

Combination of narrow bipolar pulses and attempted leaders in Melaka, Malaysia

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Article Info

Article history:

Received Nov 19, 2021

Revised Feb 1, 2022

Accepted Feb 9, 2022

Keywords:

Association

Attempted leaders

Initial breakdown

Narrow bipolar pulses

Pulse trains

Tropical thunderstorm

ABSTRACT

This paper presents the characteristic of the positive attempted leaders preceded by positive narrow bipolar pulses (NPBPs). Attempted leaders are the preliminary breakdown process with no subsequent event (return stroke). On the other hand, narrow bipolar pulse is the lightning event commonly isolated and produces a strong electromagnetic field (in a short period). Attempted leaders hardly occurred in the tropics, and the preceding of the NBP (the combination) should be considered unique. In this present study, we found four samples in which the arithmetic means of duration of NPBPs pulse was 32.19 μ s, with separation between the positive attempted leader was 1.86 ms apart. For the positive attempted leader, the arithmetic means of the whole pulse train, individual pulse and interval pulse of positive attempted leaders were 3.47 ms, 29.66 μ s and 486.53 μ s, respectively. The pulse train in this study seems to fade out fast compared to the isolated positive attempted leader pulse train. Next, the NBPB's pulse duration in this study shows well in agreement with the type of isolated NPBPs indicates that the association does not affect its pulse duration characteristic already present in the title.

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1. INTRODUCTION

The preliminary breakdown process is the in-cloud process that triggers the initiation of the first step leader before producing a very high luminous feature of the return stroke. The process has been discussed for several decades by [1]–[7]. Still, the exact mechanism of this process remains not fully understood. Studies show that sufficient charge and concentration of the low positive charge region (LPCR) lead to a higher probability of ground flashes [8]–[10]. However, [11] speculate that a full-fledge of negative cloud-to-ground lightning flashes could be discouraged by the abnormal large in the magnitude of the LPCR. The authors presumed that this condition (dense LPCR relative to main negative charge region) prevented the initial step leader from building into a full-fledge of negative cloud-to-ground flash. As result, there will be no return stroke observed. In this case, it was reported as attempted leaders by [12] and [13] and also as isolated breakdown pulse train by [14]–[16]. This type of initial breakdown is known as an "attempted leader" throughout this study. The previous studies show that attempted leaders scarcely occurred in the lower region compared to the temperate region [14], [15]. Generally, it was due to the less dense LPCR [8], [16]. In most cases, the attempted leader was not preceded by any known even. In other words, they were reported isolated in previous research.

Narrow bipolar pulses characteristic first report was by [17]. NBPs are the electric fields of intra-cloud flash that emits strong radio frequency (RF) radiation. This cloud process of a characteristic shape not preceded leader-type of cloud flash and typically bipolar has an initial half cycle followed by an overshoot. The strongest RF radiation emitted appears to be by the cloud processes (NBP), not the ground flashes (return stroke) [14], [17], and [18] report that NBPs are generally not preceded or followed by any other known activities within a time interval of tens millisecond [19]. As compared to the attempted leader, the NBP occurrences are frequent in the tropics. In other words, the emission of NBP pulses increases with the decreasing of latitude [14], [15].

Across the latitudes, in general, there is numerous research on cloud-to-ground lightning flashes compared to cloud flashes. It is most likely due to the harm it caused towards humans at ground level. Consequently, the present information is not adequate in comprehending the physics of cloud flashes. The common reason for this divergence of interest among researchers is the measurement taking constraint associated with the location of the discharge process. Next is due to its less threatening towards human lives and properties at ground level (except who lives at higher altitude) [20]. However, with the advanced, sophisticated, and extensive technologies, there are also damages caused by cloud flashes. Mainly in the aviation industry. Since the NBP emit strong RF radiation in which even surpassed the amplitude of the return stroke, thus, the vulnerability of the avionic system exposed to this electromagnetic field which is also 30 dB louder than other known lightning discharges processes [21], should not be overlooked.

In this study, we present the cloud flashes of NPBP followed by positive attempted leader analysis of a few parameters within the separation of tens milliseconds apart (after the pulse emission). This study focuses on the association of NPBP with the positive attempted leader's analysis. Specifically, we analyzed the temporal characteristic of these associations and compared them with the isolated results.

2. METHOD

The study present 1466 examined data of electric radiation fast field recorded on 19th January–28th April 2017. The measurement conducted in Melaka, Malaysia (2.1896° N, 102.2501° E) has recorded four samples (0.27%) of NPBP pulses with succeeding positive attempted leaders. There are few isolated samples of positive (N=28, 1.9%) and negative (N=1, 0.07%) attempted leaders observed throughout the measurement campaign. Uniquely, neither negative polarity of NBP nor succeeding attempted leaders recorded in this present study.

The number of positive attempted leader preceded by NPBP activities were found inconsistent with the number of a thunderstorm. Also, they occur at the early and end-stage of the thunderstorm. For instance, on 26th January 2017, only 1 out of 120 samples was found and seen during the early stage. However, on 22nd February 2017, 3 out of 202 data was found and occurred slightly at the early and mid-stage of the thunderstorm. The summary is present in Table 1.

The electric radiation fields of the lightning discharge measurement were using the antenna system consisting of the vertical plate antenna, buffer circuit, coaxial cable, and transient recorder (Teledyne Lecroy HDO4024). The set-up was according to as reported by [22], [23]–[25]. The antenna was set perpendicular to the electric field vector and parallel to the ground for vertical electric field detection. This setting will also keep the horizontal field component away. The physical height of the antenna was 1.5 metres with an effective height of 0.25 metres. A 60-centimetre-long coaxial cable (RG-58) connect the antenna to the electronic buffer circuit. Next, the signal was transmitted from the antenna to a 12-bit digital transient recorder (Teledyne Lecroy HDO4024) using a 10-metre-long coaxial cable (RG-58). This high-speed transient recorder has a 200 MHz High-Definition Oscilloscope. The transmission to the digital transient recorder occurs after passing through the electronic buffer circuit.

The waveform recorded was 2 seconds, while the sampling rate adjusted to 12.5 MS/s. The oscilloscope's trigger setting capture both positive and negative polarities. The trigger level is from 100 mV to 300 mV and the transient recorder operated at 300 milliseconds pre-trigger mode. The rise time of the broadband antenna system (fast field) for the step input pulses was less than 30 nanoseconds, while the decaying time constant was to approximately 15 milliseconds

Table 1. The occurrence of positive attempted leader preceded by positive narrow bipolar pulses with the total activities recorded in Melaka

Date	Data	Total of data	Time
26/1/2017	1	120	10.03 am
22/2/2017	17	202	2.21 am
22/2/2017	112	202	6.49 am
22/2/2017	119	202	7.42 am

3. RESULTS AND DISCUSSION

This study focuses on the analysis of positive attempted leaders preceded by NPBPs. Since the negative polarity of both events were not observed, only the positive polarity of the electric radiation field waveform sample is presented (Figure 1). The atmospheric electricity sign convention is applied in this study. The overall positive attempted leader preceded by NPBPs with no activities in between is shown in Figure 1 (a). Next, the extended part of NPBP is in Figure 1 (b), and a whole pulse train of the positive attempted leader is shown in Figure 1 (c).

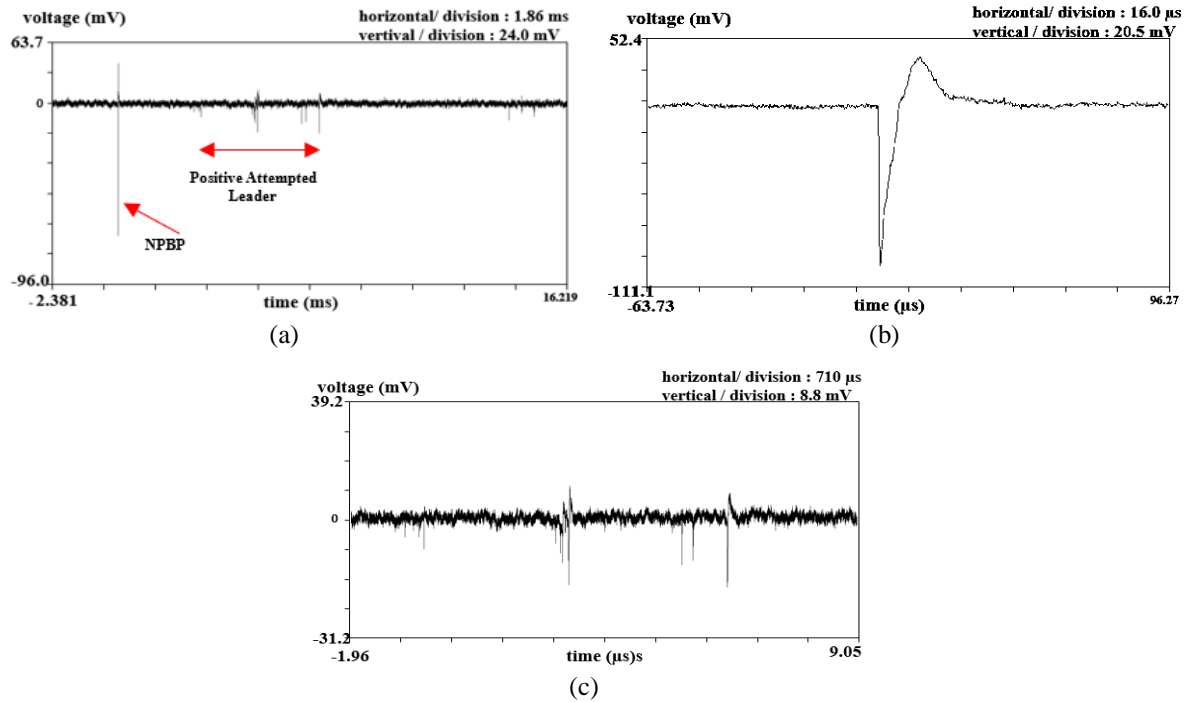


Figure 1. Electric radiation field waveform of (a) attempted leaders preceded by NPBPs recorded on 22nd February 2017 during Northeast monsoon. No subsequent activity happened. (b) The extended part of positive narrow bipolar pulse and (c) further extended part of the positive attempted leader pulse train

The measurement conducted in Sweden failed to record any NBP activities, whereas numerous positive NBPs was recorded in Sri Lanka [14]. On the other hand, no attempted leaders were recorded in Sri Lanka. However, often in Sweden with both polarities, but the negative is common [14]. The result indicates that the NBPs are common in tropical thunderstorms while attempted leaders in the higher region. Uniquely, the present study presents the analyzed sample of the combination of NPBPs and the positive attempted leaders. The NPBP was analysed similar to [14][19][15][26]. In this study, two NPBP were recorded with a hump at decaying, one was observed with a peak at the rising while the remaining showed a smooth initial half cycle followed by an overshoot. The duration of NPBPs was 32.19 μ s with the separation of 1.86 ms apart before the succeeding event of positive attempted leaders (depicted in Table 2). [19] reported that the NBPs preceded or followed by other lightning activities such as return stroke are commonly separated by a few tens milliseconds of an interval, this duration is parallel with the result in the present study. The NPBPs pulse duration in this study is in good agreement with the isolated type reported by [19] (30.2 μ s) depicted in Table 3. The comparable results may be due to the same producing thunderstorm since both events happen in the same region. However, the duration of NPBPs in this study is two factors longer than [26] (13.3 μ s) and two factors shorter than [27] (75 μ s) in Sri Lanka. Next, the duration of negative NBPs (24.6 μ s) reported by [19] was slightly shorter than the NPBPs reported in the present study. A summary of NBP activities from different studies is in Table 3.

A few parameters of the positive attempted leader pulse train such as the whole duration pulse train, individual pulse duration and inter-pulse duration as described by [5][22][12][16] and [28] were analyzed. The arithmetic mean of the whole pulse train duration of the positive attempted leader in this study is 3.47 ms. The arithmetic means of the individual pulse train and interval pulse is 29.66 μ s and 486.63 μ s, respectively (Table 2). The average number of the pulse of the attempted leader is 8.75. A summary of the temporal analysis is in Table 2.

Studies of attempted leaders do not associate with known lightning activities is in Table 4. The whole pulse train of positive polarity in this paper (3.47 ms) shows the shortest duration (by two factors) compared to the positive initial polarity of those isolated pulse trains reported by [13] (7.4 ms) and [16] (6.9 ms). As compared to the negative attempted leader, the present study shows a slightly greater result than [12] (2.7 ms), however, four factors greater than [16] (0.98).

According to Proctor [29], the initial leader progression for higher origin discharge (positive discharge) shows 4-5 times slower for either lower origin of cloud or cloud-to-ground flashes. Thus, the positive initial leader progression of the present study is consistent with [29] since its propagation took more time than the negative initial leader progression (from the previous studies). However, the present study has the shortest duration of initial leader progression compared to the positive polarity of those isolated either in the same region or temperate region. The duration pulse train of the present study seemingly faded out faster than the isolated event of positive attempted leaders from the same and higher region. We speculate that the association of NPBPs might be one of the reasons for this behaviour.

Table 2. Temporal analysis of positive narrow bipolar pulses preceding positive attempted leaders

Researcher	Location	NPBP		Positive attempted leader			
		Pulse duration (µs)	Event separation (ms)	Whole pulse duration (ms)	Individual pulse duration (µs)	Pulse interval duration (µs)	No of pulse (N)
Present Study (2021)	Melaka, Malaysia (2.1896°N, 102.2501° E).	32.19	1.86	3.47	29.66	486.53	8.75

Table 3. Comparison of narrow bipolar pulses with earlier studies

Researcher	Location	Pulse Duration (µs)
Present Study (2021)	Melaka, Malaysia (2.1896°N, 102.2501° E).	32.19
[19]	Positive Narrow Bipolar Pulse Johor, Malaysia (11N, 1031E)	30.2
[26]	Sri Lanka (6.91N, 79.61E)	13.3
[27]	Sri Lanka	75.0
[19]	Negative Narrow Bipolar pulse (11N, 1031E) Johor, Malaysia	24.6

Table 4. Comparison of attempted leaders with earlier studies

Researcher	Location	Positive attempted leader preceding NPBP			No of pulse (N)
		Whole pulse duration (ms)	Individual pulse duration (us)	Pulse interval duration (us)	
Present study (2021)	Melaka, Malaysia (2.1896°N, 102.2501° E).	3.47	29.66	486.53	8.75
[13]	Melaka, Malaysia (2.1896°N, 102.2501° E).	7.4	50.3	803.3	10.2
[16]	Uppsala, Sweden (59.81N and 17.61E)	6.9	-	375.0	3.9
[12]	Gainesville, Florida	2.7	17	73.0	-
[16]	Uppsala, Sweden (59.81N and 17.61E)	0.98	-	82.5	8.5

Despite both measurements being in the same region and during the same monsoon seasons, the individual pulse duration in the present study (29.66 µs) and [13] (50.3 µs) is inconsistent by two factors (Table 4). The present study also shows inconsistency with the individual pulse duration of negative polarity in the higher region (Florida) reported by [12] (17.0 µs). On the other hand, for the interval duration, the present result (486.53 µs) is less by two factors compared to the isolated of positive polarity reported by [13] (803.3 ms). However, it is slightly similar to [16] (375.0 ms) reported in the temperate region. The present result shows a distinguishable result with negative polarity reported by both [12] and [16]. The smaller duration of the pulse train, individual pulse, and interval pulse of the positive attempted leader in the present study indicates that the association with NPBPs lead the pulse train to be faded out fast, narrower pulses and more compact compared to the isolated type (same polarity).

4. CONCLUSION

From 1466 data of electric radiation fast field, only 4 (0.27%) samples of the uncommon event of the attempted leader preceded by NBPs. The arithmetic means of the whole pulse train duration, individual duration, interpulse duration and the number of pulses in the present study is 3.47 ms, 29.66 μ s, 486.63 μ s and 8.75, respectively. The whole pulse train duration is shorter in two factors compared to the result from Sweden and Malaysia. Next, the individual pulse and inter-pulse of positive attempted leader in this study are also shorter in duration than the result from the same region.

The initial leader progression of positive attempted leaders preceded by NPBP in this study are seen to fade out faster than the isolated breakdown of positive attempted leaders from the same and different region. On the other hand, the NPBP in this study (32.19 μ s) shows well in agreement with the isolated NPBP from the same thunderstorm. This result indicates that the association of NPBP with the attempted leaders does not affect its pulse duration.

The measurement was during the Northeast monsoon in a tropical thunderstorm. Uniquely, the event subjected in this study appears in positive initial polarity only. Further investigation involves a larger scale of data is required to see whether the result in this study is consistent during other monsoon seasons. Also, to identify the characteristic of negative polarity in which is considered very rare to occur.

ACKNOWLEDGEMENTS

This work is funded by Zamalah Scheme under Universiti Teknikal Malaysia Melaka. The authors would like to thank the Minister of Education (MOE), Malaysia and the Center for Research and Management (CRIM) of UTeM for equipment and measurement facilities, moral support, and cooperation during our measurement campaign. The device and equipment of this research from the MOE funding under the Exploration Research Grant Scheme (ERGS/2013/FKE/TK02/UTEM/03/01).




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