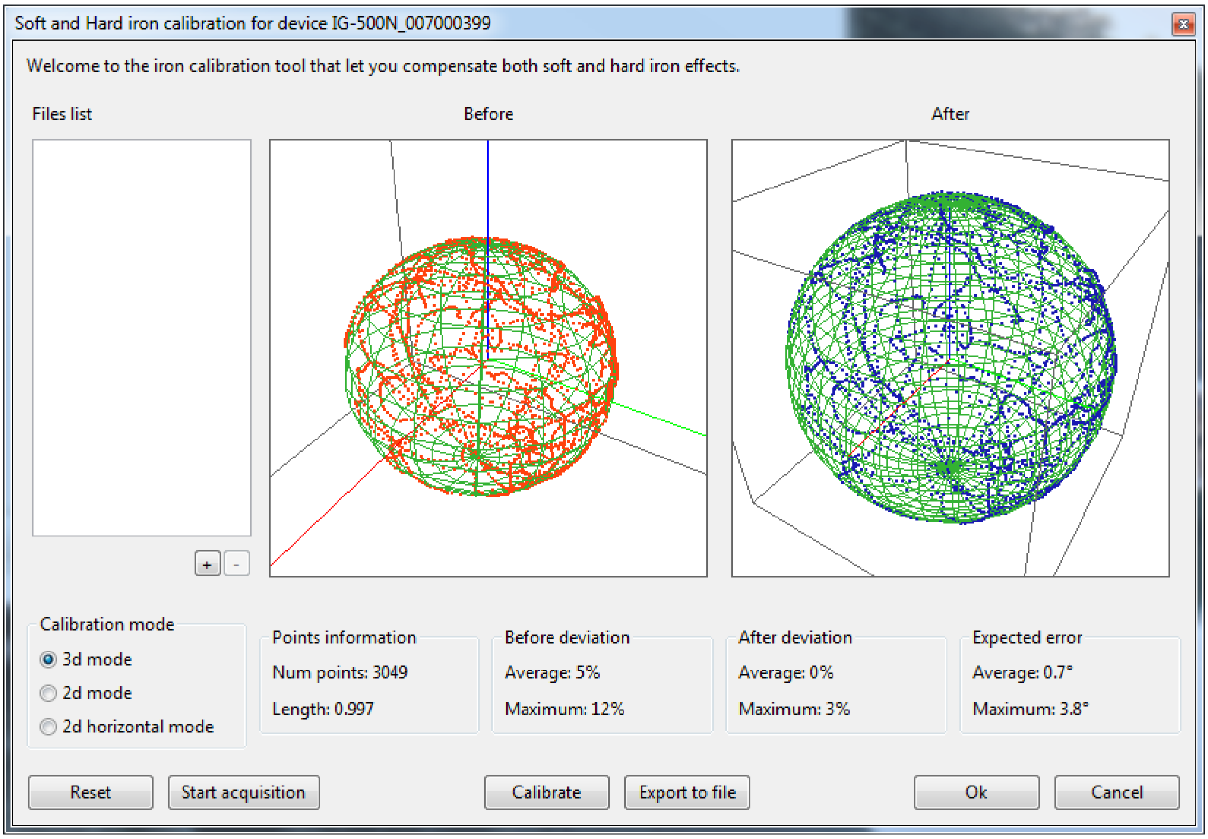
# IG Devices Magnetometers Calibration Tools

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# Revision history

| Rev. | Date | Author | Information |
|---|---|---|---|
| 5 | 19. Apr. 2012 | Alexis GUINAMARD | Updated documentation with new firmware behavior<br>• Added 2D Horizontal calibration method<br>• Added calibration Library information<br>• Removed Deprecated onboard calibration |
| 4 | 11. May. 2010 | Alexis GUINAMARD | Updated Address information |
| 3 | 16. Nov. 2009 | Alexis GUINAMARD | Updated specifications of the sbgCenter method, with the use of log files. |
| 2 | 5. February 2009 | Alexis GUINAMARD | Updated with IG-30 particularities, especially added a notice about magnetometers low pass filter cutoff frequency. |
| 1 | 8. July 2008 | Alexis GUINAMARD | First version of this document |

# Index

# 1. Overview and background

This document describes how to calibrate IG-500 and IG-30 devices, when they are strapped on an object that affects the local magnetic field.

IG devices are fully calibrated in factory. As for other sensors, magnetometers are fully temperature compensated. However, magnetic sensors are very sensitive to their close environment (mainly the object on which they are strapped) : Some materials can generate magnetic fields that will be summed with Earth magnetic field, and some other can distort the existing magnetic field. These effects will be measured by magnetometers and will not be distinguished from the Earth magnetic field, and therefore error will occur in heading estimation. The amount of error can be really significant in some cases.

SBG Systems chose carefully materials that do not disturb magnetic field in the IG devices hardware design. So the unit itself should not disturb the magnetic field so much. Unfortunately, it is sometimes impossible to remove that kind of materials in customer system. There are two kinds of distortions, which are described below.

## *1.1. Hard Iron distortions*

This kind of distortion is caused by magnets, or anything that acts as a magnet. It is very easy to magnetize objects like screws or nuts. Hard irons generate magnetic fields that are summed with the Earth magnetic field. Hard Iron effect shifts the magnetic field measured by magnetometers by a constant offset, whatever the device orientation is. Power supplies, which generate high current (several amperes) and their associated wires, may also generate magnetic fields.

## *1.2. Soft Iron distortions*

This kind of distortions are caused by ferromagnetic objects which are placed in the vicinity of the device. Iron, and some steels for example are ferromagnetic materials, but more generally, anything that sticks to a magnet is ferromagnetic. Ferromagnetic materials do not generate their own magnetic field. Instead of that, they react to existing magnetic field (in our case Earth magnetic field). By this way, Soft Irons distort the local magnetic field in a different way depending on the magnetic field direction. This is why soft Irons are much more difficult to compensate for.

SBG Systems magnetometers calibration tool provides a calibration method for both **Hard AND Soft iron effects**.

## *1.3. What can be compensated for and what cannot*

First it is important to distinguish two origins of distortion :

1. Distortions that come from materials which are fixed with respect to the device coordinate frame.
2. Distortions that are not fixed with the device, and move independently with respect to the device, or distortions that change over time.

The first origin can be compensated by using the calibration procedure, described in the next section.

As it is not possible to predict what will be the distortion of the second origin, it is not possible to compensate for those distortions. Distortions of the magnetic field act generally very locally, so in practice keeping the device far enough from the origin of the distortion will make the error negligible. Ideally, keep the device away from source of disturbances from at least 3 meters.

***Note:*** *Thanks to its internal Kalman filter, the IG-500 is able to cope for short term external distortions. Distortions that last up to a few minutes are handled without significant heading drift.*

# 2. Procedures

The main goal of the procedure is to rotate the device in different orientations to measure the magnetic field. SBG Systems' exclusive algorithms are able to map the magnetic distortions in each orientation and compensate for them. The more orientations will be passed through, the best will be the results.

If you cannot rotate the device freely in all possible orientations, the calibration algorithm will not be affected by that, and you will still get a good precision in orientation that were covered. However, a minimum of 9 significantly different orientations is required to perform the calibration.

Three types of calibration are provided depending on the degree of freedom of the device:

***Important Note:*** *In order to get good results, it is important to keep away from at least 3 meters all external sources of magnetic disturbances. Keep in mind that a building structure generally contains steel and other sources of interferences, as well as computers, chairs, desks, etc.*

## 2.1. 3D Calibration

3D calibration procedure is the standard procedure and will provide best performance in most applications. When user starts it, the device has to be rotated through the maximum amount of different orientations. User has simply to rotate the device regularly at a relatively slow rate (300°/s rotations are acceptable). Too fast movements may weaken results.

Ideally, the points should draw a complete ellipsoid shape. User has to try to cover a maximum of this ellipsoid shape to get the best results. After calibration, the magnetic field length should equal 1.0 in all orientations. In this case, all points after calibration should be placed on a unit 3D sphere.

## 2.2. 2D Calibration

Sometimes, it is not possible to move the device in 3D. A 2D calibration is intended for these cases. The procedure is just to rotate the device through a 2D circle. It is possible to cover less than a full circle, but best results are achieved with a full 360° coverage. Before the calibration is performed, the magnetometers readings should form a 2D ellipse. After calibration, the magnetic field length should be equal to 1.0 in all orientations. In the 2D case, all possible magnetic fields should be placed on a unit circle.

***Note:*** *This method do not require the 2D motion to be horizontal, but the motion should precisely fit on a plane. In addition, the sensor has to be used only in 2D after calibration is performed. Please consider the 3D or 2D Horizontal method if the plane requirement is not met.*

## 2.3. 2D Horizontal Calibration

In some applications, the sensor is intended to cover 3D orientations, but the calibration cannot be performed in 3D for technical, cost or time requirements. If we consider for example an aircraft, the 2D horizontal calibration can be used to quickly calibrate magnetometers on the ground. After this method is applied, the IG-500 sensor will only use magnetometers when it's horizontal. When a maneuver is being performed, then heading will rely on gyroscopes to keep accurate heading tracking.

# 3. Calibration methods

SBG Systems now supports two calibration methods that will provide either ease of use or tight integration into customer system. Both methods provide the same level of performance.

To compute magnetometers calibration, the two methods are using the `SBG_OUTPUT_MAG_CALIB_DATA` output. This 12 bytes buffer contains all necessary data to represent a magnetometers calibration point.

Thanks to this easy to use mechanism, advanced magnetometers calibration computation scenario can be imagined. For example, you can use the device while magnetometers calibration data are being acquired and compute, in real time, a new magnetometers calibration.

In the table bellow, you can see the main differences between the sbgCenter or sbgIronCalibration library methods.

| | sbgCenter | sbgIronCalibration Library |
|---|---|---|
| **Advantages** | • Very easy to perform<br>• Real time calibration or from log files<br>• Calibration results graphical display | • Real time and offline calibration<br>• Tight integration into customer solution.<br>• Integration possible on any platform that handle C programming with sufficient memory. |
| **Drawbacks** | • Needs a direct communication to a PC or a data-logger to store calibration data | • Requires C programming knowledge |

***Note:** In previous firmware revisions, an onboard calibration method was included. This method is now deprecated as IG-500 hardware cannot provide sufficient performance level (not enough memory to handle large amount of data points storage).*

## *3.1. SbgCenter method*

This method is advised to any user that can connect the device to a computer running the sbgCenter. This method is very flexible and allows real time calibration, as well as calibration with log files.

### *3.1.1. Presentation of the calibration window*

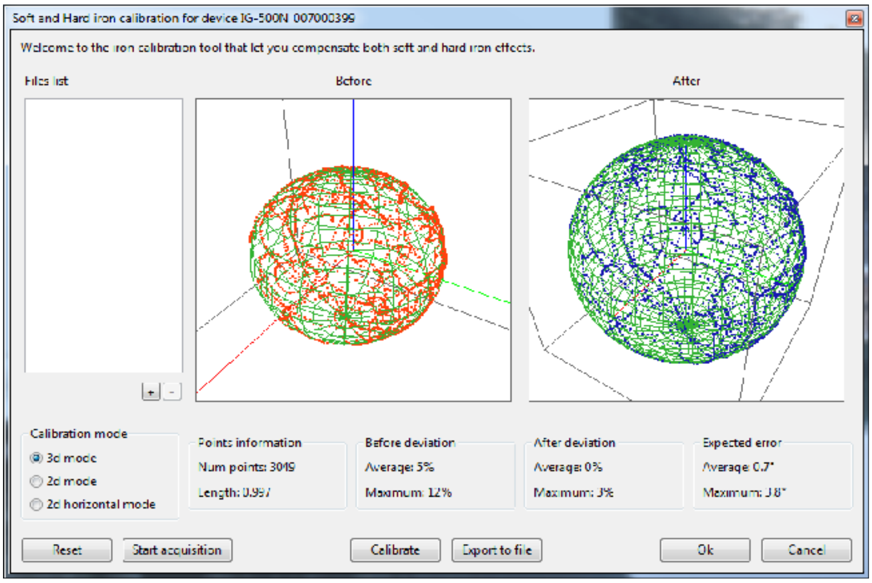

*Figure 1: Main window of the Iron calibration tool.*

On the left of the window, a file list is available to include log files for calibration. Multiple files can be used for a single calibration.

Then, two 3D plots are displayed :

- The first, “Before” shows all points in 3D as they are measured by magnetometers before any hard/soft iron calibration. This display is updated in real time.
- The second one, “After” will show the same points, transformed by the calibration algorithm. This display will only be updated once the Calibrate button is pressed.

These 3D plots can be easily rotated with the mouse, and you can also zoom in/out with the mouse wheel. When you rotate a plot, the second one will also rotate so that the field of view remains the same in the two displays.

On the bottom, several buttons allow to:

- Reset calibration data
- Start/ Stop Real time acquisition
- Calibrate acquired data
- Save acquired data for future use
- Finish or cancel calibration

Finally a few boxes will inform user about the calibration procedure, its results, and some quality hints :

- Calibration mode let the user choose between 2D and 3D modes. These modes can be changed anytime. If a set of orientation is already collected, the user can switch between the two modes to see where are the best results.
- Points information : The number of collected points is displayed. The more points will be collected, the best calibration will be achievable. The length of the current magnetic field is displayed once the calibrate button is pressed. This length should always equal one in all orientation with a good calibration.
- Before deviation: This information is updated each time the calibrate button is pressed. It informs about the distortion of the local magnetic field before calibration. This deviation only includes effects of the SOFT iron. Hard iron effects are already compensated. The average deviation is representative of the magnetic field. The maximum deviation informs about how noisy the environment is.
- After deviation: This is the deviation of the magnetic field, when the full calibration algorithm is applied. The average deviation is the most representative information. Max deviation represents the worse case of all measurements performed during calibration.
- Expected error: Finally, this box shows in term of degrees the expected error of magnetometers after the full calibration. The average error is the most representative information. Max error represents the worse case of all measurements performed during calibration. If the max error is high, it may come from a disturbed magnetic field during calibration.

### *3.1.2. Real Time Procedure*

Now, lets start the calibration procedure. Before launching the calibration procedure, it is recommended to put the device in a place free of external magnetic fields (more than 3 meters of any source of distortion).

*Step 1: Start/Reset the procedure*

Once you have started the Soft and Hard Iron Calibration Tool, the following window appears. When the device is ready for calibration, you can click on the Start Acquisition button.

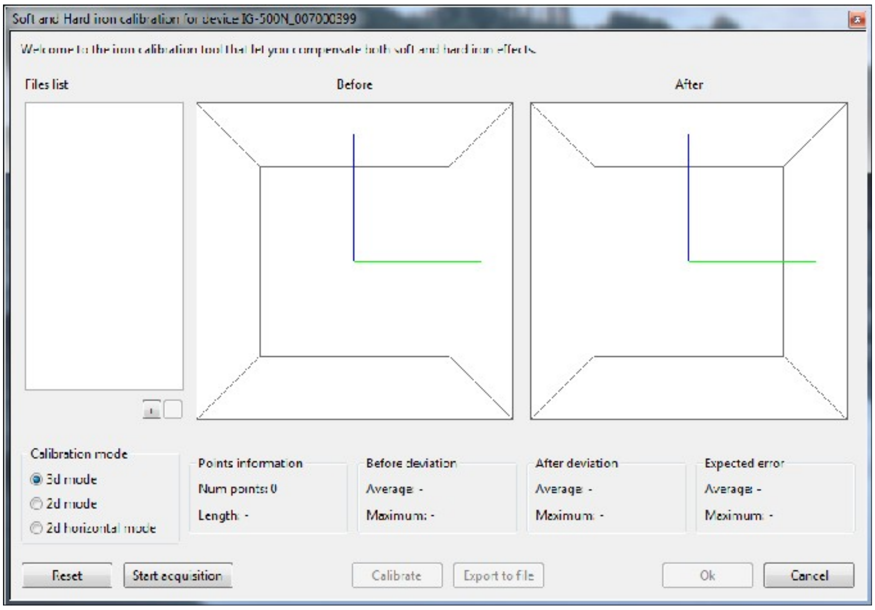


*Figure 2: The window of the calibration tool, before the calibration really starts*

*Step 2: Rotate the device*

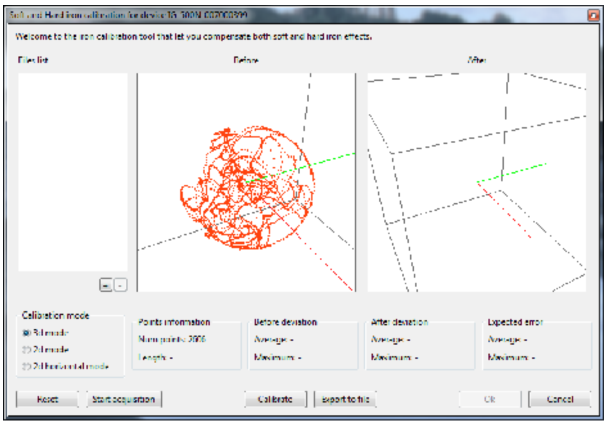

*Figure 3: Points are first displayed in the "Before" plot (3D mode)*

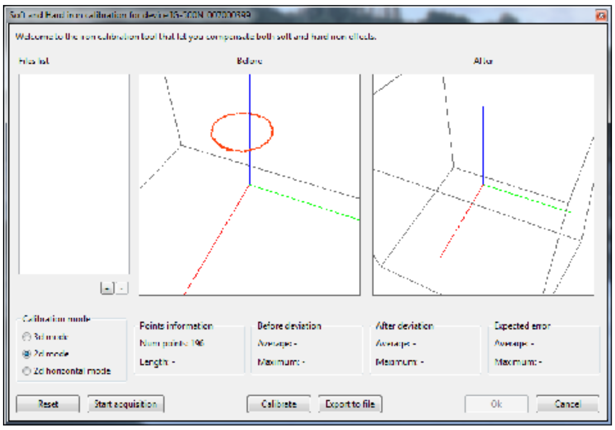

*Figure 4: Points are first displayed in the "Before" plot (2D mode)*

*Step 3: Press the "Calibrate" button*

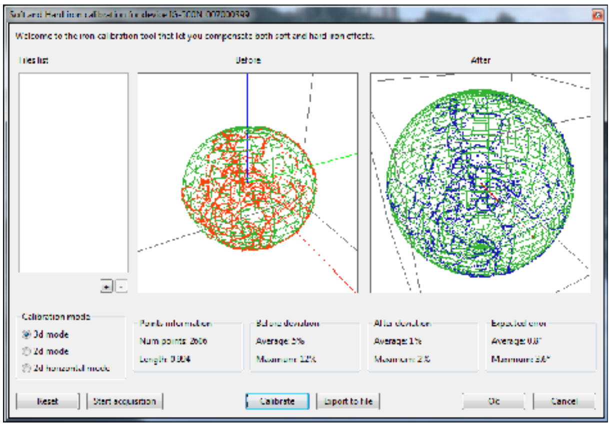

*Figure 5: The ellipsoid (left) and the sphere (right) should fit with the blue points after the calibration is performed.(3D mode)*

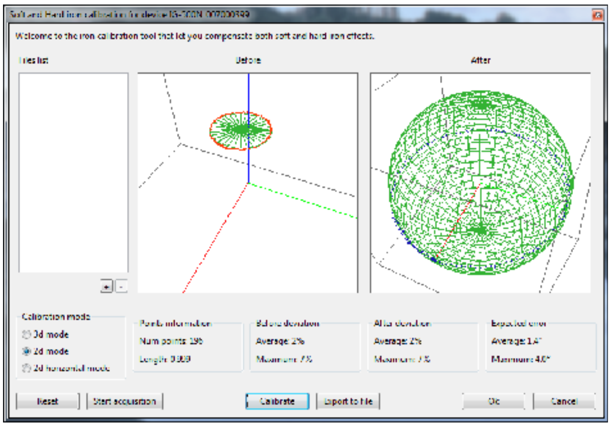

*Figure 6: The ellipse (left) and the sphere (right) should fit with the blue points after the calibration is performed.(2D mode)*

*Step 4: Write results in the device RAM*

By clicking the OK button, the calibration data will be sent to the device RAM. If the device is powered off, the new calibration data will be lost.

*Step 5: Write results in the device Flash memory*

Once the calibration is done, the sbgCenter allows the user to save current calibration data from RAM to the flash memory. By doing this, the calibration will stay active after any reboot of the device.

### 3.1.3. Log files procedure

When using the IG device in embedded environment, it is not always possible to calibrate the device while being connected to a PC.

However the log file method allows performing the calibration with the device in place, by simply logging the Magnetometers Calibration Data buffer of the device. This n*12 bytes buffer has to be written in binary format directly into a ".mag" file.

The Magnetic calibration tool can import these logs, and multiple files can be used for a single calibration. The tool also allows saving the log data files after real time acquisition. The sbgCenter is also able to generate these ".mag" files directly from a sbgCenter recording using a provided export plugin.

In order to start the log file procedure, once you have logged some magnetic calibration data, you simply have to push the [+] button in the main window. It is possible to select multiple files directly in the file window.

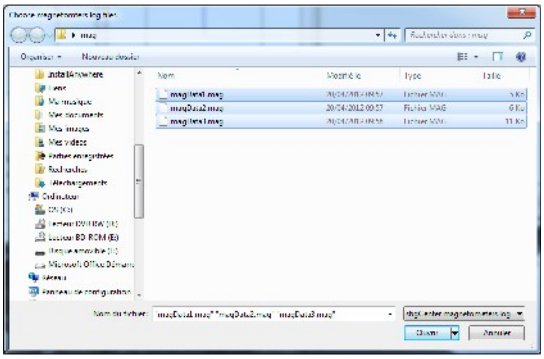

*Figure 7: Magnetometers file selection*

Then the main window shows the different logs selected, with each log a different color. It is possible to remove a log file from the calibration by pressing the [-] button.

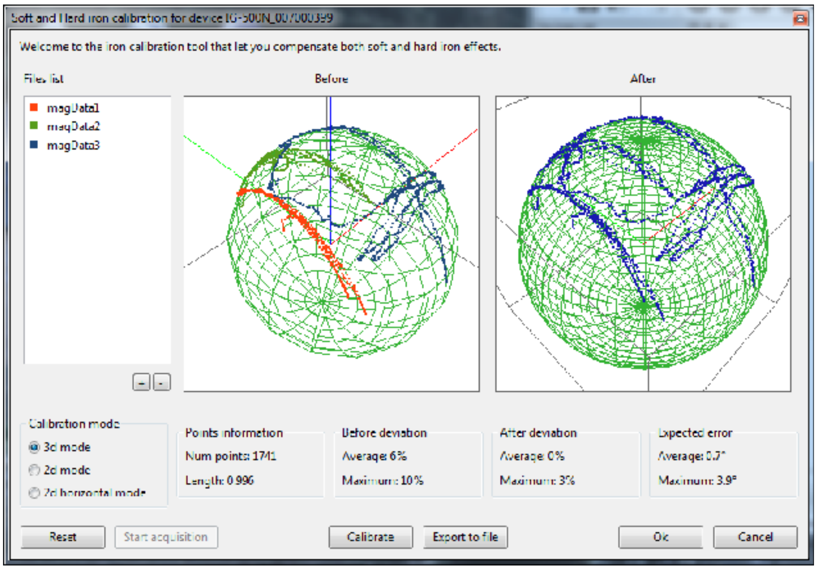


*Figure 8: Results of a calibration performed with three log files*

***Note:** See the ig500LogMagFile example project to see how to generate .mag log files.*

## 3.2. The sbgIronCalibration library

The sbgIronCalibration library is a C library designed to compute magnetometers soft and hard iron compensation based on a list of magnetometers calibration data buffer. The library has been designed to use indifferently real time data and/or log files.

### 3.2.1. Procedure

When using the library, the following procedure is followed:

- Initialize the sbgIronCalibration library with your SDK serial key
- Add some magnetometers data either in real time or by using a magnetometers calibration log file (.mag file). This file format is the same as for the sbgCenter, so the log file can be easily checked with the sbgCenter.
- After you have added enough points, compute the magnetometers calibration. This method will fill a magnetometers calibration results structure that contains the calibration parameters and some quality indicators.
- The calibration parameters are finally fed into the sensor thanks to the sbgCom, sbgCan libraries, or direct low level communication.

### 3.2.2. Getting the library

If you intend to use the calibration library please contact SBG Systems support team.

The library is cross-platform and is provided with the following items:

- Full C source code (Visual C++ project, or Unix build script tool)
- Pre-compiled static library or DLL for Windows operating systems.
- Full library doxygen documentation
- ig500IronCalibExample for real time magnetometers calibration
- ironCalibExample for log based magnetometers calibration

# 4. How to solve problems and improve results

## 4.1. Troubleshooting

The magnetic calibration algorithm has some requirements that need to be met in order to provide consistent and accurate calibration data.

| Description | How to solve |
|---|---|
| The calibration procedure could not end correctly because not enough significantly different points were available. | ● Move the device in significantly different orientations. |
| The points do not describe a valid ellipsoid (3D mode) or ellipse (2D mode) : Magnetic field is too noisy or distorted by external disturbance. | ● Move the device away from external magnetic field, power supplied, or other sources of disturbance<br>● Turn off disturbing electronic devices.<br>● Check that magnetometers has a sufficient bandwidth : A 30Hz low pass filter setting is good. |
| The magnetic field is too strong, or the device has been magnetized and magnetometers are saturated. | ● Try to let more distance between strong magnetic fields<br>● Try to degauss the device |
| 2D calibration procedure could not be performed because the rotation is not performed in a real plane | ● Try to keep movements through a real plane.<br>● Try the 3D procedure, or the 2D Horizontal procedure. |

## 4.2. Advises and limitations

### 4.2.1. Cover a maximum of different orientations

Best results will always be given when a wide range of orientations is covered during calibration. In theory only a few orientations would be necessary to map the whole magnetic field. But due to noise measurement, external magnetic fields and other effects, it is always better to collect the maximum amount of data to get good results.

### 4.2.2. Limited degrees of freedom

If the device cannot be rotated freely in all orientations, the algorithm will still be accurate, but only in orientations that were covered during calibration procedure.

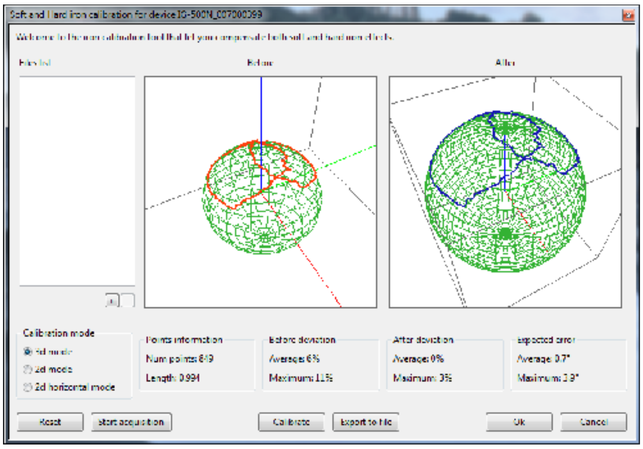

*Figure 9: Example of a calibration that can be achieved in marine applications (3D mode)*

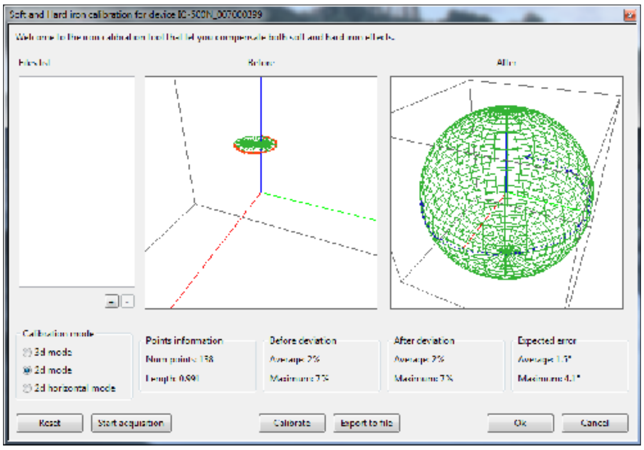

*Figure 10: Example of a calibration with limited rotations (2D mode)*

### 4.2.3. Keep away from any external sources of distortion

The magnetometers and the calibration algorithm cannot distinguish between distortions caused by external magnetic fields and distortions caused by the object on which the device is strapped. Those external distortions can be generated by the building structure, or Iron desks, computers etc.

It is therefore very important to move away the device from ferromagnetic objects within about 3 meters.

***Note:*** *This recommendation becomes even more important if the calibration is performed within a limited set of orientations.*

### 4.2.4. Problems inherent to 2D mode

In 2D mode, the calibration has to be carefully performed on a plane, which can be horizontal, or not. If it is not possible to cover a real plane, try the 3D, or the 2D horizontal modes.

# 5. Support

If you still have some questions after reading this document, we would be glad to help you, so please feel free to contact us. Please do not forget to mention your Device ID of your IG-500 (written on your IG-500's label).

You can contact us by:

- Email : support@sbg-systems.com
- Phone : +33 (0)1 80 88 45 00