ABSTRACT

This article will focus on the solar prominences that occur during the 4th September 2015. On that day, there were two sunspots on the surface of the sun, which were AR2409 and AR2410. These two active regions did not produce any threat for strong flare and thus the solar activity was very low. The prominences that will be focused were both occurred at 0353 UT and 0427 UT respectively. There were minor (G1) geomagnetic storm observed on that day. For solar prominences that occurred at 0353 UT, solar radio burst type (SRBT) IV was detected by CALLISTO spectrometer. From the CALLISTO, two bursts at low intensities with the duration of about 7 minutes for the first burst of 280-320 MHz and 6 minutes for the second burst of 360-430 MHz were observed. For the first burst, energy calculated was between $1.855 \times 10^{-25}$ J and $2.12 \times 10^{-25}$ J with the drift rate of 0.095 MHz/s. For second burst, the energy obtained was between $2.385 \times 10^{-25}$ J and $2.849 \times 10^{-25}$ J with the drift.
rate of 0.194 MHz/s. At 0427 UT, SRBT III was recorded with a frequency of 240-350 MHz with the energy which was obtained between 1.590 x 10^{-25} J and 2.319 x 10^{-25} J. The drift rate of this type of burst was 0.61 MHz/s. During this event, the solar wind value was 499.3 km/Sec with the proton density of 15.1 protons/cm^3.

**Keywords:** Solar prominences; active region (AR); solar burst; type III; type IV; e CALLISTO

### 1. INTRODUCTION

The Sun is a star in our solar system has 16 million K of its core temperature and has a distance of 1 AU from the Earth [1]. Sun is located at the main sequence region where we can see it in the Hertzsprung-Russell Diagram which converts hydrogen to helium in its energy supply [2]. Solar prominence or filaments are formed above the chromosphere, which is a cool structure embedded in the corona. Prominences can be formed from active and quiet sun regions over filament channels [3-5]. Quiescent prominences are found in the coronal cavities [6-10] and formed from cool and dense plage concentrations far from active regions eg. [5,11,12]. They can persist for a few months and usually disappear by eruption [13]. There are a few parameters of quiescent prominences (lecture notes by K. Petrovay) which may form i) in active region (less common), ii) between two active regions or iii) over polar crown neutral line near the expanding AR. The magnetic forces to support them against gravity. The quiescent prominences have a height (above the chromosphere) in the range of 15-100 Mm, a length of 60-600 Mm, a width of 5-15 Mm, a pressure of 0.1-1 dyn/cm^2, 10^{10} – 10^{11} cm^{-3} of average electron density, a temperature of 4300-8500 K, 4-20 G of magnetic strength [14-16]. Larger-scale structure of quiescent prominences remain the same while the fine structure changes rapidly [17]. Prominences can be attached to active regions or hang above the quiet chromosphere. Moreover, for this type of prominences, the polar (polar crown) filaments and low-latitude (sunspot) filaments can be distinguished. Polar filaments are the one with quietest prominences, largest and lasts longest where the low-latitude filaments can end in sunspots. There are smaller, shorter lived filaments which lasts for less than one day, have stronger magnetic fields of 20-70 G and also has a flow of v < 60 km/s along the filament which is called as plage filaments [18].

Solar flares can excite plasma oscillations which are classified by five types which are type I, II, III, IV and V [19, 20]. In this sub-section, we are going to focus on type III and IV. Solar radio burst type III was first introduced by Wild in 1963 [21] with the frequency range of 500-10 MHz [22-24]. This burst can be characterized by rapid drifting of the radiation from high to low frequencies. The drift rate (df/dt) can be determined using the formula of:

\[
\text{Drift rate (df/dt)} = \frac{f_e - f_s}{t_e - t_s} \text{ [Unit: MHz/s]} \tag{1}
\]

Drift rate is a peak displacement in frequency per unit time. It can be calculated by using the value of the end frequency (f_e) subtract the value of the start frequency (f_s) divided by the value of the end time (t_e) subtract the value of the start time (t_s) of the solar burst.

According to [25], the rate for this type III is about 100 MHz s^{-1} in metric range which is 100 times larger than in type II burst. Besides that, type III bursts are formed from the beams of electron that flow outwards from the corona into interplanetary (IP) space along the
open magnetic field lines. Type III burst is found when there is an active region on the visible side of the sun and indicates the increased in solar activity. It can occur singly, group or even in a storm where they are formed from relatively low energy electron beams of kinetic energy approximately 30 keV with a speed of about c/3 [26-28]. The speed is said to be dangerous to space weather and so does the Earth climate where it can extends to 1 AU [29]. This type of burst also produced from energetic particles that released through open magnetic field lines [19].

Type IV bursts give rapid varying fine structures and broad continuum emission [19]. This burst’s type shows that there is formation of a new active region [30, 31]. A type IV event that is fully developed is very complex. This type is known to occur from type II burst. Solar radio burst type IV has two categories which are (i) broadband radio pulsations (BBP) and (ii) zebra patterns (ZP). Besides that, in the low corona, the flare plasma are being diagnosed of the fine structures (FS) of solar type IV [32]. BBP source occurs near the active region and decays away from it [33]. The motion follows the magnetic field direction where the apparent speed is a fraction of the speed of light. BBPs and ZPs are usually observed a few days before solar flare and coronal mass ejection (CME) event occur [19, 34].

2. METHODOLOGY

There are two types of instruments used to obtain the data which were Lunt Solar 100 mm H-Alpha telescope and CALLISTO spectrometer. The observation was carried out at Telok Kemang Solar Observatory, Port Dickson, Malaysia with coordinate of N02°26′42.7″ and E101°51′16.4″. Lunt Solar with hydrogen alpha filter was used to get the optical data of the solar prominences. A CCD camera, ZWO ASI120MM with a 2x Barlow lens were attached to the Lunt Solar 100mm H-Alpha telescope and linked to a software to see the images of the sun. The ZWO CCD is a monochrome camera which has a proper filtration when observed the sun where the 2x Barlow lens was used to increase the magnification of the eyepiece so that the sun can be seen clearly. A setting of the camera was set in the software such as the frame number and color setting. Then, searched for the desired image, for example the solar flares, sunspots, filaments or solar prominences and started capturing the images. The captured images, then will be edited by using AutoStakert, RegiStax and Adobe Photoshop to get the best image result of the sun. After the images were processed, all the data of the solar prominences was collected (sunspot number, solar wind, etc.). Then, the images of solar prominences by using an optical telescope was compared with the radio telescope images of the type of burst produced.

CALLISTO spectrometer is a programmable receiver built to observe or detect solar radio burst that occur at a particular time and location. This program is applied to observed solar radio burst and Radio Frequency Interference (RFI) that is used to monitor for astronomical science, education and others. CALLISTO operates between frequencies of 45 to 870 MHz using a modern, commercially available broadband cable TV tuner having a frequency resolution of 63.5 KHz. There are a lot of CALLISTO instruments have been deployed in Malaysia, Indonesia, Australia, Switzerland, Russia, South Africa and many more.
Figure 1. Solar Telescope at Teluk Kemang Solar Observatory (Credited to: Teluk Kemang Solar Observatory, Malaysia)

Radiospectrometer: CALLISTO

Figure 2. CALLISTO System (Credit: CALLISTO)
3. RESULTS AND ANALYSIS

From Figure 3, two sunspots can be detected on 4th September 2015. These two sunspots were AR2409 and AR2410. The prominences that occurred on that day were shown in Figure 4 and Figure 5 on 0353 UT and 0427 UT respectively. Based on Figure 6 of e-CALLISTO spectrometry, the structure of the Type IV radio burst was presented with two low intensities of solar burst. This event occurred at a starting frequency of 280 MHz of 03:45 [UT] and end frequency of 320 MHz of 03:52 [UT]. The other intensity start at 360 MHz on 03:53 [UT] and end frequency of 430 MHz on 03:59 [UT]. The energy minimum for starting frequency of 280 MHz was $1.855 \times 10^{-25}$ J while the energy maximum was $2.12 \times 10^{-25}$ J and have a drift rate of 0.095 MHz/s. For the other intensity with starting frequency 360 MHz, the energy minimum obtained was $2.385 \times 10^{-25}$ J and its energy maximum was $2.849 \times 10^{-25}$ J with the drift rate of 0.194 MHz/s.

The event was recorded by the e-CALLISTO using RCAG antenna located in Mongolia. The solar wind recorded during this event was 499.3 km/Sec with the proton density of 15.1 protons/cm$^3$. The data were updated for every 10 minutes from the Space Weather website. They were obtained from real-time information transmitted to Earth from Advanced Composition Explorer (ACE) spacecraft located between the Earth and the Sun which enables
it to give a one hour advance warning of impending geomagnetic activity and reported by NOAA Space Environment Center.

Figure 4. The prominence that occurred at 0353 UT
(Credited to: Telok Kemang Solar Observatory, Malaysia)

Figure 5. The prominences that occurred at 0427 UT
(Credited to: Telok Kemang Solar Observatory, Malaysia)
Figure 6. Details of e-CALLISTO spectrometry on 0353 UT (Credit: e-CALLISTO)

Figure 6. Solar Radio Burst Type IV.
Figure 7. Details of e-CALLISTO spectrometry on 0427 UT (Credit: e-CALLISTO)

Figure 7. Solar Radio Burst Type IV and III.
From Figure 7 of e-CALLISTO spectrometry, structure of Type III radio burst was observed with low intensity of solar burst. The starting frequency of this event was 240 MHz of 04:15 [UT] and end frequency of 350 MHz of 04:18 [UT]. This event was recorded by e-CALLISTO using RCAG antenna. The solar wind recorded for this event was 499.3 km/Sec and 15.1 protons/cm$^3$ of proton density. The minimum energy obtained was $1.590 \times 10^{-25}$ J and energy maximum was $2.319 \times 10^{-25}$ J. Both prominences were detected as quiescent prominences as they were not produced from the AR2409 and AR2410 on 4th September 2015.

Table 1. The condition of the sun on 4th September 2015 (Credit: Space Weather).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio sun</td>
<td>10.7 cm flux: 87 sfu</td>
</tr>
<tr>
<td>X-ray Solar flare</td>
<td>6-hr max : B3 1930 UT Sep04</td>
</tr>
<tr>
<td></td>
<td>24-hr : B4 0518 UT Sep04</td>
</tr>
<tr>
<td>Planetary K- index</td>
<td>Now : Kp = 2 quiet</td>
</tr>
<tr>
<td></td>
<td>24-hr max : Kp = 5 storm</td>
</tr>
<tr>
<td>Interplanetary Magnetic Field</td>
<td>$B_{\text{total}} = 6.2$ nT</td>
</tr>
<tr>
<td></td>
<td>$B_z = 0.7$ nT north</td>
</tr>
</tbody>
</table>

4. CONCLUSIONS

Solar radio burst type III is a fast drift burst which can occur singly, in groups or even storms. This radio emission is caused by flare accelerated electron beams that propagates with high velocity through the corona. Based on the analysis, the duration of the formation of the burst was 3 minutes with the drift rate of 0.611 MHz/s. The minimum energy obtained was $1.590 \times 10^{-25}$ J and maximum energy of $2.319 \times 10^{-25}$ J for the frequency of 240 MHz to 350 MHz. For solar radio burst type IV, the burst shows a broadband continuum with fine structure characteristics. The analysis showed that there were two bursts at low intensities with the duration of about 7 minutes for the first burst (280-320 MHz) and 6 minutes for the second burst (360-430 MHz). The drift rate was 0.095 MHz/s for the first burst while for the second burst, the drift rate was 0.194 MHz/s. The energy calculated was between $1.855 \times 10^{-25}$ J and $2.12 \times 10^{-25}$ J for frequency of 280 MHz and 320 MHz. The other intensity of frequency 360 MHz and 430 MHz, the energy calculated was between $2.385 \times 10^{-25}$ J and $2.849 \times 10^{-25}$ J.

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References


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