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Investigation of UAV Noise Reduction for Electromagnetic Induction Surveying

T. Bjerg¹, E. Lima Simões da Silva¹, A. Døssing¹

¹ Dtu Space

Summary

Reducing the electromagnetic signal from the UAV by towing the frequency-domain electromagnetic induction instrumentation in a suspension system underneath the UAV, at 6 meters separation the noise from the UAV appears to be neglectable compared to other sources of electromagnetic noise.

Introduction

Electromagnetic induction methods are widely used for geophysical prospecting. Traditionally, electromagnetic induction is employed for large scale geophysical structures, such as mining, groundwater, and geothermal explorations (Everett, 2013). However, it is also used for near-surface applications such as archaeology and unexploded ordnance (Keiswetter, 2000) (Billings, 2017).

The electromagnetic induction techniques are seen in both airborne and handheld applications. The airborne, typically by helicopter setups, can cover large areas quickly and effectively and is mostly associated with large scale geophysical prospecting. The handheld instrumentation is for the low scale geophysical prospecting, by its smaller instrumental size and a higher special resolution it is well suited for the near-surface targets. Between these two methods, the small *unmanned aerial vehicle* (UAV) can be used as an instrumentation carrier. A small electromagnetic induction instrument mounted on a UAV can improve the handheld mobility to increase the range and access.

However, the UAV is a source of electromagnetic noise, which is inconvenient for a method such as electromagnetic induction and will generate a high level of noise in the data. i.e. the electromagnetic system needs to be separated from the UAV in a stable manner to be useful for near-surface target detection.

The scope is to reduce the electromagnetic signal from the UAV by moving the instrumentation further away from the UAV, at a certain distance the noise from the UAV can be neglectable compared to other sources of electromagnetic noise.

Survey system

At DTU Space, the CMAGTRES group has worked on a setup for separating the measuring instruments from the UAV without compromising a steady flight. This is constructed by three main parts: a UAV, an electromagnetic induction instrument as the measuring device, and a suspension to combine these two.

The measuring device is the GEM-2 UAV version from Geophex (Geophex, 2020), related to the GEM-2, which have shown useful for near-surface geophysical prospecting such as archaeology (Tang, 2018). The GEM-2UAV is shaped like a "ski" and is suited for being towed underneath a UAV, in a similar manner as a classical magnetometer bird. By towing the sensor in a wire suspension underneath the UAV, the measurements can be placed in a noise-free environment. Usually, a long wire suspension will make the bird twist and turn around its axis. By adopting the DTU-patented sensor suspension system (Døssing, et al., 2018), we have created a stable and noise-free towed setup for a UAV-borne electromagnetic sensor system.

The GEM-2UAV is a multi-frequency electromagnetic sensor system using frequency-domain electromagnetic induction (Won, 1996). The frequency-domain electromagnetic induction (FDEM) method uses controlled-source time-varying electromagnetic induction to produce a secondary magnetic field in a conducting target. By measuring, the produced secondary magnetic field GEM-2UAV will derive in-phase and quadrature data. The unit is parts-per-million (ppm) and is the raw data from GEM-2UAV; this is a sensor-specific unit.

In-phase and quadrature are related to the apparent magnetic susceptibility and the apparent electrical conductivity, respectively (Telford, 1990). GEM-2UAV can operate up to 10 frequencies simultaneous ranging between 25 Hz and 96 kHz. GEM-2 is production for handheld measurements, and it is generally expected to have the lowest measurements noise when doing a walking survey.

Fieldwork test

For testing the measured noise produced by the UAV, three tests were carried out: The first was a simple walk with the GEM-2UAV. In the second and third survey, the GEM-2UAV was towed 6meters and 1.5meters underneath the UAV, respectively. Moving forward, these three surveys will be addressed to as *walking survey*, *UAV survey 6m*, and *UAV survey 1.5m*. In Figure 1, the raw data from the three surveys are plotted using the 425Hz in-phase as an example of data output. The noise related to this frequency was generally higher than the other output frequencies. In Figure 2, the same raw dataset at 425Hz in-phase are plotted continually. Both Figure 1 and 2 indicates low special and time tends. We may therefore conclude that the inhomogeneity in the near-surface is not dominant as compared to the noise level at this frequency. If any geophysical structure was detected at this frequency, a trend would be visual. Some features could maybe be recovered by processing the data, but at the current state, no geophysical structure can be observed.

Figure 1 Raw in-phase data at 425Hz plotted at the site. All three subplots are in the same area from walking survey, UAV fight with 6m and 1.5m wire suspension.

Figure 2 Raw in-phase data plotted continually.

However, an evident difference is observed between the three surveys in Figure 2. The spread of data point between the two UAV measurements is significant, and since the only difference is the length of the wire suspension, it would be reasonable to assume the noise relates to the UAV. This becomes even

more visible in Figure 3, showing a histogram of the three surveys for raw in-phase data at 425Hz. The histograms for the three dataset resemble Gaussian distributions, which would be expected from a source of noise. This enables us to rank the noise level from the standard deviation of the data for each frequency although we note that the standard deviation is not a direct measure for the noise, but an indicator. The data distribution is expected to match the magnetic and conducting inhomogeneity at the near-surface, and therefore not desirable to get a lower standard deviation. In Figure 4 the standard deviation is plotted for all the output frequencies for both in-phase and quadrature data. We observe that the UAV survey at 6m and the walking survey have similar values while UAV survey at 1.5m is significantly higher.

Figure 3 Histogram of the raw in-phase data at 425Hz at the site. The three distributions do resemble a Gaussian distribution.

Figure 4 Standard deviation of all measured frequencies for both quadrature and in-phase data. The standard deviation cannot be used directly as a measure of noise level, since the distribution at the certain frequency may reflect some features in the underground.

Conclusion

The sensor system and test were presented; an early version of the suspension was tested together with the newly acquired GEM-2UAV instrumentation and a UAV (DJI Wind4). Two lengths of suspension were tested, where a walking survey worked as a reference for the UAV based surveys.

Even though the standard deviation cannot be used as a direct measure for the signal to noise ratio, it can be used as an indicator with the walking survey as a baseline. From that perspective, a visual tendency from the standard deviation indicates a low noise impact from the UAV with a 6m suspension, while the 1.5m suspension makes the UAV noise very dominant.

At the specific output frequency of 425Hz a lower standard deviation was observed for the UAV survey with 6m suspension than the walking survey. This may indicate that specific output frequencies are UAV noise-free, and produce less noisy dataset than the walking surveys. The 6m suspension could potentially be a good case, but it needs further investigation. If all the frequencies result in a signal to noise ratio at the same level as the handheld version, we would gain a lot by the UAV mobility in the less accessible areas and is a strong motivation for further improvements.

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