ELF field measurements near Hortobágy and Magyargencs

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Abstract

Extremely low frequency (ELF) field measurements were organized near Hortobágy in 2019 and near Magyargencs in 2020 to survey the observability of Schumann resonances (SR) and properties of the ELF noise environment in the magnetic field in Hungary. The measurements serve our aim to find an appropriate location for a new permanent magnetic SR station. The location of the second test site (near Magyargencs) was selected on the base of experience we gathered from reprocessing high frequency magnetotelluric (MT) measurements in Hungary. Initial evaluation of the field measurements confirmed that it is not easy, but possible to find places of such low ELF noise levels in Hungary, which are suitable for monitoring SR.

Keywords: Extremely low frequency, Schumann resonance, Magnetotellurics.

Motivation

Recording of the magnetic field in the ELF band began in November 1996 in the Széchenyi István Geophysical Observatory (NCK) near Nagycenk, Hungary (Sátori et al., 2013; Bór et al., 2020). Unfortunately, the strong disturbing effect of the nearby electrified railway line hinders the detection of clear ELF spectra and the extraction of high-quality spectral parameters of SRs from these measurements. This strong, artificial noise contamination in the ELF band, which is connected to stray currents induced by the railway traffic, varies in time and in frequency which makes its analog or digital filtering practically impossible. Therefore, our group has decided to find a new location appropriate for establishing a new permanent magnetic SR station. In order to gain a more general knowledge about ELF noise conditions in Hungary and to find the most appropriate location for the planned station, field measurements were organized and high frequency MT measurements (with sampling frequency that enables the observation of SRs) were evaluated.

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Description of the measurements

First, two test measurement campaigns were organized near Hortobágy in Eastern Hungary (47.577192° N, 20.940759° E) in 2019. The location was in the area of a large national park, far from railway traffic and industrial areas. The first campaign was about 24 hour long (2-3 October, 2019) while the second, more than two week long campaign took place between the 25^{th} of November and the 12^{th} of December, 2019. Next, high frequency MT measurements made earlier at 8 locations in Hungary were re-processed to survey the suitability of the covered area for making specifically SR observations. Based on the experience we gathered from this analysis, a second test location was selected near the village Magyargencs at the border of the Little Hungarian Plain in western Hungary (47.385014° N and 17.199848° E), closer to NCK. The field measurement near Magyargencs started on the 8^{th} of July and ended on the 30^{th} of July, 2020. All these locations are displayed on Fig. 1.

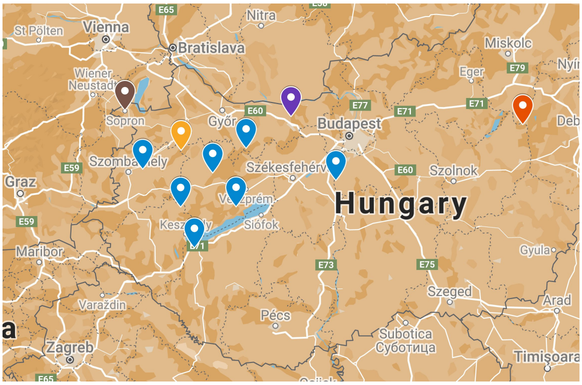

Fig. 1: Location of Sopron (brown), the field measurements (red: Hortobágy, orange: Magyargencs) and the 8 MT sites (7 stations with blue, purple: Vértesszőlős).

In case of the test measurements, the data acquisition was implemented by a high frequency LEMI-423 magnetotelluric station using 500 Hz sampling frequency. The sensors were installed under the surface (∼0.5 m) and the data logger recorded the signals together with GPS timestamps. One vertical and two horizontal components of the magnetic field (B_X, B_Y, and B_Z) were measured by LEMI-120 induction coils. The telluric field components E_X and E_Y were observed between pairs of non-polarized Cu-CuSO4 electrodes placed 50 m apart. The field orientation of the magnetic and telluric sensors was set to the geomagnetic NS and EW directions. The signal from the induction coils is fed into a built-in amplifier. Local feedback circuits in the amplifier ensure that the transfer function of the system is fairly flat within the frequency band from 1 to ∼1000 Hz. The analog output from the electronics is sampled by a 24 bit A/D converter (LEMI-423 document, 2017).

The raw binary data files collected during the field measurements were transformed to text files, data were bandpass filtered (by applying the built in butterworth bandpass filter of the scipy.signal Python package) in the 4-40 Hz frequency range and dynamic spectra were generated with 1-min time and ~ 0.25 Hz frequency resolution for each day of the measuring campaigns. The visual inspection of the dynamic spectra allowed us to get a general impression about the ELF noise conditions at the test sites.

The 8 considered MT measurements were carried out from April to July in 2019 (Tab. I) and were recorded by a LEMI-419 data acquisition system with 640 Hz sampling frequency. For evaluating the detectability of SRs in the MT measurements, the same data processing steps were applied as for the field measurements. These records were usually less than 2 hours long.

Table I: Date, location and exact coordinates of the 8 MT measurements.

Date	Location	Coordinates
2019.04.08.	Mihályfa	17.19402° E, 46.96285° N
2019.04.10.	Réde	17.91118° E, 47.39947° N
2019.04.16.	Balatonújlak	17.34578° E, 46.65665° N
2019.04.25.	Porpác	16.77927° E, 47.24524° N
2019.05.08.	Magyarpolány	17.54579° E, 47.21791° N
2019.05.23.	Ráckeve	18.89396° E, 47.16264° N
2019.06.12.	Vértesszőlős	18.4016° E, 47.6357° N
2019.07.24.	Pécsely	17.8017° E, 46.9654° N

Results

The first, 24 hour long test measurement at Hortobágy indicated the suitability of the site for carrying out high quality ELF measurements while the second campaign unequivocally verified the low ELF noise conditions (Fig. 2) and confirmed the detectability of clear ELF spectra by our recording system. 5-6 SR bands can be recognized in these spectrograms up to 38 Hz. However, the test site at Hortobágy was more than 400 km away from Sopron (Fig. 1) which would make the regular maintenance and occasional repairing of a permanent station very difficult. Therefore, we attempted to find another location closer to Sopron with ELF noise conditions ideally as good as at Hortobágy.

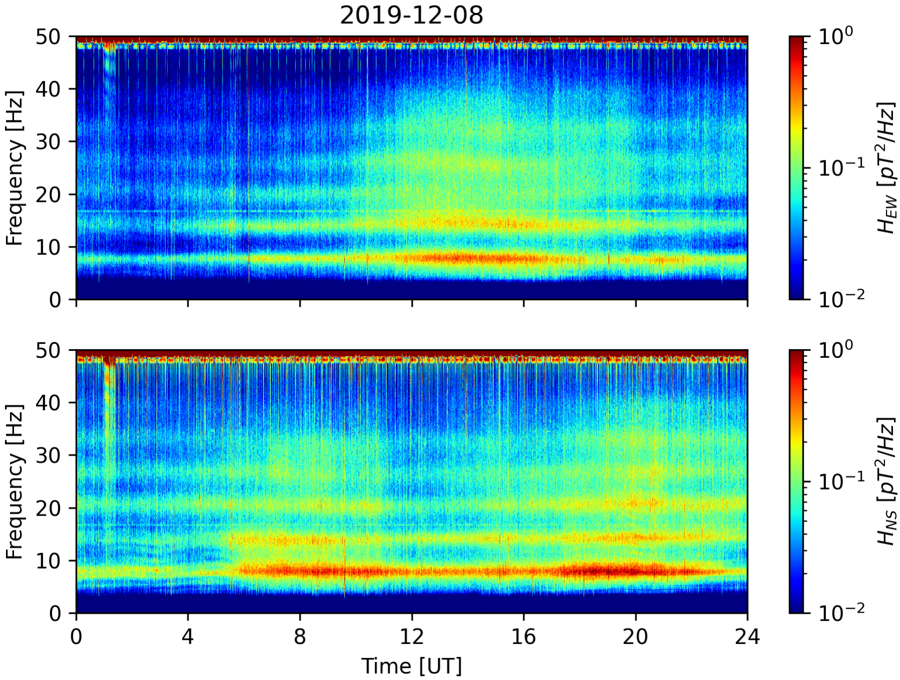

Fig. 2: Dynamic spectra corresponding to the H_{EW} (top panel) and H_{NS} (bottom panel) field components measured near Hortobágy on the 8^{th} of December 2019.

In order to gain a more general knowledge about the ELF noise conditions in Hungary, we reprocessed the MT measurements described in the previous section. This analysis revealed that it is possible to collect high quality ELF data in more locations in Hungary but one needs to find a place at least 10-20 km away from electrified railway lines. As an example for the noise contamination, Fig. 3 shows power spectral density (PSD) spectra corresponding to $\sim$ 1 hour long records (in the same hour of the day: 13-14 UT) from the MT station near Vértesszőlős as well as from the field measurements near Hortobágy and Magyargencs. Despite the apparently different amplitude transfer characteristics of the LEMI 423 and 419 detection systems, it is clear that there is more explicit noise contamination at Vértesszőlős than at Hortobágy. This high noise level is probably caused by the nearby electrified railway line running less than 5 km away from the measurement site in that case. Based on this experience, we selected a location near Magyargencs, Hungary for our next test measurement.

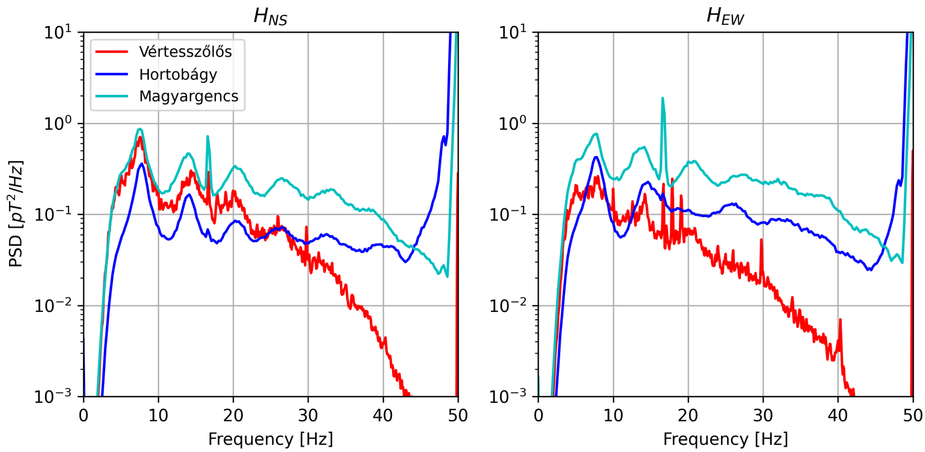

Fig. 3: PSD spectra corresponding to ∼ 1 hour long records from Vértesszőlős, Hortobágy and Magyargencs.

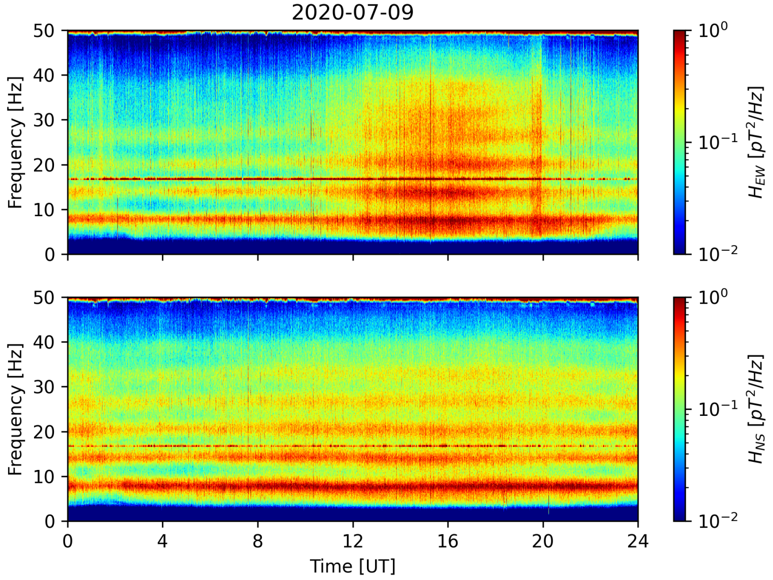

Fig. 4: Dynamic spectra corresponding to the H_{EW} (top panel) and H_{NS} (bottom panel) field components measured near Magyargencs on the 9^{th} of July 2020.

Figure 4 shows very clear dynamic spectra corresponding to the H_{EW} and H_{NS} field components from the 9^{th} of July 2020 measured at our second test site, near Magyargencs. The first five SR modes are clearly visible in the H_{NS} field component (bottom panel) while the dynamic spectrum of the H_{EW} field component (top panel) shows the expected characteristic daily pattern, namely a remarkable intensification between 13 and 18 UT corresponding to the intensification of the African lightning chimney (Williams et al., 2021). This figure confirms that the test site is appropriate for carrying out SR measurements. The higher signal levels compared to those recorded in wintertime at the first test site, Hortobágy, (Fig. 3), can be attributed to the fact that main centers of lightning activity are closer to the test site in summer. Note that, in addition to the seasonal variation, SR signal levels and peak amplitude ratios also change hour-by-hour and day-to-day according to the actual distribution and intensity of the global thunderstorm activity (Sátori et al., 2013).

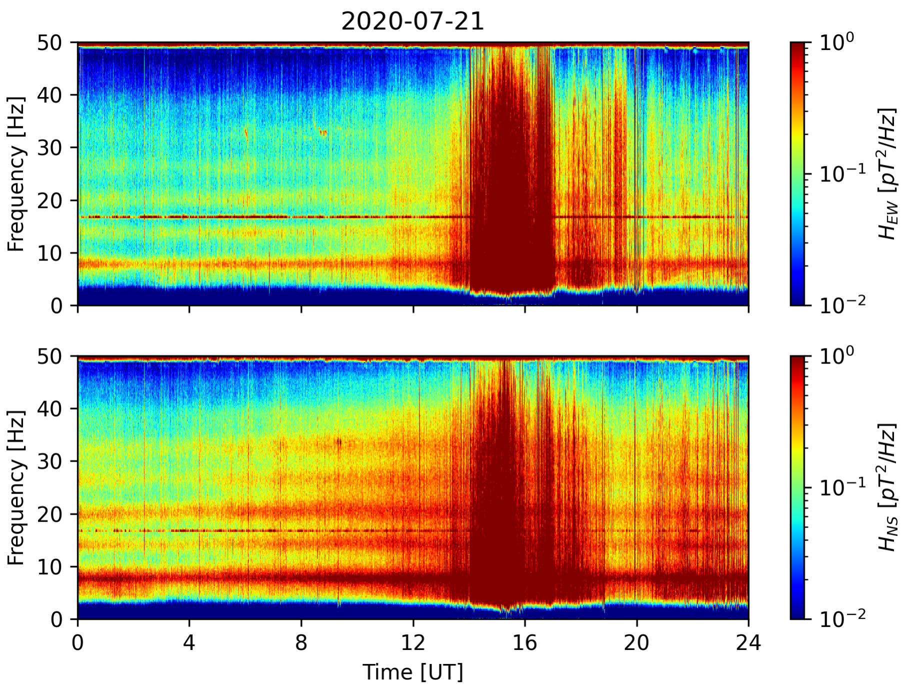

Fig. 5: Dynamic spectra corresponding to the H_{EW} (top panel) and H_{NS} (bottom panel) field components on the 21^{st} of July 2020.

Such clear dynamic spectra are relatively rare in summer months when the fingerprint of local thunderstorms often appear as strong intensifications in the ELF spectra. This situation is demonstrated in Fig. 5 which shows dynamic spectra from the 21^{st} of July 2020. The effect of local lightning activity, appearing as very strong intensifications in the dynamic spectrum of both magnetic field components, is clearly visible between 14 and 17 UT. After 17 UT, strong intensifications appearing as individual (distinguishable) vertical lines are probably connected to regional lightning activity (Tatsis et al., 2021). Nevertheless, the dynamic spectra show clear signatures of the SR in the morning which again confirms desirable ELF noise conditions at the test site.

Note the particularly strong, constantly present signal at $50/3 \approx 16.67$ Hz in both field components (Figs. 3, 4, and 5). This signal is produced by the power system that serves electrified railway lines in Austria (Ogunsolar & Mariscotti, 2013). This signal is more or less present in ELF-band records taken at any location to the west from River Danube in Hungary but it may also appear in measurements done further to the east. Fortunately, the frequency of this artificial signal lies between two SR modes and can be handled by digital filtering techniques fairly well.

Summary

The location of the test measurement near Magyargencs seems to be an appropriate place to establish a site for making magnetic SR measurements. It is not known yet if the location is good for making SR measurements in the vertical electric field component, too. This is to be determined yet. As there is neither electric power supply nor internet access point in the area, any measurement must be run on batteries and the collecting of the recorded data requires regular personal visits to the site. These aspects also need to be considered before the establishment of the measurement site is decided.

Acknowledgements

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