Accurate estimation of variometers' frequency response and synchronization errors

Andriy Marusenkov

The goal of the paper is to determine the transfer function and time-stamp accuracy of a LEMI-025 fluxgate variometer against the specifications of the INTERMAGNET one-second data standard. The results obtained by the two methods - modified impulse response analysis and direct measurements at selected frequencies - are entirely consistent with expected characteristics of the 61-point digital filter used for decimating 10 Hz variometer raw data to final 1-second values.

The two methods are used for testing compatibility of a variometer LEMI-025 with the INTEMAGNET one-second definitive data specifications (Turbitt et al., 2013) concerning time-stamp accuracy and frequency response in the pass and stop bands.

The first method is based on the approach described by Shanahan et al., 2009 - the impulse response (IR) of the system is estimated and then using the Fourier transform the amplitude and phase at any frequency could be calculated. The impulse response of 1 Hz data is estimated as the first differences of the overlaid instrument responses to phase-shifted impulse inputs, thus obtaining the same time resolution as if we are using 10 Hz data. This is achieved by using as input signals the sequence of 0.05 Hz square waveform oscillations delayed by 0.05, 0.15, ..., 0.95 s relatively to the top of an UTC second.

Another method is a set of the direct measurements of the system response to an input signal with a given frequency, so called a multiply frequency test.

For the both methods the same test bench (Fig. 1) is used to generate the packets of square or sine waveforms synchronized with an UTC second. In order to cancel out external magnetic signals, the sensor with a calibration coil is placed inside a magnetic shield.

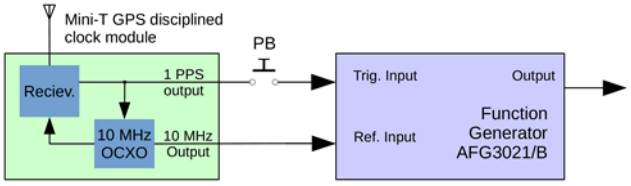

Figure 1: Test bench diagram

The group delay estimations in the band 0.02 to 0.5 Hz, obtained by the both methods, are within INTERMAGNET specifications of 0.01 s. The amplitude estimations as well as the response of the 61-point digital filter and the required limits are given in Fig. 2.

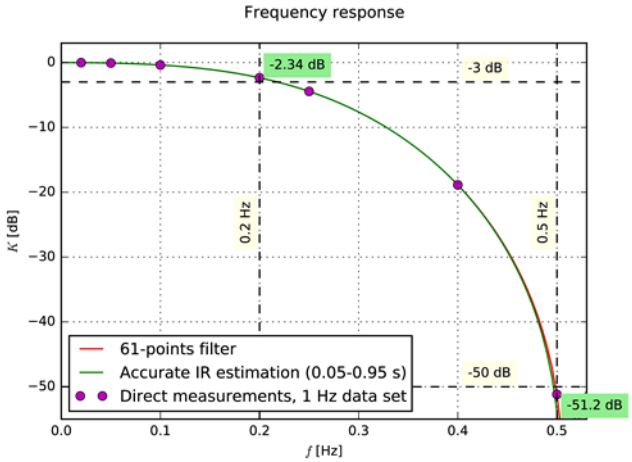

Figure 2: Amplitude vs. frequency response estimations

The impulse response method yields accurate results at the proper set of input signals. Frequency response estimations obtained by the two different approaches are mutually consistent. A variometer LEMI-025 with the 61-points filter meets INTERMAGNET requirements to 1-second data.

References:

Turbitt, C., Matzka, J., Rasson, J., St-Louis, B., Stewart, D., An instrument performance and data quality standard for INTERMAGNET one-second data exchange, Proceedings of the XVth IAGA Workshop on Geomagnetic Observatory Instruments and Data Processing, Boletín ROA No.03/13, Royal Institute and Observatory of the Spanish Navy, Cadiz, Spain, 2013, p. 186-188.

Shanahan, T.J.G., Turbitt, C., 2009, Evaluating the Noise for a Commonly Used Fluxgate Magnetometer – for 1-second Data, Proceedings of the XIIIth IAGA Workshop on geomagnetic observatory instruments, data acquisition, and processing: U.S. Geological Survey Open-File Report 2009–1226, p. 239–245.

Author:
Andriy Marusenkov[1]
1) LLC "LEMI"; Lviv Centre of Institute for Space Research, Lviv, Ukraine

Corresponding author:
Andriy Marusenkov
LLC "LEMI"; Lviv Centre of Institute for Space Research
Naukova 5A, 79060 Lviv, Ukraine
Tel.: +380 32 2540266
e-mail: marand@isr.lviv.ua