STUDY OF SUDDEN IONOSPHERIC DISTURBANCES USING VERY LOW FREQUENCY RECEIVER IN NHA TRANG, VIETNAM

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ABSTRACT

The technique of using very low frequency signals (VLF-Very Low Frequency) is a very effective tool to study the sudden ionospheric disturbance (SID) due to the fact that the VLF signals are almost entirely reflected at D layer (60 - 90 km altitude) of the ionosphere when disturbance occurs. For the requirement of quickly grasp advanced engineering and technology to master the research equipment, we bravely set a target for manufacturing equipment to serve the research and application. In this paper, the research group would like to present the obtained results of applying the VLF receiver made at Nha Trang Institute of Technology Research and Application to study the sudden ionospheric disturbances.

Keywords: VLF signal, VLF receiver, sudden ionospheric disturbance.

1. INTRODUCTION

A sudden ionospheric disturbance is a natural phenomenon, in which the Earth's ionosphere is temporarily disturbed by increasing of ionization sources. There are many sources, which creat sudden ionospheric disturbances but the most common source is solar flare. Radiations from solar flares, especially high energy X-rays can take about 8 minutes to the earth [1].

In the day time, free electron density of D-layer is not high enough to reflect VLF waves so they go through the D-layer and are reflected by higher layers (E-layer and F-layer). Energy of VLF waves is decreased strongly by adsorption of D-layer (Figure 1).

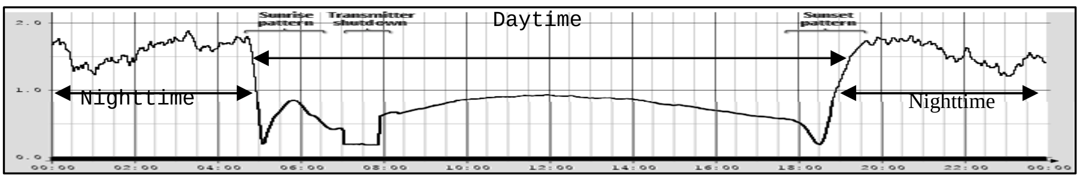

Figure 1. Variation of VLF signal for a quiet day [1].

At night, the D-layer and E-layer disappear and VLF waves are reflected by the higher F-layers therefore strength of VLF signals increase significantly compared to the time of day.

During a solar flare (solar flares are classified as A, B, C, M or X, each letter represents a 10-fold increase in energy output. So an X is ten times an M and 100 times a C), X-ray radiations penetrate to the D-layer of the ionosphere and increase the ionisation process and the electron density, thus leading a sudden ionospheric disturbance. The result is an increase in amplitude of obtained waves because almost VLF waves are reflected at the D-layer (Figure 2).

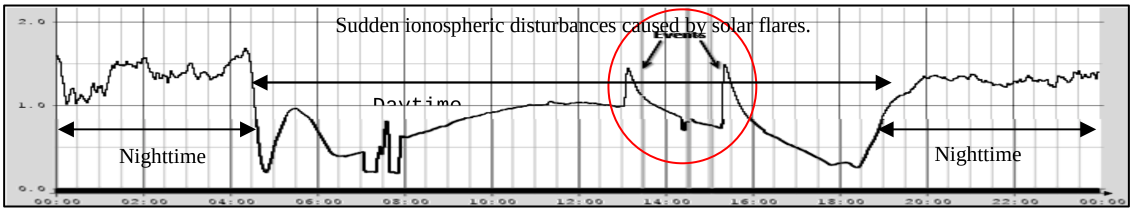

Figure 2. Variation of VLF signal for a disturbed day with two solar flares [1].

Through the International Space Weather Initiative (ISWI) program of the United Nations (UN), the AWESOME receivers of Stanford University being used in conjunction with world-wide VLF transmitters system to investigate the variability of climate, ionosphere and Earth's magnetic field. In addition, nearly 300 simpler SID (Sudden Ionospheric Disturbance monitor) have been designated by Stanford University for developing space weather education to be provided to many schools of the world. Based on the design of the SID monitor of Stanford University [2], we made a VLF receiver for researching sudden ionospheric disturbances in Vietnam.

2. VLF RECEIVER (SID TYPE) MADE IN NHA TRANG

2.1. Antennas of VLF receiver

The VLF receiver used a wire loop antenna [3], the research group has built a small antenna with 50 turns (0.6 mm diameter core) on a 1 m square frame (Figure 3).

Figure 3. Manufacturing a small square frame antenna used for VLF receiving antenna.

This antenna is easy to build but it has the disadvantage of being not durable when used outdoors, due to direct impacts of rain and sun. In addition, the direction chart of this antenna can be distorted by the antenna effect to frame [4]. Therefore, we have decided to build a small circular frame antenna with metal casing (Figure 4) to enhance the quality and protection ability of the antenna against the effects of the environment. By using an old direction finding antenna, we have to disassemble the frames, cables and use approximately 200 meters of insulated wire to wind the wires in metal casing.

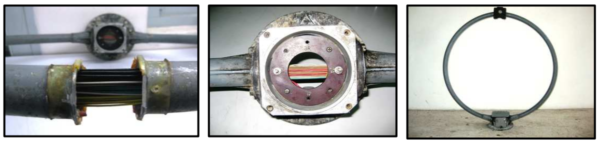

*Figure 4. M*anufacturing a small circular frame antenna with metal casing.

2.2. Main board and frequency filter board

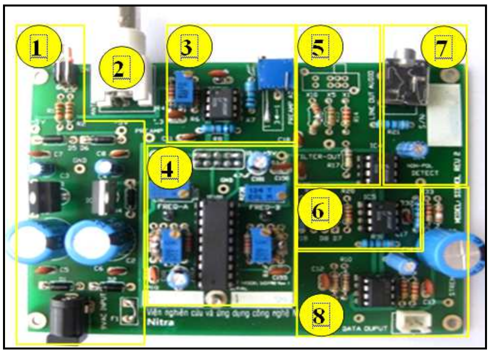

Figure 5. Boards of the VLF receiver have been manufactured completely.

The main board includes parts, which are numbered 1, 2, 3, 5, 6, 7, 8. The frequency filter board (numbered 4) is made independently for easy adjustment of frequency and is mounted to the main board (Figure 5).

1- The Power Supply +/- 5 Volt DC.
2- The TNC input feeds the broadband signal in from the antenna.
3- The Preamp circuit: Based on the amplification function of the operational amplifier, preamp circuit is designed with two stages, which are non-inverted input and inverted input. The total gain is about 42,000 times and can be adjusted by an adjustable potentionmetter.
4- The Frequency filter board: The Frequency filter board is designed based on the MAX275, which is continuous-time active filter [5]. The center frequencies can be up to 300 kHz,and are accuracy to within ±0.9%. The MAX275 comprises two 2^{nd}-oder sections. Eeach section can implement any all-pole bandpass or lowpass filter response, such as Butterworth, Bessel and Chebyshev, and is programmed by four external resistors.
5- The Post gain amplifier: This stage is a backup solution for the too weak input signal or poor quality antenna designs. This is done by an gain slide switch, which allows the selection of three different gain factors.
6- The Amplitude Modulation Detection Circuit: The VLF transmitting station’s signals often have a fixed frequency and a fixed amplitude. However, under the effect of the ionosphere these VLF signals received at the receiving station will be changed phase and amplitude. The variation of VLF signal amplitude is monitored using a circuit full wave rectifier.
7- The Audio output circuit.
8- The Data output circuit.

3. RESULTS AND DISCUSION

3.1. Result of VLF receiver manufacturing

On Figure 6 is the VLF receiver completely manufactured at the Nha Trang Institute of Technology Research and Application.

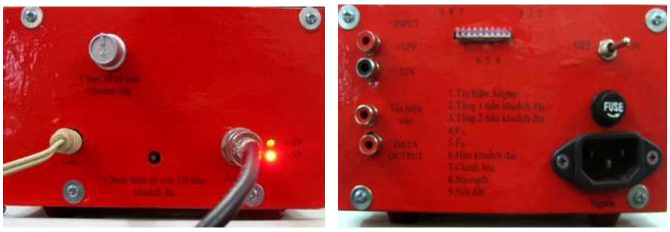

Figure 6. The VLF receiver has been manufactured completely in Nha Trang, Vietnam.

Because the received signals directly from the antenna vary with the fluctuation of the ionosphere so the output DC voltages at the Data output circuit also vary and are stored as data files on a computer via USB NI card 6009 and Labview program (Figure 7).

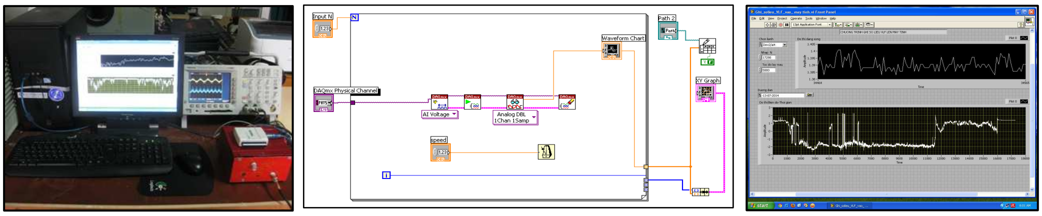

Figure 7. Recording data to computer using USB NI card 6009 and Labview program.

3.2. Results of monitoring the SID events by the VLF receiver in Nha Trang, Vietnam

The VLF receiver was manufactured completely in August 2014 and has begun to collect data continuously from September 2014 untill now. The VLF data have been collected in the text files (* .txt). The sampling frequency is 1 sample / 5 seconds (Figure 8).

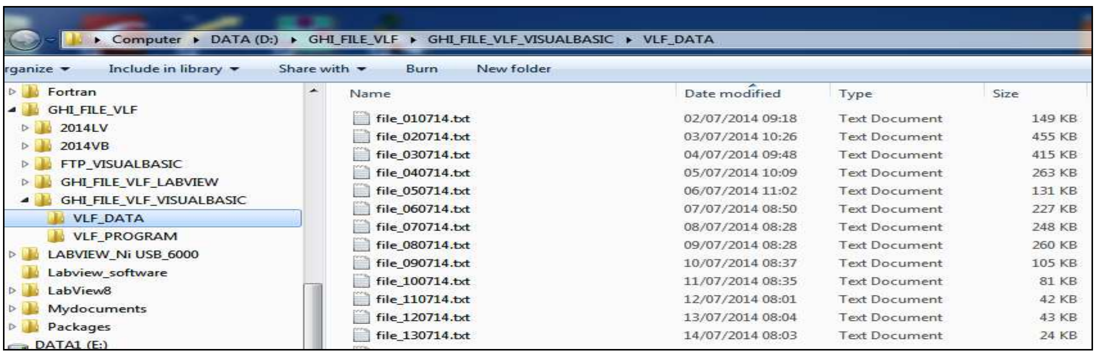

Figure 8. The original data of the VLF receiver in Nha Trang, Vietnam.

The VLF data have been processed by the programs that have been written by the research group in IDL language (Figure 9).

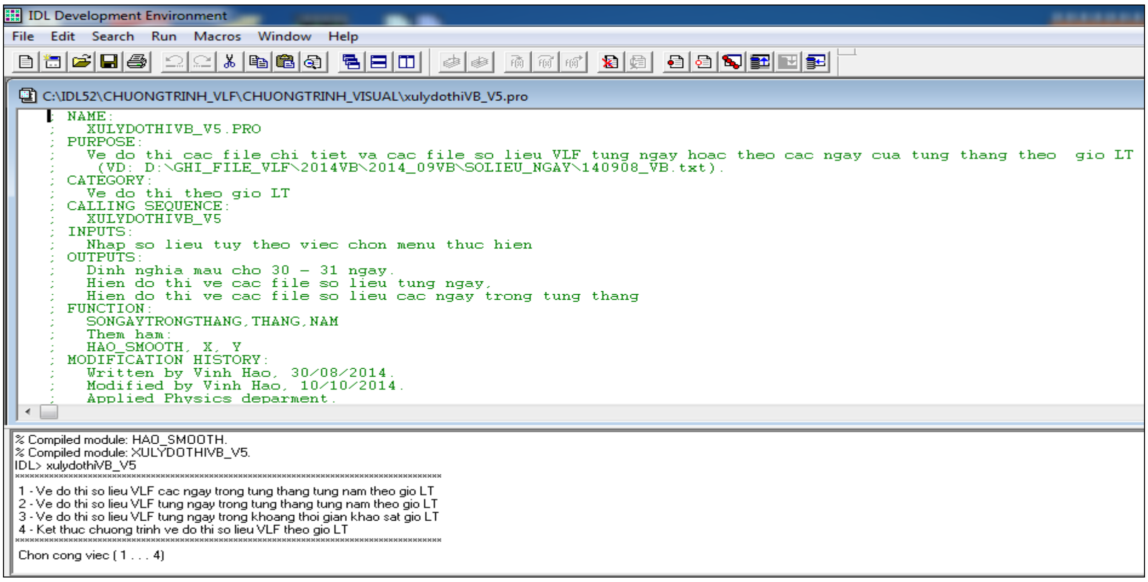

Figure 9. Data processing programs of the VLF receiver in IDL language.

Some initial processing results for the months September - December 2014 are presented on the Table 1, Figure 10 and Figure 11.

Note: - SID events are published by website American Association of Variable Star Observers [6].

- LT in Nha Trang, Vietnam = UT+7.

Table 1. SID events that were observed on data of the VLF receiver in Nha Trang, Vietnam.

Importance	Peak of event (UT)	Day	Peak of event (LT)	Day	Month	Year
2+	23:16	23	06:16	24	09	2014
3+	05:44	26	12:44	26	09	2014
2+	02:58	28	09:58	28	09	2014
2	04:41	29	11:41	29	09	2014
2+	03:10	2	10:10	2	10	2014
2+	04:20	3	11:20	3	10	2014
2	09:28	9	16:28	9	10	2014
2+	09:35	10	16:35	10	10	2014
2+	08:50	16	15:50	16	10	2014
2	09:09	20	16:09	20	10	2014
3+	10:30	29	17:30	29	10	2014
2+	08:25	3	15:25	3	11	2014
2	08:38	4	15:38	4	11	2014

2	03:13	9	10:13	9	11	2014
3+	03:18	12	10:18	12	11	2014
2+	08:38	25	15:38	25	11	2014
2	10:10	27	17:10	27	11	2014
2+	02:07	29	09:07	29	11	2014
2	09:27	2	16:27	2	12	2014
2	08:53	4	15:53	4	12	2014
2	04:32	14	11:32	14	12	2014
2+	02:38	18	09:38	18	12	2014
2	05:24	25	12:24	25	12	2014

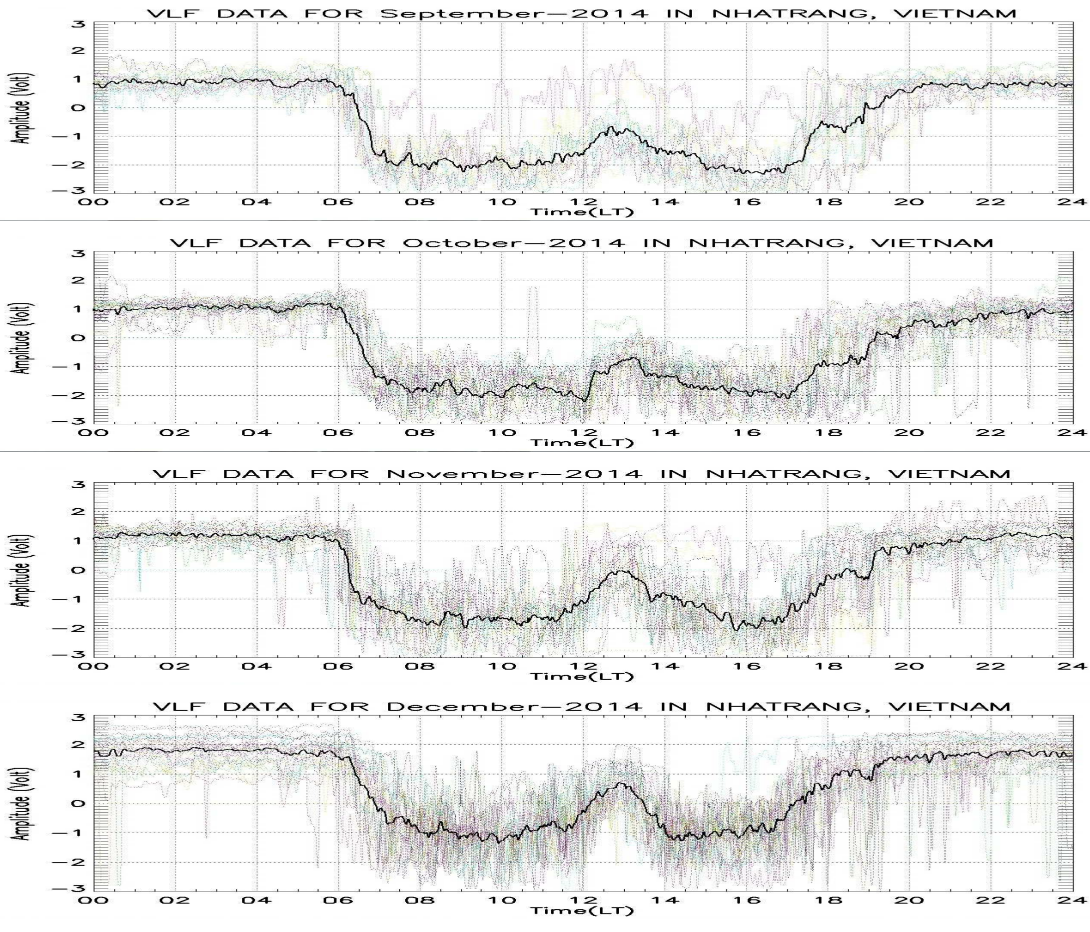

*Figure 10***.** The VLF average data for the months September – December 2014 in Nha Trang, Vietnam.

3.3. Comparing processed data of the VLF receiver in Nha Trang with the other results

The data processing results of the VLF receiver (SID type) in Nha Trang, Vietnam with signal frequency 21.1 kHz from 3SA station (China) are compared with the results of the VLF receiver (SID type) at A118 station, France with signal frequency 22.1 kHz from GQD station (England) and signal frequency 23.4 kHz from DHO38 station (Germany) [1].

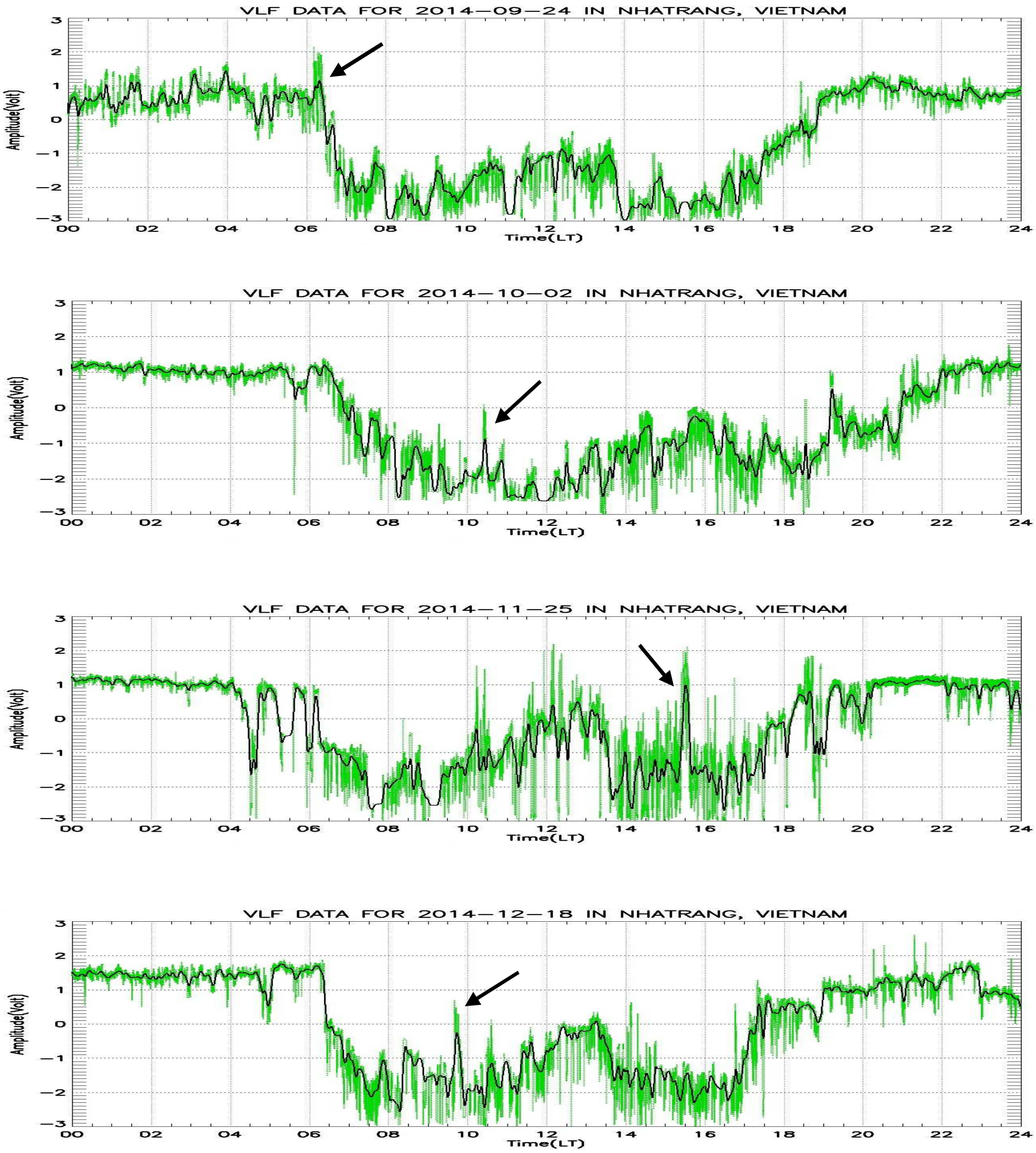

Figure 11. Some results of monitoring the sudden ionospheric disturbances for the months September - December 2014 by the VLF receiver in Nha Trang, Vietnam (the arrow indicates the position, at which appears sudden ionospheric disturbance caused by solar flare).

In addition, these data were compared with the data of the AWESOME receiver equipped by UN in Nha Trang. However the data of the AWESOME receiver used to compare are presented in decibel scale and duration of each survey plots is 400 seconds. Some comparative results between 3 receivers are presented in Figure 12 - Figure 17.

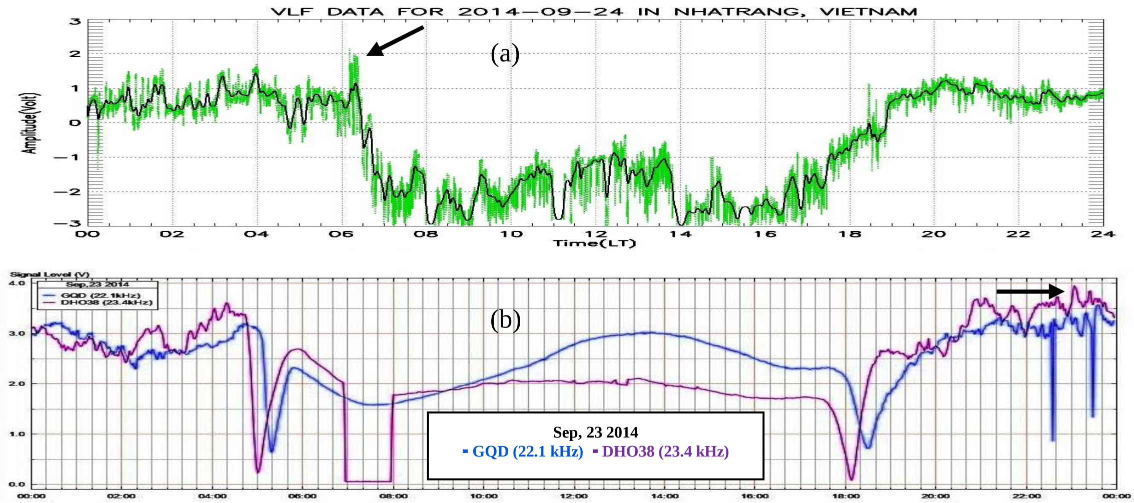

Figure 12. Results of monitoring the sudden ionospheric disturbance event with level of importance 2 and peak occurred at 23:16 UT on the 23 Sepember 2014 were observed by the VLF receiver in Nha Trang, Vietnam (a) and the VLF receiver at A118 station, France (b).

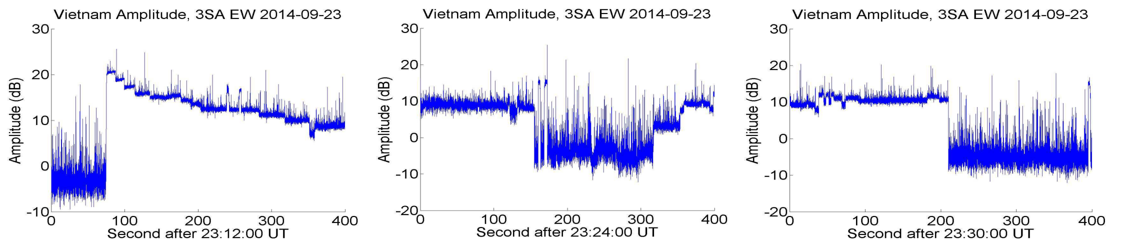

Figure 13. Increase in the amplitude of 20 dB and lasted longer than 25 minutes of 3SA signal on the data of the AWESOME receiver in the event occurred at 23:16 UT on the 23 September 2014.

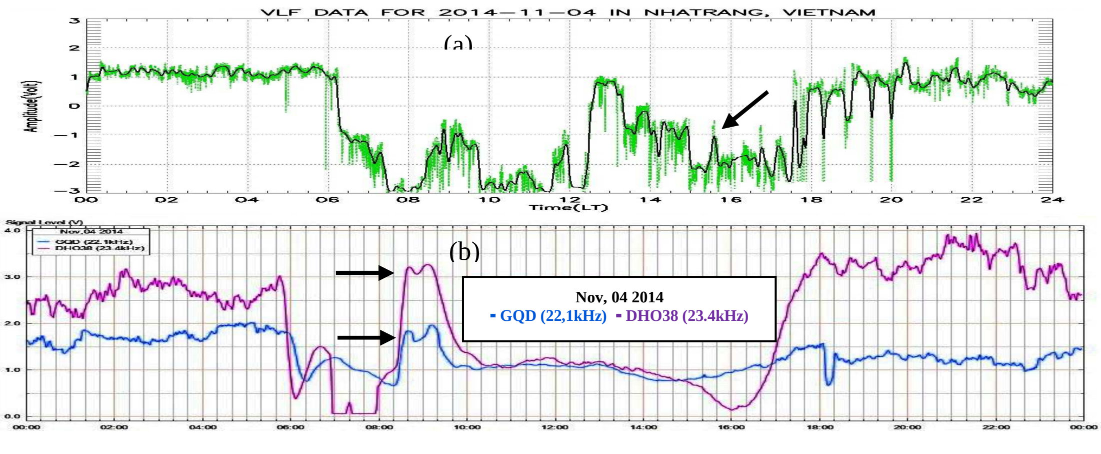

Figure 14. Results of monitoring the sudden ionospheric disturbance event with level of importance 2 and peak occurred at 08:38 UT on the 04 November 2014 were observed by the VLF receiver in Nha Trang, Vietnam (a) and the VLF receiver at A118 station, France (b).

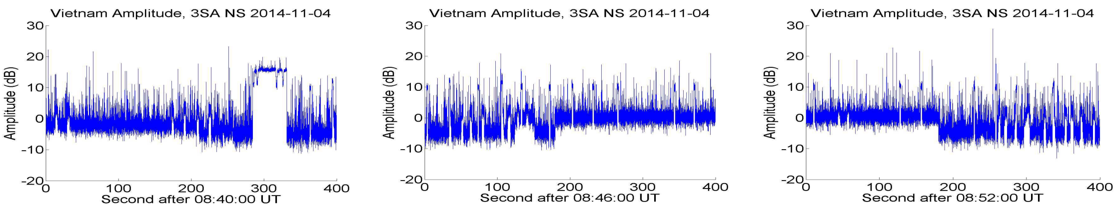

Figure 15. Increase in the amplitude of 10 dB and lasted longer than 10 minutes of 3SA signal on the data of the AWESOME receiver in the event occurred at 08:38 UT on the 04 November 2014.

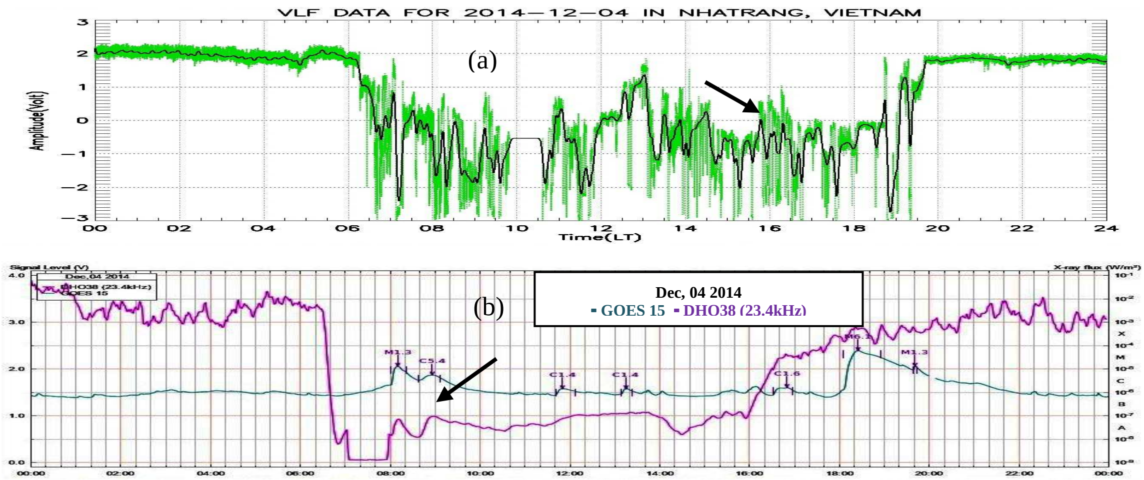

Figure 16. Results of monitoring the sudden ionospheric disturbance event with level of importance 2 and peak occurred at 08:53 UT on the 04 December 2014 were observed by the VLF receiver in Nha Trang, Vietnam (a) and the VLF receiver at A118 station, France (b), GOES 15 is satellite data on solar flares.

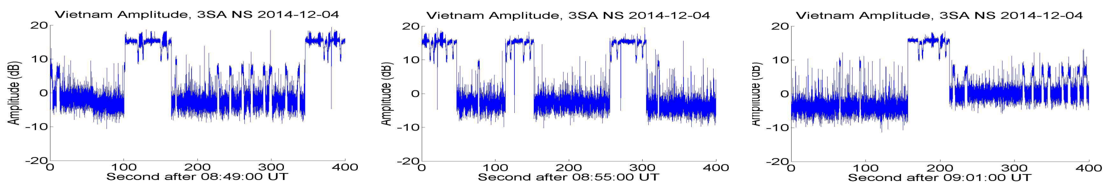

Figure 17. Increase in the amplitude of 20 dB and lasted longer than 15 minutes of 3SA signal on the data of the AWESOME receiver in the event occurred at 08:53 UT on the 04 December 2014.

4. CONCLUSION

The research group has manufactured completely the VLF receiver in Nha Trang, Vietnam and has written successfully the data colecttion and data processing programs for the VLF receiver.

The results of data processing for the VLF receiver in Nha Trang, Vietnam are consistent with the results published of the VLF receiver at A118 station, France. The VLF receiver in Nha Trang has also observed a number of sudden ionospheric disturbances monitored by the AWESOME receiver of UN in Nha Trang.

The VLF receiver data in Nha Trang, Vietnam have been collected continuosly 24 hours. These data have been organized and stored in a systematic way and have been always ready to serve for scientific research. Thus, besides the existing equipments in the country, we believe the VLF receiver in Nha Trang would be an effective means to enhance monitoring data system for study the ionosphere in Vietnam.

This initial success opens the possibility of developing space weather education and reseach in the universities and colleges in Vietnam and is a motivation for us to develop confidently towards equipment manufacturing for research and application in the field of space science and technology in Vietnam.

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TÓM TẮT

NGHIÊN CỨU NHIỄU LOẠN TẦNG ĐIỆN LI BẤT NGỜ BẰNG MÁY THU TÍN HIỆU TẦN SỐ RẤT THẤP TẠI NHA TRANG

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Kĩ thuật sử dụng tín hiệu tần số rất thấp (VLF-Very Low Frequency) là một công cụ rất hữu hiệu để nghiên cứu Nhiễu loạn Tầng điện li Bất ngờ (NLTĐLBN) do tín hiệu này hầu như bị phản xạ tại lớp D Tầng điện ly (ở độ cao 60 - 90 km) khi xảy ra nhiễu loạn. Với yêu cầu nhanh chóng nắm bắt các kĩ thuật và công nghệ tiên tiến để làm chủ các thiết bị nghiên cứu, chúng tôi đã mạnh dạn đề ra mục tiêu tự chế tạo thiết bị phục vụ cho nghiên cứu và ứng dụng. Trong bài báo này, nhóm nghiên cứu xin trình bày kết quả ứng dụng máy thu tín hiệu VLF được chế tạo tại Viên NC&UDCN-NT để nghiên cứu NLTĐLBN cho mục đích giáo dục thời tiết không gian.

Từ khóa: tín hiệu VLF, máy thu VLF, nhiễu loạn tầng điện li bất ngờ.