Automatic display of ELF measurements recorded in the Széchenyi István Geophysical Observatory

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Abstract

From July 2020, ELF data recorded in the Széchenyi István Geophysical Observatory (SZIGO, IAGA code: NCK) near Nagycenk, Hungary is automatically displayed on the website of the observatory (http://nckobs.hu/data/sr/). The automatically generated figures contain the dynamic spectra of the H_{NS}, H_{EW} and E_Z field components as well as the amplitude and frequency of the first three Schumann resonance (SR) modes as extracted by the complex demodulation algorithm from the E_Z record. This important achievement allows us to continuously monitor the actual state of the measurements. Currently, the figure corresponding to the actual day is accessible for the public while the archive of figures is available only for the staff of the research institute. The number of people visiting the website is continuously tracked and the statistics confirm that there is considerable public interest in our measurements.

Keywords: Schumann resonance, extremely low frequency, data processing, data visualization.

Motivation

At the SZIGO, continuous monitoring of AC phenomena in the global electric circuit, specifically the Schumann resonances (SRs), started in the early 1990s with the installation of a ball antenna (Sátori et al., 2013; Bór et al., 2020). The system was upgraded with induction coil magnetometers in 1996. The complex demodulation algorithm was selected as an adequate algorithm to extract the modal frequency and the amplitude of the first three SR modes (Sátori et al., 1996). Only these spectral parameters were stored until 2003 when the system was upgraded to save the digitized raw time series as well.

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Probably due to the senescence of the recording system, there were more and more problems with the measurements in the recent few years, which raised the need for the continuous monitoring of their actual state. Furthermore, quick-looks are usually standard, freely accessible data products at many geophysical observatories (like at the Sodankylä Geophysical Observatory, https://www.sgo.fi/) so we decided to develop our own process for displaying ELF records automatically on the website of the observatory.

Implementation

The automatic plotting program processes raw data files of .fw4 file extension every 10 minutes. These files are obtained using a Symmetric Research (SymRes) 4-channel data logger. The program is started by a scheduled task running a batch file. The batch file executes a Python code, which performs the complex demodulation and calculates spectra from 10-minute long data series. The end of the processed time period is always 5 minutes earlier than the start of the actual program run. The spectral parameters for the dynamic spectra are calculated from each .fw4 file using 10 s long time windows slid by 5 s between calculations. Then, the 1-minute averages are calculated and saved into three .csv files (one for each data channel). The amplitudes and frequencies of the first three Schumann resonance modes, calculated only for the E_Z field component via the complex demodulation algorithm, are saved to another .csv file. The program creates the .csv files at the beginning of each day and appends data to them every 10 minutes. Then, the data from the .csv files are read and plotted.

The north-south (NS) component of the magnetic field is measured by the induction coil which is the original instrument that was installed on-site in 1996. Since November, 2016, the east-west (EW) component is measured by a LEMI-120 type magnetic antenna that has been installed because the corresponding other original induction coil had to be replaced. Note that the two magnetic antennas have different sensitivities and transmission characteristics. To have a good view on the operation of the signals from both antennas, the color scale for each plot was set up differently. The maximum value of the color scale of the spectrogram of the signal from the EW-oriented (old) coil is 57% higher than that from the NS-oriented LEMI coil.

The automatically generated plot has five subplots (Fig. 1). The first three subplots show the dynamic spectra of the H_{NS}, H_{EW} and the E_Z field components, respectively. The last two subplots show the results of the complex demodulation: the amplitudes and the frequencies based on the E_Z component. The frequencies of the first three SR modes are about 7.9, 14.1 and 20 Hz, respectively. To plot them on one subplot, three y axes were set up as it is indicated by different colors.

The plot is saved to a .png file whose name is always the same. This .png file is uploaded to the nckobs.hu web page via ftp connection and it is displayed on the web page. At the end of the day, the .png file which shows data from all day is saved with a filename which contains the date of the actual day. Then, this file is also uploaded to the nckobs.hu for internal use. Additionally, it is also uploaded to

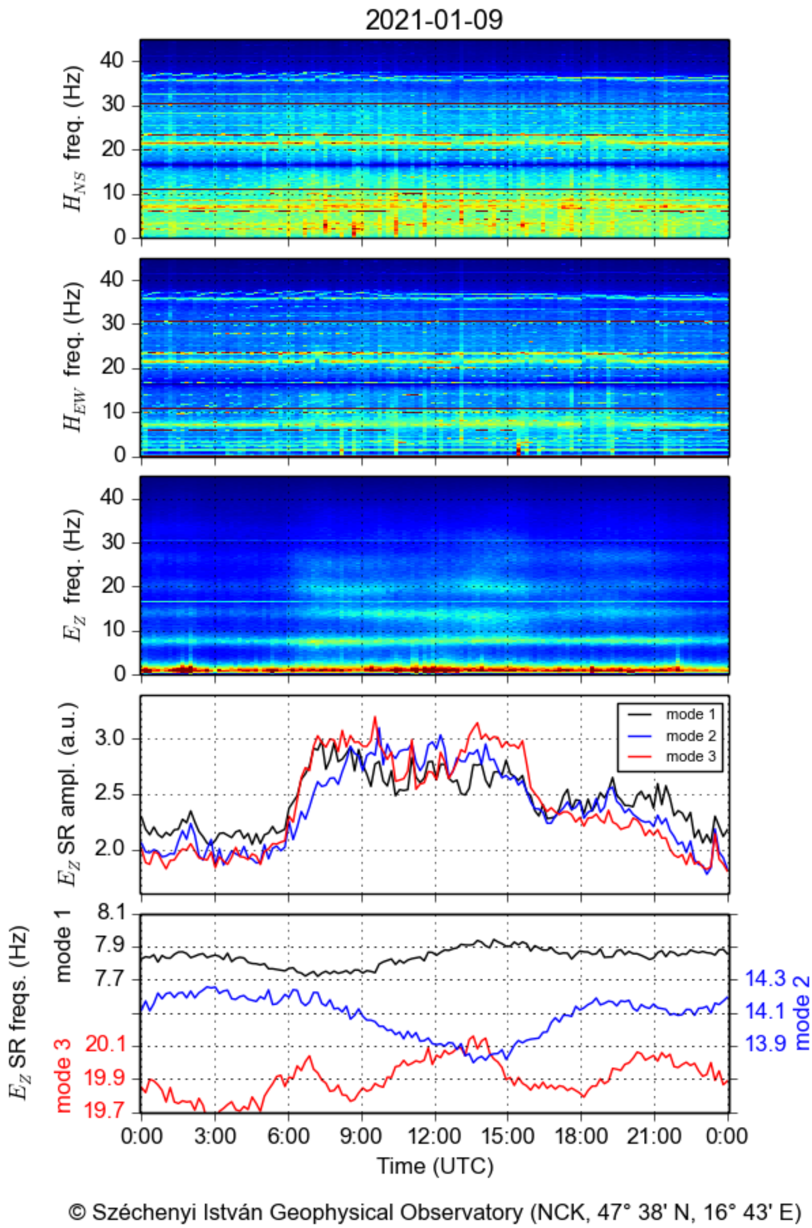

Fig. 1: The automatically generated figure showing the Schumann resonance measurements at the SZIGO on the 9^{th} of January, 2021.

a NAS storage, next to the archived data files.

The program is set to send a warning email when the amplitudes and frequencies can not be calculated via the complex demodulation because the signal from the ball antenna is lost. The program also sends an email when the signal is received again.

The information mirrored by the picture

The primary role of the produced plot is that it helps to check that the SR measurement is working correctly. The color scales are set so that the plot shows SR peaks well when the local environment for the measurements is quiet, i.e., there is no strong wind, precipitation, or nearby thunderstorms in which strong electrical activity takes place in the ELF band, too. If the local environment is disturbed, mechanical vibrations of the antenna or strong ELF-band signals cause that the SR pattern is not visible due to the noise of high amplitude. In these cases, the complex demodulation method cannot work properly and either it produces biased values or cannot provide any output at all. Therefore, the curves and values on the plot produced by the automatic data processing code should not be considered as a reference. The data and results need verification and quality check before any interpretation is made or conclusions could be drawn.

Spectrograms on the upper three panels (Fig. 1) demonstrate well that SR in the vertical electric field component in the SZIGO can be measured very well. Apart from the usual natural and few artificial disturbances, the SR pattern is well detectable. One characteristic of the noise of human origin is that it usually starts and ends suddenly. This allows the primary separation of artificial and natural noises as the latter tend to develop and ring down more gradually. One annoying noise of artificial origin in the E_Z signal is produced by the electric power management in the observatory due to the applied solar panels. This artificial signal appears for a few tens of minutes near dawn and dusk when the operation of the batteries is switched (Fig. 2).

Figure 1 and 2 also show that the horizontal magnetic field in the SZIGO is strongly contaminated by both narrow band and wide band noises so that SR cannot be detected most of the time in the corresponding signals. Occasionally, the noise level is lowered for short time periods of a few hours so that the first or second SR modes can be recognized in the H_{EW} field component (Fig. 2). This shows that noise levels in the ELF band in the SZIGO are direction dependent. Most probably horizontal electric currents cause the strong noise in the magnetic field in the SZIGO. These electric currents can flow horizontally in the upper layers of the ground and their source is most probably the imperfect, leaky grounding of the power system that serves the traffic on the electrified railway lines running in a distance of only a few km to the south from the observatory.

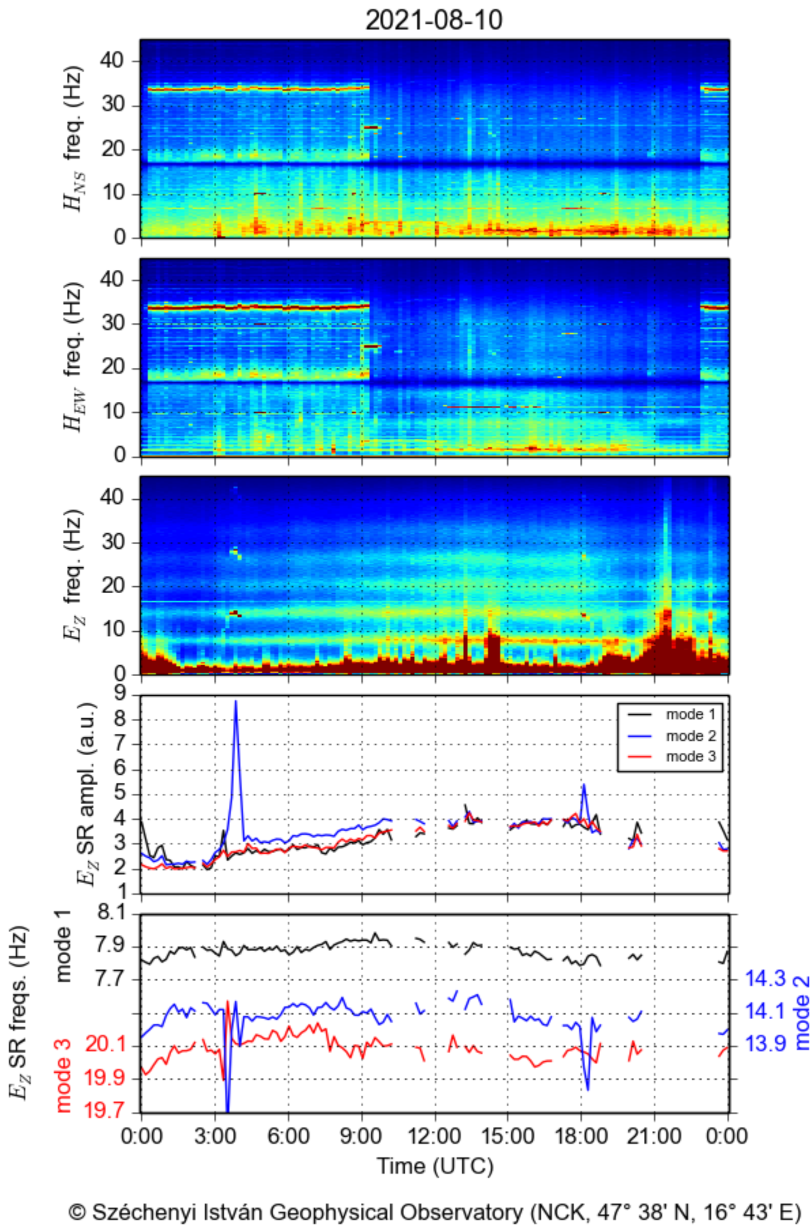

Fig. 2: The automatically generated figure showing the Schumann resonance measurements at the SZIGO on the 10^{th} of August, 2021.

Visitor statistics

This paragraph presents some interesting information about the visitors of our web page (http://nckobs.hu/data/sr/) as seen on the 9^{th} of September 2021. The visitor statistics are tracked using the free services of clicky.com. In the 28-day-long period from August 13, 2021 to September 9, 2021 our website has been visited 1149 times (excluding visits from our institute). Besides the number of visitors, the tracking program also collects information about their location. Most of the visitors in this 28-day-long period were located in Hungary (1054, 92%). Our website has been visited also from abroad, from the following countries (the number of visitors are shown in the parenthesis after the name of each country): Slovakia (17), Austria (16), Romania (14), United Kingdom (12), Germany (9), USA (6), Croatia (5), Serbia (5), Czech Republic (4), France (2), Belgium (1), Ireland (1), Spain (1), Switzerland (1) and The Netherlands (1). The large number of visitors confirms that there is considerable public interest in our measurements.

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