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Testing a scalar magnetometer for airborne EM applications

Summary

Motional noise can seriously deteriorate the data quality of airborne EM measurements at frequencies < 30~100 Hz. The reading of total scalar magnetometers is much less susceptible to motion noise and may be a useful complement or alternative to vector magnetometers (e.g. Avdeev et al., 1997). The basic conception is that the time-variations measured with a total field magnetometer approximates the projection of the time-varying field vector onto the static main field. In this way, directional information can be restored (→ right column). Here, we show that the MagArrow OPM mounted below a multicopter yields stable semi-airborne EM responses at frequencies down to 1 Hz.

UAS semi-airborne EM survey

a) Survey layout:

Scalar magnetic field data were acquired across a grounded electric dipole using an UAS and the MagArrow OPM. Flight lines are coincident with a vector magnetometer survey using a SHFT02e sensor (cf. P. Kotowski et al., this meeting).

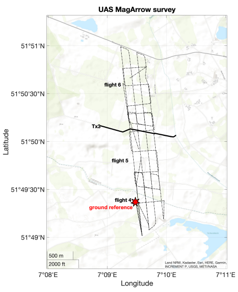


Figure 1: Sitemap. Survey parameters were: Tx: 1.5 km, 15 A, f_0 = 1 Hz; Rx: 150 m line spacing, 3500 m x 450 m area, 7 m/s flying speed, 40 m above ground; 1000 Hz sampling rate.

b) Power spectral density:

Comparison of PSD from independent UAS and helicopter flights. The noise level of the scalar magnetometer is significantly lower that that of induction coils at f < 100 Hz.

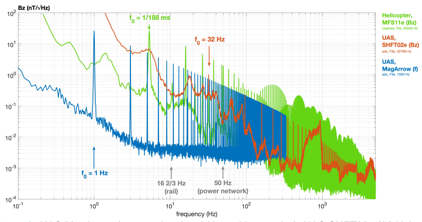


Figure 2: UAS MagArrow (source signal at 1 Hz and harmonics), UAS SHFT02e (32 Hz) and helicopter MFS11e (1/188 ms) PSD; cf. A. Thiede et al., this meeting.

c) Validation using a vector magnetometer grd. reference

Comparison of scalar and vector EM response functions of type B_x/I, B_y/I and B_z/I for a vector magnetometer on the ground, the projection $\mathbf{B}\cdot\mathbf{B}_0$ in the direction of the main field, and the scalar EM response F/I determined for the scalar magnetometer towed by an UAS.

The ground recording used a 32 Hz current square wave; the airborne recording used a 1 Hz square wave.

A time shift of 0.746 ms was estimated by matching the response phases. An amplitude offset by a factor of 1.15 is attributed in parts to the flight height above ground (40 m).

➔ Validation of scalar EM response in overlapping band.

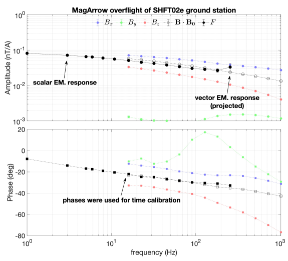


Figure 3: EM response functions estimated from independent flights using an induction coil triple located at a ground reference station (blue, green, red), the response projected in the direction of the main field (black, open symbols), and the scalar EM response estimated from an overflight (black, solid symbols).

d) Validation using independent flights with scalar and vector magnetometers

Comparison of scalar and vector EM responses along coincident flight lines, using the same projection as for Figure 3. Data for 32 Hz are shown, which is about the very lower frequency limit of the SHFT02e sensor.

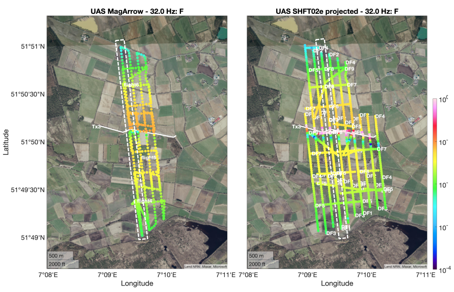


Figure 4: Imaginary parts of EM responses at 32 Hz obtained with a) the MagArrow OPM and b) the SHFT02 induction coil triple, the latter projected in the direction of the geomagnetic main field.

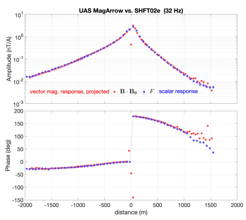
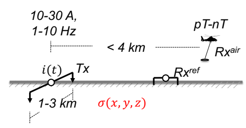


Figure 5: Amplitude an phase at 32 Hz along a merged flight-line (dashed white box in Figure 4), comparing scalar and projected vector EM responses.

Results

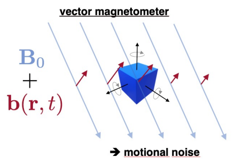
- Airborne surveying using a scalar magnetometer was validated in a UAS semi-airborne EM configuration
- Motional noise is minor at frequencies below 100 Hz
- High-quality EM responses can be obtained at frequencies as low as 1 Hz
- Scalar magnetometers can nicely complement vector magnetometer surveys to low frequencies
- Scalar magnetometers have the potential to increase exploration depth, particularly in UAS survey where low flying speeds can be realized.

Semi-airborne EM geometry:

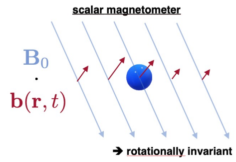


A semi-airborne EM setup uses a transmitter (Tx) on the ground and a passive airborne EM receiver (Rx).

Moving airborne receiver:



The static geomagnetic main field is time-dependent in the frame of a moving vector magnetometer. Therefore, recorded flux variations are a superposition of the flux changes due to motion and due to a time-dependent EM signal. Motional noise is a serious noise sources at low frequencies and inhibits the determination of EM response functions.



A scalar magnetometer measures the absolute value of the ambient magnetic flux. To a good approximation, the measurement of a scalar magnetometer can be described by the projection of the EM signal in the direction of the geomagnetic main field. Scalar magnetometers are much less susceptible to sensor motion.

MagArrow OPM, Geometrics

- *Weight: 1 kg + Batt.*
- *Noise: 5 pT/√Hz*
- *Sample rate: 1000 Hz GPS Synchronized*
- *Bandwidth: 400 Hz*
- *Heading error: 5 nT*
- *IMU: Bosch BMI160 Accel/Gyro*
- *Compass*

We used the MagArrow OPM suspended below the MGT-Arealis octocopter and flew a semi-airborne EM test survey near Merfeld, Germany (cf. Figure 1).

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