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RESEARCH ON POSITIVE NARROW BIPOLAR EVENTS IN PADANG

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***Abstract*— In this study, we have examined electric field records from 10 thunderstorm days containing 13 positive narrow bipolar pulses (PNBPs). It was found that PNBP occurrences have a strong relationship with thunderstorm activities. The mechanism of the NBPs was very different from intracloud (IC) and cloud-to-ground (CG) flashes. We also found that the AM values of rise time, full width at maximum time, zero crossing time, overshoot time, pulse duration and overshoot to peak amplitude ratio of the PNBPs were 1.64 µs, 1.32 µs, 9.38 µs, 15.06 µs and 0.31 µs, respectively. The pulse duration range was from 8.45 to 29.06 µs. Comparison with values from previous studies reported by other researchers showed that the mentioned parameters had no strong relationship with latitude or geographic location.**

Keywords—narrow bipolar pulse; cloud flash; ground flash; thunderstorm; lightning

I. INTRODUCTION

Narrow bipolar pulses (NBPs) are identified as one of the intracloud (IC) lightning discharge activities inside thunderclouds. However, the physical mechanism of NBPs remains a mystery. Many researchers have reported that there were two types of NBPs, namely positive narrow bipolar pulses (PNBP) and negative narrow bipolar pulses (NNBP). NBPs have strong radio frequency radiation at several MHz and a short duration with zero crossing (initial positive half cycle) and overshoot (negative half cycle) within several microseconds, followed by or not followed by any other signals [1-4]. NBPs may not be related to ground and cloud flash activities and originate inside the most active thundercloud areas [2]. PNBPs usually occur at lower latitudes than NNBPs. In addition, PNBP occurrences are rare compared to NNBP events [5]. This study is to clarify the relationship between thunderstorm activity and PNBP occurrence. We examined an electric field change data set with 13 PNBPs that were recorded during thunderstorm days in 2015. The characteristics of the PNBPs were statistically analyzed based on electric field change as presented in this paper. All data were also compared to previous researches at different locations and latitudes.

II. OBSERVATION AND DATA

The electric field records containing the PNBPs presented here were recorded from January to December 2015 in Padang, Indonesia (0° N) on 10 thunderstorm days using an electric field mill and a broadband electric field fast antenna. Both electric field sensors on the rooftop of the Electrical Engineering Department Building of Andalas University were located at 13 km from Padang Beach, Indian Ocean at an altitude of 317 m above sea level. The fast antenna with parallel flat-plate configuration was used to detect electric field changes in the thunderclouds. The fast antenna was connected to an amplifier and integrator with a time constant of 100 ms. Furthermore, all signals sensed by this antenna were recorded by a digitizer with a sample rate in the range of 1-4 MS/s and a record length of 250 ns - 1 s. To ensure that the strong electric field of lightning was recorded, the digitizer was set to window trigger mode at a trigger level of 1 V and a pretrigger time of 30% of the record length. The electric field measurement system used was similar to the one used in Hazmi et al. [6-7].

III. RESULTS AND DISCUSSION

In this study, 13 PNBP occurrences were analyzed. A summary of the PNBP events can be seen in Table 1. There are two types of PNBP events; for convenience, type A is called isolated PNBP to indicate that there are no other IC lightning occurrences, while type B is called non isolated PNBP which indicates that the occurrences are preceded or followed by other IC lightning occurrences, as displayed in Figures 1 and 2. The occurrence percentage of type A (46%) was slightly smaller than that of type B (54%). From Table 1, the PNBPs occurred during day and night time with the duration of the thunderstorms varying from 126 to 844 minutes. The background electric field changes of the thunderstorms recorded by an electric field mill sensor for negative and positive polarities varied between 0.284-4.096 kV/m and 0.364-4.094 kV/m, respectively. This indicates that the PNBPs occurred inside the most active thundercloud areas with high electric field. Our observation results were a good agreement with observation of Smith et al. [2]. However, PNBPs also occurred when the thunderstorms detected had a lower electric field, for example thunderstorm numbers 8 and 11 in Table 2. This may be due to the different distance between the PNBPs

TABLE 1. SUMMARY OF 10 THUNDERSTORM DAYS RECORDED IN PADANG FROM JANUARY TO DECEMBER 2015.

No	File Name	Date dd/mm/yy	Local Time (hh:mm:ss)	Type	Thunderstorm in 24 hours		
					Duration (min)	*Maximum E-field polarity (kV/m)*	
						Negative	*Positive*
1	20140526-0001 (25369)	30/01/2015	6:21:51	A	126	-4.096	4.094
2	20140526-0001 (25370)	30/01/2015	6:22:45	B			
3	20140526-0001 (25539)	05/02/2015	19:10:27	A	636	-3.668	3.368
4	20140526-0001 (25554)	05/02/2015	19:33:55	B			
5	20140526-0001 (25573)	16/02/2015	12:55:38	B	150	-4.096	2.926
6	20140526-0001 (26674)	08/03/2015	2:27:38	B	192	-1.668	2.756
7	20140526-0001 (27162)	14/03/2015	22.18:17	B	436	-4.096	4.094
8	20140526-0001 (27299)	18/03/2015	19:54:53	B	844	-0.284	0.364
9	20140526-0001 (28048)	24/03/2015	22:32:12	A	678	-4.096	3.874
10	20140526-0001 (30179)	10/04/2015	15:47:19	B	802	-3.202	2.228
11	20140526-0001 (30226)	15/04/2015	1:07:08	A	561	-1.378	1.856
12	20140526-0001 (31524)	11/12/2015	19:11:39	A	642	-4.096	4.094
13	20140526-0001 (31527)	11/12/2015	19:20:42	A			

and the electric field mill sensor. The more distant the measurement, the smaller the electric field magnitude recorded by the electric field mill sensor. We did not find that any of the PNBP events were accompanied by CG flash events. Thus, there is not strong relationship between PNBP, IC and CG flash occurrence.

The physic sign convention was used to examine the electric field changes in this study. An expanded PNBP is shown in Figure 3. In addition, the studied parameters in this research were full width at maximum time (0-100%), rise time (10-90%), zero crossing time, overshoot time, pulse duration and overshoot to peak amplitude ratio, as shown in Figure 3. The characteristics of the PNBPs are summarized in Table 2.

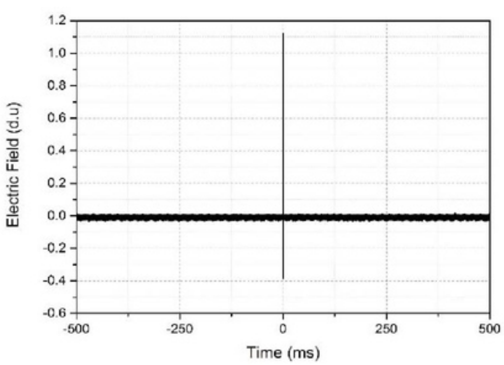

Fig. 1. A typical isolated PNBP E-field waveform.

The full width at maximum time (T_{r1}) is the time interval that relates to the values of 0% and 100% of the peak amplitude of the signal. This parameter is important to measure the initial transient signal of a PNBP. The minimum, maximum, arithmetic mean (AM) and geometric mean (GM) values of the full width at maximum time were 3.24 ± 1.20 µs, 3 µs, respectively.

The rise time (T_{r2}) is the time interval that relates to the values of 10% and 90% of the peak amplitude signal. The AM and GM values of PNBP rise time were 1.64 ± 0.51 µs and 1.56 µs, respectively, with minimum and maximum values of 0.89 µs and 2.65 µs, respectively. Comparing these values to those from other researchers, our AM value was smaller than that of Karunarathne et al. [8], Ahmad et al. [9] and Sharma et al. [10]. Their results were 2.6 µs, 2.7 µs and 2.6 µs, respectively. However, our AM value was larger than that of Medelius et al. [11] and Gunasekara et al. [12] with obtained results of 1.54 µs and 1.38 µs, respectively. The difference may be due to data limitations in this study.

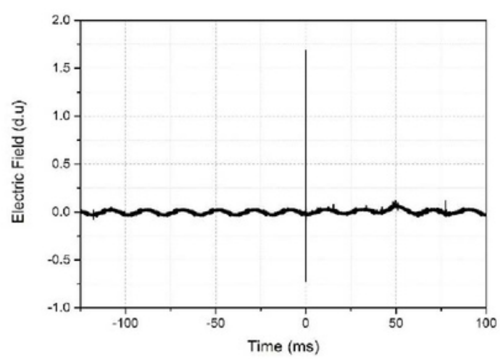

Fig. 2. A typical non isolated PNBP E-field waveform.

The zero crossing time (T_z) is defined as the time difference from the first zero point to the next zero point, represented by zero crossing of the signal. The zero crossing time varied from 3.72 to 7.03 µs with AM and GM values of 5.23 ± 1.14 µs and 5.11 µs. The AM values from previous studies in other latitudes, as reported by Gunasekara et al. [12], Karunarathne et al. [8], Nag et al. [13], Ahmad et al. [9], Sharma et al. [10] and Cooray and Lundquist [14], were 4.66 µs, 9.9 µs, 5.6 µs, 6.5 µs, 5.78 µs, and 13 µs, respectively. The zero crossing time at the same latitude had different values as reported by Gunasekara et al. [12] and Sharma et al. [10]. It was clear that the AM value did not depend on latitude.

The overshoot time (T_o) is the time interval between the first zero crossing point and the end signal to reach the next zero crossing point. It varied from 3.71 to 25.23 µs. The mean value was 9.38 ± 6.55 µs with a GM value of 8.01 µs.

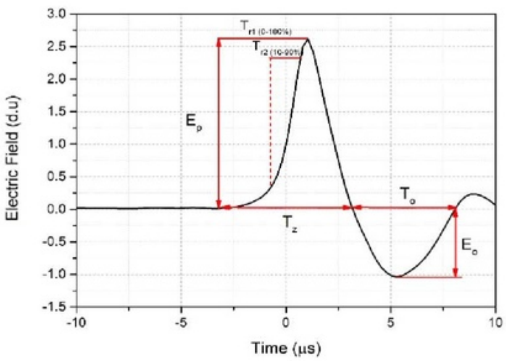

Fig. 3. The expanded narrow bipolar pulse E-field waveform.

The pulse duration is the total time interval that corresponds to the positive half cycle and the negative half cycle (overshoot) of the signal. It had an AM value of 15.06 ± 6.38 µs and a GM value of 13.90 µs, while it ranged from 8.45 to 29.06 µs. The AM values from other researchers, i.e. Gunasekara et al. [12], Nag et al. [13], Ahmad et al. [9], Sharma et al. [10] and Cooray and Lundquist [14], were 16.42 µs, 23 µs, 30.2 µs, 13.3 µs, and 75 µs, respectively. It was found that the AM value did not depend on latitude. The different results may be due to the specific characteristics of the electric field sensor system and thunderstorm type.

TABLE 2. SUMMARY OF OBSERVED PNBP PARAMETERS.

Parameters	Min	Max	AM	GM
Rise time (10-90%) (µs)	0.89	2.65	1.64±0.51	1.56
Full width at max (0-100%) (µs)	1.51	5.00	3.24±1.20	3.00
Zero crossing time (T_z) (µs)	3.72	7.03	5.23±1.14	5.11
Overshoot time (T_o) (µs)	3.71	25.23	9.83±6.55	8.01
Pulse duration (µs)	8.45	29.06	15.06±6.38	13.90
Amplitude ratio (E_o/E_p)	0.17	0.41	0.31±0.07	0.30

The overshoot (E_o) to peak amplitude (E_p) ratio is determined by comparing peak overshoot to initial peak of signal amplitude. The minimum, maximum, standard deviation, AM and GM values of this ratio were 0.17 µs, 0.41 µs, 0.07 µs, 0.31 µs and 0.30 µs. The results from previous researches, as reported by Gunasekara et al. [12], Nag et al. [13], Ahmad et al. [9], Sharma et al. [10] and Cooray and Lundquist [14], were 0.37 µs, 0.17 µs, 0.27 µs, 0.35 µs, and 0.30 µs, respectively. Our mean value showed was the same as in previous researches, except from Nag et al. [13]. We predict that the difference in this parameter was influenced by differences in season and charge distribution of the thunderstorms.

IV. CONCLUSION

10 thunderstorm days containing 13 PNBPs were examined based on electric field records. The thunderstorm activities did not always cause PNB events. However, it was found that the PNBP occurrences had a strong relationship with thunderstorm activities. The PNBP mechanism is very different from IC and CG flashes. From our observations, the AM value of rise time, full width of maximum time, zero crossing time, overshoot, pulse duration and overshoot to peak amplitude ratio of PNBPs were 1.64 µs, 1.32 µs, 9.38 µs, 15.06 µs and 0.31 µs, respectively. Comparison with previous studies, as reported by other researchers, suggests that the mentioned parameters do not depend on latitude or geographic location. The differences may be due to differences in thunderstorm types, seasonal conditions and instrumentation system characteristics. Further research is needed to gain a better understanding of the physical mechanism of narrow bipolar events (NBE).

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