# PERFORMANCE ANALYSIS OF VHF INTERFEROMETER BETWEEN ORIGINAL AND FILTERED SIGNALS BASED ON SIGNAL PROCESSING METHOD

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Thank you to all family members, my supervisor and friends for supporting me and their dedicated partnership.

# ABSTRACT

A lightning interferometer is a system that can determine the location of Very High Frequency (VHF) radiation of lightning. Such system has been studied and used for several decades ago. In this project, VHF Interferometer is used to determine the location of VHF radiations emitted by Narrow Bipolar Event (NBE) lightning flash by correlating the signals that received at three antennas. In order to get the better result, cross-correlation algorithm technique is employed to process the signals. This algorithm can determine the time delay between the antennas baselines and then determine the azimuth and elevation angles which are used to locate the location of the NBE flash. This interferometer system also can act as an earlier warning system as it detects the first cloud flash and a forecast can be made before cloud-to-ground flashes occur. Therefore, this interferometer system is very useful for the public citizens in protecting themselves from lightning strikes.

# ABSTRAK

Interferometer kilat ialah satu sistem dimana ianya boleh menentukan lokasi radiasi VHF hasil daripada kilat yang telah berlaku. Sistem sebegini telah dikaji oleh ahli saintifik dan telah digunakan pada beberapa dekad yang lalu. Oleh kerana radiasi kilat senang dikenal pasti dengan data yang boleh diukur, justeru ketiadaan data sedemikian akan menghalang kemajuan dalam sebuah penyelidikan. Untuk projek ini, Frekuensi Amat Tinggi (VHF) Interferometer adalah salah satu kaedah untuk menentukan lokasi radiasi kilat dengan menghubungkaitkan isyarat yang diterima pada dua atau lebih antena. Untuk mendapatkan hasil yang lebih baik, teknik algoritma korelasi silang digunakan untuk memproses isyarat. Algoritma ini dapat mengesan tempoh kedatangan radiasi pada antenna kemudian sudut bacaan bagi azimuth dan sudut ketinggian untuk menentukan arah kilat yang berlaku. Sistem interferometer ini juga boleh bertindak sebagai sistem amaran awal kerana ia mengesan kilat awan pertama dan ramalan boleh dibuat sebelum kilat dari awan ke tanah berlaku. Oleh itu, sistem interferometer ini sangat berguna untuk rakyat awam dalam melindungi diri mereka daripada serangan kilat.

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# LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| VHF | : | Very High Frequency |
| ELF | : | Extremely Low Frequency |
| VLF | : | Very Low Frequency |
| UHF | : | Ultra High Frequency |
| SHF | : | Super High Frequency |
| NBE | : | Narrow Bipolar Event |
| CC | : | Clod-to-Cloud |
| IC | : | Intra-Cloud |
| BFB | : | Bolts from the Blue |
| TOA | : | Time of Arrival |
| MDF | : | Magnetic Direction Finding |
| 2-D | : | Two Dimensional |
| 3-D | : | Three Dimensional |
| DC | : | Direct Current |
| SCOT | : | Smoothed Coherence Window |
| LLS | : | Lightning Locating System |

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

This chapter explains the introduction of the project for background, problem statements and objectives of this project. In addition, the scope of work and structure of thesis are also included in this section.

## 1.1 Project Background

In nature, there are so many physical processes in cloud and ground flashes that emit electric and magnetic fields. Lightning produces electromagnetic emission over broad frequency spectrum. The lightning can occur between cloud to ground and some are happen in cloud that continue for one or two seconds. The lightning strikes give a big impact to human and animal safety, interruption on the transmission line and the electrical equipment failure to function. This problem can be partially solved by providing early warning to publics by using Lightning Locating System (LLS) to

detect the locations of the lightning strikes. There are three popular methods to locate the lightning namely magnetic direction finder (MDF), time of arrival (TOA) and direction of arrival (DOA) or also known as interferometer which is the focus of this thesis. A VHF broadband interferometer is a system to locate sources of VHF based on the digital interferometric technique. It can be done by obtaining the phase differences at various frequency components of Fourier spectra between a pair of antennas.

VHF lightning mapping has been done in two ways. The first one is by using interferometric technique to determine the direction of arrival of the radiation. For another one is using TOA technique to map the lightning in 3-dimensions. The differences are the use of coherence during processing the signal. The interferometer system has a wide detection frequency range and takes no account of a carrier frequency. It observes the electric field change due to a lightning discharge in the ultra-wide VHF band. Fast Fourier Transform (FFT) is then applied to calculate various components of the received Electromagnetic (EM) pulses. Computed phase difference for each Fourier component between two antennas is a function of the incident angle of the EM pulse against the baseline. A couple of antenna as a two-element array of a broadband interferometer is able to estimate the incident angle. Two pairs of antennas and independent two baselines enable two-dimensional (2D) mapping of sources in azimuth and elevation format.

## 1.2 Problem Statements

Nowadays, there's a lot of interest in lightning-related research. In particular, studies have been done to understand better about lightning phenomenon including three common types which are Intracloud (IC), Cloud to Ground (CG), and Bolts from

the Blue (BLB). The locating system is very useful because it can detect and warn an incoming lightning strike anytime. It gives a lot of benefit to public citizens because they will receive the warning message at the very earliest time when lightning strikes are approaching. It may expose the people near the lightning strike location to danger when they are doing the outdoor activities. A lightning detector was created which is able to detect the lightning strike distance will be useful for the public citizens in protecting themselves from lightning strikes. In the end of the project, I need to analyze the differences between original and filtered signal based on signal processing method.

## 1.3 Objectives

I. To design and develop the VHF interferometer with two baselines.

II. To process the analog signal of VHF radiation by using MATLAB application.

III. To produce VHF lightning mapping by using interferometer techniques to determine the direction of arrival of the radiation.

IV. To analyze the differences between original and filtered signal based on signal processing method.

## 1.4 Scope of Work

Several scopes are listed to ensure the research is conducted within its intended boundary. In this project, it has two parts; first is experimental work. For the experimental part, the measurement was conducted in wide area such as at Pantai Klebang or in open field in UTeM. The second part is software which is signal processing plays the main role in order to locate the lightning location by using cross correlation technique.

## 1.5 Thesis Structure

The thesis is organized and separated into five major chapters. In chapter 1, the overview of VHF interferometer is discussed in project background. In addition, the problem statement, objective and scope of the project are outlined clearly in this section. In chapter 2, the past studies related to VHF interferometer are included in this chapter. In chapter 3, all relevant experiments and techniques used in the project are discussed in detail. In chapter 4, the results of the project are presented and interpreted in this section. The obtained and collected data are analyzed carefully to verify whether the objectives have been achieved or not. In the final chapter, a conclusion is drawn from the project. Besides, the recommendation for the future plan which related to the project are made in this section.

# CHAPTER 2

# LITERATURE REVIEW

This chapter discusses the literature review and background studies on topics which are related. The discussions in this chapter are supported by the knowledge that refers to the books, journals, articles, and papers.

## 2.1 Lightning Locating System

The geolocation of lightning discharges, or specific physical procedures within discharges, is vital in a wide variety of applications. These incorporate lightning cautioning and security applications, thunderstorm nowcasting and forecasting, locating lightning-caused harm assets and infrastructure, risk assessment, geophysical research, insurance, and an assortment of other continuous and forensic applications. Typical users of lightning data incorporate national and provincial meteorological organizations and aviation or air activity experts including space dispatch offices, land

management entities, forest services, electric power transmission and distribution operators, wind farm operators, and other open utilities.

Lightning locating system involves with the detection process of the electric and magnetic fields. There are three popular methods to locate the lightning namely magnetic direction finder (MDF), time of arrival (TOA) and direction of arrival (DOA) or also known as interferometer which is the focus of this thesis. All of these techniques depend on the frequency or equivalent to the wavelength, $\lambda$. There has a various frequency spectrum that involving with LLS which is VHF that has very short wavelength so that the frequency is from 30 MHz to 300 MHz and the $\lambda$ is between 10 and 1 m. For the Very Low Frequency (VLF), it has frequency range from 3 to 30 kHz and the $\lambda$ is between 10 and 1km. Meanwhile the Low Frequency (LF) has frequency range from 30 kHz to 300 kHz and the $\lambda$ is between 1km to 100km. The best electromagnetic channel imaging method is VHF while for the best ground-strike-point locating techniques is VLF and LF. The bandwidth measurement is important to have a measurement system that can reproduce the field changes of the process. So that the multiple sensors is needed to get an accurate LLS systems whether an image of the whole lightning or locating only the ground strike points. However, single station ground-based sensor cannot be used to locate an individual flash basis but can detect the occurrence of lightning.

We have known that MDF is the most common technique to locate CG flashes. The MDF is constructed by using two orthogonal loops with planes oriented through North-South (NS) and East-West (EW). So that the direction to the source can be obtained because the output voltage of a given loop, by Faraday's Law, is proportional to the cosine of the angle between the magnetic field vector and the normal vector to