THE IMPACTS OF HF AND VHF RADIATION TOWARDS PRELIMINARY BREAKDOWN EVENTS IN LIGHTNING FLASHES

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ABSTRACT: Even though the mechanisms pertinent to the generation of radiation in frequency range above 3 MHz (HF and VHF radiation) are not well understood, it is thought that this radiation is caused by the electrical breakdown of virgin air rather than by the high current pulses propagating in pre-existing channels. The data presented in this paper also show that more HF radiation (3 MHz) is generated during preliminary breakdown processes taking place inside clouds (probably associated with breakdown of virgin air) than during the subsequent return strokes that propagate along conducting channels. Moreover, we also observe that VHF radiation (30 MHz) only from Preliminary Breakdown (PB) events.

KEYWORDS: *HF Radiation; VHF Radiation; Preliminary Breakdown Event; Lightning Flashes*

1.0 INTRODUCTION

Lightning negative ground flashes are the most studied events of all the other lightning events. These events have thus far, been most understood and established events. Majority of the negative ground flashes are initiated within the cloud mostly between the main negative charge center and the lower positive charge region (LPCR). The initiation within the cloud often called initial breakdown (IB) or

Preliminary Breakdown (PB) process, is accompanied by the large microseconds scale pulses. The strength of these initial events and the corresponding amplitude of the microseconds scale are viewed to be the function of strength of LPCR [1-2]. Many features of the lightning events have been studied with the help of electric field produced by it, whether by sensing it with the wide bandwidth measurement systems or narrow bandwidth measurement system. Although, there are several works in the past on the simultaneous measurement of the wideband and narrowband, most of them were on the negative return stroke which are considered to be the strongest of all events. Lightning elctromagnetic fields, particularly in the frequency range from one to ten MHz, are the major frequency wavelength to the natural resonance of structures [3]. The most impacful event in lightning ground flashes is return stroke which is give the strongest sources of radiations of ground flashes from the low-frequency (LF) range below 300 kHz [3]. In addition, knowledge of these radio frequency (RF) radiation especially return stroke event in lightning can contributes in our understanding of the physical processes generated by lightning discharges.

The study of RF frequency also can contributes to the development of remote sensing techniques and the development of ligning location devices. This can see from the electric field measurement campaign which is studied the electromagnetic fields radiation produced by a number of severe storms and tornadoes at several certain frequencies in the range from one to ten MHz [4]. The findings of this work stated that the numbers of occurrence radio noise burst at frequencies around 3 MHz can be used as an indicator of Tornado activity. Year by year the revolution techniques were used to calculate High frequency and very high frequency signal such as Fourier Transform method, filter system and tuning circuit. A narrowband RLC tuned circuit was successfully used as HF measurement method by several researchers such as [5-6]. To the best of our knowledges, the same method was used in this study to detect HF radiation. But, the measurement made simultaneously with broadband electric field signal and very high frequency filter circuit.

The first event in lightning flashes is the preliminary process. Preliminary breakdown or also known as initial breakdown event generated by a ground lightning flash produces a pulse train with scales a microsecond-scale electric pulses duration. The event can be followed with leader or without leader inside cloud [2]. The features of PB pulse trains included the duration of pulse width , zero crossing times and electric field peak ratio in negative cloud-to-ground flashes have been reported by [7-14]. These pulse trains may provide information concerning the first event that led to the electrical breakdown in the cloud. This can answer the questions how the lightning initiated inside cloud. The fact shows that the differences in the PB pulse trains in different geographical regions may figure the signature of initial breakdown processes in the clouds [2]. The signature of initial breakdown can explain the physical process especially the way of lightning initiated at the differences region. Several researcher found that preliminary breakdowns produced strong HF radiation inside cloud by [2-3, 15]. This can be done through electric field pulse signature and statiscal analysis through electric field peak ratio. Futhermore, Ismail et al. [2] found that the initial breakdown process is stronger at higher latitude in Sweden rather than in lower latitude such as in Malaysia and Sri Lanka.

To the best of our knowledge, the information about HF and VHF radiation from the preliminary breakdown still in an open discussion. In this paper, a comparative analysis from different geographical region of the electric field radiation at wide band and narrow band systems (over HF and VHF) has been carried out.

2.0 MEASUREMENT TECHNIQUE

All observations presented here were from Uppsala, Sweden (59.837º, 17.646º). From measurement campaign that was carried out in the summer 2014, 98 flashes detected together high frequency radiation and 8 flashes detected together with High Frequency (HF) and Very High Frequency (VHF) radiations have been analyzed in this study. Three parallel plate antennas were employed to sense the electric field by lightning. One antenna was connected to the broadband circuitry with 15 ms decay-time constant. The other two antennas were connected to the narrowband circuitry tuned at 3 MHz (HF) and 30 MHz (VHF). The output of the antennas were fed to the Yokogawa. DSO and digitized at rate at the rate of 100 MS/s with a resolution of 12 bits. Data were recorded for 250 ms at the above rate which was the limitation of the digitizer .The timing for each event was provided by a global positioning system (GPS). The distance of the negative ground flashes from measurement station were estimated by using Swedish location data network (LLN) where the range of distance was estimated to be from 7 km to 100 km. The antenna system used in this study can also be found in [2,17]. Measurements in Sweden were conducted between June and July 2014.

3.0 RESULTS AND ANALYSIS

In this study, a comparative study of the strength of the electric field produced by the preliminary breakdown pulses and that of the succeeding first return stroke is carried out for both wide band and narrow band signals. Table 1 shows the statistics of the data analyzed. The arithmetic mean, the geometric mean, and the standard deviation of the ratios of peak PB to RS are obtained to be 0.706, 0.467 and 0.775 respectively, for the wide band electric field. Whereas, the minimum and maximum values of the ratios are observed as 0.032 to 5.996, respectively.

In order to minimize any role of the noise in the electric field measurement we have also analyzed the ratio of noise similar to what was done by [14]. The arithmetic mean and geometric mean of the ratio of noise amplitude to the return stroke (N/RS) at measuring site were found to be 0.021 and 0.013, respectively. Important to mentioned that, the minimum PB/RS ratio measured in the study is greater than the mean of N/RS by an approximate factor of 33.6 from which conclude that the surrounding and environmental noise has not affected the results significantly.

The statistics of the ratio of the maximum amplitude of the PB pulse train to the amplitude are also shown in Table 1. The following return stroke received at the frequencies of 3 MHz (HF) and 30 MHz (VHF). From the Table 1, it can be observed that the arithmetic mean, geometric mean and standard deviation for the ratio of amplitudes at HF are 1.92, 1.56 and 1.46, respectively from 98 flashes with the range of ratio from 0.063 to 11.19. Whereas, arithmetic mean, geometric mean and standard deviation of the ratio of the maximum amplitude of PB train to the amplitude of succeeding return stroke at VHF are found as 1.39, 1.26 and 0.65 respectively from 8 flashes. The range of ratio at VHF was observed to be from 0.56 to 2.44. However, noise to RS ratio at HF is high (arithmetic mean and geometric mean is 0.19 and 0.13 respectively) while considering the amplitude of the pulse twice from the noise. For VHF, on the other hand only 8 flashes were selected that had larger amplitudes than the noise. The arithmetic mean and geometric mean noise to return stroke ratio for the selected flashes were 0.36 and 0.35 respectively. Sample of PB peak at different frequencies in Sweden and PB single pulse together with HF frequency signal is depicted in Figure 2.

We have compared the results obtained earlier by [16] in Sweden, [12] in Finland, [13] in Florida and [14] in Malaysia also results obtained from this study for narrowband in Table 1. The observations in temperate regions such as in Sweden (59.837^{0}N) and Finland (60.4^{0}N) indicate that the average PB to RS ratio is relatively high in higher latitudes (Sweden) compared to lower latitude (Malaysia). The research reported by [13] in Florida (30^{0}N) also similar to that of two studies. This statement was supported by High Frequency analysis which giving high ratio than Broadband almost factor of 2.72 and interestingly to compare Very High Frequency analysis which is 8 flashes have PB to RS peak ratio higher than broadband ratio in Sweden with factors of 1.96. Figure 1 shows that the trend of peak PB ratio to peak RS ratio which indicate that HF and VHF radiation is dominant than wide band radiations at high latitude. On the other hand, as the latitude decreases or toward closer to equatorial region, the mean of the PB to RS ratio also decreases.

Table 1: The electric field peak ratio (preliminary breakdown to return stroke peak)

Location	Freq. Type	No of flash	PBP/RS ratio (Electric field amplitude)						N/RS ratio	
			Arith. Mean	Geometric Mean	Minimum	Maximum	Std deviation	Median	Arith. mean	Geometric mean
Present study (Sweden) 59.837° [17]	Wide Band	98	0.706	0.467	0.032	5.996	0.775	0.472	0.021	0.013
	3MHz	98	1.92	1.56	0.063	11.19	1.46	1.50	0.19	0.13
	30MHz	8	1.39	1.26	0.56	2.44	0..65	1.30	0.36	0.35
Malaysia 1° North Baharudin et al. [14]	Wide Band	97	0.278	0.146	0.026	2.281	0.422	0.122	0.07	0.06
Florida 27° (North) Nag and Rakov [13]	Wide Band	100	0.294	0.223	0.029	1.49	0.236	0.215	0.023	0.02
Florida 30° (North) Nag and Rakov [13]	Wide Band	59	0.62	0.45	0.16	5.10	-	-	-	-
Finland 60.4° (North) Mäkelä et al. [12]	Wide Band	193	0.61	0.25	1.0	6.10	-	-	-	-
Sweden 59.8° Gomes and Cooray [11]	Wide Band	41	1.01	0.485	0.083	6.27	-	-	-	-
Sri Lanka 6.9° Cooray and Jayaratne [10]	Wide Band	9	0.165	0.146	0.062	0.264	-	-	-	-

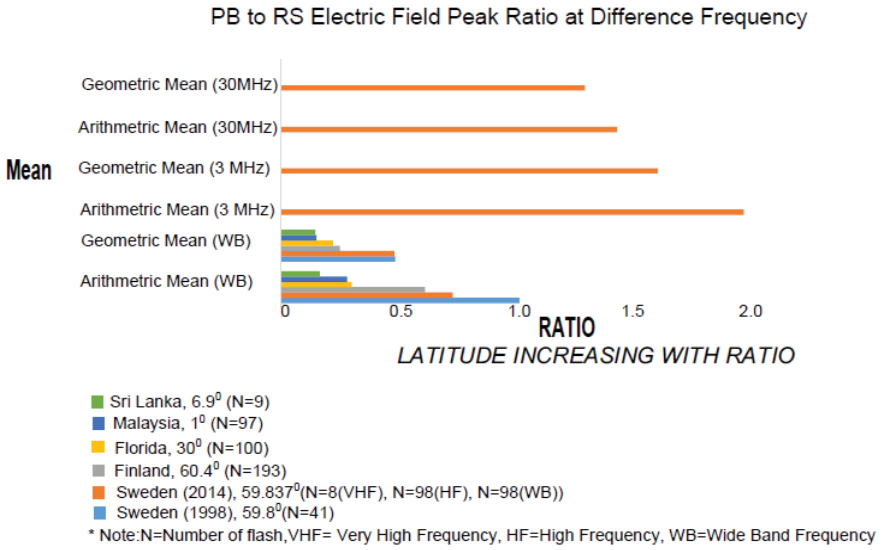
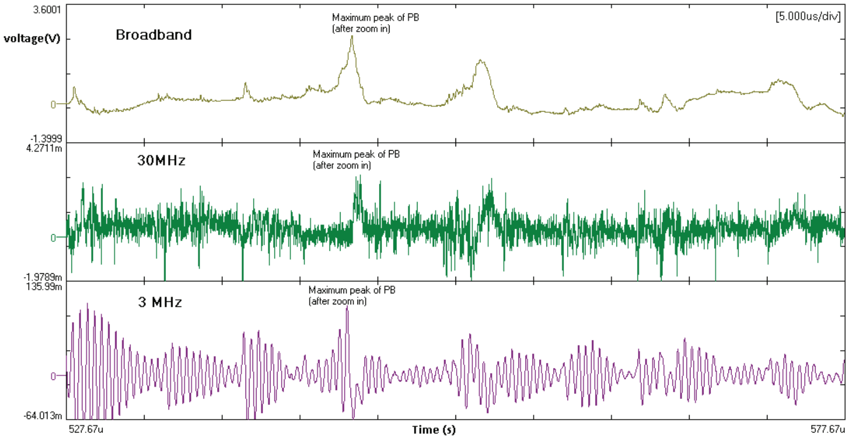
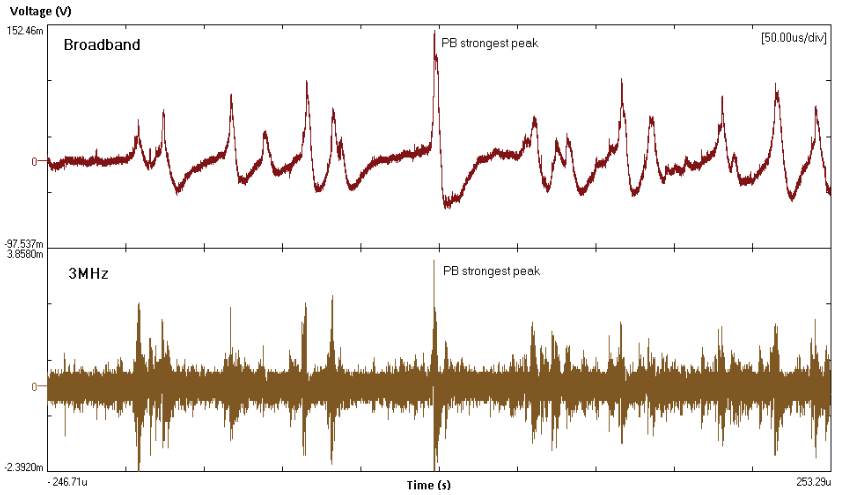


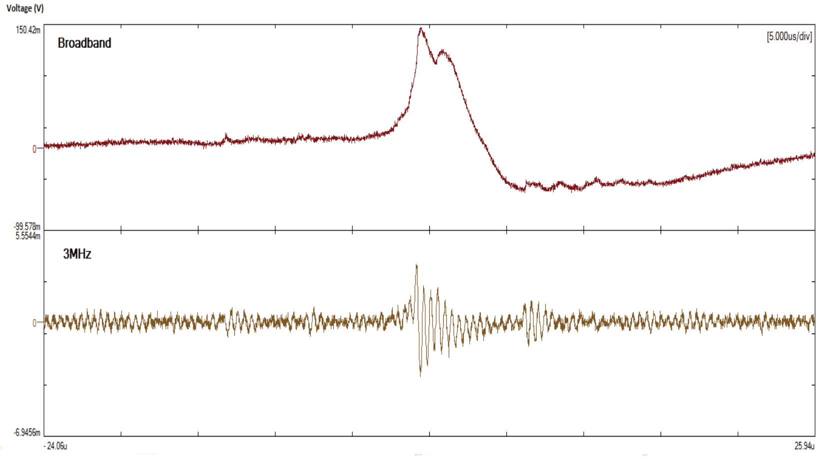
Figure 1: The statistical trend (geometric mean) of Preliminary Breakdown (PB) to RS ratio at difference frequency



(a)



(b)



(c)

Figure 2: (a) Negative cloud- to- ground flash pulse train together with HF frequency and VHF frequency, (b) A sample of a PB (Broadband and High Frequency) peak and (c) A single PB peak pulse after zoom in

4.0 DISCUSSION

In this study, a comparison of these events from different locations and a comparative study of HF and VHF radiations by the PB events and succeeding return strokes have been carried out. From the present analysis, it can be summarized that:

i. With the increase in latitude the strength of the PB pulses increases.
ii. The PB events pertinent to the temperate region radiate strong electric field both at wide band and narrow band (at HF and VHF).

The results of present study are comparable with those of previous studies to further support that the PB pulses are stronger than the following return strokes and further establishes the view that the strength of PB increases with the increase in latitude. The present study further verifies that the PB events are the strong radiators at HF and VHF as compared to that of return strokes over the temperate region. This is an indication of the fast and stronger discharges within the cloud and hence the indication of the strong LPCR in the temperate region.

This analysis strongly supports the argument by [1] and [10] which is at high latitude the more PB pulse train detectable from lightning discharges due to the larger or stronger lower positive charge region (LPCR) than main negative charge center. If this argument is acceptable, ground corona process increases the positive charge in the cloud below the negative charge center. The larger strength of HF radiation and VHF radiations at higher latitude can be viewed as the presence strong LPCR and fast neutralization process. This process may lead to high ground flash densities. The presence of strong LPCR can also result in the complete neutralization of the charge residing in the negative charge center and hence culminating in an isolated breakdown pulses as were reported by Sharma et al. [18].

In addition, the peak ratio of HF radiation of preliminary breakdown to return stroke is larger than one. However, Ismail et al. [2] presented the peak ratio of HF radiation of subsequent return stroke to return stroke is mostly less than one. From the both findings with different events confirmed that the more HF radiation (3 MHz) is generated during preliminary breakdown processes taking place inside clouds (probably associated with breakdown of virgin air) than during the subsequent return strokes that propagate along conducting channels.

Moreover, we also observe that VHF radiation (30 MHz) only from Preliminary Breakdown (PB) events. Therefore, HF radiation and VHF radiation validate the wideband measurement findings where Preliminary Breakdown events are stronger electromagnetic field radiation generated by lightning flashes.

5.0 CONCLUSION

A statistical comparison of our measurement with those obtained earlier in Sri Lanka, Malaysia, Florida and Finland give strongly validation that the PB pulse to RS is higher in the temeperate regions compared to the tropical region at wideband with supported by HF and VHF analysis. The result of comparative study depend on metrological conditions, region, latitude effect, altitude of cloud and temperature to explain physical process of ground flash pulse characteristics. In our study, we could observe 30 MHz only from PB. This can concluded that, the radiation at 30 MHz and above can occur at virgin air rather than high current pulses in pre-existing channel.

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