CASE STUDY

Mag648

Magnetic anomaly mapping using an underwater glider equipped with a Mag648 low power fluxgate sensor

This case study examines how a low power, low noise Bartington Instruments Mag648MXL magnetic field sensor may be installed on an underwater glider for the purpose of magnetic anomaly measurements.

Magnetic anomalies are defined as the deviation of the magnetic field from the Earth reference field at that location. These measurements can be visualised in a similar way to the topographic map of a terrain. Magnetic anomaly maps may be used to assist the navigation of unmanned vehicles during periods when the sea is frozen, extending their available usage time beyond the summer months.

Underwater gliders are a specialized type of unmanned vehicle which uses ballast to profile the water column for environmental monitoring. The vehicle cycles between negative and positive buoyancy, causing it to sink and float and travel forward in a sawtooth-like manner. A typical mission for an underwater glider will last around four weeks and cover up to 500 miles. An attractive feature of underwater gliders is the low level of dynamic noise from motors and pumps during steady state glides.

Navigation

The glider uses dead-reckoning while underwater, using the horizontal velocity calculated from the depth rate and inclinometer and a magnetic compass to estimate its position. Due to uncertainties in velocity estimation and the presence of unknown currents the error in the position estimate grows with time and must be compensated for by surfacing every few hours to obtain a GPS fix.

The need to surface for a position update is a considerable drawback in areas where surface access is denied, such as the ice-covered regions of the Labrador Sea and the north coast of Newfoundland. To help with navigation during the ice season, an underwater glider outfitted with the magnetic sensor suite described below is used to create magnetic anomaly maps of the region during the ice-free season.

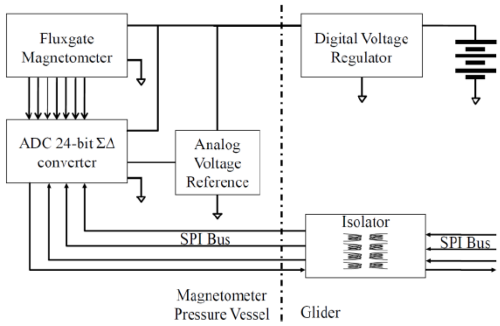

Figure 1. System flow chart.

Magnetic sensor suite

The signal flow chart describing the integration of the Mag648 sensor into the glider's systems is shown in Fig. 1. A 24-bit sigma delta converter, the AD7794, is connected over the Serial Peripheral Interface (SPI) through a digital isolator (Fig. 2). The sensor has a dedicated battery pack containing three primary lithium AA cells which will run it for approximately 30 days – about the same amount of time as a glider deployment. The resulting system is capable of reading data into the vehicle with a full scale effective resolution of around 22-bits at 1Hz or 0.025 nTrms/√Hz. This resolution is only slightly larger than the published accuracy of the Mag648 of 0.01 nTrms/√Hz.

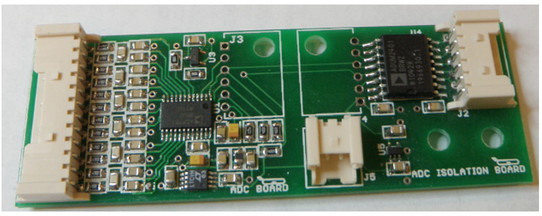

Figure 2. Isolated analogue to digital interface board.

Figure 3. Non-magnetic gimbal with vehicle attached.

Calibration

An instrument for measuring a time invariant magnetic field in a perfect world would show a constant magnitude irrespective of the orientation of the instrument. However, since the sensor is installed on a vehicle which contains various ferrous parts such as batteries and other items the effect of the vehicle on the measurements must be calibrated out. The instrument itself also has effects on the measurement.

To achieve this calibration the distortion of the measurements is treated as a lumped effect which causes a scaling, bias and rotation of the measurements. To find these parameters the vehicle is attached to a non-magnetic gimbal (Fig. 3) and rotated through all three axes to cover the measurement space while the magnitude is recorded (Figs.4, 5). An ellipsoid is then fitted to this data (Fig. 6) from which the calibration parameters may be estimated by finding the terms which convert the ellipsoid to a sphere centered at the origin (Fig. 7) [1]. The corrected data may be estimated by subtracting the bias and removing the rotation and scaling as in [2]:

$$h_c = S^{-1}R'(h_r - b)$$

where S is the scaling matrix, R is the rotation matrix, b is the bias, h_r is the raw magnetic data and h_c is the calibrated magnetic data.

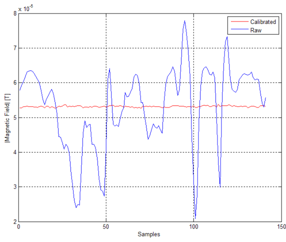

Figure 4. Magnetic data from rotations through constant

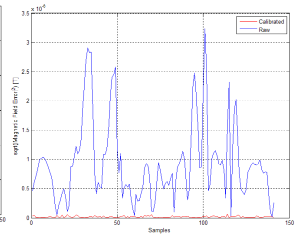

Figure 5. Root squared of magnetic error.

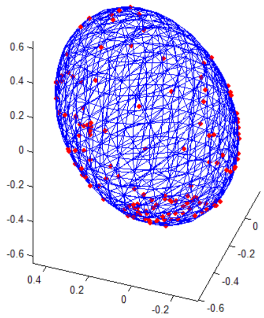

Figure 6. Ellipsoidal fit to the uncalibrated data.

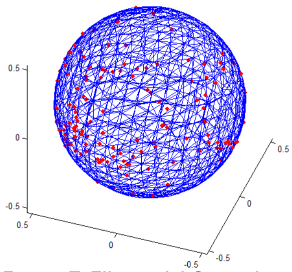

Figure 7. Ellipsoidal fit to the calibrated data.

Conclusion

As of April 2012 the calibration of the system is nearing completion, and field trials to collect data and begin compiling maps are to take place this summer.

References

[1] Petrov, Yuri. "Ellipsoid Fit," MATLAB Central File Exchange, 2009.

[2] Vasconcelos JF, Elkaim G, Silvestre C, Oliveira P, Cardeira B. Geometric Approach to Strapdown Magnetometer Calibration in Sensor Frame. Aerospace and Electronic Systems, IEEE Transactions on. 2011 April; 47(2): 1293–1306.