, *UPDATE*, to store the new setting as the power on default.

Appendix 3: 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 H1. This coil is shown cross-section along with the other sensor components in Figure A11.



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:

I = 7/2
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 to 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 discrete 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 3.49872 times the ambient field measured in nano-Teslas (gammas). In the G-862RBS 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.

Appendix 4: CSAZ

Cesium Sensor Azimuth Program

CSAZ is a 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 Earth field dip angles (field inclination). AZ stands for azimuth or inclination.

The program is located on the MagMap2000 install disk included with the G-862RBS. Once MagMap2000 is installed, CSAZ will also be installed.

The CSAZ program is available from our FTP site at

ftp://geom.geometrics.com/pub/mag/software

Please read the manual that is included with the program for complete instructions on how to use the CSAZ program for sensor orientation solutions at various locations on the globe. Note that you should use the "generic" CSAZ mode for G-862RBS solutions.

Appendix 5: Instrument Specifications

Magnetometer:	Self-oscillating split-beam Cesium Vapor (non-radioactive)
MAGNETOMETER OPERATING RANGE:	20,000 to 100,000 nT
OPERATING ZONES:	The earth's field vector should be at an angle greater than 10° from the sensor's equator and greater than 10° from the sensor's long axis. Automatic hemisphere switching.
SENSITIVITY:	< 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)
ABSOLUTE ACCURACY:	< 3 nT throughout range
GPS Receiver	Time accuracy; 20ns, RMS, max. data rate; 1 Hz
Data Logger	Serial logger, removable USB thumb drive.
Data Format	ASCII, MS Windows PC compatible, FAT32 file format.
Capacity	22 days using 1Gbyte USB thumb drive while recording magnetometer at 10 Hz rate with GPS receiver output set to provide GPRMC data sentence (UTC) at 1 Hz rate. Logger will accept 0.5 to 8 Gbyte USB thumb drive with FAT32 file format.
Mechanical / Environmental	Shipping weight: 12.7kg (28Lbs.)
OPERATING TEMPERATURE:	-30° F to +122° F (-35° C to +50° C)
STORAGE TEMPERATURE:	-48° F to +158° F (-45° C to +70° C)
ALTITUDE:	Up to 30,000 ft (9,000 m)
WEATHERPROOF:	O-Ring sealed for operation in the rain and/or 100% humidity
Power:	10 to 36 VDC, 30 Watt. or 110-220VAC (50-60hz)
Standard Accessories:	110-220 VAC (50-60hz) power supply, Flash card reader, shipping/storage case, Geometrics MagMap2000 data processing and display software.

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE