Preliminary Result of VLF Receiver Installation For Space Weather Research

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ABSTRACT

About 40 km altitude, VLF radio waves are partially reflected and partially absorbed by the D-layer of the ionosphere. By measuring the amplitude of radio signals after they have reflected from the ionosphere, it is possible to detect various kinds of ionospheric and space activity taking place. Recently, Division Ionosphere and Telecommunication, Space Science Center, National Institute of Aeronautics and Space (LAPAN) have installed VLF receiver to investigate effects of solar flare to ionosphere, mainly Sudden Ionospheric Disturbances (SIDs). By monitoring transmissions from Earth-based beacons, which are affected by changes in the ionosphere, giving an indirect indication of events on the Sun. The VLF Receiver output is a voltage varying with time, which may be fed to any data logger or digital multimeter. In this paper, we discuss about system of UKRAA (United Kingdom Radio Astronomy Association) VLF receiver, our research plan related to this instrument, and preliminary result of installation of VLF receiver.

Keywords: VLF Receiver, Sudden Ionosphere Disturbances, solar flares.

1 INTRODUCTION

The ionosphere is a region of the Earth's atmosphere where the gas density is low enough for atoms that become ionised to exist for a significant period of time before meeting andcolliding with another atom and becoming neutralised again (collisional recombination).This region is at an altitude of between 50 km and about 1000 km above sea level. Theionising energy arises mainly from the Sun in the form of particles and electromagneticradiation from the visible spectrum right through to gamma rays.

A flare in solar flare terminology is defined as a sudden, rapid, and intense variation in brightness. A solar flare occurs when magnetic energy that has built up in the solar atmosphere is suddenly released. Radiation is emitted across virtually the entire electromagnetic spectrum, from radio waves at the long wavelength end, through optical emission to x-rays and gamma rays at the short wavelength end. The amount of energy released is the equivalent of millions of 100-megaton hydrogen bombs exploding at the same time.

The first solar flare recorded in astronomical literature was on September 1, 1859. Two scientists, Richard C. Carrington and Richard Hodgson, were independently observing sunspots at the time, when they viewed a large flare in white light.

The part of the Ionosphere that interests us from the point of view of flare detection isreferred to as the D-layer (at 50 km to 90 km altitude) and the lower E-layer (90 km to150 km altitude). In the radio field the D-layer is known mainly as an absorbing blanket thatstops long distance propagation at lower "short wave" frequencies. At VLF and LF, which aredefined as frequencies below 300 kHz, the D-layer provides the means by which thesefrequencies could reach world-wide before the short-wave bands were opened up in the1930s. The D-layer is often explained as forming a (lossy) "waveguide" with the Earth'ssurface that guides the waves round the curvature of the Earth. Squeezing of this waveguideby changes in the D-layer change the amplitude and phase of waves passing through theguide. Although the simpler analogy of a mirror "reflection" can be used to describe the propagation mechanism, the

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physical mechanism is actually 'refraction'. The term'reflection' is used here in quotes when describing the ionosphere returning an upward radiosignal back towards the Earth.

The Ionosphere is characterised by an increasing electron density from about 50 km altitudeupwards. At low electron densities and the higher air pressures around 50 km, the incomingradio wave loses energy to the free electrons, which recombine before they have chance toreturn energy to the wave. However at higher altitudes the electrons have a chance tointeract with the wave for longer, in a way that apparently speeds up the wave, bending itsdirection back towards Earth again. These two mechanisms, absorption and "reflection" arevital to the understanding the SID detection mechanism.

The UKRAA Very Low Frequency (VLF) Receiver is designed to record Sudden Ionospheric Disturbances (SIDs) induced by solar flares. It does this by monitoring transmissions fromEarth-based beacons, which are affected by changes in the ionosphere, giving an indirectindication of events on the Sun. The main motivation for this work is to correlate these radioobservations of solar activity with those from optical observers, and to follow the cycles ofsunspots as they appear on the Sun.

2 SYSTEM OF UKRAA VLF RECEIVER

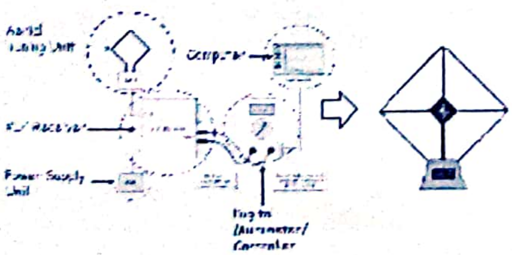


Figure 1. System of United Kingdom Radio Astronomy Association (UKRAA) VLF Receiver.

In the simplest mode, UKRAA VLF receiver consist of four components are Antenna and Aerial Tuning Unit, VLF receiver, Power Supply Unit, and computer for data logger and storage (Figure 1).

The VLF Aerial Tuning Unit (ATU) is designed to provide a means of tuning a VLF loop aerial over a wide range (50 pF to 3500 pF) of capacitances. The ATU uses a switchable bank offixed value capacitors and a variable tuning capacitor.When used in conjunction with the UKRAA VLF Aerial, it will form a 'parallel tuned circuit' toprovide an input signal to the VLF Receiver in the frequency range 15-35 kHz, enabling thelatter to receive VLF radio transmissions at suitable frequencies.The ATU is a passive device and does not require a power supply.

The UKRAA Very Low Frequency (VLF) Receiver record Sudden Ionospheric Disturbances (SIDs) induced by solar flares by monitoring transmissions fromEarth-based beacons, which are affected by changes in the ionosphere.

The VLF Receiver output is a voltage varying with time, which may be fed to any data logger or digital multimeter. The output from the VLF Receiver is a varying voltage that is proportional to the strength ofthe signals received from the target transmitter. A continuous record of this voltage isrequired to indicate the presence of a Sudden Ionospheric Disturbance (SID) and thus a SolarFlare.

The UKRAA VLF Receiver has a tuning range of about 12kHz to 35kHz, requires a supply of 15V DC at 35mA, and provides output signals at 0 – 2.5 Volts and 0 – 5 Volts.

It is possible to use the UKRAA VLF Receiver to monitor the output of two VLF Receivers,monitoring two different frequencies. This makes it much easier to distinguish SID eventsfrom other changes, say due to variations in transmitter power. The new system for monitoring two different frequencies can be seen in Figure 2.

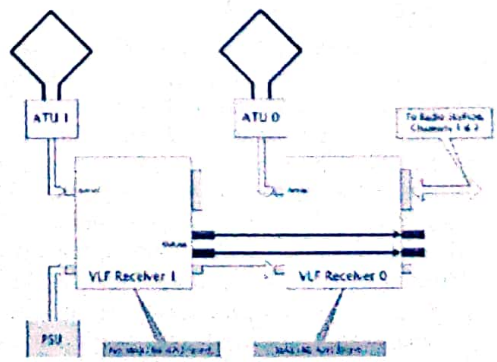


Figure 2. System of United Kingdom Radio Astronomy Association (UKRAA) VLF Receiver.

3 METHOD

Flare Detection Using VLF Radio Signal by continuously recording the signals from some of the VLF tramsmitters (usually used by military). The effect of solar flare depends upon the response of ionosphere to the burst of solar radiation and the mechanics of the radio propagation mechanism.

Radio Propagation Mechanism.

At relatively long distances, less than 1000 km, the radio signal from the VLF transmitter reaches the receiver by two paths are ground-wave and the other is via reflection from the ionosphere, called the Ionospheric-wave, often colloquially known as the skywave (Figure 3). These two paths are of The different path lengths for the two signals means that the phases of these signals will differ at the receiver. If the path difference is an even number of half wavelengths the signals on the two paths will reinforce and if the number of half-wavelengths is odd there will be some cancellation.

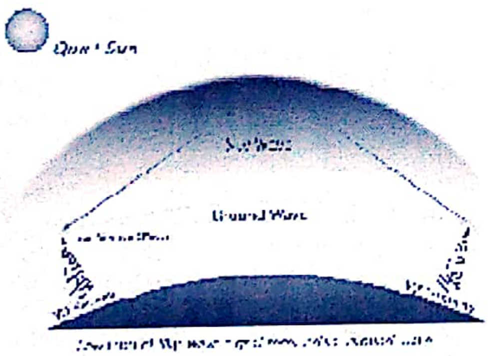


Figure 3. Two paths of radio signal propagation at quiet Sun.

As in the case of the ionosphere, the reflector moves up and down there isa continuous change in the received signal which is normally referred to as fading.In daytime the Sky-wave is attenuated by the absorbing part of the D-layer, but the amountof absorption is dependent on the amount of penetration. High angle waves penetratedeeply and are severely attenuated, but waves at low angles of incidence penetrate moreshallowly and are less attenuated. The ground-wave component of the signal progressivelyweakens as the receiver becomes further from the transmitter. At about 700 km range theground and sky waves are approximately the same strength.

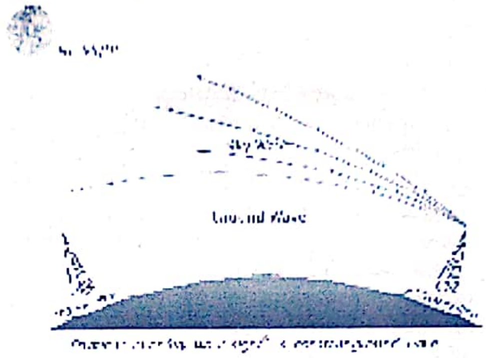


Figure 4. Radio signal propagation at Night.

After dark the D-layer, which is mainly ionised by Solar Ultra Violet rays, quickly disappearsand with it all the absorbing ionisation. Reflection now occurs from the lower part of theE-layer at around 90 km to 100 km altitude. The result of this is that once the mid point ofthe path is in shadow at 100 km altitude, the signal strength will usually increasesignificantly (Figure 4), while the ground wave signal stays exactly the same strength. Thus night-timereception is marked by large and rapid swings in signal strength as the two, now morenearly equal strength, signals swing in and out of phase.

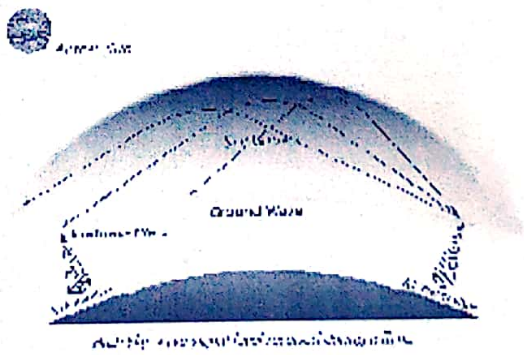


Figure 5. Radio signal propagation at active Sun.

The shape of VLF Receiver recording depend on distance between the VLF transmitter and the receiver, and also depend on the effects of the signal level going both up and down before returning to normal.

By analysing VLF Receiver signal we can monitor effects of solar flare to ionosphere region known as Sudden Ionospheric Disturbances (SIDs).

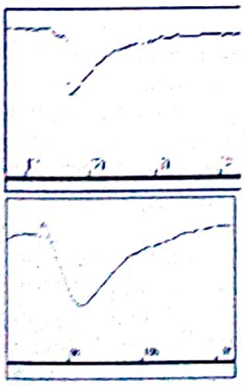
4 PRELIMINARY RESULT

Firstly, we should defined of Flare classification and Importance. Flare clasification consist of A, B, C, M, and X class, describe magnitude of energy of solar flare. The amplitude of the disturbance usually correlates with flare class, but will depend on the state of the ionosphere at the time. The duration of the SIDs does not always correlate with flare class, but can be recorded as the Importance of the event on the earth, traditionally been recorded as table follows :

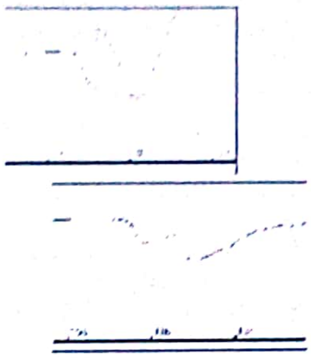
Tabel 1.Table of Duration and Inportance of flare event.

Duration	Importance
<18min	1-
19...25min	1
26...32min	1+
33...45min	2
46...85min	2+
86...125min	3
>126min	3+

Figure 6 shows the shapes of SIDs recording related to solar flare events time term.



(a) (b)

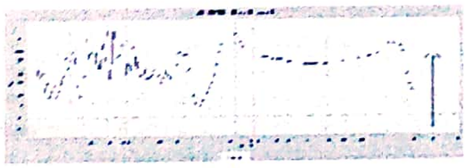


(c)(d)

Figure 6. Shapes of SID Recording

Figure 6. Shapes of SIDs recording : (a). Ordinary SID. (b). SID caused much more energetic solar flare. (c). SID, when solar flare occured during the sunset dip in signal strength. (d). SIDs overlap caused by 2 rapid solar flare succession. (Source : VLF Receiver Manual File).

Figure 7 shows examples of recorded data of VLF receiver from Ramsloh transmitter at North Germany.



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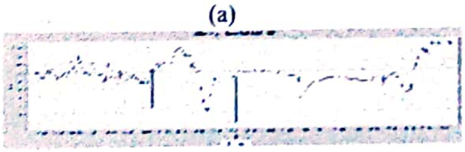

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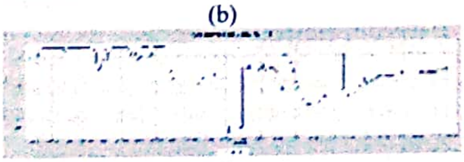

(c)

Figure 7. Record of 23,4 kHz from Ramsloh Transmitter (Germany)

Figure 7. Record of 23.4 kHz from Ramsloh Transmitter, North Germany; (a). Normal day. (b). C class of flare occured. (c). X class of flare occured. (Source : VLF Receiver Manual File).

We finished our VLF Receiver installation about end of Agust 2011, so we have already obtained data since September 2011. Figure 4 shows daily data recorded of September 2011.

Figure 8 shows preliminary record of VLF Receiver of 19.8 kHz from NWC's transmitter, Australia. It also shows response of ionosphere to solar radiation in normal day. It describe variation of VLF signal follows solar radiation. Signal less fluctuation for early day and then enhance in noon and return to normal for dusk.

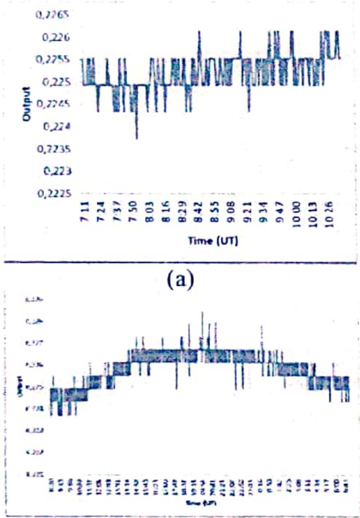

Figure 8. Preliminary Result of VLF Receiver of 19,8 kHz (Australia)

These result coincide with result of receiver of Ramsloh transmitter, Germany. It need further recording of VLF signal to monitor SIDs relate to solar flare events at active Sun.

5. CONCLUSION

Recently, Ionosphere and Telecommunication Division install and operate VLF Receiver for observing response of ionosphere to solar flare event known as SIDs. Data result can show variation of VLF signal correlate with solar radiation and solar flare (if any). Furthermore data result can be used for SIDs monitoring purpose.

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