Jewell Instruments
ECV™ eCompass
User's Guide

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Contact:

Jewell Instruments LLC
850 Perimeter Rd.
Manchester, NH 03103

Voice: 603-669-6400
Web: www.jewellinstruments.com
Email: sensors@jewellinstruments.com

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Introduction

The Jewell ECV eCompass combines a 3-axis magnetometer, a 3-axis accelerometer, 2-axis electrolytic tilt sensor, and 3 MEMS rate gyros to provide accurate heading and tilt measurements over a wide range of environmental conditions. The eCompass sends heading, pitch, and roll information to a host computer using an NMEA 0183 compatible protocol via an RS232 or RS485 serial port.

The ECV is an enhanced version of the Jewell ECS eCompass that is designed to operate accurately in dynamic environments. It accomplishes this by stabilizing pitch, roll, and yaw inertial measurements. Information from the MEMS rate gyros is blended with accelerometer and electrolytic tilt sensor signals to produce accurate pitch and roll over a wide bandwidth of frequencies.

A good first test is to take the eCompass outside to a magnetically clean area[1], and hold it steady at different attitudes (heading, pitch, and roll). Use the eCompassTest PC software to display readings and verify that the horizontal field strength remains roughly the same for different orientations. Expect to see some variation in the horizontal field strength, but it should be less than one or two percent if the eCompass is steady and tilt is less than 20°.

Before installing the Jewell ECV eCompass, make note of the dip angle measurement and compare it to the published value[2] for your location. The two values should be very close, usually within 0.5°. The horizontal and total field strengths can also be checked. Each count displayed by the eCompass represents about 5 nT; so a Mag H count of 4000 in the NMEA Sentence display represents a horizontal intensity of 20,000 nT.

If the eCompass will be mounted in a large vessel or vehicle, it is a good idea to capture and save a vertical reference as described in the section on *Calibrating the eCompass*. After the eCompass is mounted in-situ, this reference is used to partially compensate for any local permanent magnetism (hard-iron) that may be present.

Contents of the eCompass kit

The Jewell ECV eCompass evaluation kit contains the following primary items described in detail in this section:

- Jewell ECV eCompass
- eCompassTest Software CD
- Serial Cable
- User's Guide

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[1] Away from anything that contains ferrous material (steel, iron, or nickel).

[2] On the web go to: https://www.ngdc.noaa.gov/geomag-web/#igrfwmm

Jewell ECV eCompass

The Jewell ECV eCompass represents the state of the art in magnetic compassing. It consists of a PC card housed in an ABS enclosure or optional aluminum housing. The base of the enclosure has 4 mounting holes for permanent installation. Only brass or non-magnetic stainless steel screws should be used. Connection to the eCompass may be made via the RJ12 connector or by the 8 pin header (for system wiring). See the diagram(s) included with the cable(s).

eCompass Features

The Jewell ECV eCompass is a strap-down device that delivers high accuracy for its small size, low cost, and low power consumption. It provides both RS-232 and RS-485 communication links. For battery operation, a low-power standby mode is incorporated to reduce required current to 5mA. Wake up from standby requires only 40 milliseconds.

Additional features of the eCompass include:

- Exceptional dynamic performance
- High static accuracy
- Wide operating range
- Precise factory calibration
- Fast response
- Single supply operation
- Low power options

- Two independent serial channels
- In-system configuration and test
- Run (continuous) or Sample mode operation
- Wide selection of ASCII or binary output data:
  - Heading, pitch and roll
  - Magnetometer X, Y, and Z
  - Temperature, input voltage, and dip angle
  - Output ASCII or binary
  - Horizontal X and Y magnetic field strength
  - Raw and conditioned gyro data

eCompass Test Software CD

The CD contains the eCompassTest interface software for a Microsoft® Windows™ PC. When the CD is loaded into a CD-ROM drive, a display similar to the one shown in Figure 1 will automatically appear if the auto-run feature is enabled.

eCompassTest™

Software Installation

eCompass Test Software
(Revision: 1.00, File Size: 18106KK)
- View and record compass data
- Modify compass settings
- Perform magnetic calibration of compass

Documentation

User's Guide (June 2018, Rev ECV, PDF format: 1139KB / 30 pages)
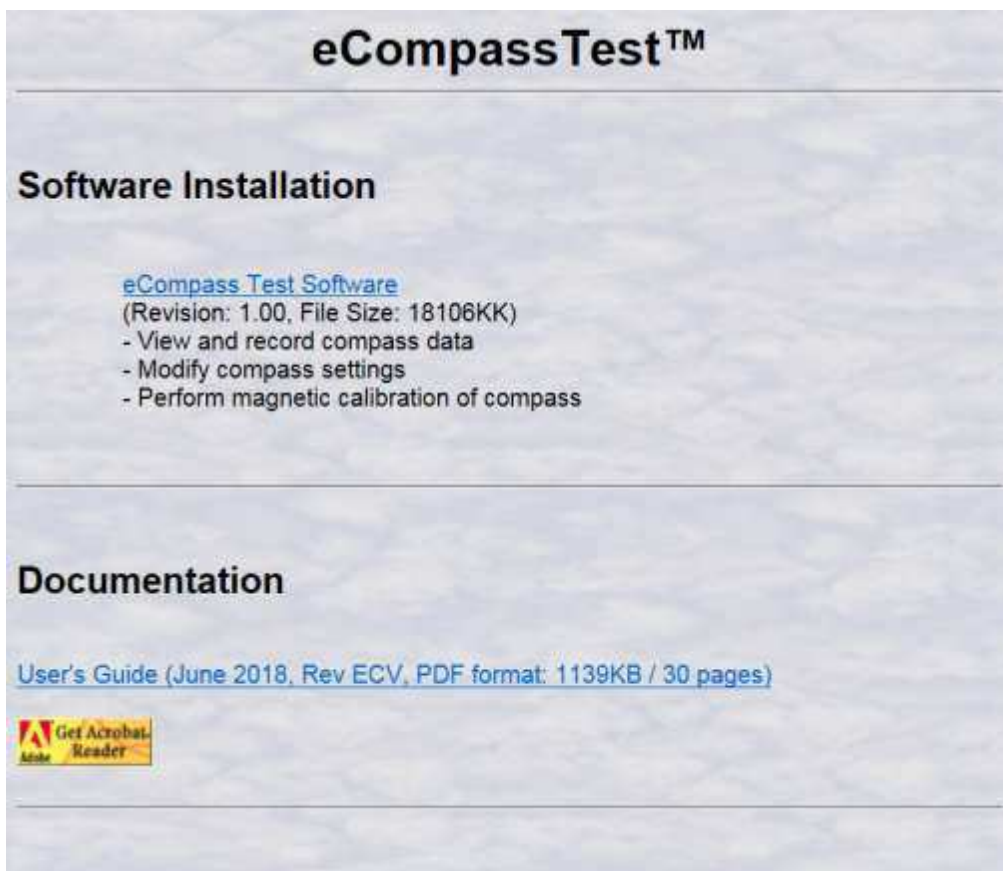
Get Acrobat Reader

Figure 1

eCompassTest Software Features

The eCompassTest application is designed to run on Microsoft Windows XP or newer. There are two main components:

- A VB.NET program (eCompassTest.exe) that provides the graphical user interface, recording, and logging functions, and
- A windowless DLL (eCompassLib.dll) that implements the eCompass serial interface and calibration functions.

The DLL can be used separately from the eCompassTest application to simplify the task of integrating the eCompass into an end-user system. It provides methods for reading and writing parameters for reading, parsing, and converting NMEA sentence data and for performing hard and soft iron calibration functions. It also maintains a text log of communication between the PC and eCompass that can be read by a host application.

Functions provided by the eCompassTest software include:

- Cockpit attitude display of heading, pitch, and roll (from HTM sentence)
- Display and capture NMEA sentence data
- Modify eCompass operating parameters
- Perform hard and soft-iron calibration procedures
- View and maintain communication logs

Serial Cable

The following cable assembly is included (with evaluation kits) and is shown in Figure 2.

> 4-Wire PC to eCompass: 8 ft. cable with DB9F connector and 9V battery strap going to 6-pin RJ12 plug.

Figure 2

Getting to Know the eCompassTest Software

System Requirements

- Microsoft® Windows™ XP with .NET Framework 2.0 or greater
- VGA or greater
- Keyboard
- 10 Mb disk space (more for log files, recorded data files, and synchronized files)
- RS-232 serial port for serial cable or USB port for USB cable

System Recommendations

- Microsoft® Windows™ 7 with .NET Framework 2.0 or greater
- SVGA 1024 x 768, High Color (16-bit), Large Fonts or greater
- Keyboard and Mouse
- 50 Mb disk space
- RS-232 serial port for serial cable or USB port for USB cable

eCompassTest Software

The eCompassTest software allows you to use your PC to communicate with the Jewell ECV eCompass.

To install the eCompassTest software, insert the eCompassTest CD into the CD-ROM drive of your PC. If the CD does not autorun, run the eCompassTest Setup.exe application from the ECV eCompassTest folder on the CD. The InstallShield® wizard will guide you through the installation process.

During the installation, you may select the folder in which the eCompassTest software will be installed or accept the default folder of C:\Jewell Instruments\eCompassTest. Once you run the eCompass Test software, the LogFiles subfolder will be created to store log files. Once you record data using the eCompassTest software, the RecordedData subfolder will be created to store files of data recorded from the eCompass. Once you use the zip files option, a ZipFiles subfolder will be created to store the desired files.

Is important to note that starting with Microsoft Windows 7, an application installed in the Program Files or Program Files (x86) folder cannot create or modify folders or files under the Program Files folders. Instead, the subfolders must be stored in the AppData folder structure. For this reason, the eCompassTest installation will default to installing the application in C:\Jewell Instruments\eCompassTest. If you do install the application in a Program Files folder, the LogFiles, RecordedData, and ZipFiles folders, their subsequent files, and application INI and XML files will be stored in the appropriate AppData folder automatically.

The following list describes some of the files placed in the application folder:

- eCompassTest.exe   eCompassTest software application
- eCompassTest.ini   INI file of user-modifiable settings
- eCompassTest Settings.xml   XML file of settings changed by software
- eCompassTest.chm   Help file for eCompassTest software

- eCompassLib.dll   Dynamic Link Library for communicating with ECV eCompass
- Air.ocx   ActiveX control used for attitude display
- DisableMicrosoftSerialMouse.reg Registration file that can be executed to disable the Microsoft Serial Mouse when it interferes with the GPS signal (if applicable)
- Various DLLs   Dynamic Link Libraries used to accomplish various tasks
- Readme.txt   Readme file explaining installation logic

To remove the eCompassTest software, use the Add/Remove Programs or Uninstall A Program function from the Control Panel, or run the eCompassTest setup again and choose Remove. Do not simply delete the eCompassTest folder and files. Please note that any log files, recorded data files, or other files created since the software was installed will not be deleted by the uninstall process. Once you have properly uninstalled the software, you may freely delete the additional files.

Preliminary eCompass Evaluation

How the Jewell ECV eCompass is Prepared

After factory calibration, test, and verification, the Jewell ECV is setup as follows:

- 19200 baud serial data rate
- Run mode – no automatic NMEA data output
- 0.2 s magnetometer time constant (Mag TC)
- 0.2 s pitch and roll time constant (Tilt TC)
- 4.0 s roll complementary filter time constant (Gyro P TC)
- 6.0 s pitch complementary filter time constant (Gyro R TC)
- 5.0 s azimuth complementary filter time constant (Gyro H TC)
- 2.0 s magnetic field alarm acquire time (Acquire Time)
- 5% magnetic field deviation limit (Alarm Limit)
- 1.5 s sample averaging time (used in Sample mode only)
- 55° pitch and roll warning level
- 60° pitch and roll alarm level (heading blanks above this)
- Both accelerometer and electrolytic tilt sensor for pitch and roll[3]

Time constants for the 3 complementary filters set the crossover frequency for blending gyro and accelerometer signals. Mag and tilt time constants are for single pole, low-pass IIR filters that smooth the magnetic and blended tilt measurements. If you switch to Sample mode, then these filters are reset and the magnetic field alarm is disabled.

The magnetometer gain is factory set to accommodate a full-scale range of approximately ± 750 mG (± 75 µT). The gain can be reduced to allow more hard-iron, or it can be increased to provide greater sensitivity. A magnetic calibration procedure must be performed after changing the gain.

Prior to factory calibration, the eCompass is demagnetized to eliminate any residual magnetic fields from the circuit components. If the eCompass is exposed to a strong magnetic field of 10 G or more, then it should be demagnetized again before performing a magnetic calibration.

In the Magnetic category of the Settings page, you can see the results of factory calibration of the magnetometer. The X, Y, and Z offsets can only be viewed on this form. X, Y, and Zr are changed automatically after acquiring data using the Calibrate Magnetics option on the Tools menu. The value for Vref will be 32767 if a vertical reference has not been saved. Vref is changed automatically when a good vertical reference is calculated using the "Capture Vertical Reference" option on the Tools menu.

If your ECV eCompass is equipped with both a liquid electrolytic sensor and a 3D accelerometer, the accelerometer bias correction feature is enabled. This feature

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[3] In this mode, the electrolytic sensor is used to correct accelerometer bias.

improves accuracy by combining data from the two inclination sensors. The electrolytic sensor has inherently stable offsets that can be measured near level in a quiet environment. There is virtually no change with time or temperature – gravity keeps the surface of the liquid level. However, electrolytic tilt sensor gain varies with temperature and the degree of liquid agitation. In unfortunate situations near resonance, the undulating liquid can produce measurement spikes that greatly exceed the actual motion.

On the other hand, accelerometer offsets can vary due to thermal hysteresis and drift over time and temperature. But MEMS are superior when operating at higher inclination and when mechanical vibration is present. Blending signals from the two sensors can produce a superior measurement of gravity.

The way the signals are combined can be tuned by the user for a specific application. Parameter settings direct the eCompass to capture only appropriate electrolytic tilt sensor data to be used for MEMS offset corrections. The eCompassTest application provides a special settings dialog to adjust parameters and view the calculated bias corrections.

Pitch and Roll Check

This is a simple test to check pitch and roll accuracy near zero degrees tilt. Place the eCompass on a flat surface and take readings for pitch and roll angles. Now rotate the eCompass precisely 180° and take another set of readings. The second pitch and roll readings should be the same magnitude but opposite signs of the first, i.e. the sum of the two pitch readings should be zero and the sum of the two roll readings should be zero.

This test is valid even when the flat surface is oriented at a steep angle of 20° to 40°. It does not, however, verify the scale factor accuracy of the tilt sensor. A known angle reference is needed to verify that the scale factor is also correct.

To get the best results, a great deal of care must be exercised. The bottom of the eCompass must be smooth and the surface must be very flat and free of dust and dirt. It is best to put the eCompass in Sample mode and acquire several samples for each direction to establish repeatability. A nearly invisible bump of 0.003" (thin sheet of paper) can easily result in 0.2° difference (±0.1°) depending on where it affects the eCompass.

If the liquid electrolytic tilt sensor is being used, its scale factor may be off due to agitation or splashing of the liquid. If the eCompass has been turned upside down or abruptly jostled, it is best to wait 10 or 15 minutes to allow some settling of the liquid. There may be residual change after this short time, but it occurs very slowly and should not affect results of this test.

Magnetometer Check

To verify that the magnetometer is calibrated and operating properly, place the eCompass on a flat surface along the edge of a fixed, non-magnetic straight-edge, like a wooden ruler. Make sure the eCompass environment is magnetically clean (no motors, ferrous materials, etc.). Using the query button on the View NMEA Sentences page in Sample mode, capture CCD samples to see MagX, MagY, and MagZ measurements from the magnetometer.

Rotate the eCompass and straight edge until either MagX or MagY approaches zero. Once there, rotate the eCompass exactly 180° by aligning the opposite side with the straight edge, taking care to position the magnetometer end of the eCompass at the same point along the straight edge. Capture additional CCD samples to verify that the measurement that was near zero, MagX or MagY, is still near zero and ideally the opposite sign. Any variation should be within 1% of the magnitude of the other measurement which is near full scale.

This technique works with a flat surface at any orientation; it doesn't have to be perfectly level. The test verifies that the magnetometer offset is null. Additional steps can be performed to verify that the full-scale readings for MagX and MagY are the same.

Using the eCompassTest Program

Running the eCompassTest Program for the First Time

The first time you run the eCompassTest software, you will see the dialog similar to the one in Figure 3 prompting you to enter the serial communication port and baud rate. The baud rate defaults to 19200 which is the rate used by the eCompass when it is shipped. Once you have established communication with the eCompass, you will not be prompted in this way unless the software is unable to communicate with the eCompass.
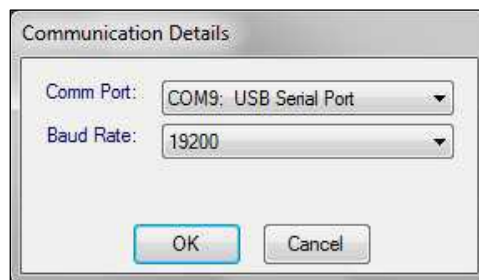

Figure 3

If the software cannot communicate with the eCompass, you will receive a dialog similar to the one in Figure 4:
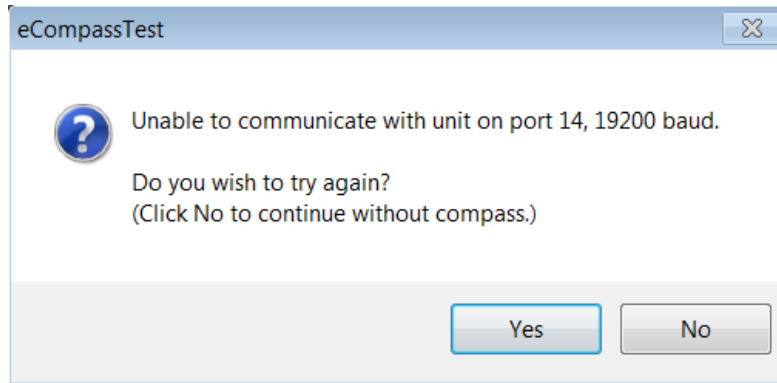

Figure 4

Click Yes from the dialog in Figure to try again. You will be prompted to enter the communication port and baud rate as in Figure 3. Clicking No allows you to proceed without connecting the eCompass.

If the software is able to communicate with the eCompass, a window similar to the one in Figure 5 (showing correct version information for the eCompass) will appear centered in the application's main window.
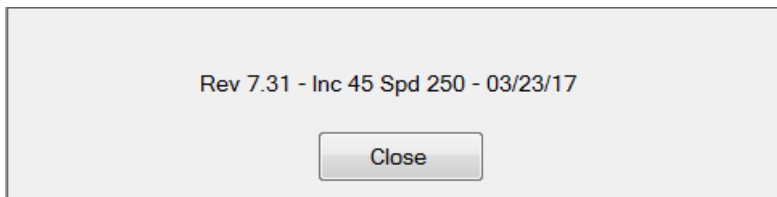

Figure 5

If you choose to proceed without connecting the eCompass, the window in Figure 6 will appear centered in the application's main window.

Figure 6

Any menu items and toolbar buttons requiring the eCompass will be disabled, but you will still be able to do the following functions:

- View log information
- View settings log information
- Modify software options
- Reconnect to the eCompass
- Create zip file to be sent to Jewell Instruments for debugging purposes
- View help

Description of the Software Main Screen

The eCompassTest Software Main Screen contains a menu, toolbar, information bar, and a scrollable area to hold application dialogs and windows. The toolbar allows easy access to a subset of the menu items. The information bar shows the eCompass ID, Port, Baud rate, unique Unit ID, Angles value, and (when applicable) GPS status. The Main Screen appears as shown in Figure 7.
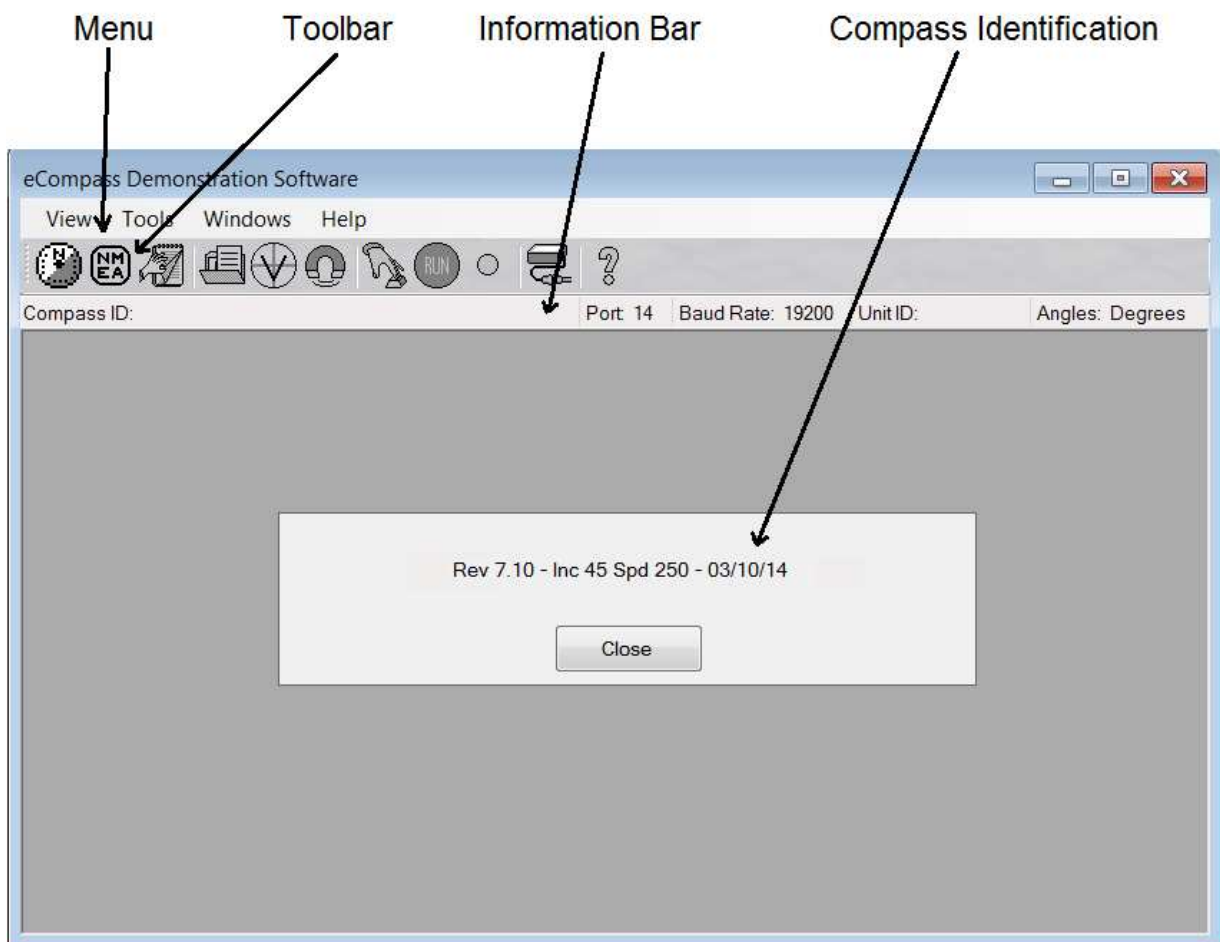

Figure 7

eCompass Installation

Before installing the eCompass, consider the following:

- Verify that the eCompass performs as expected in a test location free from magnetic interference and mechanical vibration.
- If the target location is free of local magnetic fields (permanent and induced), then the magnetic calibration procedure should not be necessary.
- If a magnetic calibration will be needed, you will need to capture a vertical reference in a magnetically clean location. Refer to section on Capturing a Vertical Reference.
- The reference is used to determine the magnetometer Z-axis offset during calibration.
- If the J2 connector is going to be used, install the cable before permanently mounting the eCompass.

Location

Choose a location with as little magnetic interference as possible. If there is a lot of ferrous metal, it may be necessary to decrease magnetometer gain to keep the X, Y, and Z signals from saturating. In this case, heading accuracy will decrease. The magnetization of the disturbing material may also change over time, which will require repeated calibrations to maintain eCompass accuracy.

Magnetic fields that arise from 50 or 60 Hz AC currents are significantly compensated, because the eCompass averages magnetometer signals over 18.2 milliseconds, which corresponds to 55 Hz. However, intermittent magnetic fields generated by motors or solenoids may not be compensated. Also, nearby wires carrying DC current can affect the magnetometer. If the generated field is static, it can be compensated. Otherwise, the field may affect the eCompass reading.

Finally, consider mechanical vibration to minimize its effect on the tilt sensor. Most of the noise caused by a piston engine can be compensated by tuning algorithms in the eCompass firmware. However, it may be desirable to orient the eCompass on an axis that is not aligned with the vehicle so that engine noise affects pitch and roll equally.

Mounting

Use brass or stainless steel screws to secure the eCompass in place. The label on the Jewell ECV enclosure indicates directions for positive pitch, roll, and magnetometer readings. The eCompass indicates North when the magnetic field is maximum in the positive X direction, and null in Y.

If the mounting platform is not level, pitch and roll offsets can be zeroed without affecting eCompass accuracy. An auto-zero function is provided on the tilt settings page in the eCompassTest software. Although it can be mounted in any

orientation within range, the best eCompass accuracy is achieved for small tilt angles because scale factor errors do not affect the tilt readings near zero.

Wiring to the Internal Connector (J2)

Perform the following sequence of steps to install the optional system wiring cable provided in the Jewell ECV eCompass evaluation kit. If a cover is not required, it can be removed and the MTA connector can simply be plugged into J2 as shown in Figure 8. In this case, the connector will not be retained in place by the cover. Contact Jewell Instruments about supplying a locking header and connector instead.

Figure 8

1. Remove the Jewell ECV cover by unscrewing the 4 stainless steel screws from the bottom of the case. If the screws are lost, replace with 10mm, M3-05, flat, Philips-head, non-magnetic #316 stainless. With the screws out, lift the cover first from the end opposite the connectors to remove.

   WARNING! DO NOT DISTURB THE POSITION OF U9.
   This is a vertical, thru-hole IC (HMC1001). Bending this sensor from its factory-set position will invalidate the magnetometer factory calibration.

2. Remove the black, snap-in plug from the 5/16" hole in the cover.
3. Insert a grommet into the hole. Make sure it is properly seated on both sides and that the opening for the wire is uniformly circular.
4. Feed cable (4-pair, #24 AWG, CAT5, non-plenum) through the grommet starting from inside the cover. The entire length of the wire will have to be fed through the grommet.

5. Rotate the wire to align the connector so that it can be plugged into the header on the card. Pin 1 will line up naturally so there is little chance of reversing the connection.
6. Plug the connector onto the 8 J2 header pins, making sure all 8 pins are inside the body of the connector. Also make sure that the connector is fully seated onto the pins.
7. If there will be any tension on the wire, it may be desirable to clamp a plastic cable tie or non-magnetic clamp around the wire on the inside edge of the grommet to relieve strain. Otherwise, cable stress will be transferred directly to the connector.
8. Pitch the cover down at the connector end and work it back over the RJ12 connector until it is properly seated.
9. Turn the eCompass over and replace the 4 stainless steel screws.

Calibrating the eCompass

Once the eCompass is mounted in its target location, the detrimental effects of local magnetic fields, both permanent and induced, can be largely compensated. An advantage of an electronic compass over its mechanical predecessor is that the compensation can be performed without additional hardware. A strap-down electronic compass like the Jewell ECV can be compensated more precisely than a mechanically gimbaled compass because the magnetometer remains fixed in its surroundings.

Compensation for permanent and induced fields is generally separated and referred to as hard-iron and soft iron calibration. Hard-iron errors are usually most severe and have the effect of shifting the center of a sphere from the origin within a 3 dimensional coordinate system. The purpose of a hard-iron calibration procedure is to determine where the center of the sphere lies so that appropriate X, Y, and Z offsets can be subtracted from the corresponding magnetometer signals to return the center to the origin. In algebraic form, hard-iron is represented by the a, b, and c coefficients in:

$$(x - a)^2 + (y - b)^2 + (z - c)^2 = r^2,$$

where x, y, and z are orthogonal components of the earth's magnetic field and r is the total field strength, which is an unknown constant.

Soft iron effects distort the shape of the sphere into an ellipsoid. The purpose of a soft-iron calibration procedure is to determine parameters of the ellipsoid, such as the relative lengths of the 3 axes and their orientation in space, so that an appropriate transformation can be generated that will reshape the ellipsoid into a sphere.

In both cases, it can be difficult or impossible to get good calibration data. The compass must remain fixed in its environment (vehicle, robot, boat, etc.) and both must be rotated together in the earth's magnetic field, ideally in all three dimensions. Since the effects of local magnetic fields remain fixed relative to the magnetometer as it rotates, they can be determined and compensated.

Since a boat or vehicle of any size cannot be inverted, Jewell Instruments offers a two-step calibration that relies on first acquiring a vertical reference outside the influence of the vehicle, then performing a simple, two-dimensional rotation while roughly level to determine all three components of hard iron. The rotation can be performed continuously, or individual samples can be captured. In both cases, the data collection algorithms are designed to ensure that in-range data from a complete rotation is collected before being analyzed.

The Jewell ECV eCompass has an onboard calibration capability embedded in the firmware that implements a least squares algorithm to compute hard-iron offsets that optimize accuracy. Either 2D or 3D data can be collected. For 2D collection, the firmware supports an option to use a previously stored vertical reference to estimate the Z-axis offset.

Calibration coefficients can also be calculated externally, using more powerful algorithms implemented in the eCompassTest PC software. These algorithms determine both hard-iron and soft-iron compensation coefficients. For 2D data collection, a minimum of 7 sampled data points or one complete rotation is required. After data is collected and new coefficients are calculated, the variation in total magnetic field is calculated using both old and new coefficients to determine which are best. Results are presented with suggested best choices for the user to accept or override.

For the case where it is possible to collect good 3D data, the eCompassTest software also offers an option for 3D hard and soft iron compensation. After collecting 3D data, the software calculates a set of 9 independent coefficients that best compensate for both sources of error. The iterative algorithm works to find the ellipsoid that best fits the collected data by minimizing the sum of the squared geometric distances between the collected data and the parametric ellipsoid.

Capturing a Vertical Reference

Select Capture Vertical Reference from the Tools menu to see a dialog (Figure 9) that instructs you on obtaining a vertical reference.

You may adjust the amount of units per division on the vertical scale of the graph, the number of readings to be taken, and whether or not the graph will update automatically; however, you cannot modify these values while collecting data. If you notice that the PC cannot keep up with the incoming data (on slower computers) and that you cannot stop the data collection, turn off the automatic update option. In this case, the PC will not be bogged down with updating the graph during data collection, and the graph will be drawn once after all data has been collected.

Locate the eCompass in an open place away from large metallic objects or structures, position the eCompass approximately level, and click the Read Data button. As valid readings are taken, the graph will plot the value (if automatic update is enabled), and the status bar will show progress. Once the specified number of readings have been taken, the Vertical Reference is calculated based on the data. You may then choose to apply the new value.
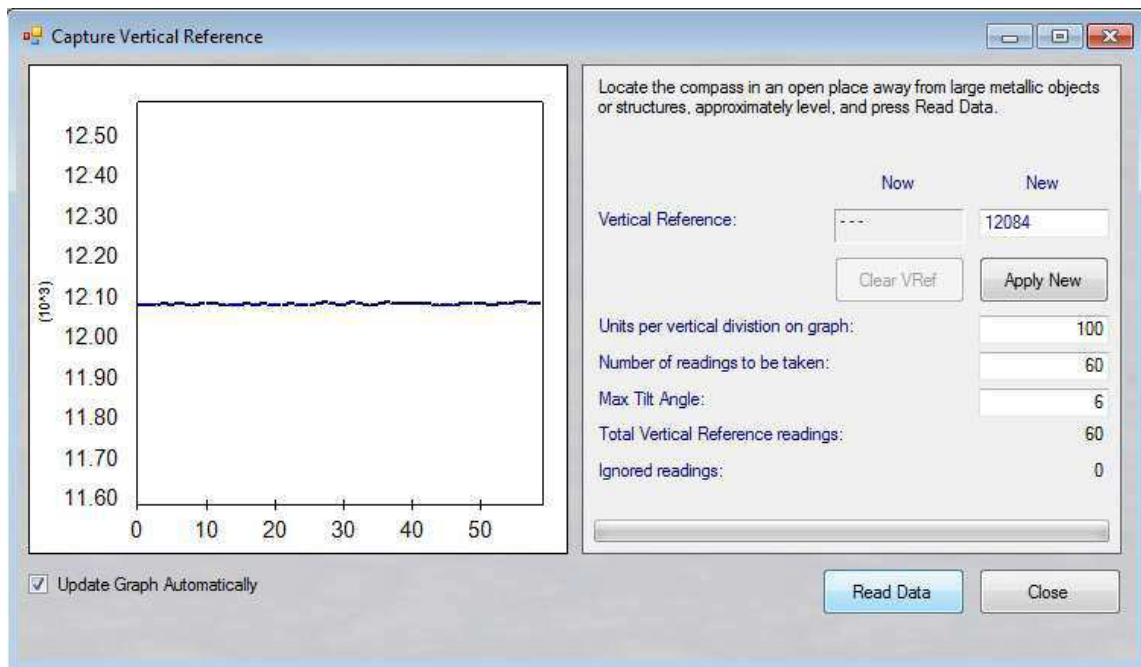

Figure 9

External Magnetic Calibration

Select Calibrate Magnetics from the Tools menu to perform magnetic calibration using the software algorithm residing on the computer being used. Select 3D data geometry where sample points are not coplanar or 2D when sample points are in an approximate horizontal plane. Use 3D only when large tilt angles can be achieved to generate enough variation in Z-axis data to produce a reliable offset. Use 2D if the eCompass is mounted in a boat, truck, RV, or other vehicle that only operates near level. If you have captured a vertical reference, the select 2D with Vertical Reference will also be enabled. In this mode, the stored Vref value is used to estimate the Z Offset.

Once you have selected the data geometry option, select the data collection option: Capture Every [n] Readings, Capture Readings Every [n] Degrees of Rotation (2D only), or Multi-step Samples Triggered Manually. Based on the selected option, you may specify various values such as the number of readings to take, the number of degrees between captures, the number of readings to average for each captured sample, etc.

The relationship between "Readings [n] to skip between captures" and "Number of readings to take" is important for timed data collection. The reading rate is 825 per minute and the maximum number of readings to take is 3000. If n=0 (no skipping) and the number of readings to take is 850 (default value), then the capture sequence will complete in a little over a minute. During this time, the eCompass carrier must be maneuvered through at least one rotation to collect a complete set of magnetic data. If the maneuvering will take longer, either n or the total number of readings to take can be increased.

The software will record three files in the LogFiles subfolder:

1. a data file containing the data that was collected, CalData
2. a results file containing the results of the calibration, CalResults
3. an intermediate file containing progress data, CalProgress

These files contain information that can help to diagnose calibration issues.

For the Jewell ECV eCompass, a Switch to Onboard Magnetic Calibration button will be visible at the bottom of the window. While not collecting data, click this button to switch to onboard magnetic calibration.

3D (Figure 10)

To collect continuous 3D data where sample points are not coplanar, select the "Capture every [n] readings" option, begin rotating, pivoting, and rolling the unit, and click the Start button. Three histogram style graphs show the X, Y, and Z data distribution as it is being captured. During data collection, use the Pause/Resume button to suspend/resume taking readings. Once you have collected the specified number of readings, data collection will stop and results

will be calculated. The Finish button is enabled after ten readings have been collected, but it may be necessary to collect many more than this minimum number to produce accurate results.

To manually collect 3D data, select the "Multi-step samples triggered manually" option and specify the number of readings to average for each captured sample. After clicking the Start button, position the eCompass at different fixed positions and click the Sample button to take each sample. Three histogram style graphs show X, Y, and Z data distribution as it is being captured. The Finish button is enabled after ten samples have been collected, but it may be necessary to collect many more than this minimum number to produce accurate results.
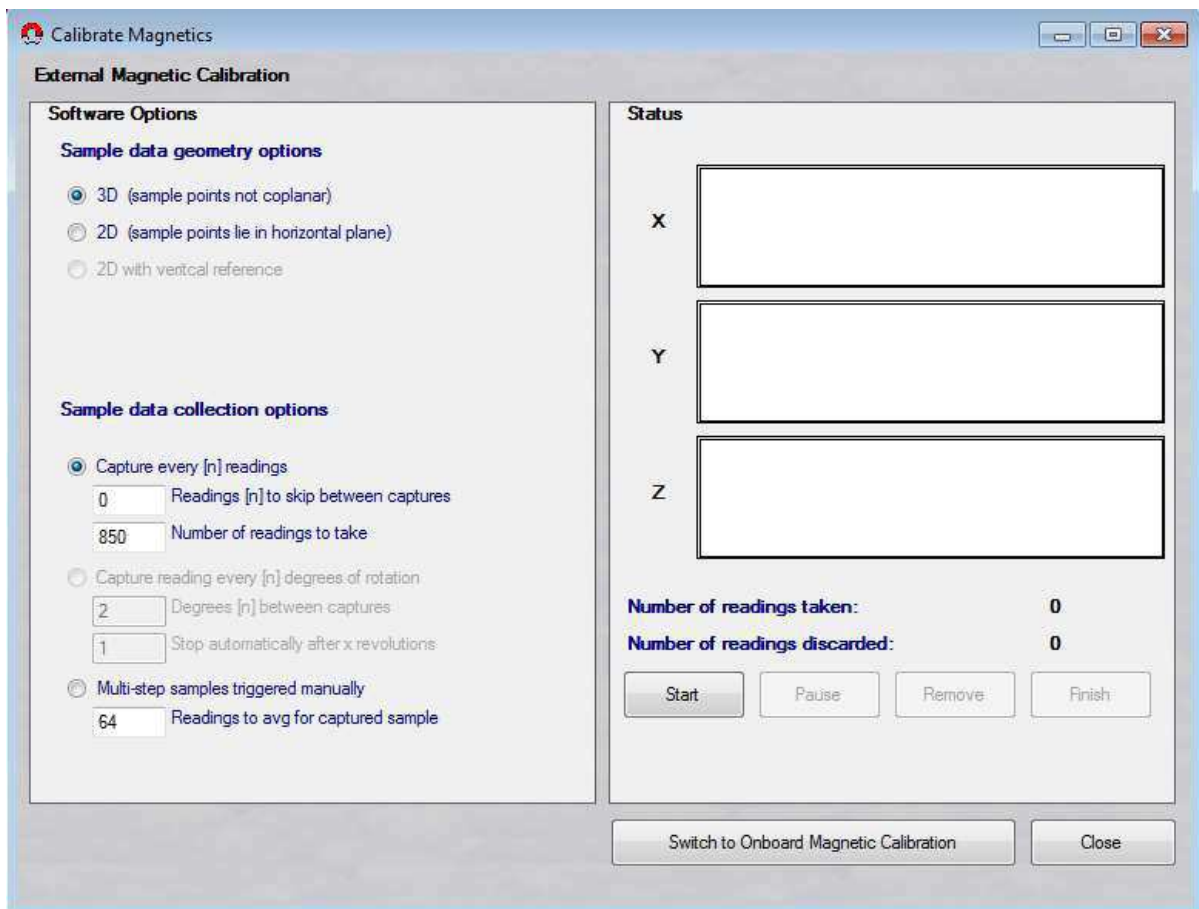

Figure 10

When not collecting data, you may click the Switch to Onboard Magnetic Calibration button to switch to onboard magnetic calibration.

2D or 2D With Vertical Reference (Figure 11)

To collect 2D data continuously in a circle, select the "Capture every [n] readings" option and specify the number of readings to take and the number of readings to skip between captures. Begin rotating the eCompass and click the Start button. A series of blue dots will be drawn on the circular graph to plot the data points. During data collection, use the Pause/Resume button to suspend/resume taking readings. Once you have collected the specified number of readings, data collection will stop and results will be calculated. The Finish button is enabled after six readings have been collected, but it may be necessary to collect many more than this minimum number to produce accurate results.

To collect 2D data based on angle, select the "Capture reading every [n] degrees of rotation" option and specify the number of degrees between captures and the maximum number of rotations. Begin rotating the eCompass and click the Start button. A series of blue dots will be drawn on the circular graph to plot the data points. Once you have completed the specified number of rotations, data collection will stop and results will be calculated. The Finish button is enabled after six readings have been collected, but it may be necessary to collect many more than this minimum number to produce accurate results.

To manually collect 2D data, select the "Multi-step samples triggered manually" option and specify the number of readings to average for each captured sample. After clicking the Start button, position the eCompass at different fixed positions and click the Sample button to take each sample. On the circular graph, discarded readings will appear as gray dots, and each collected sample is drawn as a blue X. The Finish button is enabled after six samples have been collected, but it may be necessary to collect many more than this minimum number to produce accurate results.
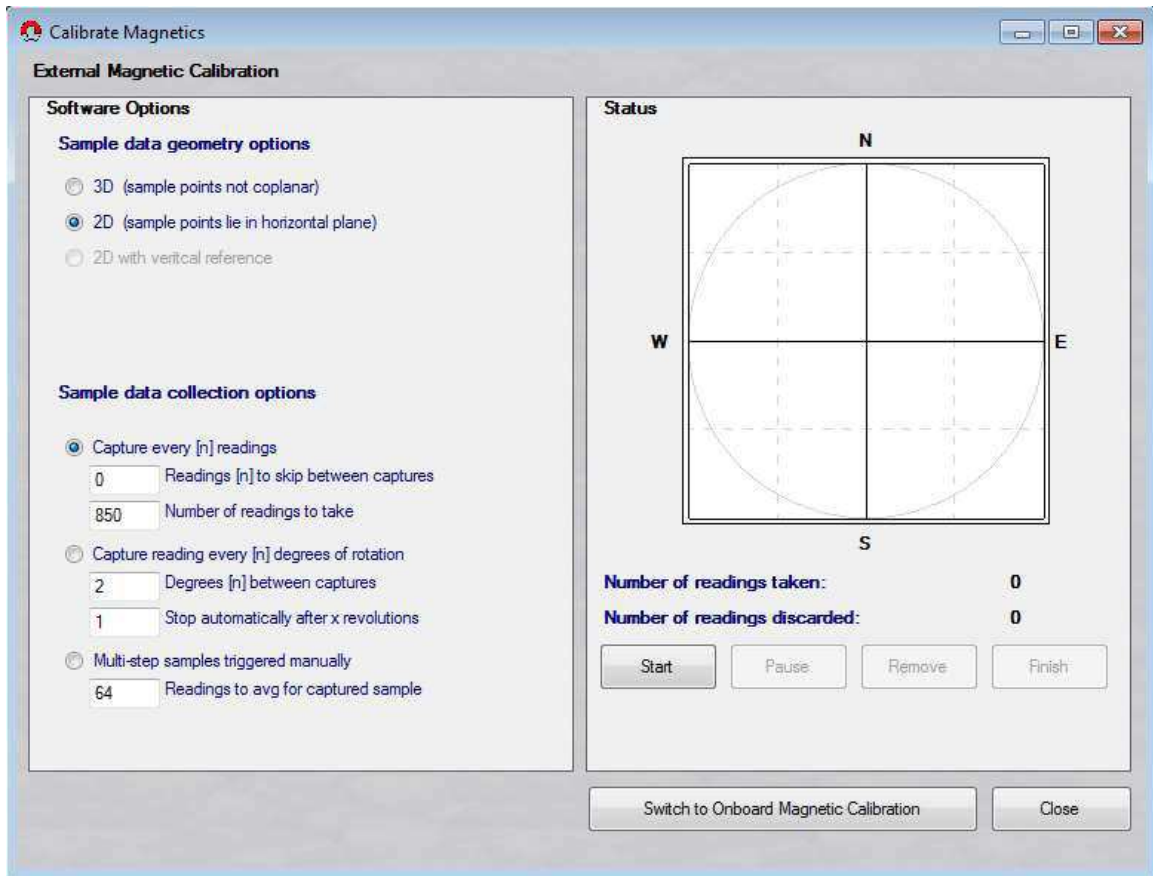
Figure 11

If you have trouble performing a magnetic calibration on the eCompass, this may mean that the magnetic settings have been corrupted. In this case, you can Reset the Magnetic Calibration to restore the factory default magnetic settings. You will then need to successfully perform a magnetic calibration. Use this option with caution!

External Magnetic Calibration Results

If the new results produce less variation in total magnetic field strength than the old, then the new offsets will be shown in boldface, and the Use New button will be highlighted in Figure 12. Likewise, if the application of soft-iron gains produces the least variation, the Use Soft Iron Gains checkbox is checked. Either or both of these can be overridden. You can toggle between using the old and new values by clicking the Use Old and Use New buttons, respectively.

The value labeled Mag Total 3 Sigma in the dialog is a percentage that means that 97% of the calculated total field magnitudes fall within a range centered on the average, plus or minus the indicated percent of average. The value shown in the New column includes soft-iron correction when the Use Soft Iron Gains checkbox is checked. The value shown in the Old column depends on the existing soft-iron setting in the eCompass.

The value labeled Ellipticity is the percentage difference between the major and minor axes of the calculated ellipse that best fits the data. The value shown is 100 times the ratio of the major axis divided by the minor axis. For 3D soft iron, the ratio is between the longest and shortest of the three axes. Using soft-iron compensation will not be suggested if the two axes differ by less than 0.5%.

Figure 12

External Magnetic Calibration Settings

The CalMag section of the eCompassTest.INI file contains various settings that affect external magnetic calibration. Most of these settings correspond to the data geometry and data collection options on the external magnetic calibration screen. However, the following settings are configurable only in the INI file:

CalMagTC

Smoothing time constant for calculated magH

CalNumAvg2DTilt

Number of tilt readings to average on both sides of each data point

CalSoft3DMaxIter

Number of iterations before aborting soft-iron algorithm

CalBeforePauseIgnoreCount

Number of CCD sentences to discard before pausing data collection

CalIgnoreCount

Number of CCD sentences to ignore when data collection starts initially or resumes after being paused

CalTimeoutCount

Number of CCD sentences to capture before terminating automatically

CalVrefMaxTilt

Maximum tilt angle for averaging calculated vertical magnetic component to determine Z hard iron

Onboard Magnetic Calibration

Embedded in the firmware of the Jewell ECV eCompass are routines to collect and analyze magnetic calibration data. Select Calibrate Magnetics from the Tools menu to perform magnetic calibration. If the external magnetic calibration dialog appears, use the Switch to Onboard Magnetic Calibration button to switch the eCompass from external to onboard calibration mode. Also, you may specify onboard or external calibration from the Magnetic Tab of the Settings dialog.
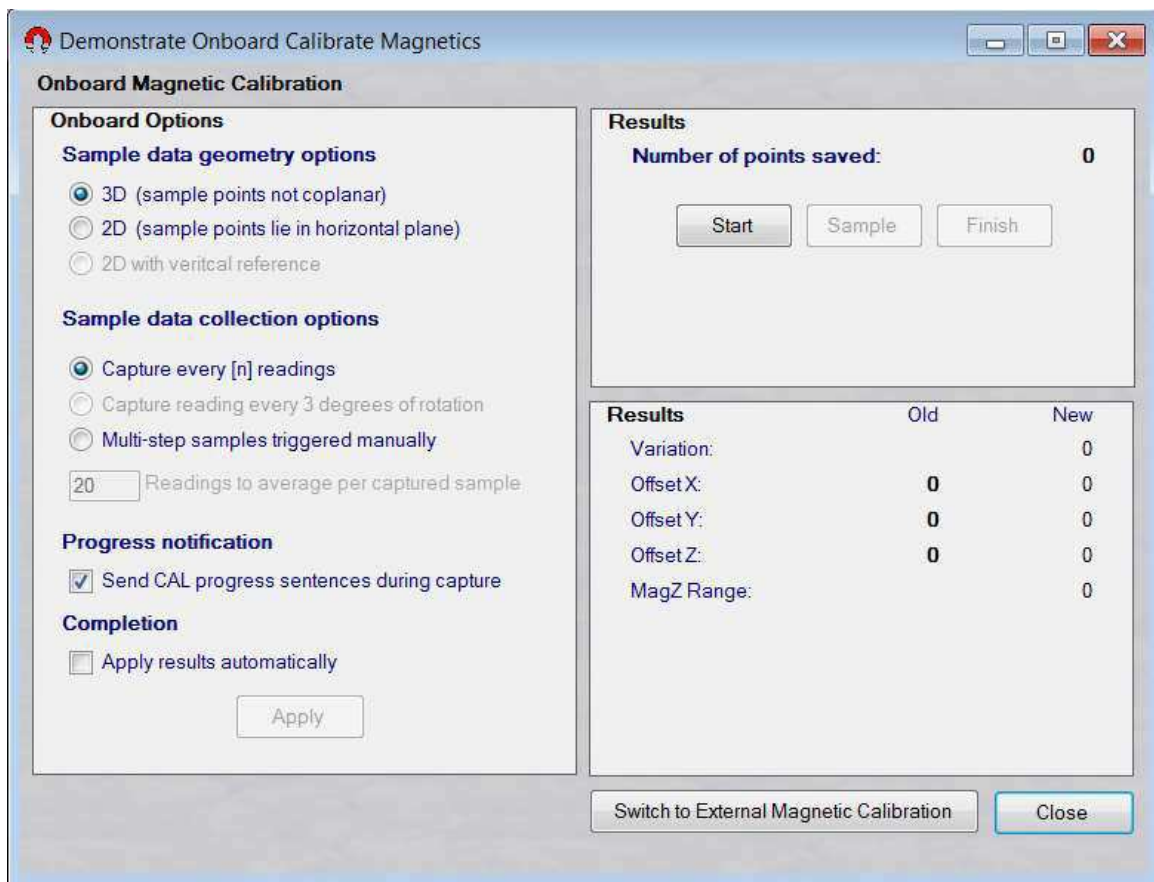

Figure 13

Select 3D data geometry if sample points are not coplanar or 2D when sample points are in an approximate horizontal plane. Use 3D only when large tilt angles can be achieved to generate enough variation in Z-axis data to produce a reliable offset. Use 2D if the eCompass is mounted in a boat, truck, RV, or other vehicle that only operates near level. If you have captured a vertical reference, the 2D with vertical reference will also be enabled. In this mode, the stored Vref value is used to estimate the Z Offset.

Once you have selected the data geometry option, select the data collection option: Capture every [n] readings, Capture readings every 3 degrees of rotation

(2D only), or Multi-step samples triggered manually. Based on the selected option, specify either "Readings [n] to skip between captures" or "Readings to average per captured sample."

The relationship between "Readings [n] to skip between captures" and the fixed number of readings to take is important for timed data collection. The reading rate is 825 per minute and the number of readings to take is 120. If n=0 (no skipping), then the capture sequence will complete in less than 9 seconds. Set n=6 to complete the capture sequence in a little over a minute (825 / 7 = 118). During this time, the eCompass carrier must be maneuvered through at least one rotation to collect a complete set of magnetic data. If the maneuvering will take longer, increase n up to a maximum of 255 (roughly 37 minutes of capture time).

You may also specify whether the eCompass should send the CAL calibration NMEA sentences during capture and whether the eCompass should apply results automatically.

3D

To collect continuous 3D data, select the "Capture every [n] readings" option, begin rotating, pivoting, and rolling the eCompass, and click the Start button. Once you have collected the specified number of readings, data collection will stop and results will be calculated. Also, after enough readings have been collected, you may click the Finish button to calculate the results.

To manually collect 3D data, select the "Multi-step samples triggered manually" option and specify the number of readings to average for each captured sample. Click the Start button, begin rotating, pivoting, and rolling the eCompass, and click the Sample button to take each sample. Once you have collected at least six samples, you may click the Finish button to calculate the results.

2D or 2D With Vertical Reference

Select the 2D sample data geometry option or you may select 2D With Vertical Reference if you have captured a vertical reference.

To collect 2D data continuously in a circle, select the "Capture every [n] readings" option and specify the number of readings to take. Begin rotating the eCompass and click the Start button. After enough readings have been collected, you may click the Finish button to calculate the results.

To collect 2D data based on angle, select the "Capture reading every 3 degrees of rotation" option. Begin rotating the eCompass and click the Start button. After enough readings have been collected, you may click the Finish button to calculate the results.

To manually collect 2D data, select the "Multi-step samples triggered manually" option and specify the number of readings to average for each captured sample.

Click the Start button, begin rotating the eCompass, and click the Sample button to take each sample. Once you have collected at least six samples, you may click the Finish button to calculate the results.

Onboard Magnetic Calibration Results

If you did not check the Apply Results Automatically checkbox, the suggested offsets will be displayed in boldface and the Use New or Use Old button will be highlighted appropriately.

The Old and New Variation values provide quantitative measures of how well the new and old offsets compensate for hard-iron. Accuracy is improved as variation decreases. If new offsets are not calculated, a message on the screen will provide an explanation.
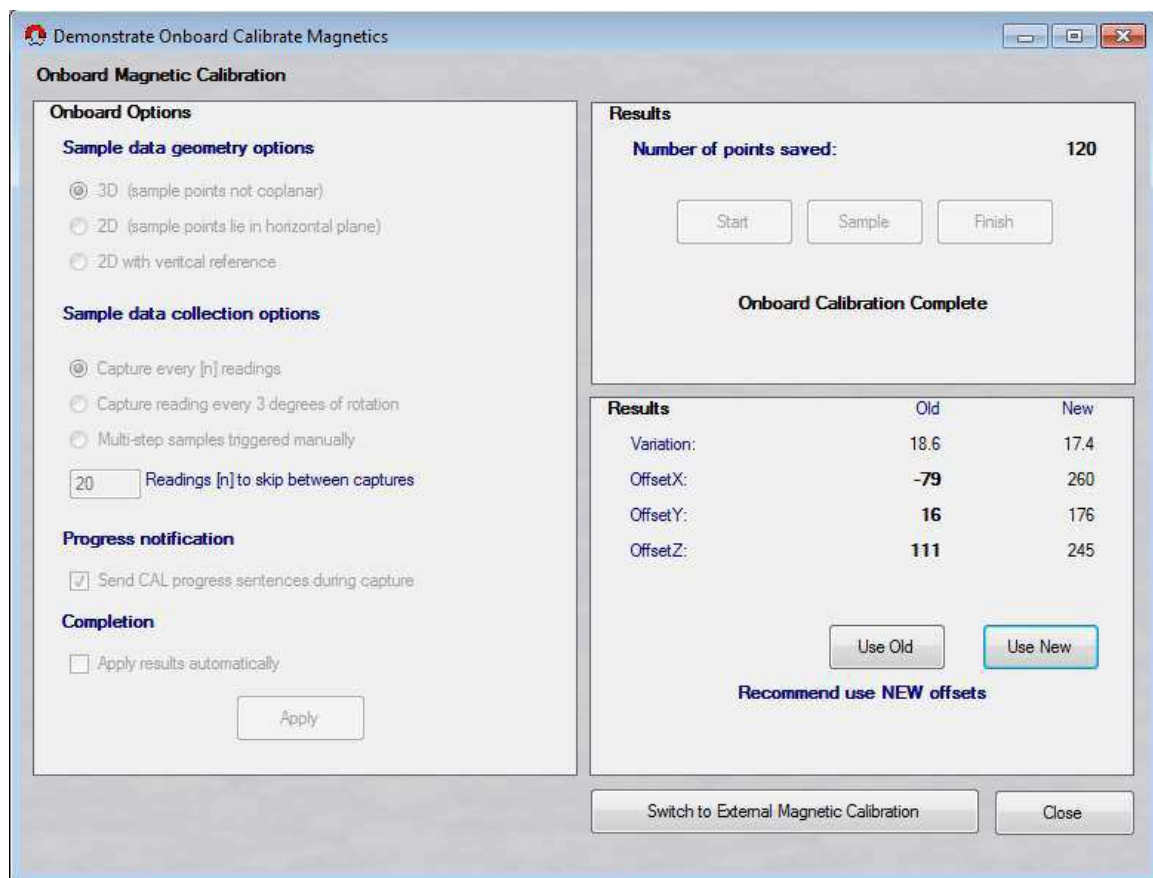

Figure 14

If you have trouble performing a magnetic calibration on the eCompass, this may mean that the magnetic settings have been corrupted. In this case, you can Reset the Magnetic Calibration to restore the factory default magnetic settings. You will then need to successfully perform a magnetic calibration. Use this option with caution!

Connecting a GPS

Augmenting the Jewell ECV's suite of sensors with GPS data can improve inclination and azimuth accuracy. When the eCompass carrier is circling, centripetal acceleration affects the roll sensor, resulting in an error that is proportional to rotation rate and ground speed. By combining ground speed from GPS and rotation rate from the onboard rate gyro, the Jewell ECV can calculate a centripetal acceleration component and use it to correct roll axis acceleration.

For the ground speed correction to work properly, the eCompass must be mounted such that the carrier and eCompass axes are in alignment. The roll-axis of the eCompass must experience the same centripetal acceleration, in the same direction, as the carrier. Any misalignment will lead to error in the corrected measurement.

Ground speed is obtained from a GPS $GPRMC sentence shown in the following example. The status field must be active and the field for ground speed must not be null. If the checksum is present, it must also be correct.

$GPRMC,123519,A,4807.038,N,01131.000,E,022.4,084.4,230394,003.1,W*6A

Where:
RMC	NMEA Recommended Minimum sentence C
123519	Fix taken at 12:35:19 UTC
A	Status A=active or V=Void.
4807.038,N	Latitude 48° 07.038' N
01131.000,E	Longitude 11° 31.000' E
022.4	Ground speed in knots
084.4	Track angle in degrees True
230394	Date - 23rd of March 1994
003.1,W	Magnetic variation
*6A	Optional hexadecimal checksum, always begins with *

If there is data in the magnetic variation field, it is used to calculate true heading. The value will be shown for the Variation setting on the General tab of the Settings dialog in the ECompassTest software. However, it will not replace the value stored in non-volatile memory which is restored following a reset. The GPS variation will also be reported in the HDG sentence and is used to calculate heading in the HDT and HTM sentences.

The serial GPS signal will usually be connected directly to the eCompass. For evaluation, the GPS can be connected to the PC using a USB or direct serial port. The ECompassTest software monitors the designated GPS port and automatically forwards the RMC sentence to the eCompass. The RMC string is shown in the communication log and the GPS status is displayed in the user interface.

Jewell Instruments can offer an economical USB-connected GPS for evaluation. The device is based on the Garmin 18x LVC receiver and connects through a Jewell Instruments USB cable assembly. The receiver is provided with a magnetic mount which must be kept well away from the eCompass.

Note Plugging in a USB GPS or a serial GPS connected via a Serial-USB adapter may cause Windows 7 to improperly recognize the device as a serial mouse, and due to the rapid data stream, the mouse pointer will begin to move erratically. If you experience this problem, exit the application and double click on the DisableMicrosoftSerialMouse.reg file located in the application folder. This file edits the registry to disable the serial mouse driver.