Detection of the Weak CMEs by CALLISTO System

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Abstract. CALLISTO (Compound Astronomical Low Frequency Low Cost Instrument for Spectroscopy and Transportable Observatory) is one of the projects from ISWI and initiative of United Nation and NASA as a support to help developing countries to monitor activities of the Sun for the whole day. Today, more than 164 instruments at more than 100 locations use this system to do research on the Sun. The objective of this paper is to show that even the activity from the Sun is not too intense and large, the CALLISTO system can detect the signal, hence the importance of this system is acknowledged. This is as a hint for us to use the antenna as the part of the CALLISTO system to get the full coverage all day long with the contributed data from around the world. A weak Coronal Mass Ejection (CME) with the median velocity of 231 km/s was observed on 9th March 2019 by SOHO coronagraph and detected by CALLISTO system from multiple sites of UK, Switzerland and Italy. This faint CME was not giving the high impact to the Earth’s magnetosphere and thus no minor occurrence of the geomagnetic storm.

1. Introduction

A Coronal Mass Ejection (CME) is a major solar activity. It causes the large amount of plasma and magnetic field to expel from the corona into the solar wind at a high speed. If the events (CMEs) are strong, intense and has higher solar wind speed, it might disturb the Earth’s magnetic field and produce the geomagnetic storms that involves in the reconnection with the magnetosphere of the Earth [1, 2]. Slow wind speed cause not so intense space weather whereas the high-speed winds cause the geomagnetic storm [3]. Besides, the communications, space satellites and navigation system of the flight can be disturbed too. When at solar minimum, the Coronal Mass Ejections form in the coronal streamer belt near the equator of the Sun while at solar maximum, the active regions are the place for the production of CMEs as the latitudinal distribution is more homogenous.

CME can be classified into two categories. One is flare-related CMEs and another one is CME that is related to the filament eruption [4, 5]. The flare related CME is usually caused by the magnetic flux in the active region and can be detected when there is a solar flare occurred [6]. The filament eruption category for CME is associated with the solar burst type IV and type II that is caused by the sunspot evolution where the CME is formed when the filament is erupting. CMEs mechanism involves the gradual CMEs, impulsive CMEs and CMEs related to solar radio burst type IV [4, 7]. For gradual CMEs, it is formed when the cavities of the prominences increase in the speed range between 400 to 600 km/s from the coronal streamers before it leaves 30 R☉ [4, 8]. The impulsive CMEs are related to the Moreton
waves and the flares while the third mechanisms of the CMEs are correlated to the type IV burst where it requires the larger events of ejection of the proton flares [4, 9].

Solar radio burst type II is the earliest indicator of CME driven shocks. The formation of type II burst is caused by the accelerated electrons at an outward propagating coronal shock front [10]. Payne et. al. had identified the type II burst [11] and [12] discovered this burst. It is classified that solar radio burst type II is a broadband and can last from 20 minutes to a few hours. Type II can be classed into two main components of fundamental (F) and harmonic (H) structure and has a slow drift burst [13]. The emission frequency gives the grasp of the distance of the heliocentric at which the radio emission originates [14]. This type of burst is studied at meter-decimeter wavelengths using the ground-based telescopes [15] in the range of 150 to 15 MHz. Type II radio burst emission is interpreted when electrons accelerate in the MHD shock front generate the plasma waves [16]. The waves then being converted to the electromagnetic radiation at the fundamental and harmonic of local plasma frequency. In nature, solar bursts type II is electromagnetic and they reach the Earth’s orbit approximately 8.3 minutes, where this can be a warning sign of the interplanetary shocks arrival [14].

The solar radio burst can be detected from the ground-based radio telescope such as the CALLISTO system which used the antenna to detect the signal. The Compound Astronomical Low cost, Low frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) is mainly used for the educational purposes and astronomical sciences for the RFI monitoring other than detecting the solar radio burst [17-19]. Today, there are about 100 locations that are using the CALLISTO with the number of 164 instruments in 27 countries around the world. CALLISTO system consists of hardware and software which the main instruments are the antenna, low noise amplifier and CALLISTO spectrometer. This system is a huge success in monitoring the Sun activities for 24 hours per day with the contribution data from all the sites around the globe and it is one of the International Space Weather Initiative projects [20, 21]. The e-CALLISTO is a global network that is connected by using the internet [22, 23].

2. Methodology and Observation
The identified data of solar radio burst type II were collected from the e-CALLISTO website. The solar radio burst data were recorded by the Observatory at Acre Road, University of Glasgow, UK, Trieste Astronomical Observatory, Italy and Bleien Observatory, Switzerland. The Space Weather Live and Solar Monitor websites were selected to get the data for other parameters such as the solar wind speed, and the data about the sunspot. Both websites combined the data from NASA, SDO and NOAA for the best images of the Sun and make it easy for the public to access the data. The CACTus website shows the CMEs images that was observed by the LASCO coronagraph on the SOHO spacecraft.

3. Results and Discussion
On 9th March 2019, there were two minor solar flares ejected from the active region (AR) 2734 together with the weak Coronal Mass Ejection (CME) tailed. The region of 2734 produced B class flare type of B1.1 and B6.5 where it started at 0428 UT and 1215 UT respectively. The CME produced very faint plasma cloud and the speed was so slow than the ambient solar wind speed with the reading of 468 km/s. Although the active region is facing the Earth with its position on the Sun at N08W17, the impact of the CME was not strong as the speed was slow. From [24], the Sun can even produce solar flares and CMEs even the activity on the Sun is not active. The production of the CME was recorded by the CALLISTO system in Glasgow, Trieste and Bleien site. The plasma emissions from the Sun started at 1215 UT, reached its maximum at 1226 UT and ended at 1237 UT. The spectrogram images detected by the CALLISTO was around 1230 UT. Figure 1 shows the solar radio burst metric type II, which was associated with CME in fundamental and harmonic structure. The spectrogram images show the burst at frequency range 45 MHz to 80 MHz.
Figure 1. Solar radio burst type II recorded from Glasgow, Trieste and Bleien sites on 9\textsuperscript{th} March 2019 at 12:29 UT. (Credit: e-callisto.org)
The activity of the Sun can be detected by the GOES Satellite where it focusses on the X-ray brightness of the flares and can be seen from Figure 2 with the ejected flare of B class type along with the CME. The image of CME that erupted from the Sun was captured by SOHO where the lowest velocity detected within the CME was 190 km/s and the median velocity was 231 km/s. This speed is considered slow and the impact was expected to not be visible, thus no minor geomagnetic storm was happening because of this faint CME.

4. Conclusion
On 9th March 2019, solar radio burst type II, which is related to a Coronal Mass Ejection (CME) was detected by CALLISTO system at various sites including Italy, Switzerland, and UK. From this finding, we can see that the CALLISTO system really plays a big role in monitoring the activities of the Sun such as the solar flares and the CME. The median speed of the CME that day is around 231 km/s which can be considered as weak CME and the geomagnetic storm occurrence was far from happened. This CME also considered as filament eruption type CME as it occurred with the very small flares of B class.
Although the CME was weak that day, which was produced by the B class flares, its emission from the Sun still can be detected by the CALLISTO system. Thus, we can conclude that this system is crucial for early detection of the solar storm and from that, the precautions can be made in the future to prevent any harmful or destruction of the space or Earth livings.

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References
[1] Z. Hamidi et al., "Magnetic Reconnection of Solar Flare Detected by Solar Radio Burst Type III," in Journal of Physics: Conference Series, 2014, vol. 539, no. 1, p. 012006: IOP Publishing.
[2] G. D. Fleishman, D. E. Gary, and G. M. Nita, "Decimetric spike bursts versus microwave continuum," The Astrophysical Journal, vol. 593, no. 1, p. 571, 2003.
[3] Z. Hamidi, N. Ramli, and N. Shariff, "Statistical Analysis of Solar Radio Burst Type III and Type IV with Relation to Solar Activities," in Journal of Physics: Conference Series, 2019, vol. 1152, no. 1, p. 012018: IOP Publishing.
[4] Z. Hamidi et al., "An X-ray Observations of A Gradual Coronal Mass Ejections (CMEs) on 15th April 2012," International Letters of Chemistry, Physics and Astronomy, vol. 8, 2004.
[5] N. Gopalswamy, "Coronal mass ejections of solar cycle 23," Journal of Astrophysics and Astronomy, vol. 27, no. 2-3, pp. 243-254, 2006.
[6] A. Zabidi, I. M. Yassin, M. H. Jusoh, and Z. I. Rizman, "Remote Data Acquisition and Archival of Magnetic Data Acquisition System (MAGDAS)," International Journal on Advanced Science, Engineering and Information Technology, vol. 7, no. 5, pp. 1722-1727, 2017.
[7] N. Gopalswamy and M. Kundu, "Thermal and nonthermal emissions during a coronal mass ejection," Solar Physics, vol. 143, no. 2, pp. 327-343, 1993.
[8] N. Gopalswamy et al., "Relation between type II bursts and CMEs inferred from STEREO observations," Solar Physics, vol. 259, no. 1-2, p. 227, 2009.
[9] Z. Hamidi, Z. Abidin, Z. Ibrahim, C. Monstein, and N. Shariff, "Signal Detection Performed by Log Periodic Dipole Antenna (LPDA) in Solar Monitoring," International Journal of Fundamental Physical Sciences, vol. 2, pp. 32-34, 2012.
[10] N. H. Zainol, Z. S. Hamidi, N. N. M. Shariff, and C. Monstein, "An Automated System for Signal Detection of Solar Radio Burst Type II Due to Coronal Mass Ejections Phenomena," in Information Science and Applications (ICISA) 2016: Springer, 2016, pp. 195-205.
[11] R. Payne-Scott, D. Yabsley, and J. Bolton, "Relative times of arrival of bursts of solar noise on different radio frequencies," Nature, vol. 160, no. 4060, p. 256, 1947.
[12] A. Boichot, A. Riddle, and J. Pearce, "JW and Warwick," Solar Phys, vol. 65, 1980.
[13] Z. Hamidia, Z. Abidina, Z. Ibrahimia, N. Shariffia, and C. Monsteinc, "Observations of coronal mass ejections (CMEs) at low frequency radio region on 15th April 2012," in AIP Conf. Proc, 2013, vol. 1528, pp. 55-60.
[14] N. Gopalswamy, E. Aguilar-Rodriguez, S. Yashiro, S. Nunes, M. Kaiser, and R. Howard, "Type II radio bursts and energetic solar eruptions," Journal of Geophysical Research: Space Physics, vol. 110, no. A12, 2005.
[15] G. Nelson and D. Melfrose, "Type II bursts," Solar Radiophysics: Studies of Emission from the Sun at Metre Wavelengths, pp. 333-359, 1985.
[16] N. Gopalswamy, "Interplanetary radio bursts," in Solar and Space Weather Radiophysics: Springer, 2004, pp. 305-333.
[17] Z. Hamidi, Z. Abidin, Z. Ibrahim, and N. Shariff, "Indication of radio frequency interference (RFI) sources for solar burst monitoring in Malaysia," in AIP Conference Proceedings, 2012, vol. 1454, no. 1, pp. 43-46: AIP.
[18] R. Umar, Z. Z. Abidin, Z. A. Ibrahim, M. S. R. Hassan, Z. Rosli, and Z. S. Hamidi, "Population density effect on radio frequencies interference (RFI) in radio astronomy," in *AIP Conference Proceedings*, 2012, vol. 1454, no. 1, pp. 39-42: AIP.

[19] Z. Z. Abidin *et al.*, "Radio frequency interference in solar monitoring using CALLISTO," *New Astronomy Reviews*, vol. 67, pp. 18-33, 2015.

[20] Z. Hamidi *et al.*, "Designing and Constructing Log Periodic Dipole Antenna to Monitor Solar Radio Burst: e-Callisto Space Weather," *International Journal of Applied Physics and Mathematics*, vol. 2, no. 3, p. 3, 2011.

[21] A. Benz *et al.*, "A world-wide net of solar radio spectrometers: e-CALLISTO," *Earth, Moon, and Planets*, vol. 104, no. 1-4, pp. 277-285, 2009.

[22] S. Sabri *et al.*, "The dependence of log periodic dipole antenna (LPDA) and e-CALLISTO software to determine the type of solar radio burst (I-V)," in *Industrial Engineering, Management Science and Application (ICIMSA), 2016 International Conference on*, 2016, pp. 1-5: IEEE.

[23] N. Anim, Z. Hamidi, Z. Abidin, C. Monstein, and N. Rohizat, "Radio frequency interference affecting type III solar burst observations," in *AIP Conference Proceedings*, 2013, vol. 1528, no. 1, pp. 82-86: AIP.

[24] N. Norsham and Z. Hamidi, "An Analysis on the Formation of Solar Radio Burst Type II, III and IV by Using e-CALLISTO, IUGONET and Space Weather Data," in *Journal of Physics: Conference Series*, 2019, vol. 1298, no. 1, p. 012018: IOP Publishing.