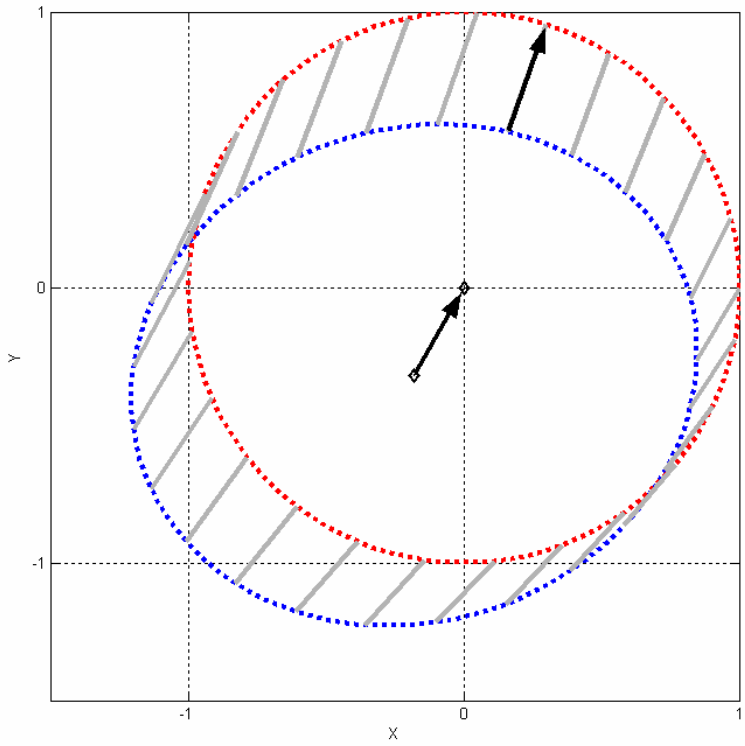
Magnetic Field Mapper

MT Software Add-on

User Manual



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Revisions

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1 Introduction

An MTi / MTx motion tracker (miniature inertial measurement unit) can be used to easily and accurately record 3D orientation. When an MTi or MTx is mounted to an object that contains ferromagnetic materials, the measured magnetic field is distorted (warped) and causes an error in measured orientation.

However, the disturbance of the magnetic field caused by mounting the MTi / MTx on a ferromagnetic object can be corrected for using a specialized calibration procedure that is described in this document. The calibration procedure can be executed in a few minutes and yields a new set of electronic datasheet values (extended Motion Tracker Specification (eMTS) data) that can be written to the MTi / MTx non-volatile memory. Once written to the eMTS-data, the orientation data calculated by the MTi / MTx, will be accurate even when mounted on the ferromagnetic object.

The calibration procedure is suitable for both 3D applications, where the object is rotating through a substantial range of orientations (e.g. a camera), and 2D applications where the object moves more or less in one plane (e.g. a car or boat).

An accurate calibration is obtained by recording the MTi / MTx signals while rotating the object, with the MTi / MTx mounted on it, in a space without other, nearby, ferromagnetic materials. Once the object is rotated over a sufficiently large amount of orientations, the MagField Mapper add-on can then calculate new calibration parameters that can immediately be used in the MTi / MTx.

The calibration has only to be performed once during the period in which the MTi / MTx is mounted on the same location on the object. If properly carried out, the resulting accuracy will be comparable to the accuracy experienced with the MTi / MTx without any ferromagnetic materials nearby.

NOTE: the Magnetic Field Mapper add-on is backwards compatible with the MT9-B.

2 Theory of Operation

2.1 Background

The direction of the measured earth magnetic field is used as a (3D) compass to determine the direction of the north (heading or yaw), used as an absolute reference in the calculation of 3D orientation.

A locally disturbed (warped) magnetic field causes an error in orientation that can be quite substantial. The earth magnetic field is altered by ferromagnetic materials, permanent magnets or very strong currents (several amperes). Whether or not an object is ferromagnetic should preferably be checked by using the motion tracker's magnetometers. It can also be checked with a small magnet, **but be careful, you can easily *magnetize*** some ferromagnetic materials, causing even larger errors. If you find that some object is magnetized (hard iron effect), this is often the case with for example stainless steels that are normally not magnetic, it may be possible to "degauss[1]" the object.

NOTE: **Never expose the MTi or the MTx to strong magnetic fields.** The MTi and MTx contains the absolute possible minimum of ferromagnetic materials ("hard" and "soft" magnetic materials). Nonetheless, some minor components can be magnetized permanently by exposure to strong magnetic fields. This will not damage the unit but will render the calibration of the magnetometers useless, typically observed as a (large) deviation in heading. For mild magnetization it may be possible to compensate for the magnetization of the device by a re-calibration (magnetic field mapping). Taking care not to expose the MTi or the MTx to strong magnetic fields, such as close proximity of permanent magnets, speakers, electromotor, etc. will make sure magnetization does not occur.

In practice, the distance to the object and the amount of ferromagnetic material determines the amount of disturbance.

The disturbance of the earth magnetic field can be divided into two kinds of effects:

1. Disturbance caused by objects in the environment near the motion tracker, like file cabinets or vehicles, that move ***independently***, with respect to the MTi / MTx. This type of disturbance is ***non-deterministic***, and cannot be fully compensated for. However, the amount of ***error*** caused by the disturbance can be ***reduced*** using the option 'Adapt to magnetic disturbances' in the MT Software/SDK.

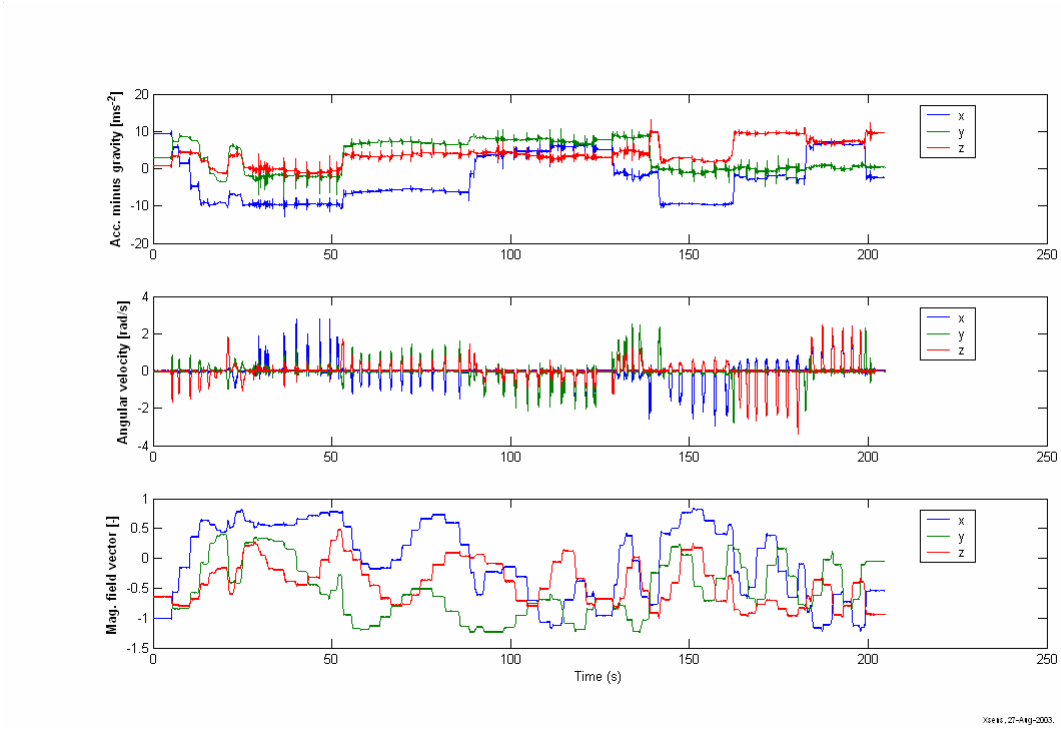
2. Disturbance caused by mounting the MTi / MTx to an object of which the motion is to be recorded (the MTi / MTx moves with the object). The error in magnetic field only depends on the orientation, and can therefore be predicted (i.e., it is deterministic) and

[1] Degaussing is a procedure to apply strong alternating magnetic fields with decreasing magnitude in random direction to an object that has been magnetized. The effect of the strong alternating fields is to remove any magnetized (aligned) domains in the object. If you degauss, please make sure the MTi / MTx is not anymore mounted on the object!

taken into account during motion capturing. Using a mapping of the disturbance (warping) of the magnetic field the errors caused by this type of disturbance can in theory be reduced to zero. The calculations and methodology required to achieve this is supplied by the MagField Mapper add-on and this documentation. This type of correction is commonly known as compensation for hard and soft iron effects.

2.2 Method

In a non-disturbed magnetic field, the 3D measured magnetic field vector has a magnitude of one and therefore all measured points lay on the circumference of a sphere with the centre at zero. In the case of a disturbed magnetic field, this sphere is both shifted and warped. The calibration procedure described in this documents aims to derive a function that maps the measured magnetic field vector to a sphere. This function is then implemented in new eMTS data, stored in non-volatile memory in your MTi / MTx.

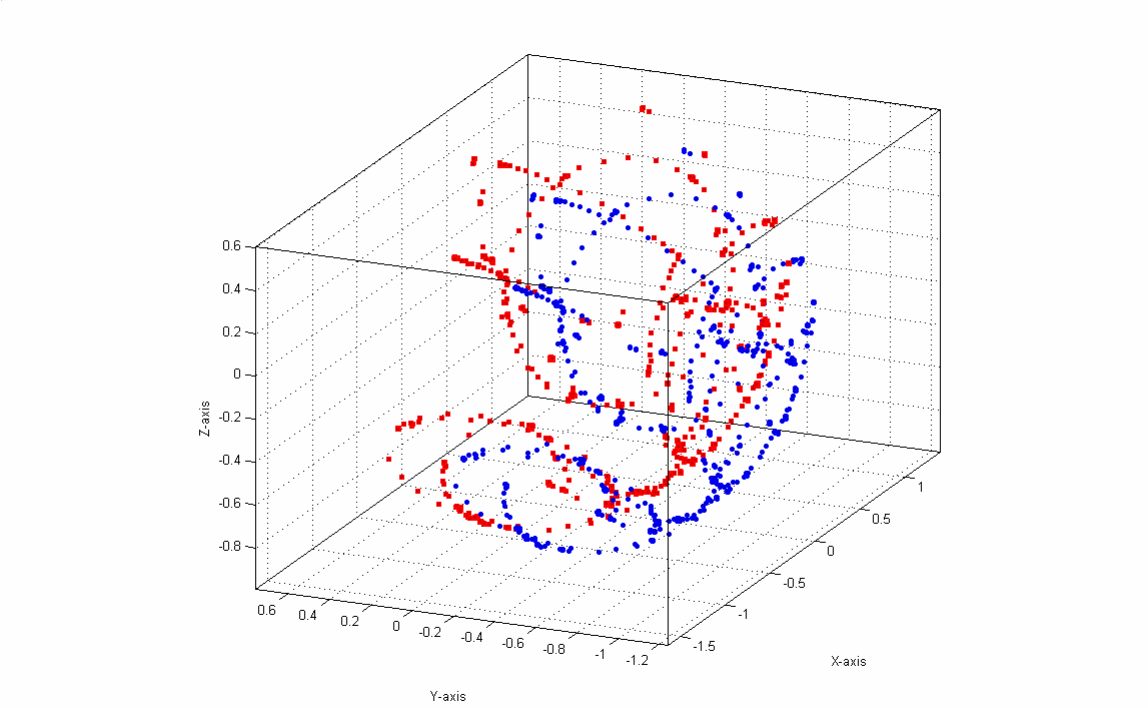


Example of time sequence of MTi / MTx data used for 3D magnetic field mapping. The accelerometer, rate gyro and magnetometer signals with respect to the three sensor axes are plotted. Note the many different orientations where the MTi / MTx is briefly held still.

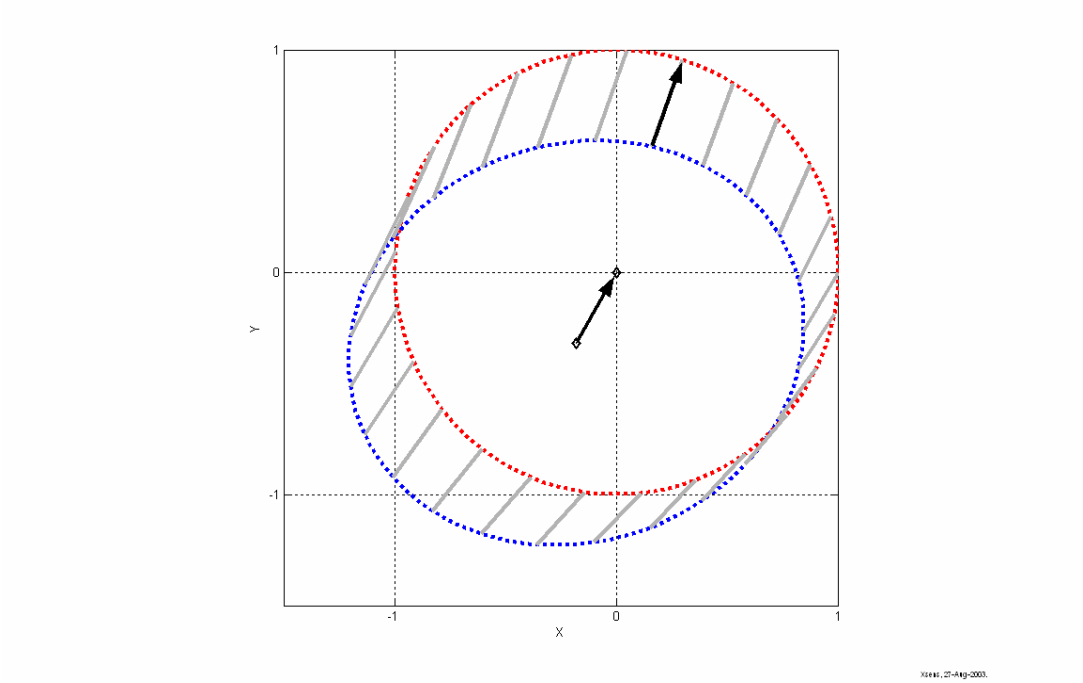
The calibration procedure requires the inclination, which is obtained using accelerometers. Accuracy of inclination is influenced by linear accelerations. Large accelerations will have a large effect on the accuracy of the calibration results. Therefore it is **very important to move the object as slowly as possible** during the measurement, or alternatively to hold the object briefly still in many different directions.

The Magnetic Field Mapper add-on is designed to disregard periods with large accelerations and reduce any errors, therefore you can move fast without causing errors, but there must be sufficient periods of "stillness". This requirement is only applicable for a 3D calibration measurement since e.g. a boat can not be held still. For details see next section about the Calibration Procedure.

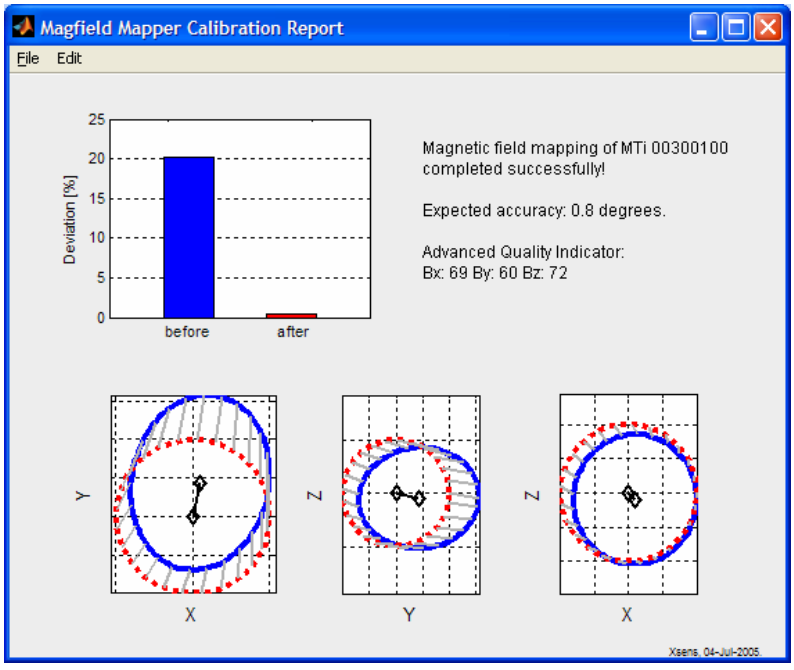
Since the MagField Mapper algorithm can not distinguish between an external disturbed magnetic field and a disturbance caused by the object on which the motion tracker is attached, it is extremely important that the ***measurement is carried out in a homogeneous magnetic field***. As a rule of thumb there should be no ferromagnetic objects within *at least* three meters from the place in which the measurement is carried out. Keep in mind that the structure of the building you are in (floor and ceiling) is likely to contain magnetic materials.



3D representation of magnetic field vector before (blue) and after (red) compensation using magnetic field mapping.



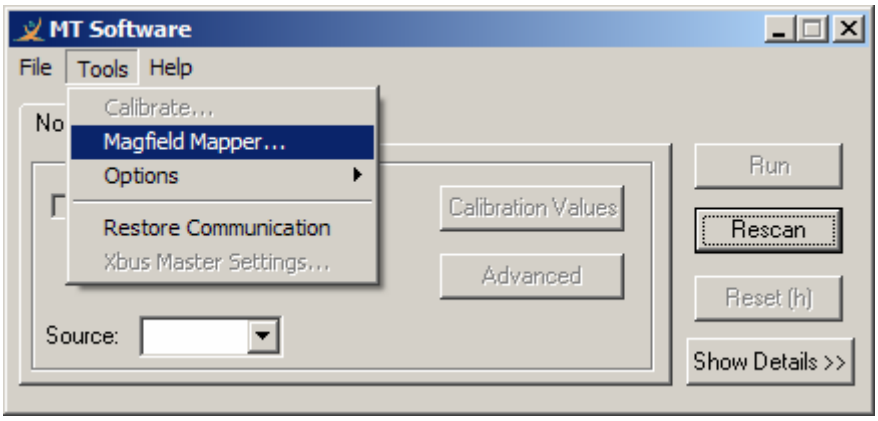
2D representation of magnetic field vector (projected on X-Y plane) vector before (blue) and after (red) compensation using magnetic field mapping. The arrows represent the "transformation" applied.



Calibration report, including a projection of the obtained fit in three planes.

3 Magnetic field mapping Procedure

Start the Magnetic Field Mapper plug-in from the Tools menu in the MT Software.



The magnetic field mapping procedure consists of the following steps:

Mounting of MTi / MTx

The MTi / MTx is attached to the object for which the magnetic field mapping procedure is carried out. Make sure that wherever the MTi / MTx is placed, it can not move with respect to the object.

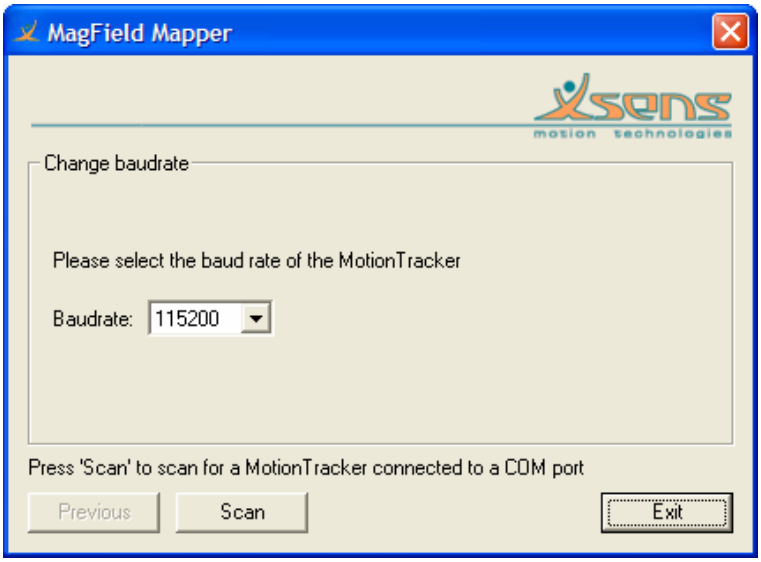
There are ***no*** specific requirements in terms of mounting orientation of the MTi / MTx on the object.

Remarks:

- ➔ Every time the sensor is temporarily removed from the object, it is advised to repeat the calibration procedure.
- ➔ If the geometry of the object is significantly altered, e.g. the geometry is changed or components are added or removed, it is advised to repeat the calibration procedure.
- ➔ The calibration procedure is more accurate for smaller disturbances. If possible, try to position the sensor one to a few centimetres/inches away from ferromagnetic materials. The MagField Mapper will automatically warn you if the magnetic field sensors in the MTi / MTx become saturated.

Recording of calibration measurement

Follow instructions provided by the MagField Mapper dialog:



Default sequence:

1. **Connect** the MTi / MTx you wish to calibrate to a COM-port (adapt baudrate if necessary).
2. Press "**Scan**" to scan for connected MTi's / MTx's (max 1 at a time).
3. Select input type (new measurement or previously recorded file).
4. Select the required mapping mode 2D or 3D.
5. Press "**Start**" to record a measurement.
6. Press "Stop" if sequence of rotations is completed.
7. If successful:
8. Press "**Write**" to write the magnetic field mapping to the MTi / MTx non-volatile memory.

During a 3D calibration measurement, the object to which the sensor is attached has to be rotated through as **many different orientations as possible,** it may help to think about 'scanning' the surface of a sphere with the MTi / MTx x-axis. Not only is it important to cover many orientations, the object also has to be moving sufficiently slow. **The best is to keep the object still for a few seconds in at least 12 significantly different orientations, preferably more.**
In case of a 2D calibration measurement, the object has to be rotated through at least a full 360° circle. It is recommended to do this with constant speed.

Don't worry! The MagField Mapper add-on will tell you if the measurement was OK.

	Remarks: • A longer calibration measurement is generally better. As a rule of thumb, a calibration trial of around 3 minutes should suffice, provided that the object is rotated over a sufficiently large angle and held sufficiently still. If one of these requirements is not met, a longer calibration trial may prove to be useful. • For a 2D calibration measurement it is recommended that the object moves through a full 360° circle. • It is extremely important to perform the calibration in a magnetic homogeneous field. Try to conduct the measurement *at least* 3 meters from large ferromagnetic objects such as radiators and iron desks. • During the calibration trial, the accelerometers are used for inclination measurement, much like a water dial (spirit level). This means that the inclination accuracy will be less when the sensor is accelerated. Especially centripetal accelerations that occur e.g. during swinging result in a large inclination error, since centripetal acceleration error do generally not average out. • In 3D mode, the algorithm only uses periods with low activity to perform the calculation. Therefore it is more important to keep the object still for a few seconds in every orientation than to slowly rotate the object during the entire calibration.
Writing new values in MTi / MTx non-volatile memory	If you select to write the magnetic field mapping to MTi / MTx non-volatile memory, the motion tracker will from now on automatically be able to compensate for the disturbed magnetic field! **NOTE**: If you remove the MTi / MTx from the object, please remember to **restore the extended Motion Tracker Specification data (eMTS data) to factory settings**! Use the “Properties” dialog in the MT Software, select “Revert” to revert to Factory Set eMTS data.

3.1 Mapping Residuals

The residuals give a measure on how well the measured signals could be mapped and results in an estimate of the remaining orientation error. This number is displayed in the Magnetic Field Mapper dialog window.

Note:

➔ A very low number of samples will always yield low residuals. This is much like a line fitted through two measurements can always be fitted perfectly, in contrary to three or more points. The more samples the bigger the chance is that not all measurement points can be perfectly corrected and a more realistic error measure is

obtained. Don't worry: the MagField Mapper will warn you if too little useful data is captured, warning you not to use the measurement or even not allowing you to use the measurement.

➔ The residuals can only check the accuracy of the range of orientations that the object was held during the calibration measurement (the rotation range). This will not cause any problems as long as the orientations during use of the MTi / MTx are not very different from the orientations during calibration.

3.2 Limited angles

The calibration procedure works best if the MTi / MTx is rotated through a large amount of possible orientations. If this is difficult for the object for which the MTi / MTx has to be calibrated, the procedure might still give accurate results with mild magnetic disturbances. It should be noted that orientations that are recorded with a calibration file that is generated with a limited set of orientations will only be accurate for that particular range of orientations (rotation range).

3.3 Error causes

If the calibration procedure is not giving the desired results, it may be caused by one of the following error sources:

Cause	Explanation
Non homogeneous magnetic field in measurement volume	The effect of a non homogeneous measurement field shows in large residuals even though you follow procedure. To remedy this problem, try to perform the calibration measurement in a different place or remove nearby metal objects.
Saturation	The disturbance of the magnetic field can be so extreme that the magnetometers are saturated. In this case, a warning will be given. Reposition the MTi / MTx on the object, away from the ferromagnetic material and not close to sharp edges, to remedy this problem.
Large accelerations	If the object is accelerated too much during calibration this will cause an error. If large accelerations can not be avoided contact support@xsens.com.
Limited rotation.	The calibration procedure is designed to process measurements in which the MTi / MTx is rotated through a large amount of possible orientations even though measurements with a limited range of motion will most likely give good results as well.
Extreme disturbance of magnetic field	It can be that the disturbance of the magnetic field is so extreme that the program can not find any function to correct the disturbance. This could occur more easily when one of the other error causes play a significant role. The result of such an error will become apparent in very high residuals or an error message.
Wrong mapping mode (2D/3D)	If the wrong mode is selected, the calibration will most likely result in a non-optimal fit or even give an error message.

Customer Support

Please, contact us if you have any questions regarding the use of Magnetic Field Mapper, its performance for your specific application, or any other questions.

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