The Implementation of Log Periodic Dipole Antenna (LPDA) and CALLISTO system on Solar Radio Bursts Observation

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Abstract. Solar activity is very important to be observed in order to study its effects to Earth’s climate and space weather generally. In order to understand the behavior of the Sun and its activity, developing ground-based instruments is one of the ways to record the occurrence of the activity other than satellites data. We present in this paper our work on the implementation of Log Periodic Dipole Antenna (LPDA). The LPDA has been successfully set up at UiTM Shah Alam, Malaysia in 2016 with high performance with 8.4-meter height and it has achieved gain as high as 7.28 dB. It mainly records solar radio bursts during the occurrence of solar activity and has been operating at frequency range of 45-870 Hz. This project is done under International Space Weather Initiative (ISWI) by using CALLISTO spectrometer at the same frequency range to monitor solar observations in support developing countries with latest technologies of instrument. Beneficially in Malaysia, our station contributes half of the data on e-CALLISTO website due to 12 hours Sun exposure compared to other stations in different countries. All types of solar bursts obtained by e-CALLISTO are presented in this paper.

1. Introduction
Solar activity which are commonly related to space weather are solar flares, coronal mass ejections (CMEs) and solar proton events. These events can trigger plasma oscillations which can release radiation at metric and decametric wavelengths [1]. Solar flare is a sudden eruption of very high energy radiations transferred between corona and chromosphere due to the instability of magnetic fields at corona. High energy flares harm the human beings as they disrupt our power grids, Global Positioning System (GPS) signal and blocking the Earth’s upper atmosphere with hazardous radiation [2]. Meanwhile, a strong shock wave from the CMEs can generate geomagnetic storm and disturb Earth’s magnetosphere leading to break down in our satellite and ground systems. Climate change also has a close relation with the amount of Sun's energy emitted [3]. Therefore, solar radio emissions, or called as radio burst can be one of the tools in forecasting space weather. The first radio observations have commenced in 1944 from the discovery of Sun's radio waves emission by J. S. Hey [4]. A brief increasement in the radio emission is provoked when electrons are accelerated to energies well above their thermal energy in the quiet corona [5]. Furthermore, radio spectrum is more reliable in detecting weak emissions by celestial sources compared to other electromagnetic spectrums [6]. Across the electromagnetic spectrum, radio region is the only window that is available for collecting data from the Sun as only radio waves can penetrate through Earth’s multiple layers of atmosphere other than
visible light. Therefore, a ground-based instrument is needed to make it possible to detect solar radio burst emission during solar activity.

This Log Periodic Dipole Antenna (LPDA) was brought into realize in UiTM Shah Alam, Malaysia in 2016 to facilitate our study on radio burst affecting space weather. It was built with high performance and stability with 8.4m height and consists of 23 elements made up of high quality and low-cost aluminum.

Observations are carried out in radio region at low frequency and narrowed down to 45 MHz-870 MHz and it has achieved gain as high as 7.28 dB. The frequency step is quite small at 62.5 KHz to make it easier in getting rid of terrestrial interference [7]. By using CALLISTO (Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy in Transportable Observatories) spectrometer of the same range which is connected to the antenna to produce spectrographs, this project is put under International Space Weather Initiative (ISWI) program. CALLISTO name is inspired from one of the name Jupiter’s larger moons [8]. The main purpose of this worldwide project to monitor solar activities in 24 hours throughout the year has come to reality with the distribution of the instrument at more than 90 locations worldwide [9]. In Malaysia, there are 12 hours of sunlight each day which benefits us in contributing half of data in e-CALLISTO website.

Solar radio bursts (SRB) are originated by bremsstrahlung, gyrosynchroton and plasma radiations [6]. Generally, they can be categorized into 5 fundamental types which are type I, II, III, IV and V. In the case of type I burst, the spectrum is represented by short, narrow band events with a broader band continuum. Type II burst is known to be slow drift burst [10] going from high to low frequency at a range of 20-150 MHz. This burst is the closest hint in predicting the radio emissions associated to earth-directed CMEs [11]. Meanwhile, type III burst rapidly drifts from high to low frequency and often presents with large flares. Among the bursts, type III is said to be the most associated to solar flares due to energetic particles escaping along open magnetic field lines [12]. Type IV burst shows broadband continuum with rapidly fine structure [13] that is associated to very energetic CMEs with average speed of 1200 km/s. Lastly, type V burst is characterized by broadband continuum following type III burst with gradually decrease in frequency. It can be recognized by long-duration low-frequency that is seemed to be combined with the decay phase of type III burst [6]. They also can be divided by sub-type of burst depending on the physical characteristics and different mechanisms [14]. However, several types of solar radio burst which cannot be classified due to the complexity of the activity of the Sun [15].

2. Data Acquisition

In this study, the data of radio bursts are acquired from CALLISTO website as it is an open-access database for everyone to access into and make use of the data for research purpose. Total amount of CALLISTO spectrometers that have been deployed worldwide are working together as a network known as e-CALLISTO [16]. The CALLISTO system has been standardized to be operating at range of 45 MHz-870 MHz. In producing the output data files, most of the files use Flexible Image Transport System (FITS) file format which are normally produced at 15-minute intervals throughout the observation [17].

Figure 1 shows the structure of entire system that has been constructed at UiTM Shah Alam. As shown in the figure, the antenna is connected to Low Noise Amplifier (LNA) to amplify the signal and minimize the noise simultaneously. Then, the signal will be received by CALLISTO spectrometer to be processed into a form of spectrograph which is displayed on the PC. The processed data are automatically uploaded on e-CALLISTO website and can be accessed by public.
3. Results and Discussion

In this section, we present all five types of solar radio bursts in order to characterize each burst pattern.

Type I burst is a non-flare related phenomenon. It is a long duration emission as it is due to energetic electrons trapped on closed coronal magnetic field lines [18]. It can be in continuum component which is often referred as noise storm, or burst component which is characterized by a very narrow band. Figure 2(a) shows type I burst recorded by BLENSW station located at SWISS on 1st Jul. 2014. As displayed in the spectrograph, the bursts are in the burst component which are frequently occurred throughout the time. The burst frequency is in the range of 60-30 MHz and are indicated in low intensity. This burst can be the indicator of pre-solar flare and CMEs if the intensity of the burst is high [19].

Figure 2 a) Type 1 burst on 1st Jul. 2014, b) Type II burst on 4th Nov. 2015, c) Type III burst on 15th Sep. 2015, d) Type IV burst on 27th Feb. 2018, e) Type V burst on 15th May 2015.

Figure 2(b) shows SRBT II that has occurred on 4th Nov. 2015 and lasted for 4 minutes started at 0324 UT until 0328 UT. The burst was observed going from 450 MHz to 150 MHz by ALMATY station located at Kazakhstan. During the burst event, an M1.9 flare was erupted from AR2445 at 0320 UT for 9 minutes. The formation of CME is also detected as the solar wind speed exceeds normal level with 770 km/s. The burst appeared in the spectrograph a few minutes later after the minor CME at 0212 UT and settled down at 0312 UT as reported. In this case, the slow drift burst is due to plasma emission following the motion of shock wave of the CME through the corona. As the charges of the plasma reinstate their electrical neutrality, they oscillate about each other in a harmonic motion result in second harmonic emission as in the spectrograph.

On 15th Sep. 2015, type III burst has been detected by BLENSW station located at Swiss. A group of bursts occurred at between 0623 UT until 0624 showing a fast drift from 70 MHz to 20 MHz.
Solar activity has been low with the highest flare of C1.3. The highest geomagnetic index on this day is Kp4 which indicates active storm, yet, no damages reported by the ground systems on Earth. Generally, type III burst is produced when a beam of high-speed electrons rises dramatically through Sun’s corona. It is also a temporary non-thermal emission of the Sun [20]. Langmuir waves generated near the plasma frequency by the beam of electrons with speed of 0.1-0.7c [21] later are converted into radio waves and produce type III bursts as shown in Figure 2(c). Type III bursts can occur as an isolated, in groups, or storm [22].

Type IV burst is known for its broadband continuum emission. It is also related to the development of sunspot groups. On 27th Feb. 2018, GLASGOW station located at Scotland has successfully recorded a solid type IV burst at 0644 UT until 0645 UT. As shown in Figure 2(d), the zebra pattern of the burst can be clearly seen with high intensity going from 81 MHz to 44 MHz and the frequency drift is remain constant for 5 minutes. It was recorded that solar activity has been very low with only one sunspot presence. However, Kp-index shows a minor geomagnetic storm was triggered between 0300 to 0600 UT on this day. Theoretically, type IV burst can be the initiator of geomagnetic disturbance and the burst can last for from hours to a few days in the region of 20 MHz till 2 GHz [22].

The last burst which is type V burst is a short-lived continuum radiation that commonly follows some type III bursts. As it is seen as the extension of type III bursts, type V is thought to be an oscillation due to deceleration damping process of plasma radiation. Figure 2(e) displays the occurrence of type III and type V beside each other where by type V is formed a few minutes right after type III burst. It was recorded on 15th May 2015 by BLENW station at 0525 UT until 0526 UT. On this day, solar activity has been low with 7 numbered of sunspot regions and the highest event was C2 flare. Besides, there was no significant events throughout the day produced by the Sun that would generate geomagnetic storm.

4. Conclusion
In conclusion, we would like to emphasize in this paper the importance and significance of LPDA and CALLISTO system in deeply studying on the Sun’s behavior and activity. By utilizing this system in space weather studies, it will give us ideas on how the Sun is changing as time goes by and the prediction on the upcoming solar events can be made through the data obtained. The spectrographs that display all type of bursts are very helpful in analyzing the behavior and mechanism of certain events. As the bursts give us information of what event is happening at the moment, precaution steps can be taken in advanced in order to prevent our satellites and communication ground systems from being destructed by solar storm.

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