Origin of spectral anomalies in geomagnetic data at the Conrad Observatory

Ramon Egli, Barbara Leichter, Richard Kornfeld, Patrick Arneitz

The sensitivity of modern observatory variometers largely exceeds IAGA requirements and enables the detection of signals in the picotesla (pT) range after adequate data processing. Field variations in this amplitude range have a mixed origin which include ionospheric sources, geomagnetic induced currents, and other electrical currents of anthropogenic origin flowing in the underground. Here we demonstrate the use of mobile variometer stations and multitaper spectral analysis for the localization of underground currents and the detection of sensor artifacts at the Conrad Observatory.

Arneitz et al. ("Peculiarities from the frequency analysis of geomagnetic data at COBS", this journal) demonstrated the existence of periodic magnetic field disturbances in the pT range, which appear to be related to the trading interval $T_0 = 900$ s of the European power grid. In order to better understand the origin of this and other disturbances, a mobile measuring station equipped with a Lemi variometer was placed in the Conrad Observatory near the main entrance. This location is relatively close to the technical room that hosts the electrical distribution and UPS system. The mobile station was powered with a 12 V battery bank in order to exclude possible direct interferences from the power mains. Fig. 1 shows a comparison of the multitaper power spectra of the z-field components B_z recorded by the mobile variometer and by the observatory's reference variometer.

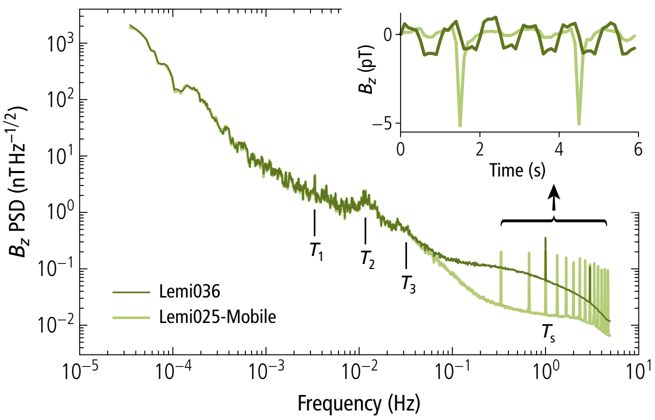

Figure 1: Power spectral densities (PSD) of the z-field components recorded by the reference variometer (Lemi036) and the mobile station (Lemi025) at the Conrad Observatory for two days (9-10.08.2020). A Slepian multitaper with $WT = 6$ was used for PSD estimation. The inset shows a time-domain reconstruction of digital sensor noise, obtained by stacking 28800 consecutive intervals of 6 s duration.

The two spectra are nearly identical, up to a noise floor difference that becomes visible above 0.1 Hz. Notable features superimposed to the $1/f$-characteristic of geomagnetic field variations include (1) a sharp peak with a corresponding period of $T_1 = 300$ s, (2) two broad peaks centred at $T_2 \approx 75$ and $T_2 \approx 30$ s, and (3) a series of sharp peaks representing harmonics and sub-harmonics of $T_s = 1$ s, which arise from a sensor-specific 1 pT rectangular signal. The frequencies of features (1) and (2) appear to be harmonics of T_0.

Further insights are obtained from the PSD of the field difference between the two sensors, which is sensitive to local current systems. The same periodic disturbances of the bulk spectra can be recognized, with sharper peaks at $T_2 = 67.6$ s and $T_3 = 30$ s, as well as an additional peak at $T_4 = 9.4$ s. These peaks affect only B_y and can be explained by N-S flowing electric currents, parallel to the main tunnel, which are stronger near the entrance. Peak broadening is caused by slow frequency variations occurring over a typical time scale of about 6 hours. It thus appears that the broad peaks affecting the bulk spectra originate from the superposition of underground currents flowing at different length scales with slightly different frequencies that vary in time around a constant mean value. All periods are compatible with harmonics of T_0 and thus seem to be related to the interaction of individual utilities with the power grid.

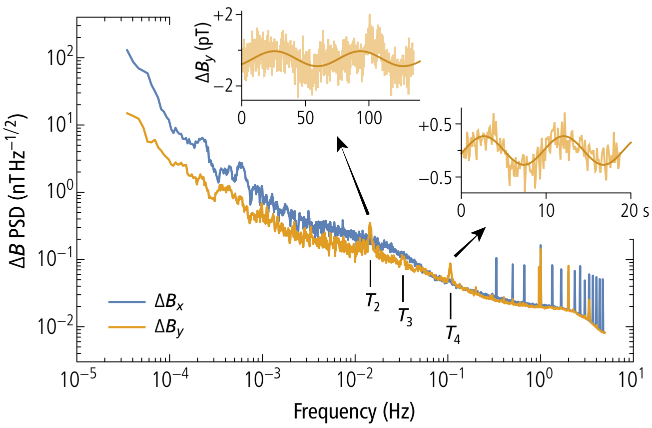

Figure 2: PSD of the horizontal field differences between mobile and reference variometer. The inset shows time-domain reconstructions of two periodic disturbances with center periods $T_{2,4}$ of 67.6 and 9.4 s, respectively, obtained by stacking intervals of duration $2T$ comprised between 06:00 and 12:00 on 09.08.2020.

Authors:
R. Egli[1], B. Leichter[1], R. Kornfeld[1], P. Arneitz[1], R. Leohnardt[1]
1) Central Institute for Meteorology and Geodynamics, Vienna, Austria

Corresponding author:
Dr. Ramon Egli
Central Institute for Meteorology and Geodynamics
Hohe Warte 38, 1190 Vienna, Austria
e-mail: ramon.egli@zamg.ac.at