Investigation of Coronal Mass Ejections Related to Solar Flare Event and The Formation of The Small Geomagnetic Storm

M. Omar Ali\textsuperscript{1}, Z. S. Hamidi\textsuperscript{1}, N. N. M. Shariff\textsuperscript{2}, C. Monstein\textsuperscript{3}

\textsuperscript{1}School of Physics and Material Sciences, Faculty of Sciences, MARA University of Technology, 40450, Shah Alam, Selangor, Malaysia

\textsuperscript{2}Academy of Contemporary Islamic Studies (ACIS), MARA University of Technology, 40450, Shah Alam, Selangor, Malaysia

\textsuperscript{3}Institute of Astronomy, Wolfgang-Pauli-Strasse 27, Building HIT, Floor J, CH-8093 Zurich, Switzerland

E-mail address: zetysh@salam.uitm.edu.my

**Keywords:** Sun; solar burst; type III; radio region; X-ray region; solar flare; active region

**ABSTRACT**

This paper is highlighted on the duration of time for the Coronal Mass Ejections (CMEs) to occur related to solar flare event and the class of solar burst type III that present within the two phenomenon. It is important to understand the evaluations of solar flare until CMEs mean to be appearing and know the basic characterization of solar radio burst type III. It can be observed that CME is even larger than the sun itself. At certain period of time, when the Sun launches billions tones of electrically conducting gas plasma into the space at millions of miles per hours it is assigned that CMEs begin to launch. The data on 23rd of April was selected whereby; solar radio burst type 3 was detected (about 17:36 UT – 17:44 UT). At 17:40 solar flare with a radio burst and CMEs were produced by the sun. Associated with this event, current condition of solar wind speed is 359.5 km/sec with density of 6.0 protons/ and sunspot number are 118. Those at the high latitude have a chance of aurora due to the small geomagnetic storm.

1. **INTRODUCTION**

Coronal Mass Ejections (CMEs) are enormous eruptions of plasma and magnetic fields ejected from the sun into interplanetary space, seen by coronagraphs as they move out of their field of view over the course of minutes to hours. CMEs can only be observed by blocking the intense glare of photosphere because their brightness is of the order of magnitude of the solar corona. Meanwhile, the solar flares are the most energetic phenomena that occur within our solar system. The huge amount of energy that is released by magnetic fields of active regions is used to characterize a flare. Solar corona and chromosphere are accelerated and electromagnetic radiation covering the entire spectrum is emitted during a flare. Besides thermal conduction, non-thermal conduction particle beam, radiation transport and the mass motions caused large amount of energy are transferred between corona and chromosphere. Coronal structure is mainly controlled by magnetic field due to the stronger magnetic force in the corona.

In radio region, type III burst is an indicator of the formation of an solar activity from an active region [1,2,3]. It reveals a wave-particle and wave-wave interactions in magnetic traps in the solar corona [4]. At meter wavelengths the type III burst is usually, though not invariably, preceded by others types of burst. This burst is still one of the interest burst in order to understand the flare plasma diagnostics in the low corona [5]. Interestingly, the motion follows the predominant magnetic field direction, the apparent speed is a significant fraction of the speed of light. These burst radio emission are rather frequently observed, especially a few days before solar flare and Coronal Mass Ejection phenomena [6,7,8].

Metric radio burst is normally a non-thermal particles accelerated and trapped during those events. The solar radio burst type III solar burst is the most dominant with the solar flare
phenomenon was first introduced by Wild in 1963 [9] in the frequency range 500 – 10 MHz [10,11,12]. There are three sub-types of Type III burst that originate in the interplanetary (IP) medium which are (i) isolated Type III bursts from energy system and small-scale energy releases, (ii) a complex Type III bursts during CMEs, and (iii) Type III storms. This stage can be considered as a pre-flare stage that could be a signature of electron acceleration [13]. It is found that 60% of fast drifts (type III) solar radio bursts are synchronized in time with solar flares [14]. Some evidence showed that type III are generated in a weak-field region comes from the absence or low degree of circular polarization of the bursts [15]. Nevertheless, the most important is that the nonlinear wave-particle interaction which involving interaction of electrostatic electron plasma that called as Langmuir waves active region radio emissions is believed to be a main subject that relevant with a type III burst [16,17,18,19,20]. It is believed that a beam-plasma system is unstable to the generation of Langmuir waves, which are high frequency plasma waves at the local plasma frequency [21,22]. Type III bursts early in the rise of impulsive solar flares may indicate that open field lines are an essential part of models for energy release by magnetic fields in such flares [23,24]. Nevertheless, it is important to analyze in radio and X-ray region to understand the distribution of high and low energy [25,26,27,28]. The next section will highlight the solar flare and solar bursts in X-ray and radio region.

2. SOLAR FLARE OBSERVATION AND e-CALLISTO SOLAR SPECTROMETER NETWORK

The solar flare is one of the main event of the Sun that affect the space weather and climate changes [29,30,31]. The observation of solar radio burst was done by using the Compact Astronomical Low cost, Low frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) from BLEIN 7 meter dish telescope at ETH, Zurich in frequency range of 45 until 870 MHz. [32,33]. Signal from the feed will be fed into the receivers. After that, the signal will be converted to a first intermediate frequency of 37.7 MHz by two local oscillators [31,34,35,36,37]. This antenna covered from 45 - 870 MHz [38,39,40,41].

The CALLISTO spectrometer is a low-cost radio spectrometer used to monitor metric and decametric radio bursts, and which has and the named CALLISTO which is inspired from the name of one of the Jupiter’s larger moons[42,43,44,45,46]. In this case, we focused the range of 150 MHz till 900 MHz [47,48,49]. CALLISTO consist three main components which are the receiver, a linear polarized antenna and control/logging software [50,51]. We have selected the data from the 150 MHz till 900 MHz region seems this is the best range with a very minimum of Radio Frequency Interference (RFI) [51,52,53,54,55]. In this paper, we have focused the study area of solar flares in an X-ray and radio region to evaluate the distribution of high and low energy [38]. At present, more than 66 instruments have been installed at more than 35 locations, with users from more than 92 countries in the e-CALLISTO network. Figure 1 shows the schematic diagram of the CALLISTO system.
3. RESULTS AND ANALYSIS

At certain period of time, when the Sun launches billons tones of electrically conducting gas plasma into the space at millions of miles per hours it is assigned that CMEs begin to launches. It is critical when CMEs and the magnetic field which laced together with CMEs’ cloud smashed into Earth magnetic field. This is because; they will dump energy into earth magnetic field that can cause magnetic storms. Widespread blackouts by overloading power line equipment will happen due to the storms.

![Figure 1. Schematic diagram of connection of e-CALLISTO (credit to: ROOPA Nandita PIRTHEE Sagar Girish Kumar Beeharry)](image1)

![Figure 2. X-ray region of solar flare image by SOHO and TRACE](image2)

The image in Figure 2 on the left and right show bright solar flare and CME exploding respectively. From the images it can be observed that CME is even larger than the sun itself. Meanwhile, flares are only erupting in an active region on the sun.

Both solar flare and CMEs are energetic event that occurs on the sun and associated with high energy particles. Both of them also depend on magnetic fields on the sun. However, CMEs are ejected into the space at high speeds and sometimes in the direction of the earth. Besides, CMEs also are larger eruptions compared to flares which are local events. The obvious difference that can
be highlighted is the spatial scale on which both events to be occurred. Solar flare and CMEs can take place in the absence of each other, but both of them are often occur together. Energetic explosion in the low solar atmosphere is called solar flare which can heat the surrounding material to millions of degrees in just few seconds or minutes. Besides, it occurs typically near to sunspots due to the concentrated magnetic field in the active region on the photosphere. Radiations of several bands of electromagnetic spectrum (white light, ultraviolet, x-rays, gamma rays) are also emitted and are observed by ground based and space based telescopes. Solar flares also accelerate particles which are ejected into space to emit large amount of radiation.

![Image of solar radio burst](image_url)

**Figure 3.** The continuous solar radio burst type III within 4 minutes (Credited to: E-Callisto network (BIR))

In this work, data was obtained from e-Callisto. The data on 23rd of April was selected whereby; solar radio burst type 3 was detected (about 17:36 UT – 17:44 UT). At 17:40 solar flare with a radio burst and CMEs were produced by the sun. The sign of the solar was detected within the region 115 MHz till 160 MHz. Associated with this event, current condition of solar wind speed is 359.5 km/sec with density of 6.0 protons/cm$^3$ and sunspot number are 118.
Figure 4. The Active regions during 23rd April 2012 and the image of the Sun by X-ray from Space Weather Website (Credited to: NOAA/ SWPC)

Image above shows solar flare with radio burst and CMEs. NASA SWC is focused on providing critical space weather notification for NASA Robotic Missions. They predicted that CMEs will reach the earth on 27th of April 2012 at 5.49 UT with only minor impact. Those at the high latitude have a chance of aurora due to the small geomagnetic storm. Geomagnetic storms induced by CMEs and effect human activity the most. Aurora only occurs near the poles when solar wind is quiet and the magnetosphere is undisturbed. However, the aurora will expand and brighten and moves to lower latitude at the moment when the solar wind and the magnetosphere are disturbed.

4. CONCLUDING REMARKS

Magnetized plasma is hurled into space interrupting the steady solar wind during eruption of CME from the sun. Disturbance will be created when the ejected coronal materials moves through the solar wind. This disturbance may include a shock wave that moves ahead of the CME and accelerating some solar wind particles to high energies as it moves. Like what has been mention earlier, once the CME reaches the Earth there can be significant consequences to communications, satellite operations and power generation. Solar flare and CMEs often seem to occur together and also can take place in the absence of each other. Solar burst type III also appear within the events that assigned big eruptions also occur. CMEs that occur will effects magnetic field of the earth and caused disturbance to communications, satellite operations and power generation due to geomagnetic storm. Fortunately, if the geomagnetic storm is small it is only cause minor affect such beautiful aurora.

Acknowledgement
We are grateful to CALLISTO network; STEREO, LASCO, SDO/AIA, NOAA and SWPC make their data available online. This work was partially supported by the 600-RMI/FRGS 5/3 (135/2014), 600-RMI/RACE 16/6/2(4/2014)and 600- RMI/RAGS 5/3 (121/2014) UiTM grants, Universiti Teknologi MARA and Kementerian Pendidikan Malaysia. Special thanks to the National Space Agency and the National Space Centre for giving us a site to setup this project and support this project. Solar burst monitoring is a project of cooperation between the Institute of
Astronomy, ETH Zurich, and FHNW Windisch, Switzerland, MARA University of Technology and University of Malaya. The research has made use of the National Space Centre Facility and a part of an initiative of the International Space Weather Initiative (ISWI) program.

Biography
Dr Zety Sharizat Hamidi is currently a senior lecturer and focused in Solar Astrophysics research specifically in radio astrophysics at the School of Physics and Material Sciences, Faculty of Sciences, MARA University of Technology, 40450, Shah Alam, Selangor, Malaysia. Involve a project under the International Space Weather Initiative (ISWI) since 2010.

Marhana Omar Ali is an undergraduate Physics student at the School of Physics and Material Sciences, Faculty of Sciences, MARA University of Technology, 40450, Shah Alam, Selangor, Malaysia.

Dr Nur Nafhatun Md Shariff is a senior lecturer in Academy of Contemporary Islamic Studies (ACIS), MARA University of Technology, 40450, Shah Alam, Selangor, Malaysia. Her current research is more on sustainability; environmental aspect. She is looking forward for cross-field research, i.e. solar astrophysics, light pollution measurement (mapping) and religious studies.

C. Monstein is a senior Engineer at Institute of Astronomy, Wolfgang-Pauli-Strasse 27, Building HIT, Floor J, CH-8093 Zurich, Switzerland and one of the researchers who initiated the CALLISTO system around the world.

References
[1] Z. Hamidi, Z. Abidin, Z. Ibrahim, C. Monstein, N. Shariff, M. Sabaghi, The Beginning Impulsive of Solar Burst Type IV Radio Emission Detection Associated with M Type Solar Flare, International Journal of Fundamental Physical Sciences 2 (2012).
[2] Z. Hamidi, N. Shariff, C. Monstein, Disturbances of Solar Eruption From Active Region AR1613, (2014).
[3] Z. Hamidi, N. Shariff, Detailed Investigation of a Moving Solar Burst Type IV Radio Emission in on Broadband Frequency, International Letters of Chemistry, Physics and Astronomy 7 (2014) 30-36.
[4] Z. Hamidi, Z. Abidin, Z. Ibrahim, C. Monstein, N. Shariff, Signal Detection Performed by Log Periodic Dipole Antenna (LPDA) in Solar Monitoring, International Journal of Fundamental Physical Sciences (2012).
[5] H. Aurass, Coronal Physics from Radio and Space Observations, in: I.G. Trottet (Ed.), Lecture Notes in Physics, Springer, Berlin, 1997.
[6] C.W. Young, C.L. Spencer, G.E. Moreton, J.A. and Roberts, Astrophys. J. 133 (1961).
[7] Ellis, Australian J. Phys. 22 (1969) 167.
[8] D.J. McLean, a.N.R. Labrum, Solar Radiophysics, Cambridge University Press, Cambridge, 1985.
[9] J.P. Wild, Smerd S.F., and Weiss, A.A., Solar Burst, Ann. Rev. Astron. Astrophysics 1 (1963) 291-366.
[10] Z. Hamidi, N. Shariff, The Propagation of An Impulsive Coronal Mass Ejections (CMEs) due to the High Solar Flares and Moreton Waves, (2014).
[11] Z. Hamidi, U. Ibrahim, U.F. Salwa, Z. Abidin, Z. Ibrahim, N. Shariff, Theoretical Review of Solar Radio Burst III (SRBT III) Associated With of Solar Flare Phenomena, International Journal of Fundamental Physical Sciences 3 (2013).

[12] Z. Hamidi, N. Shariff, C. Monstein, First Light Detection of A Single Solar Radio Burst Type III Due To Solar Flare Event, (2014).

[13] G.A. Dulk, Type III solar radio bursts at long wavelengths, in: R. Stone, E. Weiler, M. Goldstein (Eds.), Geophys. Monogr., 2000.

[14] G. Swarup, P.H. Stone, A. Maxwell, ApJ 131 (1960).

[15] Z. Hamidi, N. Shariff, C. Monstein, Scenario of Solar Radio Burst Type III During Solar Eclipse on 14th November 2012, (2014).

[16] G.B.a.L. Gelfreikh, B. I. , Soviet Astron. 23 (1979).

[17] P. Lantos, Sol. Phys. 22 (1972).

[18] A. Vourlidas, Bastian, T. S., Nitta, N., and Aschwanden, M. J., Sol. Phys. 163 (1996).

[19] E.Y. Zlotnik, Soviet Astron. 12 (1968).

[20] V.V. Zheleznyakov, Radio Emission of the Sun and Planets (1970).

[21] Z. Hamidi, N. Shariff, C. Monstein, W.W. Zulkifli, M. Ibrahim, N. Arifin, N. Amran, An X-ray Observations of A Gradual Coronal Mass Ejections (CMEs) on 15th April 2012, International Letters of Chemistry, Physics and Astronomy 8 (2014) 13-19.

[22] Z. Hamidi, N. Shariff, C. Monstein, Statistical Study of Nine Months Distribution of Solar Flares, (2014).

[23] S.M. White, Solar Radio Bursts and Space Weather, Asian Journal of Physics 16 (2007) 189-207.

[24] Z.S. Hamidi, N.N.M. Shariff, Chronology of Formation of Solar Radio Burst Types III and V Associated with Solar Flare Phenomenon on 19th September 2011 International Letters of Chemistry, Physics and Astronomy 5 (2014) 32-42.

[25] Z.S. Hamidi, N.N.M. Shariff, M.F. Ali, C. Monstein, W.N.A.W. Zulkifli, M.B. Ibrahim, N.S. Arifin, N.A. Amran, The Correlation between Solar Flare Phenomena in an X-ray Region and Radio Flux Measurement from January to September 2010, International Letters of Chemistry, Physics & Astronomy 9 (2014) 84-92.

[26] Z.S. Hamidi, N.N.M. Shariff, F.N.Z. Ulum, Z.Z. Abidin, Z.A. Ibrahim, Time Series Analysis of Variance of Sunspots in January till September 2010 and Correlation with Sunspots Areas International Journal of Astronomy 5 (2012) 101-106.

[27] Z. Hamidi, Probability of Solar Flares Turn Out to Form a Coronal Mass Ejections Events Due to the Characterization of Solar Radio Burst Type II and III, International Letters of Chemistry, Physics and Astronomy 16 (2014) 85.

[28] Z. Hamidi, C. Monstein, N. Shariff, Radio Observation of Coronal Mass Ejections (CMEs) Due to Flare Related Phenomenon on 7th March 2012, (2012).

[29] Z. Hamidi, N. Shariff, Enormous Eruption of 2.2 X-class Solar Flares on 10th June 2014, (2014).

[30] Z. Hamidi, N. Shariff, C. Monstein, Understanding Climate Changes in Malaysia Through Space Weather Study, International Letters of Natural Sciences (2014).

[31] Z. Hamidi, N. Shariff, The Mechanism of Signal Processing of Solar Radio Burst Data in E-CALLISTO Network (Malaysia), International Letters of Chemistry, Physics and Astronomy (2014).
[32] Z. HAMIDI, N. SHARIFF, Z. ABIDIN, Z. IBRAHIM, C. MONSTEIN, E-Callisto Collaboration: Some Progress Solar Burst Studies Associated with Solar Flare Research Status in Malaysia, Malaysian Journal of Science and Technology Studies 9 (2013) 15-22.

[33] Z.S. Hamidi, N. Shariff, Z. Abidin, Z. Ibrahim, C. Monstein, Coverage of Solar Radio Spectrum in Malaysia and Spectral Overview of Radio Frequency Interference (RFI) by Using CALLISTO Spectrometer from 1MHz to 900 MHz, Middle-East Journal of Scientific Research 12 (2012) 6.

[34] Z.S.Hamidi, N.N.M.Shariff, Evaluation of Signal to Noise Ratio (SNR) of Log Periodic Dipole Antenna (LPDA) Business Engineering and Industrial Applications Colloquium 2013, IEEE, Langkawi, Malaysia, 2013, pp. 434-438.

[35] Z. Hamidi, N. Shariff, Determination of Flux Density of the Solar Radio Burst Event by Using Log Periodic Dipole Antenna (LPDA), International Letters of Chemistry, Physics and Astronomy 7 (2014) 21-29.

[36] Z. Hamidi, N. Shariff, C. Monstein, The Different Between the Temperature of the Solar Burst at the Feed Point of the Log Periodic Dipole Antenna (LPDA) and the CALLISTO Spectrometer, (2014).

[37] N. Hashim, Z. Abidin, U. Ibrahim, R. Umar, M. Hassan, Z. Rosli, Z. Hamidi, Z. Ibrahim, Radio Astronomy in Malaysia: Current Status and Outreach Activities, Astronomical Society of the Pacific Conference Series, 2011, pp. 355.

[38] Z.S. Hamidi, Z. Ibrahim, Z. Abidin, M. Maulud, N. Radzin, N. Hamzan, N. Anim, N. Shariff, Designing and Constructing Log Periodic Dipole Antenna to Monitor Solar Radio Burst: e-Callisto Space Weather, International Journal of Applied Physics and Mathematics 2 (2011) 3.

[39] Z. Hamidi, N. Shariff, C. Monstein, Evaluation of Spectral Overview and Radio Frequency Interference (RFI) Sources at Four Different Sites in CALLISTO Network at the Narrow Band Solar Monitoring Region, (2014).

[40] Z.S. Hamidi, N.N.M. Shariff, C. Monstein, Z.A. Ibrahim, Space Weather: The Significance of e-CALLISTO (Malaysia) As One of Contributor of Solar Radio Burst Due To Solar Activity, International Letters of Chemistry, Physics and Astronomy 7 (2014) 37-44.

[41] Z.S. Hamidi, N.N.M. Shariff, Z.A. Ibrahim, Z.Z. Abidin, SOLAR STUDIES IN RADIO EMISSION AND OPTICAL PHOTOGRAPHY, University of Malaya Publisher, 2013.

[42] Z.S.Hamidi, S. Chumiran, A. Mohamad, N. Shariff, Z. Ibrahim, N. Radzin, N. Hamzan, N. Anim, A. Alias, Effective temperature of the sun based on log periodic dipole antenna performance in the range from 45 Mhz to 870 Mhz, American Journal of Modern Physics 2 (2013) 4.

[43] Z.S.Hamidi, Z. Abidin, Z. Ibrahim, N. Shariff, C. Monstein, Modification and Performance of Log Periodic Dipole Antenna, International Journal of Engineering Research and Development 3 (2012) 36-39.

[44] Z.S.Hamidi, Z. Abidin, Z. Ibrahim, C. Monstein, N. Shariff, Signal Detection Performed by Log Periodic Dipole Antenna (LPDA) in Solar Monitoring, International Journal of Fundamental Physical Sciences 2 (2012) 32-34.

[45] Z.S.Hamidi, N.M.Anim, N. N.S.Hakimi, N.Hamzan, A.Mokhtar, N.Syukri, S.Rohizat, I.Sukma, Z.A. Ibrahim, Z.Z.Abidin, N.N.M.Shariff, C.Monstein, Application of Log Periodic Dipole Antenna (LPDA) in Monitoring Solar Burst at Low Region Frequencies Region International Journal of Fundamental Physical Sciences 2 (2012) 4.
[46] Z.S. Hamidi, N.N.M. Shariff, Determination of Isotropic Source Spectral Power of the Log Periodic Dipole Antenna (LPDA), International Journal of Science and Mathematics 2 (2014) 3.

[47] Z.S. Hamidi, Z. Abidin, Z. Ibrahim, N. Shariff, Indication of radio frequency interference (RFI) sources for solar burst monitoring in Malaysia, ICPAP 2011, AIP Publisher, Indonesia, 2012, pp. 6.

[48] Z.S. Hamidi, N.N.M. Shariff, C. Monstein, High Time Resolution Observation of Solar Radio of A Group Type III And U Burst Associated of Solar Flares Event, The International Journal of Engineering 1 (2012) 3.

[49] Z. Hamidi, N. Shariff, C. Monstein, W.W. Zulkifli, M. Ibrahim, N. Arifin, N. Amran, Observation of the Radio Frequency Interference (RFI) at the National Space Centre, Malaysia, International Letters of Natural Sciences (2014).

[50] Z.S. Hamidi, Z.Z. Abidin, Z.A. Ibrahim, N.N.M. Shariff, U.F.S.U. Ibrahim, R. Umar, Preliminary analysis of investigation Radio Frequency Interference (RFI) profile analysis at Universiti Teknologi MARA, IEEE, 2011, pp. 311-313.

[51] R. Umar, Z. Abidin, Z. Ibrahim, N. Gasiprong, K. Asanok, S. Nammahachak, S. Aukkaravittayapun, P. Somboon, A. Prasit, N. Prasert, The Study of Radio Frequency Interference (RFI) in Altitude Effect on Radio Astronomy In Malaysia And Thailand, Middle East Journal of Scientific Research 14 (2013).

[52] Z.S. Hamidi, N.N.M. Shariff, R. Umar, Influence Factors of Radio Frequency Interference (RFI) for Solar Radio Astronomy Purpose at National Space Centre, Malaysia Thailand Journal of Physics 3 (2012) 6.

[53] R. Umar, Z.Z. Abidin, Z.A. Ibrahim, M.S.R. Hassan, Z. Rosli, Z.S. Hamidi, Population density effect on radio frequencies interference (RFI) in radio astronomy, AIP Conference Proceedings 1454 (2012) 39.

[54] N. Anim, Z. Hamidi, Z. Abidin, C. Monstein, N. Rohizat, Radio frequency interference affecting type III solar burst observations, 2012 NATIONAL PHYSICS CONFERENCE:(PERFIK 2012), American Institute of Physics, 2013, pp. 82-86.

[55] Z. Hamidi, N. Shariff, C. Monstein, Comparison of the Radio Frequency Interference (RFI) in the Region of Solar Burst Type III Data At Selected CALLISTO Network, International Letters of Chemistry, Physics and Astronomy 10 (2014) 38-45.

(Received 22 April 2015; accepted 02 May 2015)