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On the Existence of Attempted Leader in Tropical Thunderstorm

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ABSTRACT

This report is a novel initiative at analysing and characterizing attempted leader in Melaka, Malaysia which located at vicinity of tropic region. The electric fields generated by the lightning were recorded using High Speed Transient Recorder (Lecroy HDO4024) with 90 nanosecond resolution in 2 seconds duration. This study examined a total of 237 electric radiation field recorded from three thunderstorms in 1 January 2019 to 3 January 2019. Uniquely, the attempted leader from 5 samples only appeared as positive initial peak which were not identical to negative return stroke peak. Further, the average duration of the attempted leader of the positive initial polarity is 7.4 ms. The arithmetic mean of individual pulse durations and the arithmetic mean of pulse intervals are 50.3 μs and 803.3μs, respectively. The current results are compared with the existence results in northern and subtropical regions. Obviously, for a certain condition, the interval pulse duration, individual pulse duration, total pulse duration and average number of pulses are different compared to Sweden and Florida data.

Key words : Attempted leader, preliminary breakdown, pulse trains, initial breakdown.

1. INTRODUCTION

Preliminary Breakdown Pulses (PBP) is the discharge process in the cloud, exhibit as a pulse train relatively in large microsecond-scale electric field which initiates the process of ground flashes. PBP is the first process (in cloud) happened in most of the cloud-to-ground lightning discharge [1]. PBP process then make headway into the step leader which bridging the cloud charge source with the ground for the discharge process compose of descending moving leader and ascending return stroke.

Most of the lightning discharges are initiated by earthward moving leader and effectively low positive charge region (LPCR) from cloud to the ground [2]. However, the overly existence of LPCR may discourage the propagation of negative CG discharge by "blocking" the headway of descending negative leader from being attached with the upward progressing leader (ground) and thus "converting" the potential CG flash to an intracloud (IC) on which in this paper referred as attempted leader [3]. If this condition occurs, the attempted leader known as the inverted IC discharge, which were not followed by return stroke could be observed. However, only few researchers reported the existence of preliminary breakdown without followed by the return stroke and terminologically known as attempted leader.

Sharma and co-workers [4] (based on measurement of lightning both in Sweden and Sri Lanka) reported that this type of lightning event have not been seen in Sri Lanka (tropical thunderstorm) and thus theorizing such event are prominent in the thunderstorm of temperate region. Few years after, Baharudin in his dissertation based on comparative study on lightning PB process coresponds to different region lightning characteristic, reported that the strength of LPCR could be measured using the resulting ratio of peak radiation field of PB process and RS (PBP/RS). He evaluated the ratio from the result gathered in Sweden and Sri Lanka by [5], Finland by [6], Malaysia by [7] and found that the mean of the PB/RS ratio are significantly larger at northern and subtropical region, however decrease as move to the equatorial region. This results leads to a hypothetical statement, suggested the attempted leaders are nowhere to be found in tropical region. His assumption was also influenced by the statement reported by Cooray and Jayaratne [8] who speculated that the overly existence of LPCR in cloud charge configuration are more likely happened in subtropical and high latitude location compared in the tropics.

However, this study has found five samples to satisfy the criteria of attempted leaders and interestingly the initial peak of attempted leader exhibit as positive initial peak. This present finding shows that the attempted leader is actually exist in tropical thunderstorm.

2. DATA

We examined a total of 237 electric radiation field (fast field) recorded of CG lightning flashes in 1 January 2019 to 3 January 2019 (three thunderstorms). The station was located at Melaka which 132 m above sea level and approximately 34 km away from the Melaka Straits. Melaka is located at the southern part of Peninsular Malaysia approximately at 2 °N, 102 °E. Out of 237 total number of flashes, only 5 data or 2% of positive isolated pulse train were observed as the attempted leader.

The fast-electric field measuring antenna system which is identical to that used in the literatures described by Cooray and Lundquist [9], Cooray [10], and Baharudin et al. [11]. The flat antenna was used to sense the vertical electric field. In the interest of avoiding the horizontal component of electric field, the plane of the antenna is adjusted perpendicular to the electric field vector or in other words, parallel to the ground. The physical height of the antenna in 1.5 m and the effective height in 0.25 m. The antenna was connected to the electronic buffer circuit by using 60 cm long coaxial cable (RG58). Using the 10 m long coaxial cable (RG-58), the signal from the antenna is transmitted into 12-bit digital transient recorder (Lecroy HDO4024) equipped with 200 MHz High Definition Oscilloscope. This transmission happened after passing through the electric buffer circuit.

The sampling rate was set to 12.5 MS/s and the total duration of waveform recorded being 2 s. The trigger setting of the oscilloscope was such that signals of both polarities could be captured. The trigger level is set either 50 mV to 500 mV for the far flashes or 500 mV to 2 V for the close flashes. The transient recorder was operated at a 300 ms pre-trigger mode. The rise time of the broadband antenna system (fast field) for step input pulses was less than 30 ns, while the decaying time constant was set to approximately 15 ms.

3. RESULT AND DISCUSSION

Two sample from five data of positive PBP not followed by any subsequent activity recorded on 1st January 2019 can be observed in Figure 1(a) and 2(a). The expanded from Figure 1(a) (data C200086) and 2(a) (data C200087) for the overall initial breakdown process happened are shown in Figure 1(b) and 2(a) while the overall pulse train being further expanded can be seen in Figure 1(c) and Figure 2 (c).

We analyzed a few parameter such as the total PBP train duration (T_{IB}), individual PBP train duration (T_{WP}) and interpulse duration (T_{IP}) as described by Nag and Rakov [12] and Nag and Rakov [13]. The illustration of (T_{IB}), (T_{WP}) and (T_{IP}) can be seen in Figure 1(b) (data C200086). The results in this study shows the range of individual pulse variation and the arithmetic mean of the individual PBP train duration (T_{WP}) were 6.1 to 210 μs and 50.3 μs while the range of variation and the arithmetic mean of the interpulse PBP train duration (T_{IP}) were 14 to 2100 μs and 803.3μs. Next, the mean for the entire duration of PB pulse train (T_{IB}) is 7.4 ms

The presents result from Melaka, Malaysia are then compared with the PBP process of negative return stroke cloud-to-ground data from Johor (on May 2009), Malaysia reported by Baharudin and co-workers (based on comparative study on preliminary breakdown pulse trains observed in Johor, Malaysia and Florida , USA, 2012) and Table 1 shows the comparison. Note that their result for the entire duration of PB pulse train (T_{IB}), the individual PB pulse train duration (T_{WP}) and the interpulse duration (T_{IP}) for negative cloud-to-ground lightning were 12.3 ms, 11 μs, and 152 μs respectively. A comparable result of the arithmetic mean of the individual PB pulse train duration (T_{WP}) and the arithmetic mean of the interpulse PB pulse train duration (T_{IP}) can be observed although the measurement are conducted in the same region. Interestingly, the entire duration of PB pulse train (T_{IB}) is slightly different by a factor of 1.7 to present study.

For comparative study, we analyzed the attempted leader activity in the thunderstorms of tropical region and compared the result with thunderstorm of different region (subtropical and northern). The research on analyzing the characteristic of attempted leader by Nag and Rakov as well as Sharma and co-workers based on studies conducted in Florida (subtropical region) and Sweden (northern region) are summaries in Table 2. It is speculated by Sharma and co-workers that the positive PBP are initiated from the discharge between upper positive and main negative charge region (upper region) while the negative PB pulse are initiated from the discharge between the main negative charge region and the LPCR (lower region). Thus, speculating the lower region breakdown leader progress is in fast steps compared to those higher origin breakdown leader.

Table 1: Comparison of positive PB pulse train not followed by return stroke with the PB pulse train of negative return stroke CG flash from the same region.

Location	**Johor, Malaysia (2012)**	**This study Melaka, Malaysia (2020)**
1.Total duration of PB i.Arithmetic mean (ms)	12.3	7.4
2.Individualpulse duration i.Arithmetic mean(μs) ii.Range (μs)	11 1-92	50.3 6.1-210
3.Interpulse duration i.Arithmetic mean (μs) ii.Range (μs)	152 1-1908	803.3 14-2100

In other words, the progression duration for higher origin cloud discharge seem to be longer than the lower origin cloud discharge. The speculation appears to be consistent with the result observed in tropic region since the average total pulse

train duration of positive PB of attempted leader pulse train obtained in Melaka, Malaysia (7.4 ms) are more than the negative PB of attempted leader pulse train obtained in Sweden and Florida (0.98 ms and 2.7 ms). On the other hand, despite the fact that measurement is done on different region, the average total pulse duration (T_{IB}) in the presents study (7.4 ms) shows a similarity in duration with the positive PB of attempted leader pulse train in Sweden (6.9 ms). It appeared that the average number of positive PB pulses in our study (10.2) is inconsistent with the average number of positive PB pulse train reported by Sharma and co-workers (3.9).

Table 2 : Comparison of PB of attempted leader from different region

Parameter	Northern		Subtropical	Tropical
	Sweden (2008)		Florida (2008)	This study (2020) Malaysia
Type of initial breakdown activity	Positive	Negative	Negative	Positive
Average Number of pulses	3.9	8.5	-	10.2
Total pulse duration, mean (ms)	6.9	0.98	2.7	7.4
Individual pulse duration, mean (us)	-	-	17	50.3
Interval pulse duration, mean (us)	375.0	82.5	73	803.3

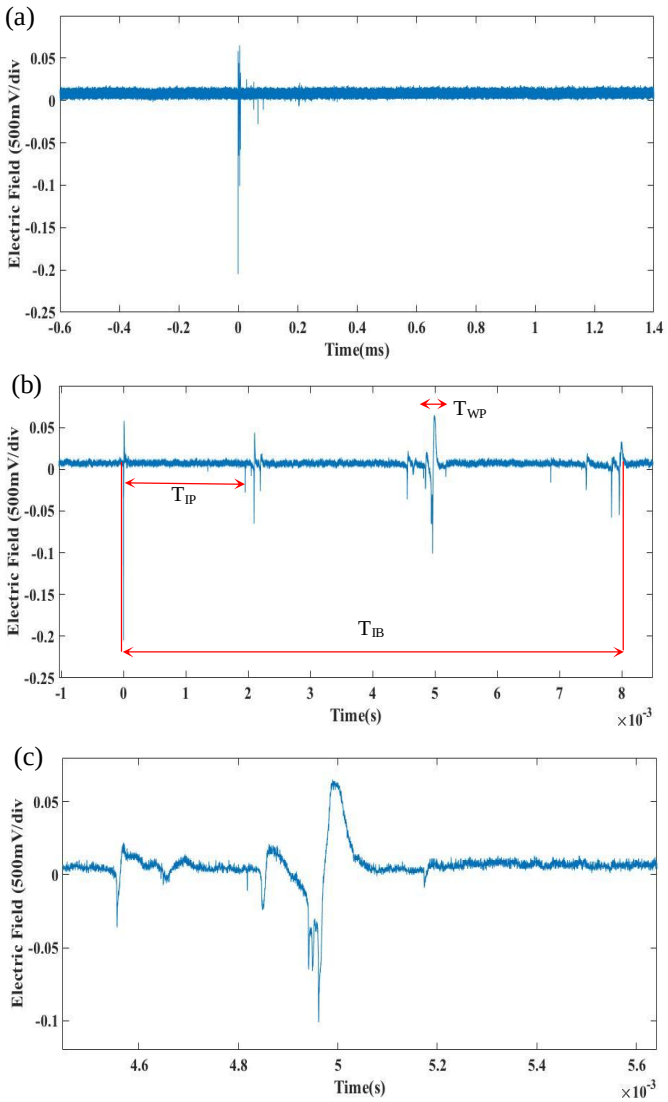

Figure 1: (a) (Data C200086) Electric field of the attempted leader recorded on 1st January 2019. No subsequent activity was seen after the PB activity. (b) expended from Figure 1(a). (c) The further extended part from Figure 1(b).

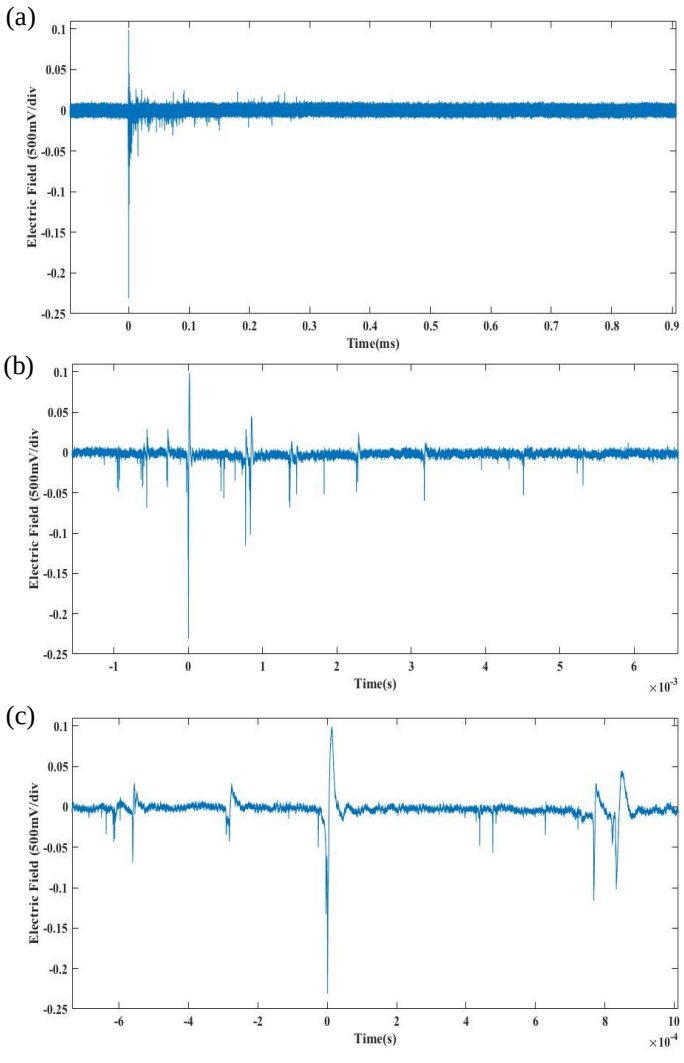

Figure 2: (a) (Data C200087) Electric field of the attempted leader recorded on 1st January 2019. (No subsequent activity was seen after the PB activity. (b) expended from Figure 1(a). (c) The further extended part from Figure 1(b).

Next, the current study show a quite similar result for the average number of positive PBP compared to the average number of negative PBP reported by Sharma and co-workers. Observed that the average number of positive PBP of attempted leader in Malaysia is triple the value observed in Sweden. From Table 2, the average total pulse duration (T_{IB}) in Malaysia which is 7.4 ms exhibited 10.2 number of pulses whereas the average total pulse duration (T_{IB}) in Sweden which is 6.9 ms exhibited only 3.9 number of pulses. Although it is inappropriate to make any assumption for the hardly recorded of unusual PBP train of attempted leader in tropical thunderstorm (five events of positive PBP train presented among 237 data), however, for the initial observation, we see that the positive PBP train are more compactly distributed in tropic compared to positive PBP train in northern region.

For the individual PBP train duration (T_{WP}), Nag and Rakov on their study in Florida found the duration to be 17 μs which is less than the present result by a factor of 3. For northern region, Sharma and co-workers apparently did not report the individual PB pulse train duration (T_{WP}). Further, the arithmetic mean of interpulse of positive and negative PB pulse train duration (T_{IP}) obtained by Sharma and co -workers in Sweden (375.0 μs, 82.5 μs) as well as Nag and Rakov in Florida (73 μs), are comparable with the present study (803.3 μs).

4. CONCLUSION

This paper presents the existance of attempted leader in tropical thunderstorm which was claimed to be non exist. Baharudin in his dissertation presented quite supportive data before claiming the non-existence of attempted leader pulse train in tropic, while Sharma and co-workers were using the same measurement in Sweden, yet claiming no attempted leader pulse train observed in tropical region of Sri Lanka. In this study, we examined a total of 237 electric radiation field (fast field) recorded of cloud-to-ground lightning flashes from 1st, 2nd and 3rd of January 2019 and found five sample (2%) of positive attempted leaders. The average number of pulses and the average duration of the attempted leader of the positive initial polarity pulses is found to be 10.2 and 7.4 ms, while the arithmetic mean of individual pulse duration and the arithmetic mean of pulse interval is 50.3 μs and 803.3μs.

From Table 2, the data in tropical region seems to have greater duration in most of the analysed parameters (compared to the northern and the subtropical region). Some of the result from Sweden are consistent with this study (average number of pulses of negative attempted leader and the average of total pulse duration of positive attempted leader) despite the different region of measurement conducted. This shows that different location indicates various characteristic of PB process. The observation of this unusual lightning discharge in tropical region, might has to do with the monsoon phenomena in tropical thunderstorm which obviously must be supported by yearly analyzation of data for further detail comprehension, and will be discussed in the next publication.

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