Optimization process of the DESMEX induction coil bird for AFMAG measurements

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Airborne electromagnetic measurements using natural signal (AFMAG) provide a dense data coverage of large areas in short time and with small effort. The audio-magnetotelluric signal is much weaker than signal from nearby artificial sources. Hence, airborne systems require an extremely low noise level for passive measurements.
As part of the DESMEX II project, we aim to optimize the DESMEX induction coil airborne system (Figure 1) to meet passive EM requirements and improve data quality for semi-airborne EM. We use an Inertial Navigation System (INS) to measure sensor movements and predict and remove the signal input caused by motion [1].

Raw Time Series u,v,w bird coordinates → **Pre-Processing** 1. Predict signal produced by motion 2. Subtract motion noise 3. Rotate data to Earth-fixed coordinates → **Cleaned Time Series** x,y,z Earth-fixed coordinates

The "cleaned" data are still afflicted with remaining motional and internal EM noise over a wide frequency range. Accessing lower frequencies (≤ 20 Hz) is essential for greater penetration depth. We analyzed noise characteristics and improved data quality in a series of optimization steps.

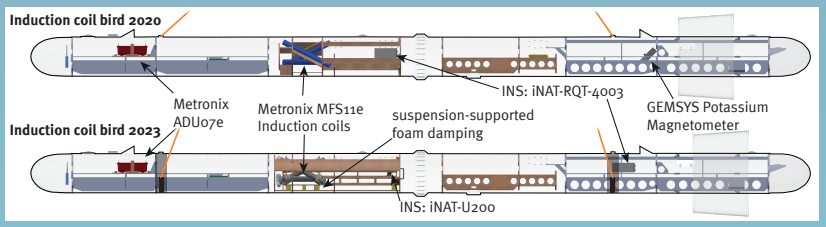
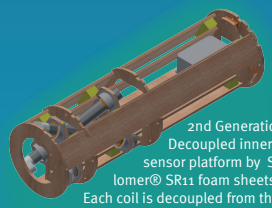
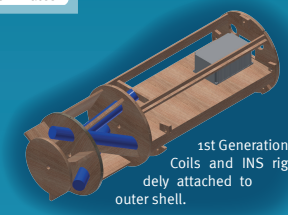


Figure 1) DESMEX Induction Coil Bird interior design. a) In 2020: Coils and INS were rigidly attached to the outer shell. The bird is towed by a 2-point suspension system. b) In 2023: Coils are mounted on a damped platform with a less noisy INS. INS RQT-4003 replaces the total field magnetometer in the back. The bird is towed using a 4-point suspension system.



2nd Generation: Decoupled inner sensor platform by Sylomer® SR11 foam sheets. Each coil is decoupled from the inner platform using 2 rings of Sylomer® SR18 foam to avoid internal high frequency vibration noise emitted by the INS.



1st Generation: Coils and INS rigidely attached to outer shell.

Conclusion

- **Reduced motion noise of up to >1 order of magnitude between 70 and 1000 Hz**
- **Presuming strong natural signal, AFMAG is possible between 200 and 1000 Hz**
- **Internal EM noise removed by changing INS**
- **New tow rope improves data quality at >70 Hz but deteriorates data quality at < 70 Hz**
- **SQUID bird with superior damping system**

Experiences from the current bird should then contribute to a completely new-designed platform that provides more space for a sophisticated and more effective damping system.

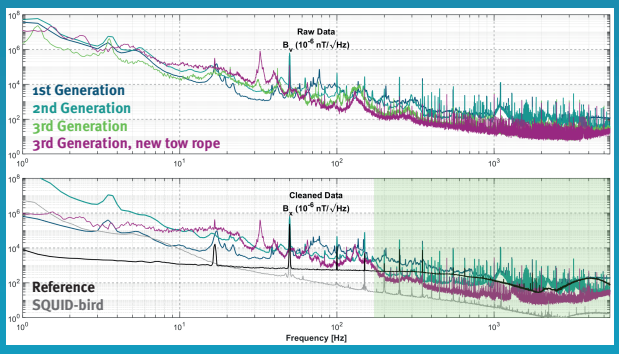
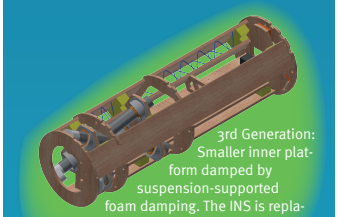
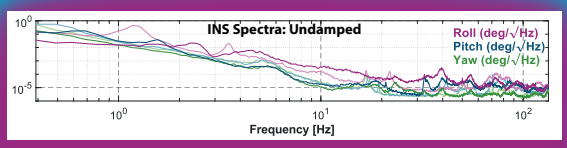
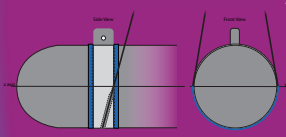


Figure 2) Noise levels of the induction coil bird after each optimization. Upper panel: Raw data of coil B_y. Lower panel: Cleaned data in B_x direction. The black spectrum represents strong signal level recorded on the ground. The gray spectrum shows the noise level of the SQUID bird [2]. Data between 200 and 1000 Hz (shaded area) reach natural signal level and can be used for AFMAG.

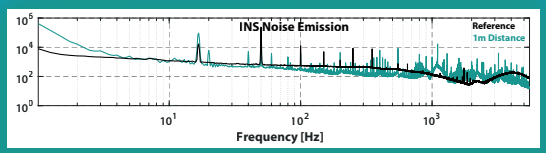


3rd Generation: Smaller inner platform damped by suspension-supported foam damping. The INS is replaced by a smaller system.





Spectra of INS recordings on an undamped platform (light color: INS on 1st generation sledge; dark color: 3rd generation sledge, INS in the back of the bird). Roll motion dominates the bird movements. Peaks at 1.2 and 3.4 Hz in 1st generation data reveal fundamental frequencies of the tow rope. A new 4-point suspension system was designed to reduce roll motion. 2023 data show that the prominent peaks could be eliminated. However, roll motion between 10 and 60 Hz became stronger and strong pitch motion at 32 Hz was detected. Data quality improved between 70 and 300 Hz.



The 2nd generation platform revealed internal EM noise at high frequencies, that was suspected to originate from the INS (1 m distance to coils). The figure shows a spectrum of the electromagnetic signal emitted by the **INS at 1m** distance to the coil center (coil and INS are arranged in line). Distinct peaks with 20 Hz fundamental frequency as well as other prominent signatures of the ground test also become evident in the 1st and 2nd generation airborne noise tests. The INS was replaced on the 3rd generation sledge by a less noisy system.

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References:
[1] M. Becken, C. G. Nittinger, M. Smirnova, A. Steuer, T. Martin, H. Petersen, U. Meyer, W. Mörbe, P. Yogeshwar, B. Tezkan, U. Matzander, B. Friedrichs, R. Rochlitz, T. Günther, M. Schiffler, R. Stolz, and the DESMEX Working Group, 2020, DESMEX: A novel system development for semi-airborne electro magnetic exploration, Geophysics, 85, E253-E267
[2] Stolz, R., Schiffler, M., Becken, M., Thiede, A., Schneider, M., Chubak, G., Marsden, P., Bergshjorth, A. B., Schaefer, M., and Terblanche, O. (2022). Squids for magnetic and electromagnetic methods in mineral exploration. Mineral Economics, 85(6):E253–E267.