The First Solar Flare Effect Observation at UiTM-SID Station during Solar Cycle 23-24

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Abstract. International Heliophysical Year (IHY; 2007-2009) has a remarkable impact on space and earth electromagnetism research and society. For Malaysian perspectives, it acts as a spiral point to the expanding of space weather-related research. The research activities involve installation of real-time Magnetic Data Acquisition System of Circum-pan Pacific Magnetometer Network, i.e. MAGDAS/CPMN for space weather study and application, which was deployed for the IHY; 2007-2009. In addition to MAGDAS system, to understand the characteristics of the lower ionospheric layer (60-150km) during space weather events, a Very Low Frequency (VLF) monitoring system has been developed. The MAGDAS and VLF monitoring system called UiTM-SID are located at Universiti Pendidikan Sultan Idris, UPSI (3.71', 101.53'), Malaysia. The first observation effects of solar flare during November 2016 to March 2017, for the period of a minimum solar cycle 23-24 have been examined on sub-ionospheric VLF signals from VTX4 (19.2 kHz) and NWC (19.8 kHz) transmitter monitored at UPSI. In general, the level of amplitude reading for VTX4 signals is higher than NWC signals for quite diurnal variations. The effects of the solar flare class C7.5 on 29th November 2016 shows an enhancement of amplitude due to increase in the lower region electron density by the radiation of solar flare. The average daily amplitude reading was compared to the average value of solar flare event, the result shows the percentage difference is 12% increased in VTX4 and NWC signals.

1. Introduction

Solar Flare is a sudden intense brightness seen at the Sun. The flares occur when speed charged particles collide with plasma in the corona and chromospheres. It converts magnetic energy to kinetic energy in the form of solar energetic particles. The unconnected magnetic field can expand to all direction including to the Earth. Thus, it shows that a solar flare erupts from the active regions on the Sun when the magnetic fields are much stronger than the average [1].

Solar flares cause perturbation in the daytime ionosphere and D region is perturbed the most. During daytime, the lower ionosphere D-region ionization is maintained by Lyman-α (121.6 nm) radiation from the Sun. It partially ionizes the nitric oxide, N₂O at ~70km altitude, a minor neutral constituent in the D-region. Under normal conditions, while there is no space weather event, the solar X-ray flux is too
small to be an important source of ionization. However, during solar flares event, the increased X-ray flux from the Sun in the wavelength range 0.2 – 0.8 nm ionizes neutral constituents along with the major O₂ and N₂ species. This modifies the electron density in the D-region ionosphere and changes the transmission conditions of Very Low Frequency (VLF; 3 - 30 kHz) waves in the Earth-Ionosphere waveguide formed between the D-region ionosphere and the Earth’s surface [2].

There are studies [3,4,5,6] focusing the various changes in lower D region caused by solar flare using VLF waves, transmitted by the navigational transmitter station. Apart from that, there have been studies mainly focused on the comparative investigations of the changes in the VLF signal amplitude/phase and time delay with respect to Solar X-ray flux. Other than that, there are studies on the D-region solar flare effects using Long Wave Propagation Capability (LWPC) code to estimate D-region reflection height (H') in km and D-region electron density gradient or sharpness factor (β) in km⁻¹ established by Wait’s parameters [7].

The present study deals with the D-region ionospheric perturbations caused by solar flares on 29th November 2016 on VTX4 and NWC transmitter signal 19.2 kHz and 19.8 kHz respectively recorded at Universiti Pendidikan Sultan Idris (UPSI), Malaysia (3.71’, 101.53’). Solar flare effects on the horizontal component (H) of the Earth’s magnetic field at the same location have also been studied from the same period at the solar cycle 23-24.

2. Experimental setup and data

A VLF receiver system is known as UiTM Sudden Ionospheric Disturbance (UiTM-SID) and Magnetic Data Acquisition System (MAGDAS) were installed at UPSI, Malaysia (3.71’, 101.53’). The UiTM-SID system is used to record 19.2 kHz and 19.8 kHz VLF signals transmitted by South Vijayanarayananam, India and North West Cape, Australia (NWC) transmitter respectively. Figure 1 shows a map of transmitter station (indicates as a star) and receiver station (indicates as a circle) over a Great Circle Path approximately ~3000 km.

![Figure 1](image-url)  
Figure 1. A map of VLF receiver system at Universiti Pendidikan Sultan Idris (UPSI). The system receiving signals from VTX4, India and NWC, Australia correspondingly over a Great Circle Path.

The data of space weather were collected from November 2016 to March 2017. The daily average values of the amplitudes gained from UiTM-SID system have been utilized to display the typical changes in amplitudes VLF due to the flares. The daily quiet days were chosen based on Kp Index <5 and DST Index > −30 nT. Kp Index is known as geomagnetic index which indicates the geomagnetic disturbance in horizontal component of Earth’s geomagnetic field that has a value between 0 to 9. The
value from 0 to 5 is a quiet conditions while the value above 5 is represent geomagnetic storm [8]. Next parameter to indicate quiet condition is by observing DST Index. DST index is a measure of the strength of a magnetic storm that reflects the variations in the intensity of the symmetric part of the ring currents at the altitude ranging from 3 to 8 radii. The DST index is divided into four classes: DST ≤ -100 nT is intense, -100 nT < DST ≤ -50 nT is moderate, -50 nT < DST ≤ -30 nT is small storm and DST > -30 nT is no storm type correspondingly.

From the average quiet day amplitude value, the data were compared to the average amplitude value during solar flare event. The data that considered in this study are, a) DST Index, b) Kp Index and c) Amplitude enhancement during Solar Flare.

3. Observations

3.1. Quiet Day

Figure 2 (a) shows DST Index on 6 quiet days. The selected days are 27th November 2016, 28th November 2016, 3rd December 2016, 4th December 2016, 24th March 2017 and 25th March 2017. The DST Index on six quiet days is in a range of -23 < DST > 18. Figure 2 (b) presents Kp Index with range 0 < Kp Index > 2. The quietest are on 3rd and 4th December 2016 recorded a 0 Kp Index value.

![Figure 2. A DST index and Kp Index on 6 quiet days with the value range DST > -30 nT and 0 < Kp Index > 2 respectively.](image)

The data from Table 1 and Table 2 tabulates average amplitude of signal strength value from VTX4 (19.2 kHz) and NWC (19.8 kHz) transmitter stations during six quiet days. The average values were divided into three categories; Average amplitude value from 12:00 am to 6.59 am (from midnight to sunrise), 7:00 am to 6.59 pm (noon time) and 7:00 pm to 11.59 pm (from sunset to midnight). This observation can lead to study the fluctuation value of average amplitude during nighttime.

**Table 1:** Data of average amplitude value of the signal frequency 19.2 kHz transmitted from VTX4, India Station.

| Date       | Ave Amplitude 12:00 am – 6.59 am | Ave Amplitude 7:00 am – 6.59 pm | Ave Amplitude 7:00 pm – 11.59 pm |
|------------|----------------------------------|---------------------------------|----------------------------------|
| 27 NOV 2016| 174.8                            | 170.21                          | 176.15                           |
| 28 NOV 2016| 182.98                           | 172.41                          | 182.94                           |
| 03 DEC 2016| 182.12                           | 147.53                          | 145.40                           |
| 04 DEC 2016| 151.69                           | 140                             | 146.87                           |
| 24 MAR 2017| 77.14                            | 85.34                           | 68.76                            |
| 25 MAR 2017| 138.22                           | 149.20                          | 125.65                           |
### Table 2: Data of average amplitude value of the signal frequency 19.8 kHz from NWC, Australia Station.

| Date         | Ave Amplitude 12:00 am – 6.59 am | Ave Amplitude 7:00 am – 6.59 pm | Ave Amplitude 7:00 pm – 11.59 pm |
|--------------|---------------------------------|---------------------------------|---------------------------------|
| 27 NOV 2016  | 89.24                           | 166.84                          | 164.76                          |
| 28 NOV 2016  | 182.98                          | 172.4                           | 182.94                          |
| 03 DEC 2016  | 164.86                          | 145.93                          | 134.20                          |
| 04 DEC 2016  | 137.46                          | 138.37                          | 128.49                          |
| 24 MAR 2017  | 103.94                          | 105.77                          | 102.81                          |
| 25 MAR 2017  | 101.47                          | 107.9                           | 106.10                          |

#### 3.2. Solar Flare Events

On 29\(^{th}\) November 2016, the Sun unleashed C-class of solar flare at 15.03 Local Time. The event of the solar flare was detected by VLF receiver system at UPSI station. The data also was a good conformity with data reported by U.S. Department of Commerce, NOAA, Space Weather Prediction Center. Table 3 displays the average amplitude value during solar flare events from the transmitted signals station VTX4, India and NWC, Australia.

### Table 3: Data of average amplitude value during solar flare event detected at UPSI, Malaysia receiver station on 29\(^{th}\) November 2016.

| Receiver Stations | Ave Amplitude 12:00 am – 6.59 am | Ave Amplitude 7:00 am – 6.59 pm | Ave Amplitude 7:00 pm – 11.59 pm |
|-------------------|---------------------------------|---------------------------------|---------------------------------|
| VTX4              | 200.84                          | 181.94                          | 176.94                          |
| NWC               | 200.84                          | 179.18                          | 165.75                          |

#### 4. Results and Discussions

During solar flare events, the result shows increased in average amplitude value. For the average signal strength from VTX4, India, the value is 181.94 and the average amplitude value for the signal from NWC, Australia station is 179.18 as stated in Table 4. The average percentage difference calculates that the value increased by 12% during solar flare events.

### Table 4: The average amplitude value of VLF signals during quiet days and on the occurrence of solar flares.

| Receiver Stations | Average Quiet Days | Average Solar Flare Days |
|-------------------|--------------------|--------------------------|
| VTX4              | 144.12             | 181.94                   |
| NWC               | 139.54             | 179.18                   |

A sudden, rapid and intense phenomenon in solar activity releases a vast amount of energy up to $10^{25}$ Joules at the solar atmosphere. During the event of solar flares, it becomes the dominant source of ionization in the ionosphere. The X-ray flux from the Sun with a wavelength below 1 nm is capable to penetrate down to the lower ionosphere D-region and results in higher additional ionization at that particular layer. Thus, the amplitude reading of VLF signals value is higher because the signals are reflected at the lower layer. The rapid increase in the electron density at the ionosphere leads to several phenomena grouped together and known as Sudden Ionospheric Disturbance (SID) [10].
5. Conclusions

The objective of this paper was to analyze the amplitude data acquired by monitoring at UPSI, Malaysia site VLF radio signals emitted by two VLF transmitters; VTX4, India (19.2 kHz) and NWC, Australia (19.8 kHz) correspondingly during solar flare event. After the analysis was made, it is proved that solar flare event gives notable impact to VLF receiver system at UPSI, Malaysia with 12% increased in amplitude for the first solar flare detection (Class C-7.5). Apart from that, the occurrence of solar flare leads to further understanding of a lower region of ionosphere typically in Malaysian region.

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