

X-Ray Solar Flares Observed and Detected by the New Very-Low-Frequency Receiver in Nasiriyah City, South of Iraq

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ABSTRACT

A receiver station was installed at Nasiriyah (Dhi Qar University - Faculty of Sciences) to receive very low frequency (VLF) radio signals from transmitters around the world. VLF waves are excellent probes of the sudden ionospheric disturbance (SID); they detect varying properties of the D layer presented as a lower region of the ionosphere when these waves propagate through the Earth-Ionosphere Waveguide. This study describes the set-up of our station system and it demonstrates its ability to detect sudden ionospheric disturbances caused by solar flares in May, June, July, August, and September 2017. We found out that the monitoring station is working successfully to receive FLV signals, and to detect sudden ionospheric disturbances. We detected 17 events resulting from solar flare C-class, 8 events from M-class, and 3 events from X-class that caused an increase in the received FLV amplitude.

KEYWORDS: Solar flares, Very low frequency, Sudden Ionospheric Disturbance.

الخلاصة

تم تركيب محطة الاستقبال في الناصرية (جامعة ذي قار كلية العلوم) لإستلام إشارات الموجات الراديوية ذات التردد المنخفض جدا (VLF) من أجهزة الإرسال حول العالم. موجات VLF هي تحقيقات ممتازة لاضطراب الغلاف الأيوني المفاجئ (SID)؛ لقد اكتشفوا خصائص متباينة للطبقة D المقدمة كمنطقة منخفضة من الأيونوسفير عندما تنتشر هذه الموجات عبر الدليل الموجي للأرض والأيونوسفير. تصف هذه الدراسة تكوين نظام محطاتنا وتوضح قدرته على اكتشاف اضطرابات الغلاف المتأين المفاجئ التي تسببها التوهجات الشمسية في مايو ويونيو ويوليو وأغسطس وسبتمبر 2017. اكتشفنا أن محطة المراقبة تعمل بنجاح لاستقبال إشارات FLV، واكتشف الاضطرابات المتأينة المفاجئة. اكتشفنا 17 حدثاً ناتجاً عن التوهج الشمسي فئة C، و 8 أحداث من الفئة M و 3 أحداث من الفئة X تسببت في زيادة سعة FLV المستلمة.

INTRODUCTION

Space physics is the study of plasmas which are naturally made up in the upper atmosphere of the Earth. Space physics include an extensive variety of topics, such as the study of the sun and the physical relations between the Sun and the solar system called Heliophysics, (from the prefix 'helio,' originally from the Greek Attic hallios, which means Sun) [1] [2]. Consequently, NASA describes it as a systematic new concept for Sun Science-Solar system Link exploring, finding and understanding the Earth's space environment [3]. Space physics is an integral part of space weather science and it has massive consequences for understanding the environment and for communications and satellite operations.

As ionosphere reflects the VLF waves, it may be used as a prospective tool for studying the D-

region ionosphere which plays an important role in the propagation of radio waves [4][5]. VLF can be used as a D-layer probe because this region is lower than the satellites location and higher than atmospheric balloons. In the Earth-Ionosphere Waveguide (EIWG) which is created between the conducting Earth and the ionosphere, there are radios of extremely low frequency (3 kHz – 30 kHz). They correspond to wavelengths between 100 and 10 km, respectively, transmitting thousands of kilometres. The ionospheric D-region (60 km–90 km altitude) works as the upper border of the Earth Ionosphere Wave Guide EIWG during the day, while at night the region is much weaker and the levels move to higher altitudes [6]. When the x-ray effect stops, the radio blackout also stops and the sudden ionospheric (SID) ends as the D-layer electrons

quickly recombine and the signal strengths go back to normal.

The research objective is to highlight the installation of Nasiriyah station which was built of Super SID system for the VLF monitoring station at Dhi-Qar University (46°16' E, 31°03' N). Evidence drawn from many solar flares of the M-class and C-class demonstrate the instrument's reaction, and the properties of the D-region which can be modeled based on these measures.

MATERIALS AND METHODOLOGY

The receiver

The goal of any receiving antenna is to convert the electromagnetic wave to voltage. An annular magnetic antenna is a winding of insulated copper wire around a frame (coil with a core of air) or ferromagnetic materials (coil with an iron core (frit)). The annular antenna is sensitive to the magnetic field rather than to the electric field (it is also called a magnetic ring).

The antenna that can receive VLF radio signals is called an annular antenna. The annular antenna is an inductor-capacitor circuit that oscillates at some frequencies. Any inductor collects and stores magnetic energy, while a capacitor collects charges; thus, it stores electrical energy. Induction is formed by a wire loop. The capacitance is formed from a metallic surface of a wire mesh, operating in parallel along a loop. The resistance of the wires is small, although it is always present in the wire and it increases as the length of the wire increases. Since the electromagnetic field of the VLF station passes through the loop, it produces a very small electrical current (~ 0.1 mV) in the wire.

We can endeavor to capture this very small signal by increasing the number of turns or enlarging the antenna size. As the number of turns increases, the amplitude also increases, reducing the resonant frequency. When the number of turns increases, the resistance of the wire increases too, causing the signal amplitude to decrease. At the beginning of this study, we used antennas of different shapes and sizes, besides wires that differ in terms of their diameters and the materials they are made from; they were wrapped around these antennas. The first antenna was a quadrilateral, half a meter in length, wrapped around a wire of copper with a diameter of 0.4mm; the number of turns was about 120, but it was not good enough to receive the

signal because of its small size and grounding that was not good at that time. As for the second antenna, it was a quadrilateral. The length of the rib was 1 meter. A copper wire was wrapped around it, and the number of turns was 30. Also, we did not get a good signal because of the bad grounding. As for the last antenna, it was octagonal, the length of one side was 85 cm, wrapped around the twin-wire phone cord; the diameter of the single wire is 0.9 mm, the length is 200 meters, and the number of turns is 30, as illustrated in Figure 1. Because of its large size and good grounding, we were able to get a good signal whereby a perfect VLF wave chart was obtained over a whole day; we relied on it to monitor the ionosphere disorders.



Figure 1. Various samples of antennas used in this work we were calibrated the system.

Setup and settings

The Stanford University Solar Energy Center has developed, as part of the international program ISWI, space weather monitors that students can install and use. These devices detect changes inexpensive in the ionosphere caused by solar explosions and other disturbances. This device is intended to direct the project by designing our antenna, which is easy to install and takes a few hours to assemble; besides, it does not cost much. The data is collected and analyzed by a desktop computer which does not need to be of high specifications. A typical VLF receiver consists of several components: antennas, cables, and a linear receiver with a digitizer amplifier, a computer and storage. Figure 2 displays a more detailed outline of the VLF receiver.

Each antenna is connected to a three-phase amplifier: a special low-noise amplifier that uses identical PNP transistors, a frequency compensation phase, and a signal output stage. A Coaxial Cable is a cable that has two conductors on the same axis, the first is a central conductor and the second is a ground shield around the central conductor. RG-58 is the standard 50 Ohm

resistance cable. We determine the length of cable that we need to connect the antenna to the receiver. The shorter cable gives a good signal and reduces noise.

RESULTS AND DISCUSSION

Record and monitor data

VLF waves have been received from various transmitters at the ISIO station in Dhi Qar University College of Science, Figure 3. These transmitters are TBB (26.7 kHz) in Turkey, DHO38 (23.4 kHz) in Germany, HWU (21.75 kHz) in France, GQD (22.1 kHz) in the UK and (29.9 KHZ) NON which is not included in the list of global transmitters.

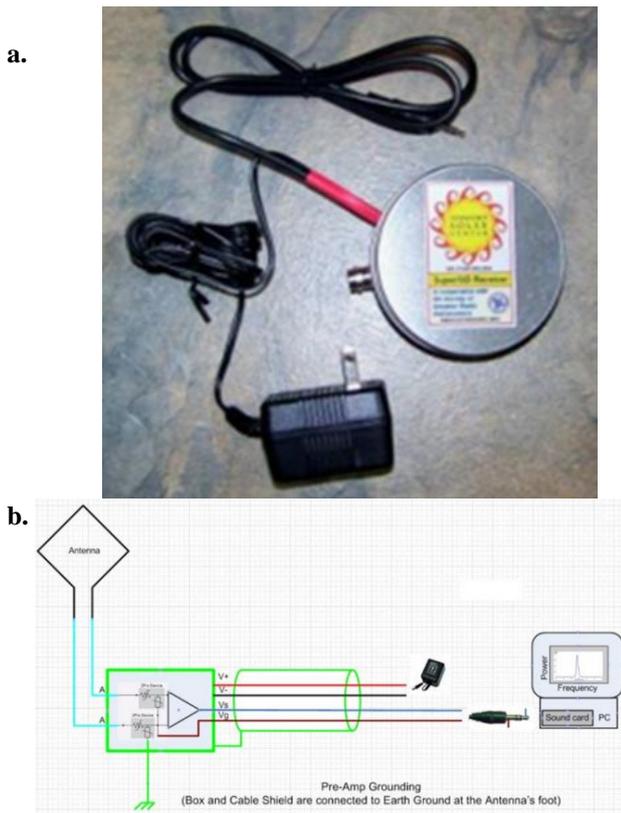


Figure 2. a. Super SID receiver, b. Diagram of the VLF signal receiver.

The radio signals obtained by the antenna are very small, approximately 0.1 milli-volts, so we need an amplifier to amplify the signal about thousands of times to a level that the sound card can sense to the computer. The amplifier was obtained from Stanford University, California, USA. The digital converter is the sound card in a computer; it converts the signal from analogue to digital. The digital converter must support a high definition (HD) sound card, which can record with the coding up to 96 kHz.

Finally, we need a program to be installed on a computer to track the intensity of the transmitted VLF waves, to process data and to display graphs (it records the amplitude and phase of the signals over time). This data is stored on the computer's storage unit. This program came with a device from Stanford University, which is designed to detect sudden ionosphere disturbances that result from the intense X-ray explosion when there are solar flares on the sun.

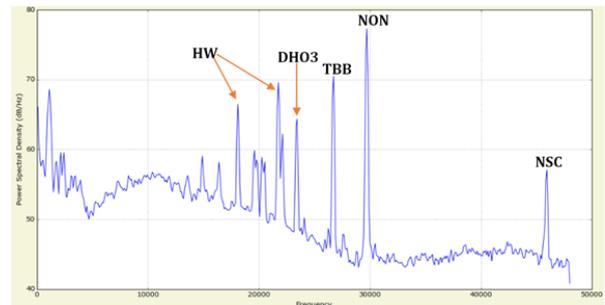


Figure 3. Power spectral density of many transmitters detected by Nasiriyah city VLF receiver.

Figure 4 clarifies the typical change in signal amplitude, where the horizontal axis represents UT and the vertical axis represents the strength of the signal.

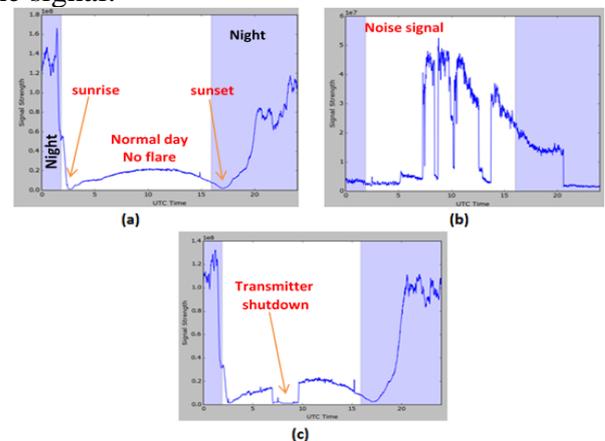


Figure 4. Typical change in signal amplitude.

Part (a) of Figure 4 exhibits the typical change in the amplitude of the received signal; no solar events are visible in the drawing, i.e. (a normal day) for 24 hours when sunrise and sunset appear distinctively; one can observe a sharp drop in that capacitance down at Sunrise and sunset. The area between sunrise and sunset is where one looks for solar events whereas part (b) of Figure 4 represents the interference that occurs in the amplitude of the signal due to the above stated

sources of interference or the recurrence of a problem in the antenna where one cannot distinguish the solar events or notice the changes in sunrise and sunset. As for part (c) of the same figure, one can observe places in the graph in the form of flat lines; they represent the interruption of the transmitter for maintenance once or more per week; this usually occurs regularly according to a mechanism followed by the supervisors of the transmitting station. These observations remain confidential and undisclosed, as they relate to the military field of the stations. The amplitude curve when solar flares is shown in Figure 5, whereby a sudden increase in amplitude occurs in the form of spines going upward and then returning to the normal level towards the end of the disturbance.

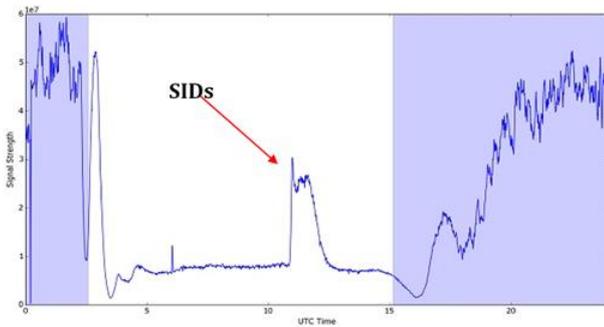


Figure 5. Amplitude changes during turbulence.

Check that the data is correct

The solar X-ray sensor over a wide area on the GOES15 satellite records the X-ray flux with two-wavelength beams: (1) 0.1-0.8 nm, which is referred to as soft (x-ray) and (2) 0.05-0.4 nm, which is referred to by a high name (hard x-ray). The solar flares fluxes are classified into B, C, M, and X according to the peak flood (in watts per square meter, W/m^2) in the ray beam.

Table 1 displays the intensity of the flux corresponding to the different categories of flares. Each class has a peak overflow ten times greater than its predecessor, a class X X-ray has a peak flow of $10^{-4} W / m^2$. Within the class, there is a linear scale from 1 to 9. For example, the class X2 X-ray is twice the power of the X1 class X-ray. The GOES detectors become saturated with the strongest solar flares of class X17, [5]. In this work, the solar power overflow data is used in the light beam that is available at <http://spidr.ngdc.noaa.gov/spidr/dataset.do>, an average of one minute. The data analysis period started from May and continued to September, 2017. The signal amplitude of the VLF waves was studied and analyzed with the solar X-ray

overflow with an average value of one minute. In the present study, several solar flares events were detected by GOES15 via recording the X-ray emission that occurred during this period, as shown in Table 2.

Table 1. Classification of solar flares in terms of intensity.

Solar flare class	Intensity (W/m^2)
B	$I \leq 10^{-6}$
C	$10^{-6} \leq I < 10^{-5}$
M	$10^{-5} \leq I < 10^{-4}$
X	$I \geq 10^{-4}$

Table 2. Observed solar flares by GOES satellites for five months.

Date	Number of X-Ray Flare from GOES15		
	C-class	M-class	X-class
May 2017	5	0	0
June 2017	17	0	0
July 2017	30	3	0
August 2017	46	1	0
To 15 Sept. 2017	66	25	4
Total	164	29	4

Classes C, M, and X of the Solar X-rays have also been adopted because they often produce observable effects on the transmit VLF waves amplitude. Solar events that give C class Solar X-rays can be seen; they occur most of the time, whereas M class events have a lower incidence, and X class has a much lower incidence than those of previous classes. The appearance of solar flares was higher during September 2017, while five solar events were observed for C class flare during May of the same year as presented in Figure 6.

NUMBER OF X-RAY FLARE FROM GOES15

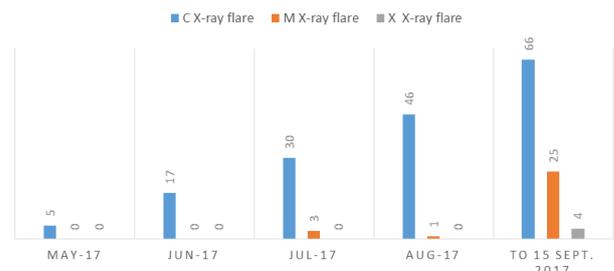


Figure 6. The numbers of solar flare and class of X-ray during the observation time.

As for the most severe events, classes X and M, no event was observed during May and June due to the low incidence of strong Flare during this period of data analysis. Several instances of amplitude disturbances were not noted; they did not appear on the graph. However, some strong class C, M and X flares produce VLF amplitude

and phase disturbances. Figure 7 reveals the number of flares detected by our receiver, which caused an increase in amplitude during the period mentioned above; the number was calculated in Table 3.

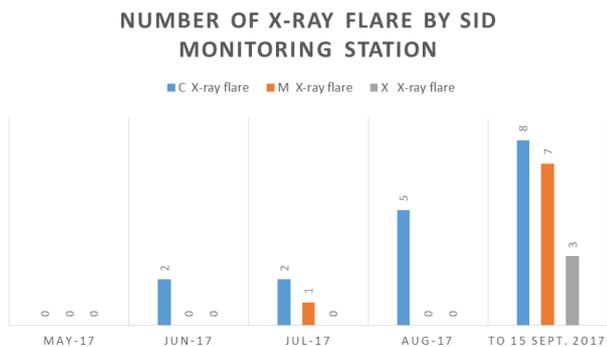


Figure 7. Numbers of X-ray flares detected by Nasiriyah VLF station.

Table 3. X-ray Flares by the monitoring station.

Date	Number of X-Ray Flare By SID monitoring station		
	C	M	X
May 2017	0	0	0
June 2017	2	0	0
July 2017	2	1	0
August 2017	5	0	0
To 15 Sept. 2017	8	7	3
Total	17	8	3

CONCLUSION

To sum up, the monitoring station has proved to be successful in receiving FLV signals and detecting sudden ionospheric disturbances. The received FLV signal strength and clarity depends on the location of the antenna; it should be far from the sources of interference, considering the good grounding of the receiving system. The signal strength varies during the night due to the disappearance of the D layer, while it remains stable during the day. The minimum amplitude

limits during sunrise and sunset depend on the distance between the transmitter and the receiving station. Solar flares only produce changes in the amplitude of the FLV waves during the day. The amplitude of the wave is proportional to the intensity of the x-ray flux, as some varieties cannot be detected due to their low intensity, which leads to an intangible increase in amplitude. The X-ray classes detected by GOES15 for the aforementioned period were more than the number of events monitored by our station because monitoring takes place only during the day while the satellite continues to monitor throughout the day.

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