# *VHF Emissions Prior to the Onset of Initial Electric Field Changes of Intracloud Flashes*

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***Abstract*— We present the observation of VHF impulses electric (E) field emissions found in two normal intracloud (IC) flashes accompanied by initial electric field changes (IECs) in a tropical thunderstorm. The data was collected on November 23rd, 2017 (within reversal distance) to our lightning sensor in Malacca, Malaysia. The durations from the onset of IECs to the first initial breakdown (IB) pulse are range between 0.68 and 0.69 ms and the magnitudes of IECs are range between 0.18 and 0.50 V/m. Besides that, before the onset of IECs there is small pulses was detected for IC flash (Nov_67) same with the VHF impulse for both IC flash. It was detected earlier before the onset of IEC by 12.69 and 251.60 µs for the VHF impulse.**

***Keywords—initial electric field changes, lightning initiation, tropical thunderstorm, very high frequency***

## I. INTRODUCTION

Initial electric field changes (IECs) were discovered first by Marshall Group based on Florida thunderstorms in USA [1, 2]. So far, there is no other reports on the IECs from the tropical thunderstorm. In this paper we present the findings of IECs from tropical thunderstorms accompanied by VHF electric field radiation.

The IEC is defined as when there is slow developing electric field change, small amplitude and short duration that occurs before the first initial breakdown (IB) pulse [1]. The identification of IECs can be determined when there are slow electric field changes start from zero going upward for negative CG (-CG) flash or going downwards for intracloud (IC) flash (physics sign convention) and ended just before the first IB pulse. To detect the IECs process, lightning flashes must be detected within reversal distance. In this paper, the analysis is focusing on two normal IC flashes that accompanied by IECs process with VHF impulses electric field radiation on November 23rd, 2017 located at Malacca, Malaysia.

## II. DATA AND INSTRUMENTATION

The observation of VHF emission from IC flashes was made from a single observation (OS) hosting with fast and slow electric field antenna systems with decay time constant of 13 ms and 1 s [3-6] and a VHF sensor (bandwidth 40-80 MHz) with centre frequency of 60 MHz. The OS is located at Universiti Teknikal Malaysia Melaka (UTEM), Malacca, Malaysia (2.314077° N, 102.318282° E). The length of the coaxial cable for fast and slow electric field antenna systems were set at 10 meters and for the VHF sensor 5 meters cable was connected to the oscilloscope.

## III. RESULTS AND DISCUSSION

### *A. The detection of VHF E-field impulses before the onset of IECs*

Based on the results, we found that two samples of normal IC flashes (with record number Nov_67 and Nov_68) within reversal distance were accompanied by VHF E-field emissions on November 23rd, 2017 as shown in Fig. 1 and Fig. 2.

Based on this observation, the VHF impulses were detected earlier than the onset of IEC by 12.69 and 251.60 µs, respectively. Besides that, the number of VHF impulses

for the first sample (Nov_67) was 89 VHF impulses. Fig. 1 shows that 16 of the VHF impulses were detected before the onset of IEC followed by 73 VHF impulses during period of IEC to the first IB pulse. On the other hand, the same pattern can be observed for the second normal IC flash (Nov_68) where the 2 VHF impulses also detected before the IEC onset and followed by 65 VHF impulses detected during the period of IEC.

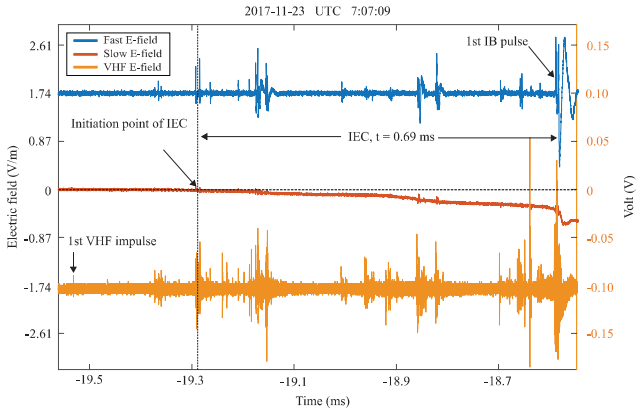


Fig. 1. The Initial Electric Field Change (IEC) in normal Intracloud (IC) flash accompanied by Very High Frequency (VHF) impulses (physic sign convention; within reversal distance) captured by our lightning sensor in Malacca at 7:07:09 UTC on November 23rd, 2017.

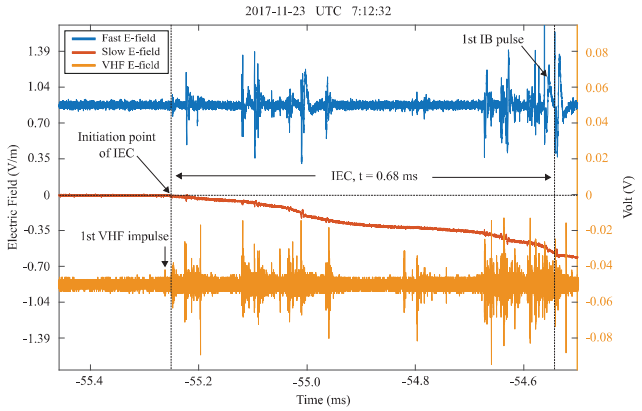


Fig. 2. The IEC in normal IC flash accompanied by V HF impulses (physic sign convention; within reversal distance) captured by our lightning sensor in Malacca at 7:12:32 UTC on November 23rd, 2017.

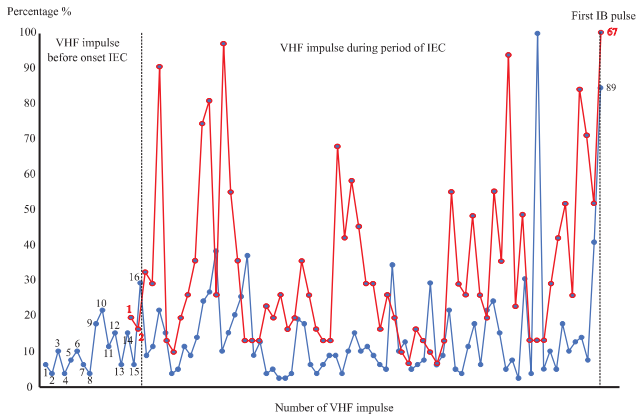


Fig. 3. The temporal development of VHF impulses for two normal IC flashes. The blue plot is for the first IC flash (Nov_67) captured on November 23rd, 2017 at UTC 7:07:09 and the red plot is for the second IC flash (Nov_68) captured on November 23rd, 2017 at UTC 7:12:32.

From this finding, it shows that VHF impulses were detected earlier than IECs in the IC flashes. By comparing our finding from tropical storm to the Florida storms [1, 2], the authors found that the first VHF impulse was detected on the onset of the IEC and not before. Our finding is a breakthrough where we can suggest that VHF impulses are the first moment of lightning initiation and not IEC as suggested in [1, 2].

### *B. Small pulses prior to the onset of IECs and during the period of IECs*

We also found that there are several small pulses (based on fast field record) detected within the period of IECs and before the onset of IECs for IC flash (Nov_67) with 5 small pulses were detected before the onset of IEC and 25 small pulses were detected during IEC as shown in Fig. 4. For the second normal IC flash (Nov_68), there is no small pulses detected before the onset of IEC and all 29 small pulses were detected during the IECs process.

These pulses temporal characteristics show that it is similar to weak NBE [7] because of the small amplitude and pulse duration less than the criteria of IB pulse [1]. These pulses were detected with both polarity either positive or negative (within reversal distance) and it seems to be similar to weak NBEs for fast positive (FPB) or fast negative breakdowns (FNB) [8].

For the first IC flash (Nov_67), the average of pulse duration, zero crossing time and the peak amplitude for positive pulses are 1.77 µs, 0.80 µs and 1.62 V/m, respectively. While for the negative polarity with 1 small pulse, the mean of pulse duration, zero crossing time and peak amplitude are 0.28 µs, 0.12 µs and -0.28 V/m, respectively.

For the second normal IC flash (Nov_68), 16 small pulses with positive polarity and 13 with negative polarity were detected as shown in Fig. 5. There are no small pulses were detected before the onset of IECs. The average of pulse duration, zero crossing time and the peak amplitude for positive pulses are 1.80 µs, 0.62 µs and 1.41 V/m, respectively. While for the negative polarity with 1 small pulse, the mean of pulse duration, zero crossing time and peak amplitude are 1.22 µs, 0.57 µs and -2.88 V/m, respectively.

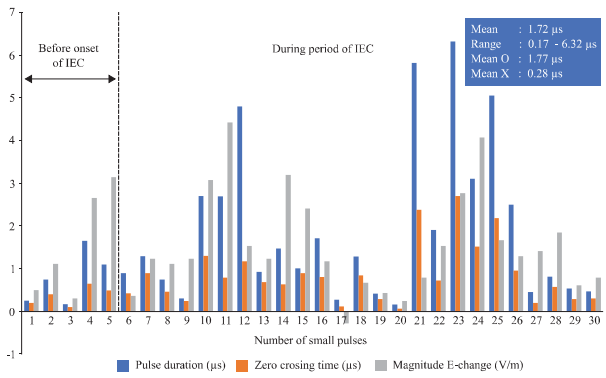

Fig. 4. The small pulses detected before the onset of IEC and during the period of IEC for IC flash (Nov_67) captured by lightning sensor in Malacca. The label 'O' for referring positive polarity while 'X' for negative polarity. The blue bar is pulse duration, orange bar for zero crossing time and grey bar for magnitude of E-field change.

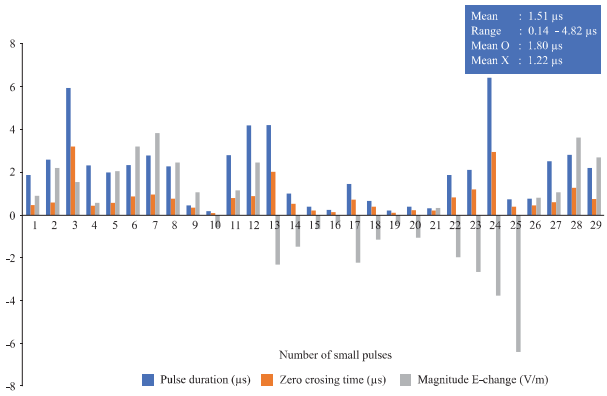


Fig. 5. Pulses of weak or small pulses that detected during the period of IEC for IC flash (Nov_68) capture by lightning sensor in Malacca. The label 'O' for referring positive polarity while 'X' for negative polarity. The blue bar is pulse duration, orange bar for zero crossing time and grey bar for magnitude of E-field change.

## IV. Conclusion

In this paper, we have observed an IEC process in two normal IC flashes accompanied by VHF impulses from a tropical thunderstorm in Melaka, Malaysia. The duration of the IECs range between 0.68 and 0.69 ms and the magnitude of IECs are range between 0.18 and 0.50 V/m. The VHF E-field emissions have been detected before the onset of IEC. Therefore, this is a strong evidence that lightning is initiated by a series of VHF emissions rather than initiated by IEC.

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## References

[1] Marshall, T., et al. "Electromagnetic activity before initial breakdown pulses of lightning." Journal of Geophysical Research: Atmospheres 119.22 (2014).

[2] Chapman, Ryan, et al. "Initial electric field changes of lightning flashes in two thunderstorms." Journal of Geophysical Research: Atmospheres 122.7 (2017): 3718-3732.

[3] Ahmad, M. R., Esa, M. R. M., Cooray, V., & Dutkiewicz, E. (2014). Interference from cloud-to-ground and cloud flashes in wireless communication system. Electric Power Systems Research, 113, 237-246.

[4] Esa, M. R. M., Ahmad, M. R., & Cooray, V. (2014). Wavelet analysis of the first electric field pulse of lightning flashes in Sweden. Atmospheric research, 138, 253-267.

[5] Ahmad, M. R., Esa, M. R. M., Cooray, V., Baharudin, Z. A., & Hettiarachchi, P. (2015). Latitude dependence of narrow bipolar pulse emissions. Journal of Atmospheric and Solar-Terrestrial Physics, 128, 40-45.

[6] Ahmad, M. R., Periannan, D., Sabri, M. H. M., Aziz, M. Z. A. A., Lu, G., Zhang, H., ... & Cooray, V. (2017, August). Emission heights of narrow bipolar events in a tropical storm over the Malacca Strait. In Electrical Engineering and Computer Science (ICECOS), 2017 International Conference on (pp. 305-309). IEEE.

[7] Rison, W., Krehbiel, P. R., Stock, M. G., Edens, H. E., Shao, X. M., Thomas, R. J., ... & Zhang, Y. (2016). Observations of narrow bipolar events reveal how lightning is initiated in thunderstorms. Nature communications, 7, 10721.

[8] Krehbiel, P. R., (2017). Narrow bipolar events and lightning initiation. Abstract presented at ISLPM 2017,Beijing, China.

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