Certification of Attendance

This is certify that

Ariadi Hazmi

attended the Asia-Pacific International Conference on Lightning on June 23-27, 2015, Nagoya, Japan.

Prof. Koji Michishita
Chairperson of Local Organizing Committee

APL 2015

Asia-Pacific International Conference on Lightning

Welcome Message

Prof. Koji Michishita
Chairperson of
Local Organizing
Committee

On behalf of the organizing committee we invite you to attend the Asia-Pacific International Conference on Lightning 2015 (APL 2015) which will be held in Nagoya city, one of the largest cities in Japan, at June 23-27, 2015. The conference venue will be the Winc Aichi, located in the city center of Nagoya and easily reachable by public transport. The APL 2015 will be co-organized by the Institute of Electrical Installation Engineers (IEIE) of Japan. In the Asia-Pacific region, lightning activity is high especially in the tropics and also there is the winter lightning in Japan, having significant characteristics such as high energy. Due to the importance of lightning protection, research on lightning in this region becomes very active. The APL 2015 offers a golden opportunity to exchange scientific and technical information related to lightning phenomena. Contributions are sought on all topics related to the study of lightning protection of buildings, electric power systems, electronic systems and transportation network as well as methods for improving protection of people and properties against the effects of lightning. The organizing committee hopes that researchers and engineers active in the field of lightning physics and lightning protection will come to Nagoya in Japan, exchange scientific and technical information related to lightning phenomena and also enjoy the traditional culture and the delicious Japanese foods.

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TC4.2-2	10:10 – 10:30	1017: Performance of Reinforcing steel with Joints for Down-conductors – Temperature Rise of Reinforcing Steel and Joints – Y. Takeda, K. Hiruma, T. Sonehara and S. Yokoyama
TC4.2-3	10:30 – 10:50	1066: Performance of Reinforcing-steel with Joints for Down-conductors -Joint Performance Evaluation Test- T. Nihei, H. Yoshihara, K. Hiruma, Y. Takeda, S. Yokoyama and H. Shimokawa
TC4.2-4	10:50 – 11:10	1074: Behavior of Lightning Surges in a Middle-Sized Building H. Hiroi, H. Sakakibara, H. Sugihara and K. Yamamoto
TC4.2-5	11:10 – 11:30	1054: Step Voltages in a Ground-grid Arising from Lightning Current F. Hanaffi, W. H. Siew and I.Timoshkin

TC1.4: Lightning Discharge IV

Wednesday, June 24, 2015, Room A
Chairs: Prof. Tomoo Ushio (Japan), Prof. Mingli Chen (Hong Kong, China)

TC1.4-1	13:00 – 13:20	1088: Characteristics of Lightning Flashes in Northeastern Qinghai-Tibetan Plateau Y. Zhang, R. Zhang and G. Zhang
TC1.4-2	13:20 – 13:40	1102: Multiple Ground Terminations of Positive Cloud to Ground Induced by a Same Stepped Leader A. Hazmi, P. Emeraldim and N. Takagi
TC1.4-3	13:40 – 14:00	1082: Interferometer Observations of Positive and Negative Breakdown M. Stock, Z. Kawasaki and P. Krehbiel
TC1.4-4	14:00 – 14:20	1103*: Flashes Initiations in a Cluster of Supercells D. Zheng
TC1.4-5	14:20 – 14:40	1194: Continuing Current Characteristics of Lightning Flashes in Summer M. Miki, T. Miki, D. Tanaka, K. Hayashi and M. Hayashi

Multiple Ground Terminations of Positive Cloud to Ground Induced by a Same Stepped Leader

Ariadi Hazmi, Primas Emeraldi and Nobuyuki Takagi

***Abstract*—We have investigated 6 of 50 positive cloud to ground (CG) flashes with multiple strike to ground in the tropical region, West Sumatra, Indonesia. It was found that the arithmetic mean (AM) and geometric mean (GM) leader pulses interval, leader-return stroke interval, and final leader/return stroke ratio are 21.52 µs, 1.3 ms, 5.1% and 18.97 µs, 1.27 ms, 4.78%, respectively. The interstroke interval varies from 7 µs to 13 µs with the AM and GM values of 10 µs and 9.73 µs, respectively. We have also found that the amplitude of the final leader pulses just prior to return stroke tends to decrease compared to that of the middle leader pulses.**

***Keywords*—Double peak waveforms, leader pulse, positive cloud to ground, return stroke, tropics.**

I. Introduction

Although downward stepped leaders have many branches, the main leader branch is usually responded by an upward leader from the ground to induce a return stroke and a strike to ground termination. Recently, several researchers have reported that a same stepped leader with many branches is able to produce different ground terminations that are separated by several tens to hundreds meters [1-4]. Guo and Krider [5] have reported that about 2% of return strokes show double peak waveforms with an interstroke interval between two peaks of about 70 µs. Takagi et al. [6] found that the occurrence percentage of double peak return stroke waveforms at middle latitude was 1%. Multiple ground terminations occurring within several microseconds are difficult to identify by a lightning location system. In this paper we report about the leader pulse and return stroke characteristics of positive cloud to ground lightning flashes induced by a same stepped leader that produces the double peak return stroke waveforms.

II. Observation

The data presented in this study were 6 of 50 positive cloud to ground lightning flashes produced by 22 thunderstorm days during May to September, 2014. Our measurement station was located on the roof of the four-story Electrical Engineering Building of Engineering Faculty at the Andalas University (-0.98 N and 100.3 E), an altitude of about 311 m above sea level and 13 km away from Padang Beach. Furthermore, a sensor of circular flat plate parallel was installed to record the broadband electric field. The area of the flat plate parallel was 0.07 m^2. The decay time constant of sensor was 100 ms with integrator capacitance (C) of 1 nF. All waveforms from a circular flat plate parallel were connected to an integrator/amplifier, a 12-bit digitizing oscilloscope with a sampling rate of 80 MS/s, and digital low-pass filter (200 kHz). The total record length was 1 s with a pretrigger time of 400 ms, and sample interval data of 1 µs. The window trigger was set ± 500 mV.

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III. Result and Discussion

In this study, we used the physics sign convention for electric fields and selected 6 of 50 positive CG flashes with multiple ground terminations based on double peak return stroke waveforms from the electric field antenna. The typical electric field waveform of a single return stroke is shown in Fig. 1. A summary of leader pulse characteristics of double peak return stroke waveforms is presented in Table 1. According to Wang and Takagi [7], electric field change produced by a stepped leader leads to the leader pulses being detectable several hundreds meter above the ground by a fast electric field antenna before the return stroke occurs. Table 2 shows a summary of double peak return stroke waveform parameters.

3.1. Leader pulses

Generally, the amplitude of leader pulses (L) increases when the leader approaches the ground to induce one return stroke (RS) and strike one ground termination. However, a same stepped leader with many branches may almost simultaneously induce two or more return strokes with different ground terminations. The typical electric field waveforms of larger and smaller leader pulses from two return strokes are shown in Fig. 2 and Fig. 3, respectively. Fig. 3 showed a smaller leader pulse that might be due to a distant lightning.

The leader pulse interval varied from 4 µs to 50 µs with the arithmetic mean (AM), geometric mean (GM), median, and standard deviation (SD) are 21.53, 18.98, 20.29, and 10 µs, respectively. Although other authors did not confirm whether their observation results contained double peak return stroke waveforms or not, they did report that the AM values from

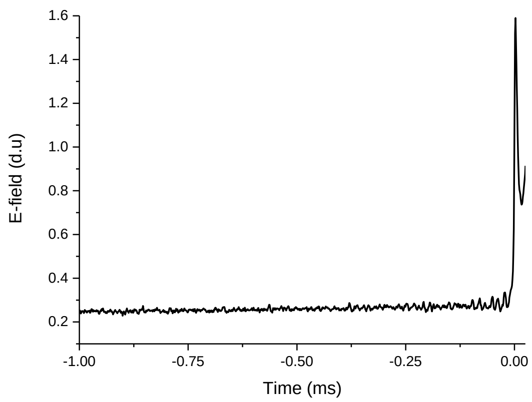

Fig. 1. Typical leader pulse electric field changes of single peak return stroke waveforms.

previous studies conducted by Cooray and Lundquist [8] and Hojo et al. [9] in Sweden and Japan were 26 and 17.4 μs, respectively, while Schuman et al. [10] found that the AM values at different stages varied from 20.2 μs at the final stage to 22.5 μs at the initial stage. Our mean value that contains double peak return stroke waveforms is quite similar to the one from Schumann et al. [10], which they found in Brazil. The distribution of the leader pulse interval is shown in Fig. 4.

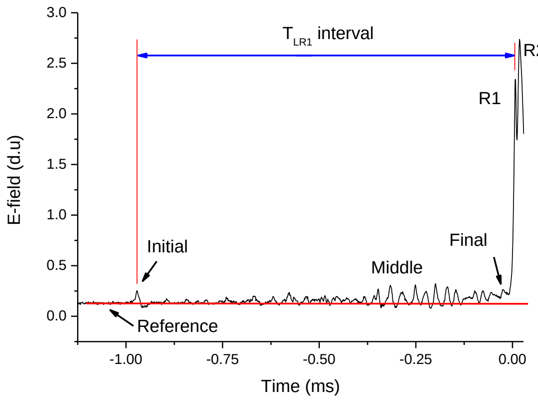

Fig. 2. Typical larger leader pulse electric field changes of double peak return stroke waveform.

Furthermore, the AM and GM time intervals between initial leader and first return stroke were 1.30 and 1.27 ms with a median and range of 1.24 ms, and 0.98-2 ms, respectively. The AM and GM time intervals between final leader and return stroke were 20.19 and 19.50 μs, respectively with time varying from 15 μs to 32.12 μs. The AM ratios of the leader pulse peak to the accompanying return stroke at the initial, middle, and final stages are 3.28, 5.90, and 5.13%, respectively. Schumann et al. [10] reported that the corresponding values at different stages were 2.1, 2.6, and 3.6%, respectively with final leader to return stroke ratio is the highest. Our observations yielded slightly higher than those of Schumann et al. [10] at different stages.

It is interesting to note that the ratio value at the final stages was lower than that at the middle stages. The difference may be caused by a mechanism of the attachment process between single and double ground terminations. We speculate that a same stepped leader inducing two return strokes gets energy from the cloud [4]. Furthermore, the same energy being divided and used to strike two ground terminations almost simultaneously led to a ratio of the leader to return stroke at the final stages that was lower than at the middle stages. According to Qie et al. [4], the all speeds of the leader branches before the attachment process of the multiple ground terminations in negative CG tend to decrease. Our investigation supports their results. More data are needed to clarify about the leader characteristics on the attachment process of multiple ground terminations induced by a same stepped leader.

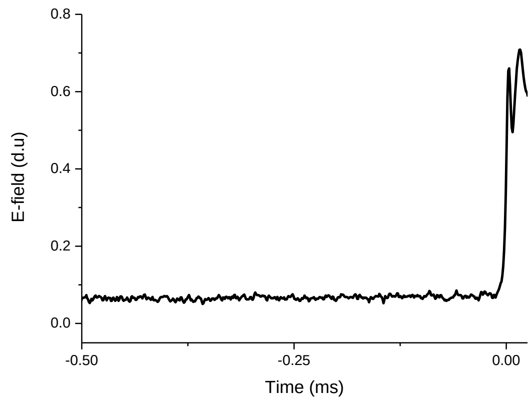

Fig. 3. Typical smaller leader pulse electric field changes of double peak return stroke waveform.

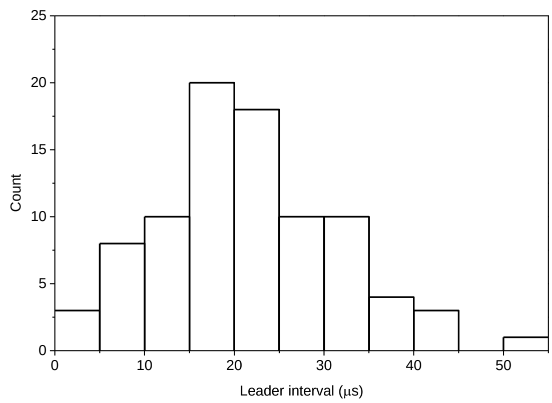

Fig. 4. Histogram of leader pulse interval for double peak return stroke waveforms.

3.2. Return stroke

Typical double peak electric field waveforms of two return strokes are shown in Fig. 5. To identify two return strokes with a same stepped leader channel, some parameters were investigated such as interstroke interval, stroke rise time, and ratio between two return stroke amplitudes. From Table 2, the interstroke interval varied from 7 μs to 13 μs with AM and GM value are 10 and 9.7 μs. Qie et al. [4] found that the interstroke interval of four branches in negative CG varied from 4 μs to 10 μs with an AM value of 7.6 μs. The ground termination point was separated with a distance variation of

TABLE 1. SUMMARY OF LEADER PULSE CHARACTERISTICS

Parameters	N	AM	SD	GM	Range	Median
Leader pulse interval (µs)	87	21.53	10	18.98	4-50	20.29
L-RS interval (ms)	6	1.30	0.37	1.27	0.98-2	1.24
Final L-RS interval (µs)	6	20.19	6.32	19.50	15-32.12	18
Initial L/RS ratio (%)	6	3.28	1.75	2.86	1.16-5.49	2.91
Middle L/RS ratio (%)	6	5.90	2.17	5.46	2.30-8.62	6.37
Final L/RS ratio (%)	6	5.13	1.96	4.79	2.79-7.50	5.45

TABLE 2. SUMMARY OF DOUBLE PEAK RETURN STROKE WAVEFORM CHARACTERISTICS

No	Date	Local Time	R1/R2 ratio (%)	Interstroke interval (µs)	Risetime (µs) 1st 0-100%	1st 10-90%	2nd 0-100%	2nd 10-90%
1	2014-05-09	22:09:51	85.19	13	16.04	7.68	8	4.6
2	2014-05-09	22:48:22	92.41	8	11.94	4.64	4	2.74
3	2014-08-12	19:12:10	84.22	10	14.97	7.93	6	3.9
4	2014-09-24	20:59:43	93.21	13	15.98	6.15	8	5.54
5	2014-09-25	04:18:15	86.71	9	7.86	3.75	5	3
6	2014-09-25	09:52:48	91.29	7	12.98	5.94	5	3.37

about 184-490 m. Furthermore, the AM and GM 0-100% and 10-90% rise times of the first return stroke (R1) were 13.3, 6.02 µs and 12.93, 5.82 µs, respectively. The AM and GM 0-100% and 10-90% rise times of the subsequent return stroke (R2) were 6, 3.86 µs and 5.81, 3.74 µs, respectively. Our observation showed that the rise time of the first return stroke is longer than that of the subsequent return stroke. Qie et al. [11] found in China that the AM 0-100% rise times for the first and subsequent return stroke were 13.96 and 6.6 µs, respectively. Other authors reported that the AM 10-90% rise times of the first return stroke found in Japan [9] and Sweden [12] was 8.7 and 6.2 µs. Compared to other authors, our rise times are similar to Qie et al.'s observations [11], which they found in Da Hingga Ling of China at a higher latitude. Our observation results indicate that the rise times of the first and subsequent return stroke for the double peak waveforms are similar to that of the single peak waveforms. Additionally, ratio of the first return stroke to the subsequent return stroke amplitude varied from 84.22% to 93.21%. Our ratio values showed that the amplitude of first return stroke was lower than that of second return stroke.

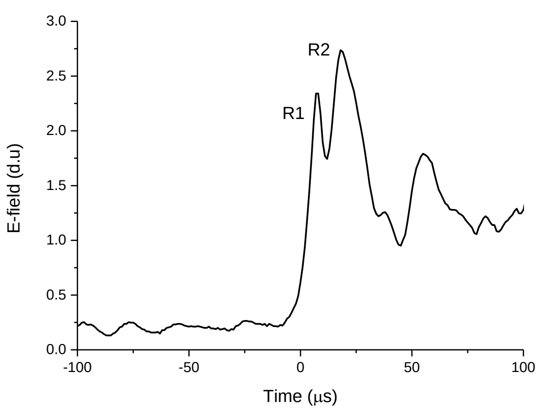

Fig. 5. Typical electric field changes of double peak return stroke waveforms.

IV. CONCLUSION

We have investigated 6 of 50 positive CG flashes containing a double peak return stroke waveform. The AM leader pulse interval was 21.53 µs similar to that of Schumann et al. [10] found in Brazil. The AM and GM time intervals between the initial leader and the first return stroke were 1.30 and 1.27 ms respectively. The AM and GM time intervals between the final leader and the first return stroke were 20.19 and 19.50 µs, respectively. The ratio of leader pulse to return stroke amplitude at the final stages was lower than at the middle stages. Additionally, the AM and GM interstroke intervals had a value of 10 and 9.7 µs, respectively. Furthermore, the AM 0-100% and 10-90% rise times of the first return stroke were 13.3 and 6.02 µs, respectively. The AM 0-100% and 10-90% rise times of the subsequent return stroke were 6 and 3.86 µs, respectively. Compared to other authors, the rise times of the first and subsequent return stroke for the double peak waveforms are similar to that of the single peak waveforms. The ratio of the first return stroke to the subsequent return stroke amplitude varied from 84.22% to 93.21%. More data are needed to be better understand the leader characteristics during the attachment process of multiple ground terminations induced by a same stepped leader.

ACKNOWLEDGMENTS

This work was supported by International Research Collaboration and Scientific Publication (KLN) grant, KEMRISTEKDIKTI, Indonesia, 2015.

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