VOL. 10, NO. 22, DECEMBER, 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

OBSERVATION OF TRANSIENT LUMINOUS EVENTS (TLEs) IN PEKAN

Chan Hwee Geem, Mohd Shawal Jadin and Amir Izzani Mohamed
Sustainable Energy & Power Electronic Research Cluster, Faculty of Electrical and Electronics Engineering,
Universiti Malaysia Pahang, Pekan, Pahang, Malaysia
E-Mail: geem_0401@hotmail.com

ABSTRACT

Transient Luminous Events (TLEs) are classified as a type of lightning events that occurs above a thunderstorm. It is a very fast event that is hardly seen by the naked eyes and happened in a very short period of time. So, a high frame rate capturing device is required in order to capture the scenes of TLEs. This paper reveals a study to verify the occurrences possibility of TLEs in Malaysia by selecting a simple and suitable device to detect and capture the event. There are various types of TLEs such as Elves, Sprites, Halos, Blue Jets, and Gigantic Jets that differs in height within atmosphere. Experimental studies are made to observe Elves and Sprites in Malaysia partially in Pekan, Pahang. The event is being traced using amplified antenna with noise filter and a data acquisition (DAQ) module used to interface between antennas and personal computer (PC) aided with online data logging device to perform a live characteristic recording through PC software. Verification of the obtained TLEs data will be carried out by comparing them with data recorded by Department of Meteorology Malaysia.

Keywords: lightning, transient luminous events, sprites, elves, data acquisition.

INTRODUCTION

Lightning is one of the phenomena that occur above the atmosphere area. It occurs during a thunderstorm and generally have three types of lightning when electrical breakdown among the cloud such as cloud to cloud (CC) lightning, cloud to ground (CG) lightning, and intra-cloud (IC) lightning. Lightning not only occurs on the lower atmosphere but also in the upper atmosphere which is 40 km until 100 km above the earth's surface area, which is called transient luminous events (TLEs). TLEs are described as short lived electrical breakdown phenomena and the flashes of light occur at lower ionosphere (D region). It occurs when gas molecules are excited and results in electrical breakdown. During the process, light is emitted for a few milliseconds when the ionised gas returns to their normal state. The process called return stroke [1].

Some of the TLEs occur at lower places which are located 80 km away from earth's surface while some of them located approximately 100 km away from the ground. The types of TLEs included Sprites, Elves, Gigantic Jets, Blue Jets, and Halos. Differences between TLEs produced with a different height as shown in Figure-1. The Figure explains that transient flashes produced in different altitudes were classified so that for every distance of altitude, the characteristics of the flashes can be identified. A Sprite, which is one kind of TLEs, was first documented by Franz and his partners in the year 1989. The Sprite was captured by using a low light level television camera. The event was recorded on the night of 22 and 23 September 1989 during a hurricane Hugo storm at the eastern coast of United States [2]. Since then, other types of TLEs were found and discussed by scientists around the world.

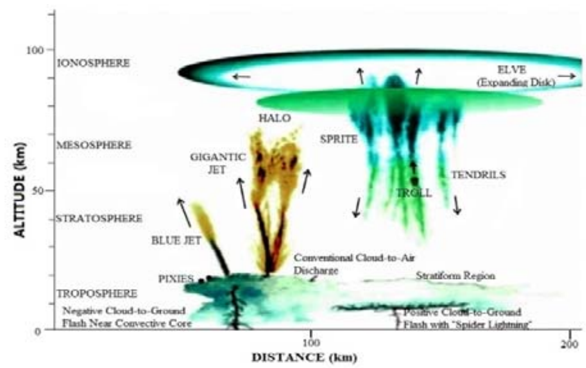

Figure-1. Different TLEs occur below ionosphere [3].

The research aimed to identify the possibility of occurrences for different transient luminous with a height limit 80 km. The events will be traced using a Lightning Detector System (LD-250). Daily and monthly lightning for six months (October 2014 until March 2015) was observed and recorded. Furthermore, the location of the frequent lightning event was traced as well and concluded at the end of the paper. Lastly, the direction of camera capture process will decide to capture TLEs.

The productions of TLEs reveal their own characteristics such as process, colour, shape, duration, frequency, and feature. The characteristics are shown in Table-1.

METHODOLOGY

The research was divided into two sections which were signal detection and image observation. These two methods were used to categories the types of TLEs by figuring out their unique signal, size, and shape. The function flow diagram of the research project is shown in the Figure-2.

VOL. 10, NO. 22, DECEMBER, 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-1. Characteristics of TLEs [4] [5] [6] [7] [8].

TLE	Process	Shape	Frequency / Period	Feature
Sprites	• Occurs after many normal CG flash lightning take place in a time. Result in high peak current produced at the same time. • Positive cloud to ground (CG) lightning flashes within the stratiform region of the storm.	• Horizontally displaced from the parent lightning.	• 0.2min-1	• Carrot Sprites: Can be associated with Halos and produced a large peak current. • Will occur again at the same location once the same event take place before. • Color: Red (due to excitation of gas nitrogen in atmosphere)
Elves	• Produced either by positive or negative CG flashes when a large peak current occurs in the event.	• Luminous rings with diameter up to 300 km.	• Shorter than 1ms • Flash speed: faster than speed of light	• Observed unique polarity during producing flash in a storm given. • Expand radially outward follow the lower edge of the ionosphere. (80km to 90km) • Color: Bright red.
Gigantic Jets (G.J)	• Produced by intra-cloud discharge without detection of CG flashes. • Leading jets (33ms to 167ms) propagated at higher altitude while tailing jets decreasing luminosity at different parts of the jet (lower channels and transition region). • Low channels produce decreasing blue luminosity at about 20km to 40km altitude. • Transition region produces bright red luminosity around 40km to 65km retracing leading jet channels.	• Large in size.		• Discharge without any charges transfer to earth • Spread altitude as high as 80km with upward-directed lightning shooting out of the cloud tops. • Normal intra-cloud discharge. Appear in between dominant level charge and screening-depleted upper level charge. • Color: Blue.
Blue Jets (B.J)	• Occurs when an electrical breakdown in between upper storm charge and screening charge was getting attracted across top of thunderclouds. • Production of sudden charge imbalanced in storm due to CG or intra-cloud discharge.	• Small size of GJ called blue starter	• 5s to 10s or less	• Upward directed lightning producing. • Extends in a few kilometers only from the top of thunderclouds up to a clear air above. • Spread altitude up to 40km (half of GJ). • Discharge process for BJ and GJ preceding propagation on top of storm. • Color: Blue
Halos	• Produced with Sprites. • Decreasing glow with side area of 40km to 70km.			• Inspected to escort the happening of more structured Sprites. • Sprites and Halos happened 25km across an average horizontal distance source from the first lightning strike. • Color: Red glow

VOL. 10, NO. 22, DECEMBER, 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

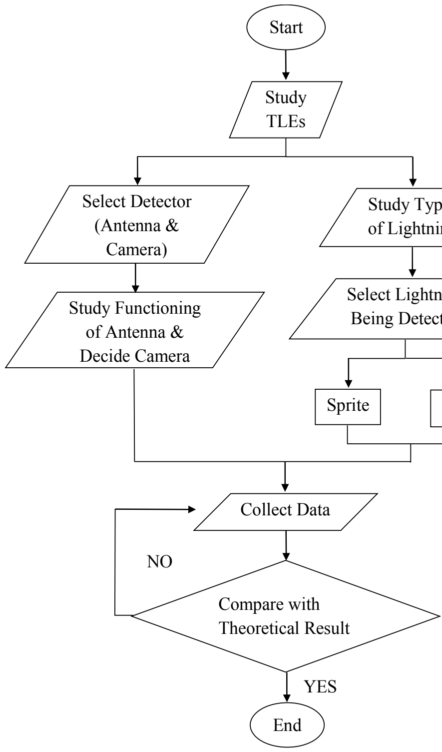

Figure-2. Function flow diagram of the project.

There is a large radio frequency produced at the atmosphere when TLEs occurs. The amplified antenna connected with noise filter is to detect the signal. The signal received was processed through a Data Acquisition (DAQ) module NI USB 6212 which transfer the signal to the desktop for researcher to tabulate data collected by the system.

There is limited information for the TLEs if research is only done by collecting lightning signal. Therefore, the image will also be captured simultaneously by using video camera along the data collection process. The researcher can make a conclusion by data collected from both systems.

Image of TLEs

A high sensitivity camera model Watec Ultimate 902H2 coupled with Nikon 50mm f1.4 lens, was used to capture TLEs image. The camera was set up at the ground floor of Block 1 in Faculty of Electrical and Electronic Engineering (FKEE), Universiti Malaysia Pahang along with an antenna. The camera is a monochrome camera used by other researcher to capture natural phenomena such as a meteor. It was operated in standby mode during the recording process. High frame rate (frame per second – fps) relative high resolution ensures high definition frames are captured during happening of TLEs. This feature is to ensure detail sequences of the event and exposes the nature of TLEs. However at this time, the available digital video recorder (DVR) frame rate is limited to 29fps. A block diagram of camera setup is shown in Figure-3.

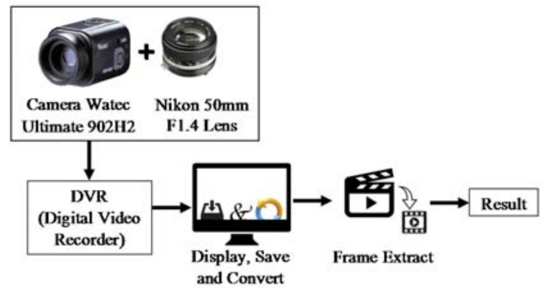

Figure-3. Block diagram of camera setup.

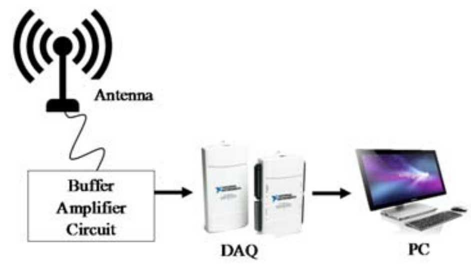

Figure-4. Block diagram of antenna setup.

Signal of TLEs

There are many types of signals propagates around the atmosphere such as radio signal, television signal, satellite signal, microwave, and normal lightning signal. When TLEs occurred, a large amount of radio frequency signal will be released. The TLEs signal will appear along that portion of frequency containing other frequencies. The frequencies range and characteristics of each signal type must be identified. Otherwise, it is a compilation of many signal including noises that makes analyse process complicated. Captured signal will be analysed using DAQ module to verify the characteristic of TLEs. The frequency of TLEs is in the extremely low frequency (ELF) range. Therefore, an antenna with high gain and low frequency response is an ideal antenna to detect signal released by TLEs. L-600S antenna from LF Engineering [9] with a frequency response from 300 Hz to 30 kHz is a suitable candidate. Currently, the system is under consideration and will not be discussed further. A possible setup is shown in Figure-4.

RESULTS

In this section, preliminary works are limited to lightning location detection, occurrence data, and image capture. These preliminary works are to verify the lightning occurrence possibility and the suitable season for TLEs observation. Lightning Detector System (LD-250) was installed at the top roof of block 1 in FKEE, UMP. Analysis on a number of flashes and strokes captured during six months was carried out. UMP was set as the midpoint and data taken within 100 miles (160.9344 km) radius away from UMP. The data were recorded and tabulated in Table-2. Figure-5 shows the changes numbers flashes and strokes from October 2014 until March 2015.

VOL. 10, NO. 22, DECEMBER, 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Table-2. Number of flashes and strokes from October 2014 until March 2015.

	Flashes	Strokes
Oct	17,785	18,992
Nov	11,408	11,945
Dec	12,069	12,892
Jan	597	627
Feb	6,283	6,415
Mac	13,127	13,979
Total	**61,269**	**64,850**

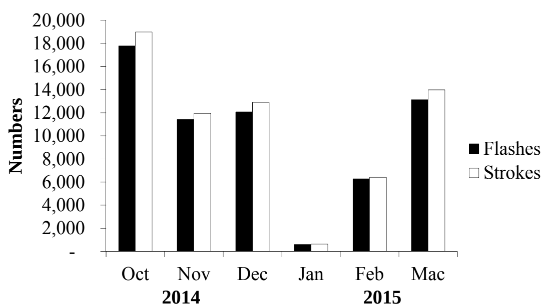

Figure-5. Changes number of flashes and strokes from October 2014 until March 2015.

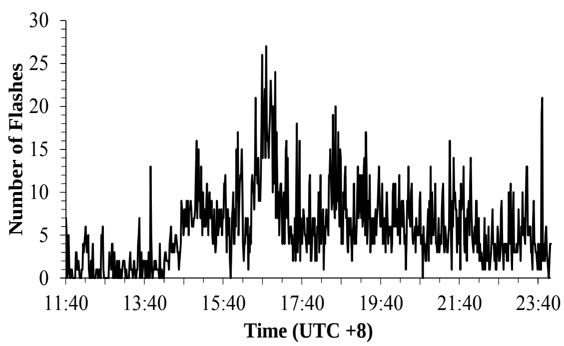

Figure-6. Number of flashes on 17th October 2014.

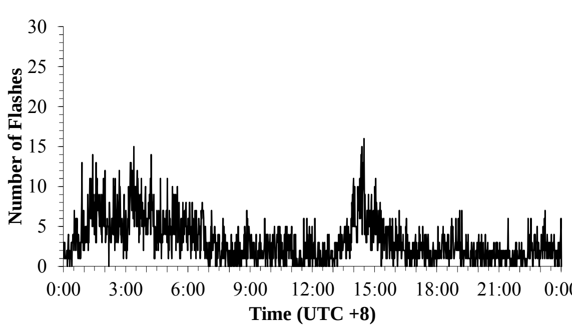

Figure-7. Number of flashes on 21st October 2014.

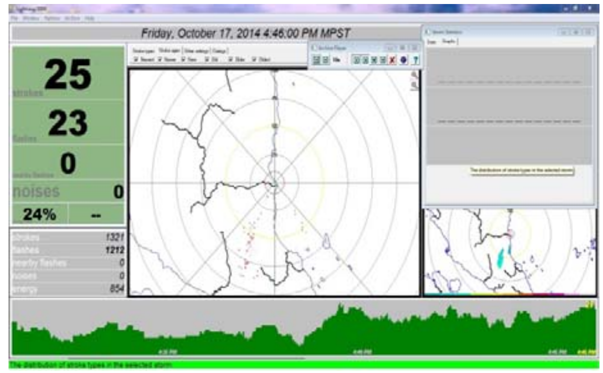

Figure-8. Lightning location.

Data of 5 days out of 31 days in October 2014 is taken out with the highest number of flashes and strokes for the past six months. It shows that a large numbers of flashes and strokes happened at the end of the year. This phenomenon continues to appear even during the dry season (starting February 2015) where the rainfall is much less. Hence, it is believed that Malaysia also has high TLEs occurrence potential by considering that some TLEs such as Sprite, which occurs after negative CG lightning strikes [10]. January 2015 shows the lowest numbers of flashes and strokes due to only 2 days out of 31 days had been recorded by Lightning Detector System (LD-250).

Analysis was done for the days experienced the highest flashes per day. Results of flashes per day for 17th October 2014 and 21st October 2014 are shown in Figure-6 and Figure-7 respectively. On 17th October 2014, the total numbers of flashes is 3937. It is found that the highest numbers of flashes is 27 in one minute. The highest flashes events take place on 16:45 pm UTC +8 and energy ratio was 99% showing a strong strike. Form the Figure-7, the total numbers of flashes on 21st October 2014 is 4669 which is the highest numbers compared to other days for overall data observation. It is also found that the highest numbers of flashes is 16 in one minute on 14:29 pm UTC +8. The energy ratio reached over 100% and nearly 400% once flashes take place.

From the lightning location data, it is understood that most of the lightning take place at above land's surface more than above sea's surface. Figure-8 shows the direction of lightning during the peak time. The midpoint is UMP Pekan Campus and Lightning Detector System traced around 100 miles radius from UMP. Lightning occurs frequently in Malaysia, especially during the monsoon season. On 17th October 2014, most lightning happened at a location between South and Southwest from UMP Pekan. Based on the location recorded, it is possible to point the camera towards the direction to capture TLEs for this research.

A Carrot Sprite like event was detected on 2nd July 2015 at the time of 21:19 pm UTC +8. Only the head of the Sprite was visible. The full view of the Sprite was unseen may be due to the cloud and the camera location on the ground. The evolution of a Carrot Sprite up to time t = 103.5ms discharge above a thundercloud is filmed with 25

VOL. 10, NO. 22, DECEMBER, 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

frames per second as shown in Figure-9. Before the Carrot Sprite was captured, there are 41 lightning observed on camera recording. At the beginning of the recording, a lightning return stroke starts to transport electrical charge to earth and the electric field produced above the cloud. The electric field produced had forms a Carrot Sprite event. The Sprite observed was a clot and small in shape due to the panel set up location near to the event take place.

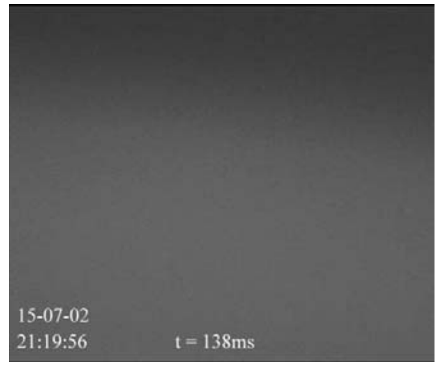

Figure-9. TLE was detected on 2nd July 2015 at 21:19 pm UTC +8.

At time t = 34.5ms, the Carrot Sprite starts to discharge and shooting down from the ionosphere. Then, the discharge was downward directed from the parent lightning flash at the time t = 69ms. Finally, the Carrot Sprite disappears at time t = 103.5ms. The whole discharging process is taking approximately 138ms. The Carrot Sprite appeared after many CG lightning and it is a CG lightning discharged based on the observation.

By comparing the data that found from the camera image captured and Department of Meteorology Malaysia, the result was matched and Sprite event taken place in between Sungai Tulang and Sungai Belat, Gambang, Pahang, Malaysia. It was located 45.7 km away from UMP Pekan. There was a large quantity of negative CG lightning occur before the only one positive CG lightning strike taken place on 9:19:50 pm UTC +8 at latitude and longitude 3.78˚N, 103.098˚E (3˚46’48.0”N 103˚05’52.8” E) respectively.

CONCLUSIONS

Preliminary results were taken to verify the feasibility of the research. Lightning happened frequently in Malaysia during a monsoon season as shown in Table-2 and Figure-5. It keeps occur although during a lesser rain after monsoon season (February 2015 and March 2015). This may be due to Malaysia is located near the Equator. According to all data result shown in the paper, the best time to do TLEs research is during the end of the year and the camera should point towards the location between South and Southwest. The first Sprite event was found in Malaysia at latitude 3.78˚N and longitude 103.098˚E. These results conclude that the occurrences of TLEs in Malaysia are possible.

REFERENCES

[1] P. Y. Yair. 1989. Sprites, Elves and Fairies : Elusive Phenomena High above the Flash of Lightning in a Thunderstorm. A report.

[2] Stanford VLF Group. Transient Luminous Events. [Online]. Available:

ARPN Journal of Engineering and Applied Sciences

http://vlf.stanford.edu/research/transient-luminous-events#FranzEtAlS1990. [Accessed: 03-Oct-2014].

[3] A. Luque and U. Ebert. 2010. Lightning above the clouds. Europhys. News. Vol. 41, No. 5. pp. 19–22.

[4] S. Soula, O. Van Der Velde and J. Montanya. 2012. Optical observations and conditions of production of transient luminous events (sprites, elves, gigantic jets). 1st TEA - IS Summer School.

[5] R. T. Newsome and U. S. Inan. 2010. Free-running ground-based photometric array imaging of transient luminous events. J. Geophys. Res. Vol. 115. p. A00E41.

[6] A. B. Chen, C. L. Kuo, Y. J. Lee, H. T. Su, R. R. Hsu, J. L. Chern, H. U. Frey, S. B. Mende, Y. Takahashi, H. Fukunishi, Y. S. Chang, T. Y. Liu and L. C. Lee. 2008. Global distributions and occurrence rates of transient luminous events. J. Geophys. Res. Sp. Phys.. Vol. 113, No. 8. pp. 1–8.

[7] V. P. Pasko, Y. Yair, and C. L. Kuo. 2011. Lightning Related Transient Luminous Events at High Altitude in the Earth’s Atmosphere: Phenomenology, Mechanisms and Effects. Vol. 168, No. 1–4.

[8] M. Passas, J. Sánchez, A. Luque, and F. J. Gordillo-vázquez. 2014. Transient Upper Atmospheric Plasmas : Sprites and Halos. IEEE Trans. Plasma Sci.. pp. 1–2.

[9] LF Engineering CO.. ELF Antennas. [Online]. Available: https://www.lfengineering.com/products.cfm#ELF Antennas. [Accessed: 17-Sep-2015].

[10] W. A. Lyons, T. E. Nelson, E. R. Williams, S. A. Cummer, and M. A. Stanley. 2003. Characteristics of Sprite-Producing Positive Cloud-to-Ground Lightning during the 19 July 2000 STEPS Mesoscale Convective Systems. Mon. Weather Rev. Vol. 131, No. 10. pp. 2417–2427.