WAVELET ANALYSIS OF THE ONSET OF VHF AND MICROWAVE RADIATION EMITTED BY LIGHTNING

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DEDICATION

Dedicated to my beloved families that love and support me unconditionally; to my supervisor that guides me regardless; to all my teammates and friends that stay beside me and most especially to Allah SWT The Almighty and Most Merciful.

ABSTRACT

Lightning flash is an electrical discharge in air (dielectric breakdown) which emits electromagnetic (EM) fields across very wide spectra from a few Hertz up to visible wavelength. Electrical breakdown process is an important event that initiates lightning. For electrical breakdown process to occur, it must fulfill two conditions which are at least has one free electron and the electric field region is more than 3 MV/m. This process starts with electron avalanche in millimeter scale then grows into streamer in centimeter scale. Lastly, from streamer it will grow into leader in meter scale. It has already established that streamer emits intensely at Very High Frequency (VHF) band as it's already proven both theoretically and experimentally. A study by Cooray and Cooray (2012) theoretically proved that emission of electron avalanche peaks at microwave band. Air-gap parallel plate antenna which could operate at 1 GHz with remote sensing is designed and simulated to measure the microwave radiation emitted by lightning. Both temporal and wavelet analyses are used to compare the onset of microwave radiation and VHF radiation in both time and frequency domains to determine electron avalanche appears at which electromagnetic band.

ABSTRAK

Kilatan petir adalah pelepasan elektrik di udara (pecahan dielektrik) yang memancarkan medan elektromagnetik (EM) di seluruh spektrum yang sangat luas dari beberapa Hertz hingga panjang gelombang yang boleh dilihat. Proses pemecahan elektrik adalah peristiwa paling penting yang memulakan kilat. Untuk proses pemecahan elektrik berlaku, ia mesti memenuhi dua syarat iaitu sekurang-kurangnya mempunyai satu elektron bebas dan rantau medan elektrik melebihi 3 MV/m. Proses ini bermula dengan runtuhan elektron dalam skala milimeter kemudian berkembang menjadi pelapis dalam skala sentimeter. Akhir sekali, dari pelapis ia akan berkembang menjadi pemimpin dalam skala meter. Ia telah menegaskan bahawa pelapis melepaskannya dengan kuat pada band VHF kerana ia telah terbukti secara teoritis dan eksperimen. Penyelidikan oleh Cooray dan Cooray (2012) secara teorinya membuktikan bahawa puncak gelombang runtuhan electron ialah di gelombang mikro. Antena plat selari udara yang boleh beroperasi pada 1 GHz dengan penginderaan jauh direka dan disimulasi untuk mengukur radiasi gelombang mikro yang dipancarkan oleh kilat. Kedua-dua analisis temporal dan wavelet digunakan untuk membandingkan permulaan sinaran gelombang mikro dan radiasi VHF dalam domain masa dan kekerapan untuk menentukan longkang runtuhan elektron muncul di jalur elektromagnet yang mana.

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LIST OF SYMBOLS AND ABBREVIATIONS

CC	:	Cloud to cloud
CG	:	Cloud to ground
CF	:	Cloud flash
IC	:	Intra cloud
NBE	:	Narrow bipolar event
FF	:	Fast field
HF	:	High frequency
VHF	:	Very high frequency
MW	:	Microwave
LNA	:	Low noise amplifier
CST	:	Computer simulation technology
UTM	:	University Technology Malaysia
UTeM	:	University Technical Malaysia Malacca
E field	:	Electric field
B field	:	Magnetic field

STEPS	:	Severe storm Electrification and Precipitation Study
UHF	:	Ultra-high frequency
h	:	Height
R	:	Resistor
C	:	Capacitor
RF	:	Radio frequency

CHAPTER 1

INTRODUCTION

1.1 Background

A sudden electrostatic discharge that caused by imbalances between clouds and the ground or within the clouds themselves can cause lightning. Basically, lightning flashes could be divided into 3 types based on the movement and direction of electrical charges namely positive cloud-to-ground flash (+CG), negative cloud-to-ground flash (-CG) and Cloud Flash (CF). For CF, it can be divided further into 2 subtypes: narrow bipolar event (NBE) flash and intra-cloud (IC) flash.

Electrical breakdown process that initiates lightning consists of three stages. It starts with electron avalanche which operates at microwave radiation band in millimeter scale. Next, fusion of many electron avalanches grow into streamers which we believe operates at Very High Frequency (VHF) radiation in centimeter scale. After that, streamers grow and develop to become leaders in meter scale which at this state, we could observe it with our naked eyes.

Wavelet technique is used to compare the onset of microwave radiation and VHF radiation in both time and frequency domains to get precise and accurate results. Comparison is made to determine which frequency band the electron avalanches appear. Besides, comparison also could be done between wavelet and temporal analysis to see if the results matched for more accuracy. All the data is obtained from the setup of antenna, bandpass filter, Low Noise Amplifier (LNA) and buffer circuit in high voltage lab which we generate spark that mimic the natural lightning flash.

1.2 Problem statement

There are still many undefined and unproven theories about lightning and research is still on going. It is very important to fully understand mechanism of lightning so that we can be prepared from any destruction caused by lightning. As we know, taller buildings usually have chances of being attacked by this very high voltage of electricity coming from the cloud and some case, same building can be attacked by lightning as many as 54 times in 84 minutes like Toronto CN Tower [1].

Electrical breakdown process is the main mechanism that initiates lightning. This process starts with electron avalanche, streamer then leader. For this process to occur, it must meet two requirements which are must at least have one free electron and the electric field region is more than 3 MV per meter. Electron avalanche starts with one free electron then collide with another electron and grows in millimeter scale. Then, electron avalanche grows into streamer in centimeter scale. Streamer then grows into leader in meter scale. Leader is the lightning that we could observe with our naked eyes.

Streamer is already theoretically and experimentally proven happens at VHF band while electron avalanche only theoretically proven happens at microwave band. The problem of this project is driven by two school of taught which are;

i. Electron avalanche and streamer emitted intensely in VHF band

ii. Electron intensely emits in microwave band alone

So, the main research question is: Is it true electron avalanche emitted simultaneously with streamer or at microwave radiation only?

1.3 Objectives

The objectives of this thesis are:

- To design and simulate a parallel plate antenna that could work with a microwave sensor which consists of LNA and bandpass filter that suitable for sensing application with center frequency 1 GHz antenna.
- Next, to capture lightning electric field radiation component at 1 GHz and 60 MHz.
- Lastly, to analyze and made comparison between the onset of microwave and VHF radiation waveform in both time and frequency domains.

1.4 Scope of work

The research scopes consist of three main parts. The first part focuses on designing and simulating a parallel plate antenna that could work with a microwave sensor which consists of LNA and bandpass filter that suitable for sensing application with center frequency 1 GHz antenna. The process of designing and simulation will be using Computer Simulation Technology (CST) software and format. Performance of the antenna will be observed based on the frequency, bandwidth, radiation pattern and return loss of the antenna. All these four antenna parameters must meet the specification of the 1 GHz antenna requirements so that it will function at maximum performance.

The second scope involves the comparison of the onset of VHF and microwave radiation that emitted by the lightning using wavelet and temporal method. Comparison of the onsets in both time and frequency domains could determine which school of thought is true and proved. But early hypothesis is already come out which I believe that electron avalanches and streamers radiate separately. Electron avalanche intensely operates at microwave radiation while streamer radiates at VHF radiation. To be exact, this hypothesis is already theoretically proven but not experimentally. That's the reason why I make comparison between the two onsets.

The third scope is to identify which frequency band the electron avalanche appears based on the onset of the VHF and microwave radiation. Method used to analyze all the data are temporal and wavelet analysis. All the data is collected from the experiment conducted in the high voltage lab at UTM Skudai. The purpose to use