Investigation of Characteristics of Noise Storm Solar Burst Type I on 11th March 2013

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Abstract Most type I bursts appear in chains of five or more individual bursts. We studied the event of solar type I solar bursts recorded by the Compact Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO-ROSEWELL) spectrometer on 11th March 2013 in the frequency range 320–450 MHz. It was observed 5 s after the flare which happens at 16:24:05UT. The drift rate of this burst is 8 MHz/s with a range of energy between 1.4081 × 106 eV to 1.739 × 106 eV. There are six sunspots were producing flares which are AR1691, AR1690, AR19692, AR1693, AR1694, and AR1689. The sunspot number is 89 and the level of energy is proportional to 680 SFU. Solar Burst Type I is normally in a storm structure and become one of the pre-burst stage. In this case, the burst is associated with a large solar flares. Type I solar burst can be as an indicator of pre-solar flare and CMEs if the intensity of the burst is high. The physical conditions inside and outside the source and the emission mechanisms are discussed.

Keywords Solar burst type I · Noise storm · Solar flare · Coronal mass ejections (CMEs)

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1 Introduction

1.1 Solar Burst Type I

Metric solar radio emissions indicate the existence of non-thermal electrons in the solar corona at altitudes of 0.1–1.0 solar radii (R). Type I storms last from a few hours to several days [1]. Type-I noise storms are one of the solar radio phenomena observed at a meter wavelength with a flux in the range of about 1–100 sfu, and a brightness temperature higher than 10^9 K [2]. The emission mechanism is fundamental plasma emission, due to the coalescence between Langmuir waves and low-frequency waves, and the driver of Langmuir waves is a population of energetic particles trapped in closed magnetic-field structures over an active region [3]. The storms have two components; one is a discrete type-I burst of short duration with a narrow band, and the other is a noise storm continuum of long duration with a broad band. The drift rate can be as a positive or negative frequency drift-rate in the interval of a few tens of $MHzs^{-1}$ to about 200 $MHzs^{-1}$ Elgarøy (1961) and limited range of frequency [4]. This components show highly circular polarization, corresponding to the ordinary mode. It is generally considered that non-thermal electrons that are trapped by closed magnetic field lines excite plasma waves. These excited plasma waves are converted into O-mode waves, which are finally observed as type-I noise storms. It is believed that A storm consists of many individual bursts with short duration, and it is assumed that each burst corresponds to an acceleration of suprathermal electrons [5]. It is also believed that the radiation is attributed to plasma waves excited by suprathermal electrons accelerated between two packets of Alfvén waves traveling in opposite directions [6]. Although the process to produce non-thermal electrons is not well understood, some models have been proposed. What is so unique is that the coronal magnetic fields change very rapidly because the appearance of the new magnetic structures and consequently radio emissions are generated by the interaction between accelerated particles and the turbulent plasma over active regions [7, 8]. The problem that we can studied is the lack of direct measurement of coronal magnetic field in the region make the evolution of coronal phenomena is difficult to be discussed briefly. Furthermore, the formation of this is very complex, long duration of this loop is the magnetic reconnection and disruption of the loops which is observed during the evolution of the active region is not fully understood [9].

Meanwhile, the classification of X-ray solar flare we can conclude with the solar flare explosion on the sun [10]. It will happen when the energy stored in twisted magnetic field is suddenly released. The flares will produce a burst of radiation across the magnetic spectrum, which is from the radio waves to X-ray and gamma rays. With that, the scientist was classified solar flares according to their X-ray brightness in the wavelength range 1–8 Armstrong. There was divide into three categories, which is X-class flares are big. They are major events that can trigger planet-wide radio blackouts and long-lasting radiation storms [11]. Lastly, C-class flares are small with few noticeable consequences here on Earth.

The objectives of this study is to calculate the formula of the drift rate of noise storm and to evaluate the range of energy of the burst. By study about noise storm, we know the activity and the dependence of some of the storm characteristics in meter wavelength region such as mean intensity and number of storms per year [12]. The type I solar burst is the starting point to predict the Sun's phenomena such as solar flare and Coronal Mass Ejections (CMEs).

2 Methodology

The CALLISTO is the short form from the Compact Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory was introduced by Arnold O.Benz. The E-CALLISTO network was set up and operates identical spectrographs in the different location in the globe for 24 h coverage [13]. CALLISTO spectrometer eC48 have a RS-232 shielded cable and have a 12 V power supply donated by the Institute of Astronomy of ETH Zurich, Switzerland [14]. An individual channel has a bandwidth of 300 kHz and can be tuned by the controlling software in steps of 62.5 kHz [15]. The CALLISTO spectrometer was covering a frequency range from 45 MHz up to the higher is about 870 MHz [16]. We use a tool available from the e-CALLISTO network for background subtraction to study the 255 chains of solar type I solar bursts recorded by the CALLISTO Roswell New Mexico, USA spectrograph on 11th March 2013 in the frequency range 320–450 MHz. We used a software in Java (RAPP Viewer) provides a set of procedures to analyze and visualize spectrograms, including a tool for background subtraction [17]. The calibration process to deduct the Radio Frequency Interference (RFI) is need to obtain a better structure of the burst [18]. Figure 1 shows the CALLISTO system.

In this analysis, the important parameter that has been taken into account are such burst duration, drift rate, energy of photon, and unique structure of the burst. We applied the background-subtract or tool to all recorded spectra. The following parameters were determined for each chain of type I bursts: start frequency (f_i), end frequency (f_f), start time (t_i), end time (t_f), total duration (Δt), total frequency range (Δf), and frequency-drift rate ($\Delta fc/fcf\Delta t$). The information about activities and events such eruptions and solar flares on the Sun were retrieved from spaceweather.com. Spaceweather.com is an official website that provides news and information about the Sun-Earth environment. Meanwhile, Coronal Mass Ejection data and images were retrieved from Large Angle and Spectrometric Coronagraph (LASCO) online database. LASCO is an instrument of 11 instruments included on the joint NASA/ESASOHO (Solar and Heliospheric Observatory) spacecraft. The data of X-ray flux which observed by GOES satellite was retrieved from Space Weather Prediction Centre official website. This website provides alerts and warnings for any disruptions that might affect people and equipment working in space and earth to the nation and the world.

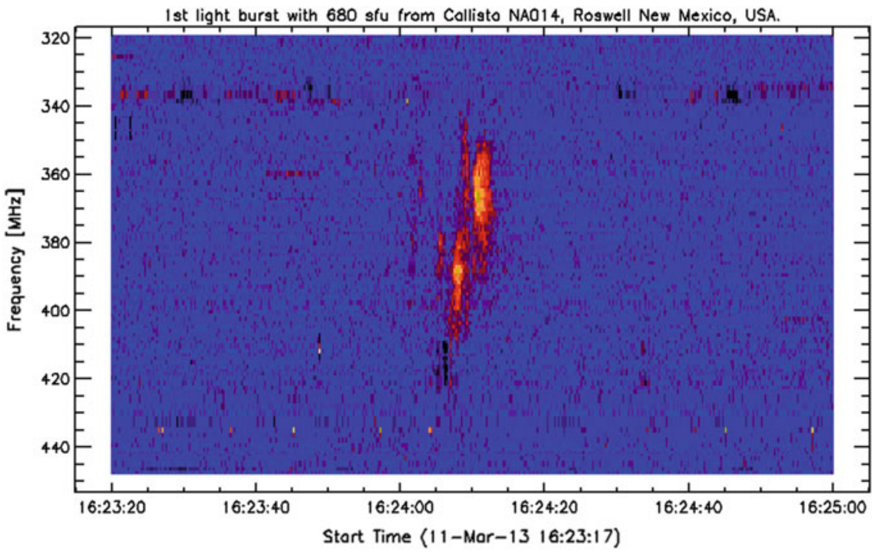

Fig. 1 SRBT I on 11th March 2013. Credit to e-CALLISTO

3 Results and Discussion

It was found that on 11th March 2013, there are also a single SRBT I observed. Whereby, it happens for ten seconds within 16:24:05UT till 16:24:15UT. It also drifted from 420 to 340 MHz, from a higher intensity of burst to low intensity. The event of solar type I solar bursts recorded by the Compact Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO-ROSEWELL) spectrometer on 11th March 2013 in the frequency range 320–450 MHz. The drift rate of this burst is 8 MHz/s with a range of energy between 1.4081×10^6 eV and 1.739×10^6 eV. The level of energy is proportional to 680 SFU.

During the day, there are 89 sunspot number were detected by SolarMonitor.org. However, there are six of them were producing flares which are AR1691, AR1690, AR19692, AR1693, AR1694, and AR1689. The solar radio burst type I was produced type C from the active region AR1691. Active region is usually indicated by sunspot. However, not all active regions have sunspot. The plentiful of magnetic field can reach 1000 times stronger in the active region as compared to the average magnetic field of the Sun. Active regions are frequently observed when the Sun's magnetic field is tremendously disturbing during peak of the sunspot cycle. There are also other types of solar dramatic activities that also frequently occurred around active regions such solar prominence and coronal loops. This is because the SRBT I was observed 5 s after the flare which happens at 16:24:05UT. The emission came from a plasma cloud ejected in association with an extensive solar prominence.

Based on the X-Ray flux data above, there are at the type of M5 (5×10^{-5} Wm^{-2}), X2 (2×10^{-4} Wm^{-2}) and X6 (6×10^{-4} Wm^{-2}) classes of solar flare suddenly ejected from the active region AR1081. While this eruption, a magnetic field filament connected to the sunspot AR1689 also erupted. The two wild filaments combined to produce a bright Coronal Mass Ejections (Spaceweather.com). The filament is the largest release of plasma and magnetic field from the solar corona. The long-term evolution of ARs confirmed that the evolution of an active region in each and every detail reflects the evolution of its magnetic field. It was found that flares mainly occur when the magnetic field of the AR has the highest complexity and magnetic flux density, and this is when the variability of AR cores are the highest, too (Fig. 2).

Based on the calculation have made, it was found that the electron density of the burst is 5.406×10^{14} e/m^3 and the drift rate of the solar radio burst are 8 MHz/s. Besides, the photon energy are ranging from 1.408×10^6 eV to 1.739×10^6 eV. The non-thermal electrons are generated through some physical process, are trapped in closed magnetic-field lines, and generate Langmuir waves, which are converted into O-mode radio waves and are later observed as type I bursts Table 1.

Solar Burst Type I is normally in a storm structure and become one of the pre-burst stage. In many cases, if we observed the solar flare phenomena, this burst is associated with C classes of flares. However, in this case, the burst is associated with a large solar flare. The aggregate lifetime of all short-lasting burst is approximately equal to aggregate lifetime of burst of any other duration. The energy of short-lasting burst with duration of 0.2–0.4 s is five times smaller than the energy longer bursts, it is constituted only 2–5% of the energy of the noise storm burst component. Solar burst chains can be some superposition of short-lasting burst on one long burst.

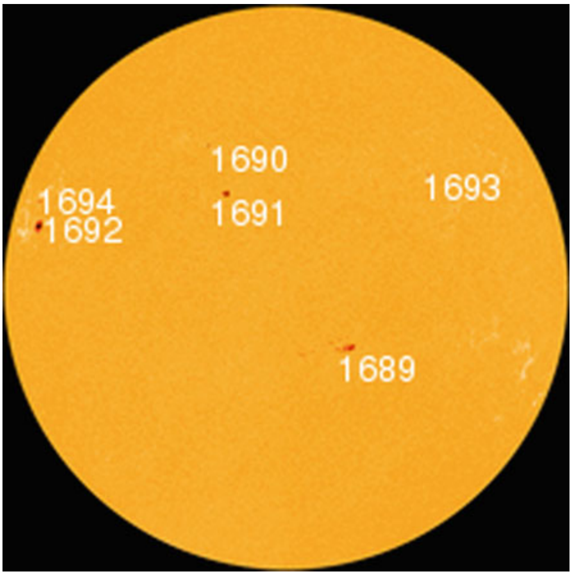

Fig. 2 Active region AR1691. Credited to spaceweather.com

Table 1 The current condition of the Sun on11th March 2013. Credited to Spaceweather

Parameter	Value
Solar wind speed	304.5 km/s
Photon density	5.7 photons/cm^3

4 Conclusion

Type I solar burst can be as an indicator of pre-solar flare and CMEs if the intensity of the burst is high. Even we could not directly confirmed that is only possible because it just based on selected event, we need consider other process to explain the detailed the injection, energy loss and the mechanism of the acceleration of the particles for the further study.

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References

1. Krucker S, Lin RP (2000) Two classes of solar proton events derived from onset time analysis. Astrophys J 542:61–64
2. Kattenberg A (1981) Solar radio bursts and their relation to coronal magnetic structures. Rijksuniversiteit te Utrecht
3. Melrose DB (1970) On the theory of Type II and Type III solar radio bursts. Aust J Phys 23:885–903
4. Malville JM (1962) Astrophys J 136:266
5. Suzuki S, Dulk GA (1985) Bursts of type III and type V. In: McLean DJ, Labrum NR (eds) Solar radiophysics: studies of emission from the sun at metre wavelengths. Cambridge Univ. Press, New York
6. Takakura T (1963) Origin of solar radio type I bursts. Publ Astron Soc Jpn 15:462
7. Hamidi Z, Shariff N, Ibrahim Z, Monstein C, Zulkifli WW, Ibrahim M, Amran N (2014) Magnetic reconnection of solar flare detected by solar radio burst Type III. J Phys: Conf Ser 539(1):012006
8. Lantos P, Kerdraon A, Rapley G, Bentley R (1981) Relationship between a soft X-ray long duration event and an intense metric noise storm. Astron Astrophys 101:33–38
9. Shariff N, Hamidi Z, Zainol N (2017) Analysis of slow partial Halo CME events with velocity of 100-200 km/s: an observation through CALLISTO system. Paper presented at the 2017 International Conference on industrial engineering, management science and application (ICIMSA)

10. Hamidi ZS, Anim N, Shariff NNM, Abidin ZZ, Ibrahim ZA, Monstein C (2013) Dynamical structure of solar radio burst type III as evidence of energy of solar flares. Paper presented at the PERFIK 2012, Malaysia
11. Hamidi Z, Zainol N, Ali M, Sabri S, Shariff N, Faid M, … Monstein C (2016) Signal detection of the solar radio burst Type III based on the CALLISTO system project management. Paper presented at the 2016 international conference on industrial engineering, management science and application (ICIMSA)
12. Husien N, Zainol N, Hamidi Z, Sabri S, Shariff N, Faid M, … Monstein C (2016) Solar radio bursts detected by CALLISTO system and their related events. Paper presented at the Industrial Engineering, Management Science and Application (ICIMSA), 2016 International Conference on
13. Zainol N, Sabri S, Hamidi Z, Ali M, Shariff N, Husien N, … Faid M (2016) Effective data collection and analysis of solar radio burst type II event using automated CALLISTO network system. Paper presented at the 2016 International Conference on industrial engineering, management science and application (ICIMSA)
14. Sabri S, Zainol N, Ali M, Shariff N, Hussien N, Faid M, … Monstein C (2016) The dependence of log periodic dipole antenna (LPDA) and e-CALLISTO software to determine the type of solar radio burst (I-V). Paper presented at the 2016 international conference on industrial engineering, management science and application (ICIMSA)
15. Ali M, Sabri S, Hamidi Z, Husien N, Shariff N, Zainol N, …, Monstein C (2016) e-CALLISTO network system and the observation of structure of solar radio burst type III. Paper presented at the 2016 international conference on industrial engineering, management science and application (ICIMSA)
16. Sabri SNU, Hamidi ZS, Shariff NNM, Monstein C (2016) The significance of e-CALLISTO system and construction of log periodic dipole antenna (LPDA) and CALLISTO system for solar radio burst study. Information science and applications (ICISA), 181–188
17. Hamidi Z, Shariff N (2017) Automatic solar radio burst Type II and III image processing tracking by using CALLISTO system. Paper presented at the 2017 international conference on industrial engineering, management science and application (ICIMSA)
18. Abidin ZZ, Anim NM, Hamidi ZS, Monstein C, Ibrahim ZA, Umar R, Sukma I (2015) Radio frequency interference in solar monitoring using CALLISTO. New Astron Rev 67:18–33