MEASUREMENT AND CHARACTERIZATION OF VHF SYSTEM FROM LIGHTNING FLASHES

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MEASUREMENT AND CHARACTERIZATION OF VHF SYSTEM FROM LIGHTNING FLASHES

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DEDICATION

I would like to dedicate a year of hard work to my mother Zaliza Ibrahim and my father Fauzi Marzuki for all their moral support and pray to complete this project. Special thanks to my supervisor Profesor Ir. Dr. Badrul Hisham Ahmad and my co-supervisor Dr. Riduan Ahmad who help me with their courage, passion, and moral support for me to complete my project during these two semesters.

ABSTRACT

There are numerous applications of frequency spectrum from 20MHz to 1000MHz in Malaysia. The Malaysian Communications and Multimedia Commission (MCMC) has designated a specific frequency bandwidth for each frequency. So, among all the applications, a specific bandwidth between 20MHz and 1000MHz was chosen to determine whether lightning was present in this frequency range. The objective of this project is to design, setup, and calibrate a VHF radiation system based on the type of lightning flashes identified from the fast electric field waveform. Next, is to analyse the characteristic of VHF electric field radiation such as total pulse duration and amplitude. The scope of study for this project are identifying the type of lightning from lightning flash radiation and understanding the characteristic of the electric waveform that was captured. The project methodology includes setting up the VHF system, collecting the measurement data and analyse the characteristic of the waveform that was captured. At the end, analysis find that, there are lightning captured within selected bandwidth that maybe interrupt the frequency spectrum application in Malaysia. As conclusion, all the objective in this project was achieved and all the finding can be concluded.

ABSTRAK

Terdapat banyak aplikasi spektrum frekuensi dari 20MHz hingga 1000MHz di Malaysia. Suruhanjaya Komunikasi dan Multimedia Malaysia (SKMM) telah menetapkan lebar jalur frekuensi khusus untuk setiap frekuensi. Jadi, antara semua aplikasi, lebar jalur tertentu antara 20MHz dan 1000MHz telah dipilih untuk menentukan sama ada kilat hadir dalam julat frekuensi ini. Objektif projek ini adalah untuk mereka bentuk, menyediakan dan menentukur sistem sinaran VHF berdasarkan jenis pancaran kilat yang dikenal pasti daripada bentuk gelombang medan elektrik pantas. Seterusnya, adalah untuk menganalisis ciri sinaran medan elektrik VHF seperti jumlah tempoh nadi dan amplitud. Skop kajian bagi projek ini adalah mengenal pasti jenis kilat daripada sinaran kilat dan memahami ciri-ciri bentuk gelombang elektrik yang ditangkap. Metodologi projek termasuk menyediakan sistem VHF, mengumpul data pengukuran dan menganalisis ciri bentuk gelombang yang ditangkap. Pada akhirnya, analisis mendapati bahawa, terdapat kilat yang ditangkap dalam lebar jalur terpilih yang mungkin mengganggu aplikasi spektrum frekuensi di Malaysia. Kesimpulannya, semua objektif dalam projek ini tercapai dan semua dapatan dapat disimpulkan.

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LIST OF SYMBOLS AND ABBREVIATIONS

BPF	:	Band Pass Filter
+CG	:	Positive Cloud-to-Ground
-CG	:	Negative Cloud-to-Ground
+NBE	:	Positive Narrow Bipolar Even
-NBE	:	Negative Narrow Bipolar Even
IC	:	Intracloud
UWB	:	Ultra-Wide Band
FKEKK	:	Faculty of Electronic and Computer Engineering
TPD	:	Total Pulse Duration
NBP	:	Narrow Bipolar Pulse
CID	:	Compact Intracloud Discharge
HF	:	High Frequency
IB	:	Initial Breakdown
PBP	:	Preliminary Breakdown Process
RS	:	Return Stroke
SL	:	Step Leader
SIR	:	Stepped Impedance Resonator

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter provides a background of project, explaining basic mechanism of lightning physics in terms of lightning flash and lightning types. This chapter also contain project's problem statement, objectives, project significant, scopes of work, and thesis structure.

1.2 Project Background

One of the most amazing occurrences ever witnessed by humans is the flash of lightning. Many ideas and studies have been conducted throughout the years to determine the nature of lightning flashes and how they occur. Lightning is defined as an electrical discharge in the air that emits electromagnetic waves (EM) in a cross-sectional pattern over a wide frequency range ranging from a few hertz to visible wavelengths [1], [2].

Cumulonimbus clouds, often known as thunderclouds, are a type of convective cloud or cloud system that produces rainfall and lightning [3]. Rainfall is nearly entirely reliant on cumulonimbus clouds in most parts of the world. A typical thunder cloud structure consists of three primary charge regions [4], which is a main positive charge region at the top of the cloud, negative charges in the middle layer of the cloud, and pockets of positive charges in the base layer of the cloud as shown in Figure 1.2[5]

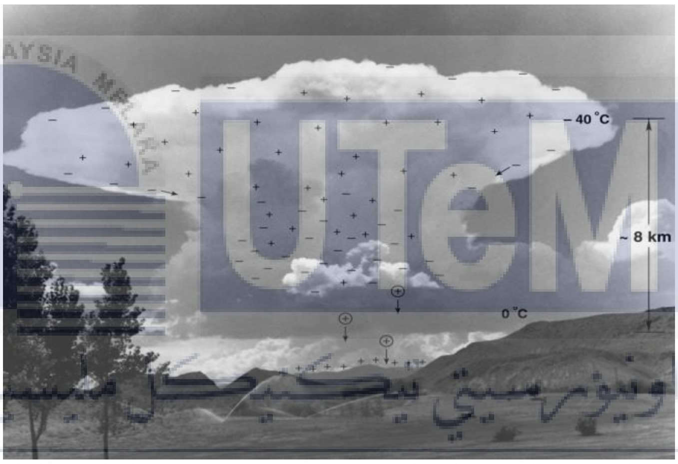

Figure 1.2: Cumulonimbus Cloud Tri-polar Structure[5]

Electrostatic discharge created by imbalances within or between thunderclouds, or between the cloud and the earth, causes lightning to flash. The lightning flash itself will emit electromagnetic radiation. This is due to the fact that, as the charges inside the thundercloud begin to break down, they attempt to construct a pathway or leader for the discharge process, leading the virgin air to act as a conducting channel after the leaders have been completed. The temperature of the air channel will suddenly rise due to the rapid propagation of the charges in a specific direction, resulting in a spectacular flash and thunder [5], [6].

There are just a few sorts of lightning flashes whose characteristics must be studied. Cloud flashes and cloud-to-ground (CG) flashes are the two types of lightning that can occur. Positive cloud-to-ground (+CG) flashes and negative cloud-to-ground (-CG) flashes are the two forms of cloud-to-ground flashes. Ordinary intracloud (IC) and cloud-to-cloud flashes are the two forms of cloud flashes (CC). Intracloud (IC) has two subtypes of flashes which are normal intracloud (IC) and narrow bipolar event (NBE) [7].

The NBE is a unique sort of IC that may be identified using only a single bipolar pulse with a significant amplitude comparable to return stroke amplitudes. Positive narrow bipolar event (+NBE) and negative narrow bipolar event (-NBE) are two forms of NBE. The positive narrow bipolar event (+NBE) occurs between the negative charge layer and the positive charge layer, while the -NBE occurs between the positive charge and the negative charge's screening layer. The heights of -NBE emissions are often higher than those of +NBE [7], [8].

1.3 Problem Statement

In Malaysia, there a lot of application of frequency spectrum from 20MHz to 1000MHz. Each frequency has its specific frequency bandwidth that was specify by Malaysian Communications and Multimedia Commission (MCMC). For example, frequency 20MHz to 115MHz was specify for mobile telco company. While for frequency from 115MHz to 150MHz was specify for mobile satellite. Frequency 150MHz to 230MHz was for broadcasting, while 230MHz to 328MHz is for radio astronomy. Lastly bandwidth from 328MHz to 470MHz for meteorological, 470MHz to 790MHz for radio navigation and frequency bandwidth 790MHz to 1160MHz is for aeronautical radio navigation. So, from all the application, a specific bandwidth was selected from 20MHz to 1000MHz to identify whereas there a lightning in this specific frequency bandwidth [9].

From previous study there are limited bandwidth regarding to capture lightning with electric field radiation [10], [11]. The bandwidth weather small and not specify on application of bandwidth frequency spectrum in Malaysia. So, an ultra-wide band (UWB) frequency was selected which is 20MHz to 1000MHz to specify all the specific application. To filter the frequency in specific bandwidth, a UWB band pass filter was used with several specific specification.

Lastly the noise issue, from previous study, noise was one of the issues regarding the lightning measurement system [12]. Noise that was capture by lightning measurements system are probably from the spark or switching around the lightning measurement system. So, to differentiate the noise data and lightning data, this project used a fast field system along with VHF system to measure the lightning radiation. The function of fast field was to identify wheatear the capture electric field radiation was from lightning or noise. So, from the measurement results, separation can be made between lightning and noise.

1.4 Objectives

There are several objectives for this project which are:

1. To design, setup and calibrate a VHF radiation system based on the type of lightning flashes identified from the fast electric field waveform.
2. To analyze the characteristic of VHF electric field radiation such as total pulse duration and amplitude.

1.5 Project Significant

There are few significant that will be obtain from this research. The first significant is, identifying the characteristic of electric field waveform by the type of lightning. It's not a simple task to sort out the different varieties of lightning. Understanding the characteristics of a few types of lightning flashes is critical to understanding the phenomenon of lightning strike. Names such as IC, -CG, -CG, +NBE, and -NBE are all variations of the lightning flash.

The second significant is, this research is to analyze the response of total pulse duration and the amplitude of the lightning waveform that was capture by the VHF system. As mentioned earlier, there are numerous applications of frequency spectrum in Malaysia. The Malaysian Communications and Multimedia Commission has designated a specific frequency bandwidth for each frequency. For instance, 20MHz to 115MHz was specified for a mobile telecommunications company. For mobile satellite, a frequency range of 115MHz to 150MHz was specified. 150MHz to 230MHz was used for broadcasting, whereas 230MHz to 328MHz is utilized for radio astronomy. The final frequency bandwidth ranges from 328MHz to 470MHz for meteorological purposes, 470MHz to 790MHz for radio navigation, and 790MHz to 1160MHz for aeronautical radio navigation. So, among all the applications, a specific bandwidth between 20MHz and 1000MHz was chosen to determine whether lightning was present in this frequency range.

1.6 Scope of Work

One of the scopes is to design, setup and calibrate a very high frequency VHF system to capture electric field radiation from lightning flashes. The focus is on designing a VHF system that consists of two antennas, band pass filter (BPF), fast field, cable wire, PicoScope 3000 Series and lastly connect to personal computer with PicoScope software to capture and plotting electric field radiation waveform from lightning flashes. The band pass filter was used to filter the received signal on specific frequency range while fast field was used to differentiate type of received signal based on lightning classification. Cable wire was used to transmit the received signal from band pass filter and fast field to PicoScope 3000 Series. Then when the system capture electric field waveforms, PicoScope 3000 Series will convert the analog signal waveform to digital signal waveform. Lastly, PicoScope software will then plot the digitalize waveform signal in a specific way.

The very high frequency VHF system was design by choosing the specification bandwidth of band pass filter (BPF) to filter the received signal. The signal then was plot in the PicoScope software to capture real time received signal. To capture the electric field radiation that was produces by lightning flashes, the system was setup and calibrate at rooftop of Faculty of Electronic and Computer Engineering (FKEKK) building. The VHF system was supported by chair and bricks to ensure the antennas was stable when blown by the wind. Lastly, the analysis for this project was focused on the electric field waveform that was capture by fast field source and VHF source plotted in the PicoScope software. The types and characteristics of the electric field waveform from two sources will be analyze.

1.7 Thesis Structure

This thesis consists of five main chapters. In second chapter, present the project's literature review. This chapter focused primarily on the investigations conducted by researchers in the past. However, only papers associated with this research are utilized. It begins with an introduction to lightning flashes and continues with an explanation of the sort of lightning flashes and the equipment utilized for this project. It also discusses about the parameter that are essential to analyze in order understand the waveform of the lightning.

The third chapter explains the methods for completing the project. This chapter describes the flowchart of the project, as a step-by-step guide for completing this project, from its inception to its conclusion. The project block diagram and software used for lightning analysis also was included, for further understanding the arrangement of the project equipment. A detail about VHF radiation system, data collection process and type of lightning according to it specific waveform will also be explain. The band pass filter detailed specifications also were included in this chapter as critical part of this project.

Fourth chapter discusses results and analysis. It provides a more in-depth explanation of the kind, characteristics, and data obtained from lightning flashes. It also includes data regarding the type of lightning flashes. The analysis and discussion will focus on the number of lightning strikes that were successfully captured and classified according to their type during a certain duration. The lightning waveform from VHF source will also be analyzed and discussed in connection to two selected parameters.

For the final chapter, it will provide an overall conclusion of the entire project's objectives, discussions, and the analysis of the findings in this thesis. This chapter also describes what can be added in the future to make this project even better.