DOI 10.59277/RoAJ.2023.3.04

VLF SIGNAL VARIATIONS SEEN IN THE BUCHAREST OBSERVATORY RECORDINGS

DIANA BEȘLIU-IONESCU[1,2], ADRIAN BRUNO ȘONKA[1]

[1]*Astronomical Institute of the Romanian Academy, 5 Cuțitul de Argint, Bucharest, 040557, Romania,*
Email: diana.ionescu@astro.ro
[2]*Institute of Geodynamics "Sabba S. Ștefănescu" of the Romanian Academy, 5 Cuțitul de Argint, Bucharest, 040557, Romania*

Abstract. This paper presents a new instrument setup at the Bucharest Observatory of the Astronomical Institute of the Romanian Academy, as well as preliminary results using this setup. It consists of records of VLF (very low frequency) perturbations using a superSID instrument. During March and December 2022 various mounts and settings tests have been performed. Starting October we obtained satisfactory data. We report on detecting the signature of moderate to intense solar flares (M and X–class). In this configuration, the C–class solar flares are less distinguishable from the background noise.

Key words: VLF signal, radio, SID, instrumentation.

1. INTRODUCTION

Solar flares are complex eruptive phenomena that release huge amounts of energy (10^{27} to 10^{32} ergs) into the heliosphere in the form of electromagnetic waves or energetic particles. The most popular classification is the one according to the amount of X–ray brightness emitted in the 1–8 Å flux as A, B, C, M and X–class flares (A being the weakest, while X the strongest), each class having 9 subdivisions. The scale is a logarithmic one. As the radiation from solar flares is not limited to the X–ray flux, they can be seen in images from space or ground–based telescopes in many wavelengths, such as EUV, soft and hard X–ray, Hα or even white light images, and are accompanied by signatures in magnetograms or dopplergrams.

Part of the radiation emitted during flares reaches the Earth, more precisely, the ionosphere (the upper part of the Earth's atmosphere) changing the rate of ion formation and recombination (Gubbins and Herrero-Bervera, 2007).

The ionosphere is ionized by the solar ultraviolet and X–ray radiation. The amount of ionization in the ionosphere varies with the amount of radiation received from the Sun and depends on diurnal, seasonal effects, the sunspot cycle, and latitude (Eshquvatov *et al.*, 2021).

As the solar wind changes its speed, composition, direction or magnetic field intensity with solar events, so does the ionising state of the ionosphere change. The density and height of ionospheric layers shift due to the excess input of energy or matter (Adesunloro *et al.*, 2016). This layer influences long distance communications on Earth and ground to satellite ones, thus impacting communication with its shifts.

The maximum ionospheric frequency deviation depends not only on the magnitude of the solar radiation, but also on the rate of its change (Liu, Chiu, and Lin, 1996).

Adesunloro *et al.* (2016) report on detecting M–class solar flares. Eshquvatov *et al.* (2021) have detected signatures of solar flares as weak as C–class ones at Ulugh Beg Astronomical Institute in Tashkent, Uzbekistan ($\sim$41°North latitude) in a much more secluded region.

Brčić, Kos, and Filjar (2012) report a case of the short–lived ionospheric disturbance, detected by SID monitor located at the GNSS laboratory, Faculty of Maritime Studies in Rijeka, Croatia, and the effects it causes to the GPS positioning performance. Flares or coronal mass ejections have profound effects on various aspects of our technological lives. Consequently, it is crucial to understand their impacts and monitor the state of the ionosphere.

Continuous data gathered from many superSID monitors around the world are available at *sid.stanford.edu/database-browser/.*

This paper is is organized into three main sections: Data (2), a Results (3) section, and a Discussion (4) section.

2. INSTRUMENT AND DATA

We use data obtained with a SuperSID monitor installed at the Bucharest Observatory (longitude 26.1°, latitude 44.1°). This instrument can detect changes to the Earth's ionosphere caused by solar flares and other disturbances.

Our receiver is a SuperSID from Stanford Solar Center, with a preamplifier and an external sound card, needed to convert analog signal to digital. This instrument is described in detail at *http://solar-center.stanford.edu/SID/DOC/.* It records the signal strength received at 23400 Hz from VLF station: DHO – Germany: Rhauderfehn, a 500 kHz power radio emitter, situated at a distance of 2000 km, in northern Germany.

The instrument has an proprietary software provided by Stanford Solar Center that records the signal with a temporal cadence of 5s. Our equipment is tuned to receive data from other five radio transmitters, TBB (Turkey), NSC (Sicily), NRK (Iceland), HWU (France), GQD (UK), but the data recorded for these stations at the Bucharest Observatory is unusable.

To ensure the optimal reception of the radio signal, it is imperative to connect a specific antenna to the device, following the instructions provided by *http://solar-center.stanford.edu/SID/DOC/.* This certifies that the device is properly equipped to capture the desired radio signals. Therefore, within our institute, we constructed an antenna measuring 1 meter square. The antenna was built using 120 meters of insulated wire and a plastic pipe frame.

As for the hardware configuration, the software is installed on a PC with an Intel(R) Core(TM) i5-6260U CPU @ 1.80GH, with 8 GB RAM, running Windows 11.

The data is gathered in cvs files having a header that describes the instrument, its location and the station that it is receiving the signal from, and a three column structured tabular form, with the first two columns showing the date and the hour, while the last column lists the signal strength. The recorded files are available online at *http://app.astro.ro/sid/*.

Our instrument was initially installed in March 2022. We conducted several tests to assess the quality of the signal, and starting from October 2022, we obtained satisfactory data.

The data for sunrise and sunset used in this study is provided by the Astronomical Institute of the Romanian Academy and is publicly available at *astro.ro*, in the Astrodata section.

3. RESULTS

The SuperSID records the radio signal of an emitter reflected by the ionosphere. The properties of this atmospheric layer change with the presence of the Sun, and its X–ray flux emission that changes at its turn with solar cycle, on long term, and with solar eruptive events, on short term.

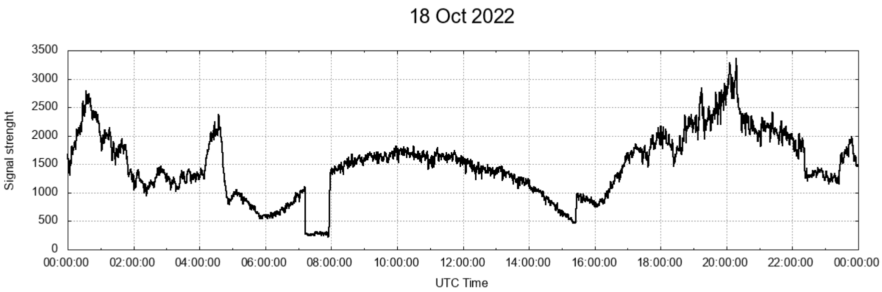

Fig. 1 – Data for 18 October 2022, a day without solar flare on the Sun. The signal shows the regular drop of signal between 7:30 and 8:00 UT. The irregular signal before sunrise and after sunset is also visible.

On a quiet day, our data shows a strong variable pattern in the signal, during nighttime (Figure 1). The signal stabilizes with the rising of the Sun, and slowly grows in strength until mid–day. Afterwards, the strength of the signal is decaying until the sunset. After the sunset we begin to record a highly variable signal. The emitter has a daily maintenance between 7:30–8:00 UT, which shows as an abrupt change in the signal. The search for the influence of flares on the ionosphere can be performed only between sunrise and sunset times.

Figure 2 illustrates one of the datasets acquired at the Bucharest Observatory on October 11, 2022. The data presented in the Figure 2 has been normalised to the maximum value recorded that day. The vertical arrows depicted in the Figure represent the time of sunrise (upwards arrow) and sunset (downwards arrow).

On this day, October 11, 2022, GOES detected nine C–class solar flares and two M–class ones. Two M–class and two C–class solar flares matched our daytime, all four of them originating from NOAA 13112.

These two M–class solar flares were an M3.9 starting at 08:36, peaking at 08:42 and ending at 08:46, and an M1.5 starting at 10:47, peaking at 10:52 and ending at 10:57 UT. Their maximum emission times are marked by solid vertical lines in Figure 2. The maximum X–ray emission from the two C–class solar flares are shown with dotted vertical lines (12:54 and 16:45, all times are local times).

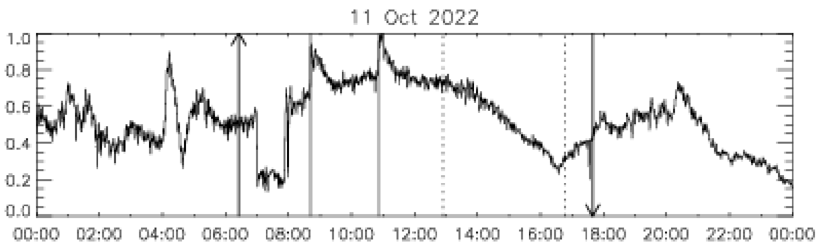

Fig. 2 – Normalised data set for October 11, 2022. Arrows represent sunrise and sunset. Vertical lines represent M–class solar flare maximum emission times. Dotted vertical line represent C–class solar flare maximum emission time.

What can easily be seen in Figure 2 is that the two M–class solar flares have a distinct signature in the data, shown as a $\sim$20% increase in the radio signal. However, the signatures for the C–class flares are not distinguishable in the Figure.

4. SUMMARY

We have presented in this study the new setup using a superSid instrument for recording ionospheric perturbations, along with preliminary data obtained at the Bucharest Observatory within the Astronomical Institute of the Romanian Academy.

We have demonstrated that the radio signal strength, as recorded in this configuration, exhibits discernible signatures of solar flares. However, a more detailed analysis must be completed in order to understand the lack or the very weak signatures for certain flares.

We have added in Figure 3 a series of graphical representations of the superSID data for the period between October 10 to 31, 2022.

In our future plans, we aim to relocate the system to a quieter region, particularly the Berthelot Observatory in Hunedoara County. By moving to this location, characterized by reduced background radio noise, we anticipate an improvement in the accuracy of solar flare detections in the data collected by the SuperSID instrument.

CONFLICT OF INTEREST

The authors declare no potential conflict of interests.

Acknowledgements. This work was supported by a grant of the Ministry of Research, Innovation and Digitisation, CNCS/CCCDI-UEFISCDI, project number PN-III-P2-2.1-SOL-2021-2-0192, witin PNCDI III.

REFERENCES

Adesunloro, G., Gbadegesin, K., *et al.*: 2016, Tracking solar flares using the supersid monitor. *American Academic Scientific Research Journal for Engineering, Technology, and Sciences* **15**(1), 96 – 108.

Brčić, D., Kos, S., Filjar, R.: 2012, A case of degraded gps performance during a short-term ionospheric disturbance in northern adriatic. In: *Proceedings of the 6th Global Navigation Satellite Systems Vulnerabilities and Solutions Conference*, 21 – 24.

Eshquvatov, H., Ahmedov, B., Tillayev, Y., Asatov, U.: 2021, Analyzing solar flares using the tashkent supersid monitor. *CENTRAL ASIAN JOURNAL OF THEORETICAL & APPLIED SCIENCES* **2**(2), 1 – 9.

Gubbins, D., Herrero-Bervera, E.: 2007, Encyclopedia of geomagnetism and paleomagnetism.

Liu, J.Y., Chiu, C.S., Lin, C.H.: 1996, The solar flare radiation responsible for sudden frequency deviation and geomagnetic fluctuation. *J. Geophys. Res.* **101**(A5), 10855 – 10862. doi:10.1029/95JA03676.

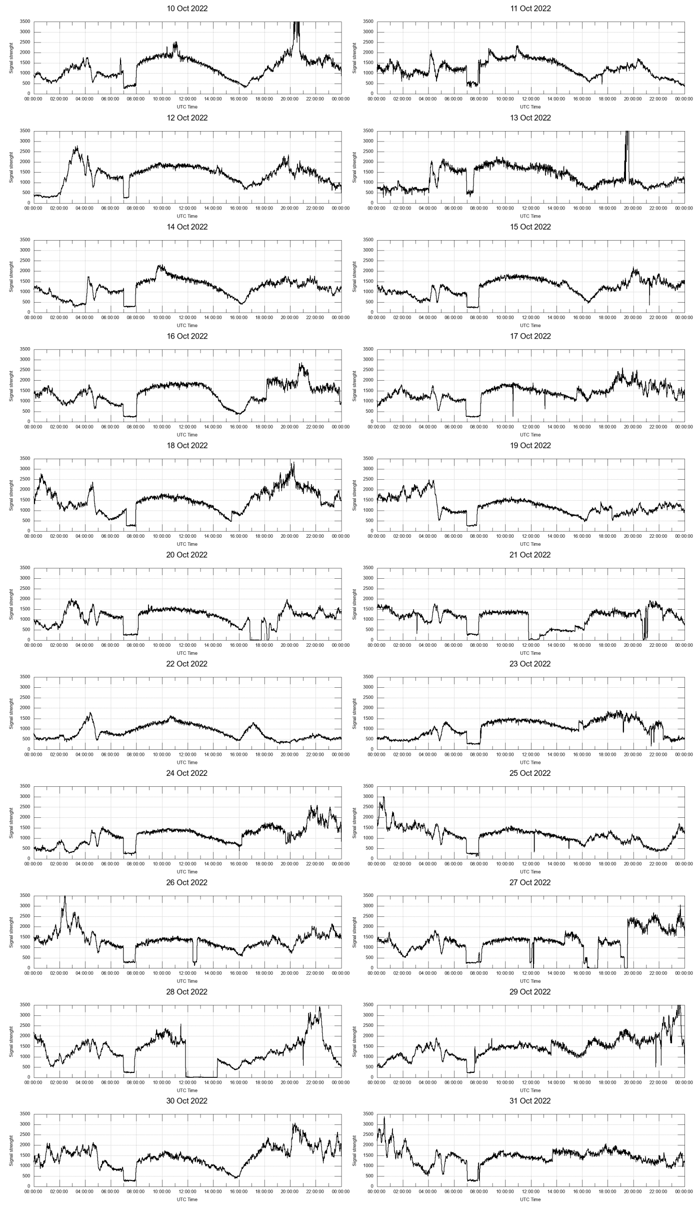

Fig. 3 – SuperSID Data for the period between 18 and 31 October 2022.