Airborne surveys worldwide

SkyTEM Survey:
Colorado, USA
Technical note on the 30 Hz noise signal

Client: USGS OAG Denver Acquisition Branch

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Introduction

In connection with the survey in Colorado for USGS, a detrimental 30 Hz noise signal (hereafter denoted noise signal) was observed in the datasets from both the Paradox and San Luis areas.

The SkyTEM system that was used to acquire the data for the Colorado surveys was used for several surveys prior to, and for one survey after Colorado. Noise of similar nature was not observed in any of the other surveys; In fact, the results were very satisfactory. No equipment changes were made to the system in any of these surveys.

The preliminary analyses of the noise signal during the reporting phase indicated that it was correlated with the 60 Hz power distribution grid and caused by a 30 Hz sub harmonic. This conclusion was supported by the fact that nothing of this kind has been observed in relation to this particular SkyTEM system.

In the final report for the Colorado survey, the emphasis was on mitigating the effect of the noise signal using a sinusoid correction of the raw data. This correction was very effective and the inversion results are very satisfying.

Based on the final report, USGS has asked for further explanation or investigation of the causes of the noise signal. This technical note investigates the possible cause of the noise signal and measures to prevent this in further surveys.

Cause of the problematic noise signal

There are some indications that the generator powering the SkyTEM system may be responsible for the observed 30 Hz noise signal. It appears that the generator can affect the receiver coil indirectly through wire-transmitted vibrations resulting in microphonics noise.

The generator type employed in the surveys has a target rotation speed of approximately 3850 rpm (≈ 64 Hz). However, the actual rotation speed depends on the power requirement of the applied TEM moment meaning that it tends to drop during high moment measurements. Because the generator has a four-stroke engine, where every second crank-shaft rotation is accompanied by a fuel ignition, the vibration noise from the generator is expected to have a significant component at half the rotation frequency (≈ 64/2 = 32 Hz). This could explain the apparent correlation between the observed 60 Hz and 30 Hz noise components.

The fact that the generator vibration frequency is so close to the power line frequency in the USA makes it difficult to distinguish it from regular power line noise at the available frequency resolution of the analyzed spectrograms. The apparent temporal correlation between the 60 Hz and 30 Hz noise signals, as exemplified by figure 1, was the reason for the initial hypothesis, namely that the 30 Hz signal was related to the power line noise.

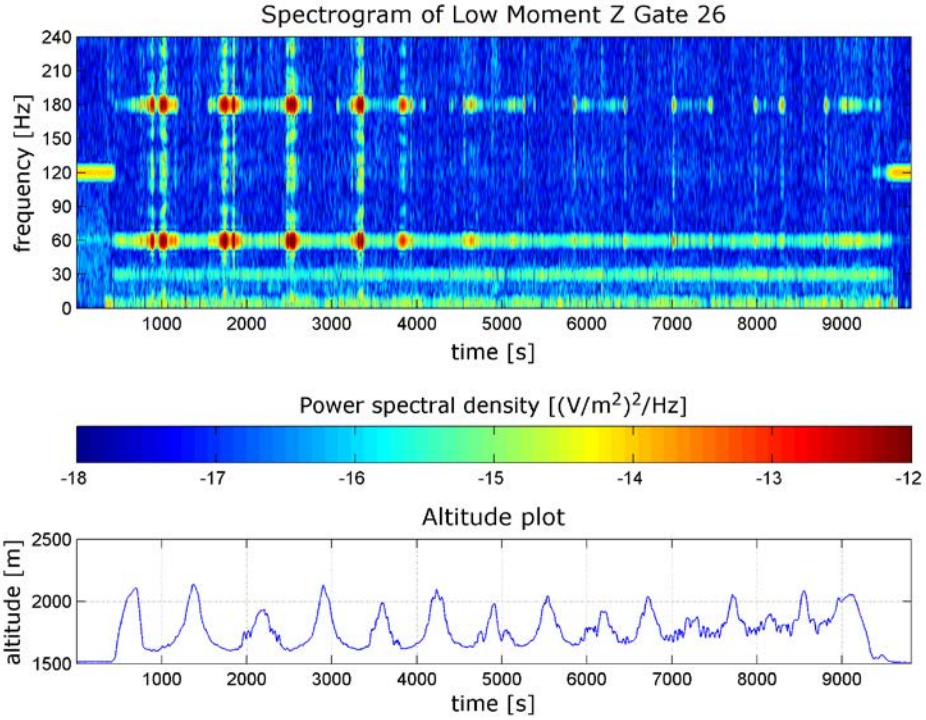

Figure 1: Spectrogram and altitude plot from flight 20111022.02 measured in the Paradox area.

Having analyzed numerous spectrograms, a common feature seems to be that the onset and termination of the 30Hz signal is correlated with the lift-off and landing of the frame. Still, there is significant variability in the amplitude of the 30 Hz noise component between flights and likewise within single flights, as shown in upper panel of figure 2.

A noise component near 30 Hz is primarily problematic in countries having a power line frequency of 60 Hz. This is due to the fact that the high moment measurements are designed to extract signal components exactly at the odd multiples of 30 Hz in these countries to minimize the influence of the 60 Hz and harmonic noise components. In the case of a power line frequency of 50 Hz, the high moment measurements are designed to extract signal components at odd multiples of 25 Hz to avoid 50 Hz power line noise and its harmonics. This implies an intrinsically much better suppression of noise components at approximately 30 Hz in countries with a power line frequency of 50 Hz.

Due to aliasing concerns, identification of the 30 Hz signal as an independent noise component is more reliable using the low moment data due to its higher sampling frequency as compared to the high moment data. On the other hand, the 30 Hz signal does not influence the averaged low moment data, while it is problematic for the averaged high moment data. Figure 2 demonstrates that the occurrence of problematic noise in the high moment data near 30 Hz is highly correlated in time with the occurrence of noise near 30 Hz in the low moment data. This indicates that the existence of high amplitude 30 Hz noise in the low moment data does indeed correspond to noise in the high moment data of the type we have observed in the Paradox and San Luis areas.

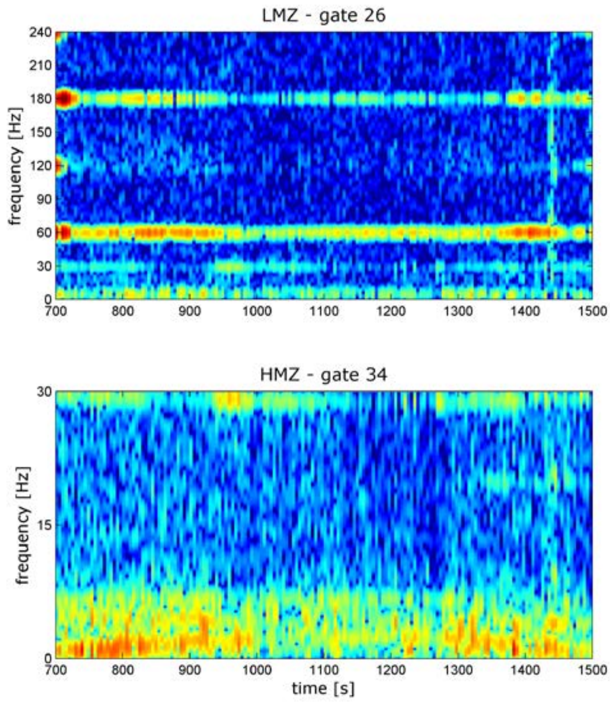

Figure 2: Comparison of spectrograms obtained from the low Moment and the high Moment measurements recorded during a high-altitude flight performed as part of the survey. The color scale used is identical to the one presented in figure 1.

The main concern in declaring the generator as responsible for the observed extraordinary noise phenomenon is that the type and severity of noise encountered in the present survey has not been identified in data from other similar North American surveys using the same SkyTEM system. However, considering the nature of vibration-induced noise, there are many factors which influence the severity of the resulting noise. Key factors are the specific way the generator has been attached to the carrier ropes as well as the location of carrier rope attachments on the frame. The tower housing the receiver coil is likewise tied down to the frame using ropes, and the specific way in which this is done is likewise likely to influence the transfer of mechanical vibrations. The tension of the carrier ropes in the vicinity of the tower will also influence the transfer of vibrations, meaning that a variation in the effective length of the carrier ropes (which may change slightly according to knots and positioning) is also significant. Furthermore, the specific rotation frequency of the generator is also very important. This frequency may change according to the temperature dependent transmitter wire resistance (controlling the intensity of the transmitted current and thereby the resulting power requirements).

Avoiding the problem in the future

The following changes will be implemented to all future surveys to prevent this problem occurring again:

- Employ generators with faster rotation frequency (which will be much less problematic in relation to the high moment measurements).
- Introduce a mechanical damping system integrated in the generator support structure to reduce the amplitude of transmitted vibrations.