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Distinct Position of Chaotic Pulse Trains Observed in Malaysia

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ABSTRACT

This paper presents the chaotic pulse train (CPT) waveforms of the vertical electric field generated by lightning observed in Malaysia. Focusing on the position where these electric field changes occur in a number of cloud to ground (CG) flashes, these CPTs were detected in different ways of occurrences, durations, intensities and amplitudes. Seventy-six chaotic pulse trains were found in this study from a sum of 172 CG flash records from three thunderstorm days. The fast field antenna was employed to do the field measurements. As opposed to the typical occurrence of chaotic pulse trains prior to subsequent strokes as reported in the literature, this study has found chaotic pulse trains occurring in different places along the CG electric field waveforms.

Keywords: Preliminary breakdown pulses, return stroke, chaotic pulse trains, electric field change, Position

INTRODUCTION

Before the emergence of a return stroke (RS) in a CG lightning strike, lightning activity must occur in order for the RS to take place. These lightning activities may be from the stepped leaders, dart leaders or dart stepped leaders depending on the order of the RS that is being initiated (Schonland & Collens, 1934, Schonland et al., 1935, Qie et al., 2002). However, latter findings show an unusual occurrence of a lightning physical process which is disordered and rare in trait can also take place before subsequent strokes in place of dart leaders. They are referred to as CPTs or chaotic leaders to describe this type of lightning activity (Rakov & Uman, 1990, Gomes et al., 2004, Mäkelä et al., 2007, Hill et al., 2012, Zhang et al,. 2014a). Figure 1 shows an example of a CPT that occurs prior to a RS, its fine structure resembling pulses that are erratic and irregular unlike other types of pulses.

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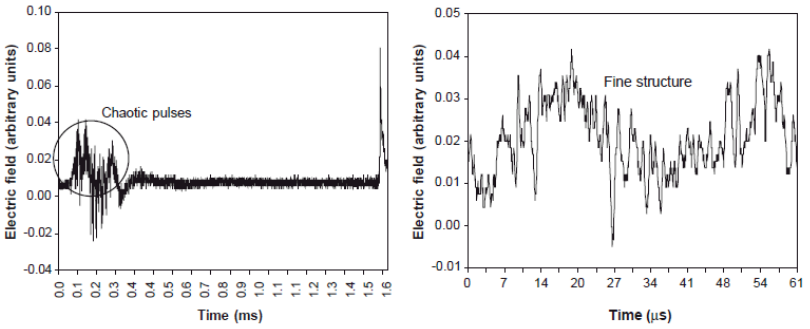

(a) (b)

Figure 1. a) CPT that Occurs About 1 ms before a RS; b) The fine structure of the CPT in a) (Gomes et al. 2004)

CPTs are a kind of lightning activity that occur predominantly before the advent of a subsequent stroke. In nature, they are similar to the preliminary breakdown pulses (PBP) and pulse bursts, being more erratic and irregular without any kind of order (Gomes et al., 2004). CPTs commonly occur prior to a subsequent negative return stroke or between RSs. There is little evidence of them in the literature commencing before a first return stroke by reason of the preliminary breakdown and stepped leader pulses being present. While reports of CPTs appearing prior to the first return stroke and after the final return stroke can be found in the literature (Zhang et al., 2014b), they are nevertheless rare. . For the case of CPTs appearing prior to a first return stroke, they do not occur whenever there are PBP trains (Zhang et al., 2014b). These occurrences can be seen in Figure 2 where CPTs are denoted by their respective locations. CPTs were also found to be occurring solely, with no association to return strokes that happens in cloud flashes that are free from RSs (Gomes et al., 2004). CPTs that have been found in the literature more specifically relate to those with cloud flashes or negative RSs. Hence, they are most probably a cloud event since CPTs can appear almost anywhere with other kinds of lightning activity. There are no reports of CPTs or chaotic leaders occurring with positive RSs. It is necessary to conduct measurements of the lightning vertical electric fields in order to have an adequate understanding of the chaotic pulse trains.

METHODOLOGY

The vertical electric field measurements were done for May, June and October 2013 at Universiti Putra Malaysia (UPM). The measurement site has a geographical coordinate of 2°59'19.9"N latitude and 101°43'29.8"E longitude and situated in Serdang, Selangor area, which is located in Central-West Peninsular Malaysia and close to the straits of Malacca. The measuring site is a large open space approximately 86 m above sea level. Malaysia generally has a tropical climate with maximum monsoon rain occurring from October to November due to southwest monsoon and intermonsoon periods which affects the Selangor area.

The measuring system that was used to measure the electric fields in this study is similar to Ibrahim et al. (2011). The physical height of the parallel plate antenna that was used for the measurement is 1.85 m from the ground. The LH0033 Electronic Buffer Amplifier with the

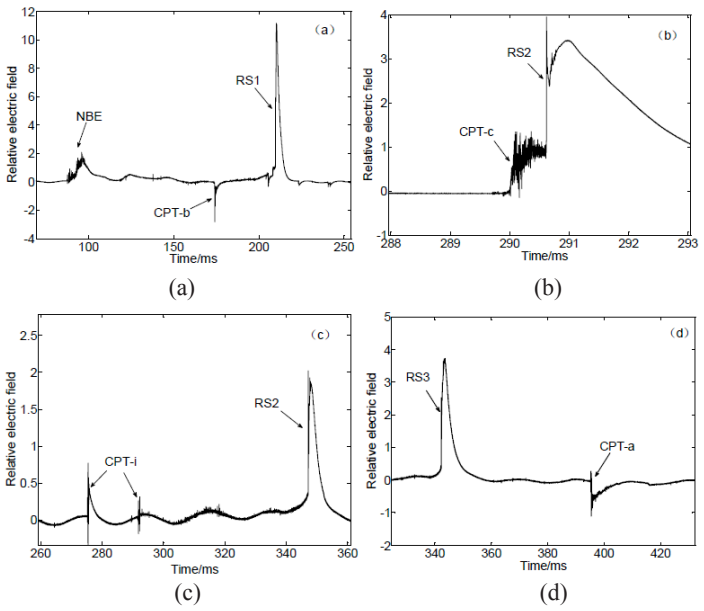

Figure 2. a) A CPT prior to a 1st RS denoted by CPT-b; b) A CPT prior to a SS denoted by CPT-c; c) CPTs prior to a SS with some duration denoted by CPT-i; d) A CPT that occurs after the final RS denoted by CPT-a (Zhang et al., 2014b)

circuitry was used to isolate the high input impedance of the antenna and offer enough power to drive the signal from antenna to the oscilloscope to through the coaxial cable. A RG58 coaxial cable was used to connect the parallel plate to the buffer electronic and then to the Tektronix MS04032 oscilloscope where the lengths of the cables are 1 m and 25 m respectively. 50 MS/s (Mega samples per second) sampling rate was set or time resolution of 20 ns with the total length of recorded waveforms being 20 ms per division with a total of 200 ms window frame. The trigger level was set at 200 mV and post-trigger time of 60 ms. A 17 ms decay time constant was set to the buffer. A figure representing the basic needs of the electric field measurement is shown in Figure 3 where *r* is the distance of a lightning flash to the measurement site.

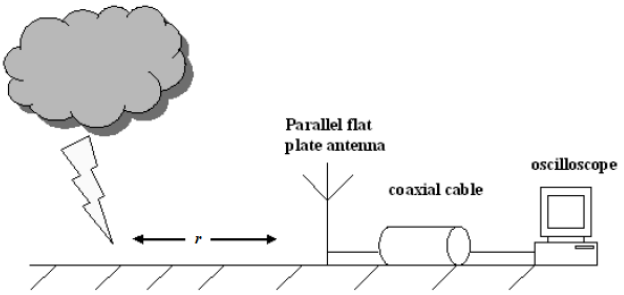

Figure 3. A representation of the measurement setup (Ahmad, 2011)

RESULTS AND DISCUSSIONS

The position of chaotic pulse trains found in this study can be categorized into three parts. The first are ones that occur in isolation or are not seemingly attached to a return stroke or any other kind of lightning activity. These chaotic pulse trains occur at more than an average of 20 ms before or after a lightning activity such as preliminary breakdown pulses and return strokes where 10 of them were found to be occurring in this study. Figure 4 shows a CPT of this nature that occurred after some time after the first return stroke. It is likely that these kinds of chaotic pulse trains are associated to cloud flashes as found in Gomes et al. (2004) as cloud flashes were also found to be occurring with CG flashes in this work. The second type of CPT occurs prior to return strokes which is the usual case as reported in Gomes et al. (2004), Mäkelä et al. (2007) and Lan et al. (2011). The criterion is taken that a CPT must occur within the range of 0 to 10 ms on average for it to be classified of this type. Figure 5 shows this kind of CPT found in this study occurring just before a RS. 42 of them were found in this study that is the highest amount found in comparison to other kinds of CPTs. A more distinct and unusual type of chaotic pulse train occurrence are ones that occur right after or are embedded with return strokes after the peak of the particular stroke which is the third type. These kinds of occurrences have never yet been reported in the literature to the best of this author's knowledge and can be considered new where 24 occurrences were found. Figure 6 summarizes all of the findings. It can be seen that chaotic pulse trains that precede return strokes has the highest amount followed by ones that occur right after or embedded with return strokes and in isolation.

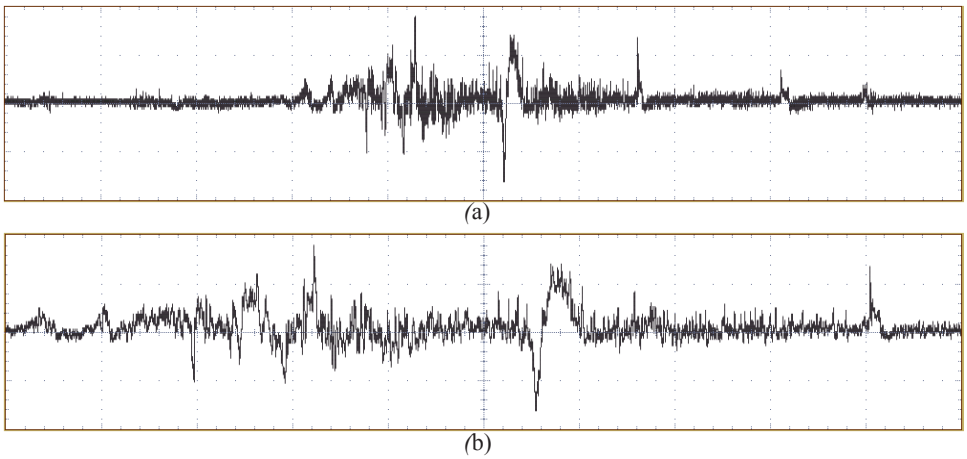

Figure 4. Isolated CPT of Flash ID TEK0056 with a Timeframe of 100 μs per Division; b) Isolated CPT with a Timeframe of 40 μs per Division

A number of CPTs were found to occur in sequences for the isolated and right after or embedded types. This implies that CPTs can occur several times in a flash as reported by Ahmad et al. (2014) where a series of two to three CPTs were detected. Every CPT found occurred after PBPs except twelve of them. This is highly unusual considering their position of occurrence. However, CPTs do occur before the advent of the first return stroke as found in Zhang et al. (2014b) but was identified as a very unusual event. It was also a unique event

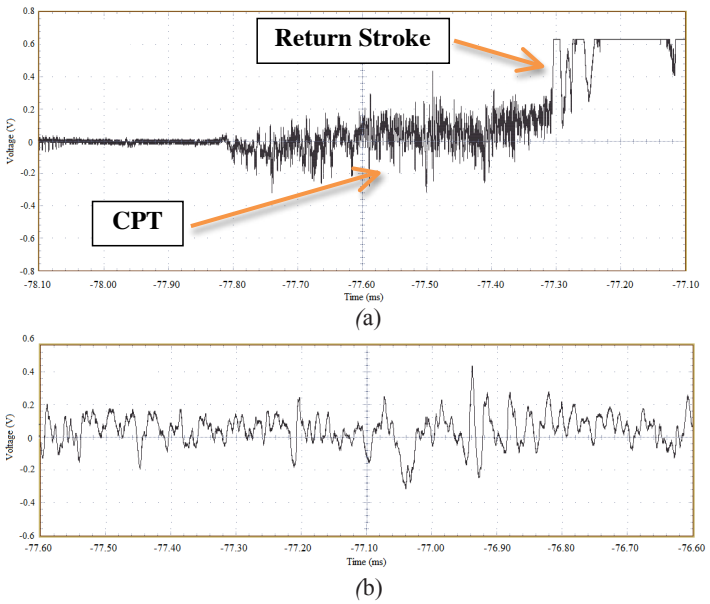

Figure 5. a) CPT of Flash ID TEK0052 with a Timeframe of 20 ms per Division; b) Part of its fine structure with a Timeframe of 10 µs per Division

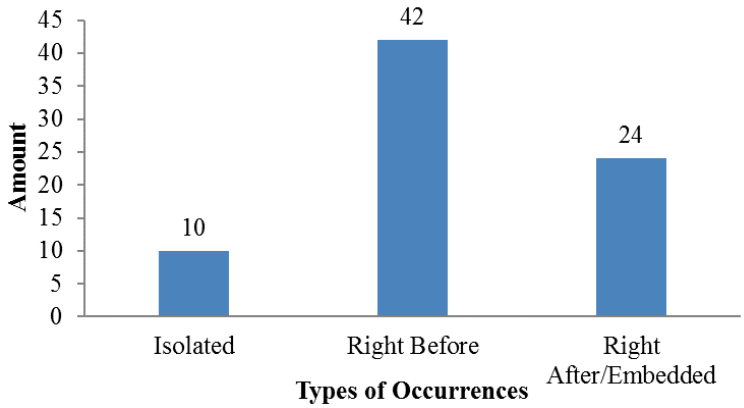

Figure 6. Types of Chaotic Pulse Train Occurrences and their Respective Numbers

because it was a flash without a PBP. This evidently shows that CPTs are more inclined to occur after PBPs and first return strokes which is usually the case despite the unusual occurrences of CPTs found in this study. This is in accordance with the studies found in Gomes et al. (2004), Mäkelä et al. (2007) and Lan et al. (2011). CPTs found in these studies show that those which occur after PBP and first return strokes are the most dominant. An example of two embedded chaotic pulse trains occurring after a return stroke can be seen in Figure 7(a) where Figures 7(b) and Figures 7(c) show their respective fine structures. This example is one of many found in the study. CPTs of this nature were found to be lower in number and duration in comparison to CPTs that occur prior to RSs. A total of three CPTs occurred with this particular RS with two of the embedded displayed in the figure.

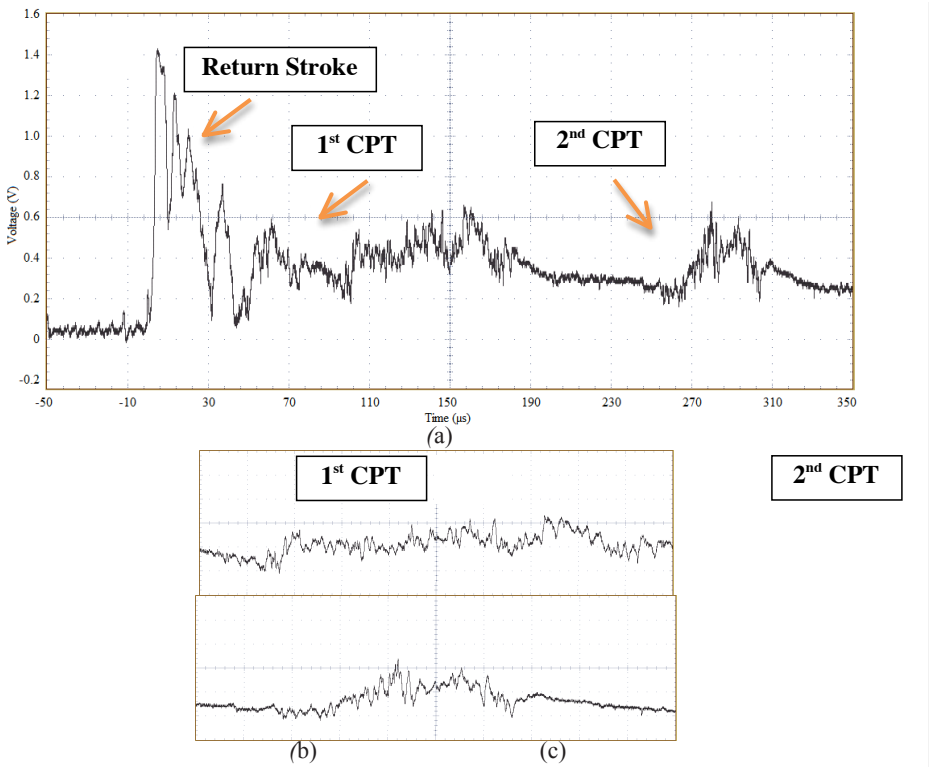

Figure 7. (a) Return Stroke of Flash ID TEK0072 with a Timeframe of 40 µs per Division; b) Embedded CPT-1 a Timeframe of 10 µs per Division; c) Embedded CPT-2 Timeframe of 10 µs per Division

CONCLUSION

It is found that CPTs occur with PBPs and RSs almost anywhere in a CG lightning electric field waveform in the Central-West part of Malaysia. The dominant feature of CPTs is that they precede RSs as demonstrated by the findings of the CPT in this study and in the literature. However, the number of CPTs that are embedded or might occur right after RSs shows an apparent number more than those of isolated in nature. This new type of CPT incidents has not been reported and can therefore be considered as a new f finding in terms of the position of an occurrence of a CPT.

Since results from only an electric field measurement cannot y explain the physical mechanism and nature of CPTs, discussion is limited as maybe discerned from (Lan et al . 2011) the conclusion suggesting CPTs remains a debatable lightning process. Since CPTs are different from other kinds of lightning activity they may be coming from an unknown physical lightning mechanism. Hence, this study aims to fulfil that purpose. This kind of analysis was also done to view CPTs in light of a perspective that has never been accomplished before. By that, this also paves way for more kinds analyses to be explored in the future for more comprehension of the lightning activities. Ultimately, this paper has shown that the CPTs can occur embedding itself with RSs or occur right after RS. This is a distinct feature of the CPT in terms of its position that has never been reported before

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