Faculty of Electronic and Computer Engineering

TEMPORAL CHARACTERISTICS OF MICROWAVE RADIATIONS EMITTED BY NARROW BIPOLAR EVENTS IN TROPICAL THUNDERSTORMS

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A thesis submitted
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DECLARATION

I declare that this thesis entitled "Temporal Characteristics of Microwave Radiations Emitted by Narrow Bipolar Events in Tropical Thunderstorms" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……..…

Name : Seah Boon York

Date : ……..…

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electronic Engineering.

Signature : ……

Supervisor Name : Dr. Mohd Riduan Bin Ahmad

Date : ……

DEDICATION

Gratitude towards the past of myself for all the time and effort had been spent;

Thanks for the supports from my parents;

Thanks, God, for granting me the opportunity to collect data from the thunderstorms;

Along the journey of completing this thesis.

ABSTRACT

A lightning flash starts with the very first process called electron avalanche followed by streamer and leader. Each process has their own peaked frequency band, such as the leader is peaked between Very Low Frequency (VLF) and Low Frequency (LF) bands while streamer is peaked at Very High Frequency (VHF) band. However, the peak frequency band of electron avalanche cannot be determined with certain. There are two postulations regarding the peak frequency of electron avalanche. First postulation suggests that electron avalanche peaked at VHF band while the second suggests electron avalanche peaked in microwave band. All simulation results suggest that electron avalanche emits strong microwave radiations. On the other hand, all experimental works were more focus on the characteristics of microwave radiation for each lightning event such as initial breakdown and return stroke rather than investigating whether microwave radiation emitted by electron avalanche or not. The significance of this project was the contribution of the new knowledge in lightning initiation by designing a microwave receiver and distinguishing the difference between microwave and VHF radiations emitted by lightning flashes. As the streamer is preceded by electron avalanche, detecting microwave radiation before the onset of VHF could be used as a method to prove that electron avalanche emits strong microwave radiation. In this thesis, microwave radiations associated with Narrow Bipolar Events (NBEs) have been chosen to analyze the onset time of both microwave and VHF radiations. In order to detect the microwave radiation, a finite-length and small air-gap parallel plates antennas with resonance frequency around 1 GHz were designed and fabricated. Then, the temporal characteristics of these microwave waveforms were analysed and compared to their corresponding VHF and LF/VLF waveforms. A total of 74 NBEs accompanied by the VHF and microwave radiations have been recorded and analysed. Microwave radiations of 16 NBEs were found to lead VHF and fast antenna (LF/VLF) records with lead time of 125.53 ± 81.32 ns and 600.65 ± 222.34 ns, respectively. Both burst trains of VHF and microwave radiations are consisting of Rising Phase (RP) and Damping Phase (DP). A total of 21 microwave and 22 VHF waveforms were found to have Initial Stage (IS) at the earlier part of the RP with clear bipolar shape waveform. Moreover, 27 VHF burst trains consist of a kind of unique temporal characteristic named as Quiet Phase (QP) where VHF radiation was absent, which was not found in any microwave radiations. This might be the transient period for the electron avalanche at a streamer tip delayed due to the attachment factor, β in the electron avalanche process was same as the ionizing factor, α before turning into a complete streamer. To conclude, the findings in this thesis not only prove that there was a process/mechanism (electron avalanche) that intensively emitted microwave radiation and different from the propagating streamer (which is peaked at VHF band), but also justify that the electron avalanche does not peak at the same frequency band as the propagating streamers.

ABSTRAK

Kilat bermula daripada proses longsor elektro, diikuti dengan penjurus dan pemimpin. Setiap proses tersebut akan menghasilkan radiasi dalam spektrum frekuensi masing-masing. Sebagai contoh, gelombang penjurus berpuncak pada spektrum frekuensi sangat tinggi (VHF) manakala puncak frekuensi pemimpin terjatuh dalam lingkungan antara frekuensi sangat rendah (VLF) dan frekuensi rendah (LF). Namun, spektrum puncak frekuensi bagi longsor elektro tidak dapat ditentukan sehingga hari ini. Terdapat dua pendapat yang berbeza untuk puncak frekuensi yang dihasilkan oleh longsor elektro. Pendapat pertama menyatakan bahawa ia memuncak pada spektrum VHF manakala pendapat kedua pula mencadangkan longsor elektro memuncak pada spektrum gelombang mikro. Pelbagai hasil kerja simulasi telah menunjukkan longsor elektro menghasilkan radiasi gelombang mikro yang amat kuat. Di samping itu, semua ujikaji lebih fokus pada mengkaji ciri-ciri gelombang mikro untuk setiap kejadian kilat seperti keruntuhan awal dan lejang kembali daripada mengenalpastikan betulkah radiasi gelombang tersebut terhasil oleh longsor elektro atau sebaliknya. Kepentingan projek ini ialah menyumbangkan ilmu baru dalam bidang fizik kilat dengan merekabentuk antena gelombang mikro dan membezakan sifat antara radiasi gelombang mikro dangan VHF yang terhasil daripada pancaran kilat. Penjurus merupakan kejadian selepas longsor elektro. Justeru, pengkajian tentang masa permulaan antara radiasi gelombang mikro dan VHF dapat membuktikan longsor elektro memuncak pada spektrum frekuensi gelombang mikro atau VHF. Dalam tesis ini, radiasi gelombang mikro yang terhasil daripda kejadian kilat sempit dwi-kutub (NBE) telah dipilih untuk perbandingan masa permulaan kedua-dua gelombang mikro dan radiasi VHF. Antena kecil dan antena plat selari terhingga dengan frekuensi resonasikannya sekitar 1 GHz telah direkabentuk untuk mengesan radiasi gelombang mikronya. Kemudian, ciri-ciri bentuk gelombang mikro ini akan dibandingkan dengan bentuk VHF dan LF / VLF masing-masing. Sebanyak 74 sampel NBEs telah dikaji dengan radiasi VHF dan gelombang mikronya. Terdapat 16 sampel NBEs didapati bahawa gelombang mikronya telah wujud sebelum radiasi VHF dan VLF/ LF dapat dikesan. Gelombang mikro tersebut mengetuai radiasi VHF sebanyak (125.53 ± 81.32) ns dan radiasi VLF/ LF sebanyak (600.65 ± 222.34) ns. Sampel yang selebihnya sama ada dimula dengan radiasi VHF ataupun VLF/ LF. Kedua-dua bentuk gelombang VHF dan gelombang mikro terdiri daripada dua komposisi, iaitu Fasa Peningkat (RP) dan Fasa Penurunan dengan nisbah 1:2 secara umumnya. Satu sifat unik yang hanya boleh didapati dalam sesetangah bentuk gelombang VHF dikenali sebagai Fasa Senyap, di mana ia tidak dapat dikesan dalam mana-mana bentuk gelombang mikronya. Hal ini mungkin disebabkan olah waktu pertukaran dari longsor elektro kepada penjurus telah dipertangguhkan. Kesimpulannya, penemuan-penemuan tersebut bukan sahaja telah menunjukkan bahawa terdapatnya suatu proses yang menghasilkan radiasi gelombang mikro dan mekanisma yang berbeza daripada penjurus/ korona, bahkan juga membuktikan bahawa puncak frekuensi terhasil daripada proses longsor elekton tidak terletak dalam lingkungan VHF seperti penjurus.

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LIST OF ABBREVIATIONS

BNC	-	Bayonet Neill–Concelman
BPF	-	Bandpass filter
CAPPI	-	Constant Altitude Plan Position Indicator
CID	-	Compact Intra-cloud Discharge
CG	-	Cloud-to-Ground
CPT	-	Chaotic pulse train
CST	-	Computer Simulation Technology
dB/dt	-	Time derivative magnetic field
dE/dt	-	Time derivative electric field
DP	-	Damping phase
d_{rev}	-	reversal distance
FA	-	Fast electric field antenna
FB	-	Fast Breakdown
FNB	-	Fast Negative Breakdown
FPB	-	Fast Positive Breakdown
FR4	-	Flame Retardant 4
IB	-	Initial breakdown
IC	-	Intra-cloud
IS	-	Initial stage
LF	-	Low Frequency
LNA	-	Low noise amplifier
MMD	-	Malaysia Meteorological Department
NBE	-	Narrow Bipolar Event

PCB - Printed circuit board

PD - Pulse duration

PTD - Pulse train duration

QP - Quiet phase

RT - Rise time

RP - Raising phase

SMA - SubMiniature version A

TPTD - Total pulse train duration

UHF - Ultra High Frequency

VHF - Very High Frequency

VLF - Very Low Frequency

ZCT - Zero-crossing time

+CG - Positive Cloud-to-Ground

+NBE - Positive Narrow Bipolar Event

-CG - Negative Cloud-to-Ground

-NBE - Negative Narrow Bipolar Event

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