EVALUATION OF COMPACT STACKED CAPACITIVE ANTENNAE FOR REALTIME RAINFALL TRACKING

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DEDICATION

The completion of this project is not only by personal hard work but also guidance, support and help from friends, seniors and supervisor. Their contributions are sincerely appreciated. I dedicated this effort to my family most importantly for my parents. This project is also dedicated to my supervisor, Dr. Mohd Riduan bin Ahmad who have been taught me many knowledges and advices which is not only useful in this project but also in our deep part of the life.

ABSTRACT

Antennae are the prior components in the lightning detection system. It is important to have effective and efficient antennae in order to detect the sensitive lightning event. Therefore, it is necessary to improve and evaluate the performance of the new antennae to make the lightning detection system more efficient. Capacitive antennae are the main part in this research in order to detect and evaluate the signal waveform whether it is which type of lightning occurring at that particular time. There are two types of antennae used in the lightning detection system which are capacitive antennae to detect electric field and loop antennae to detect magnetic field. Both antennae are in big size and not portable cause inconvenience. Thus, portable capacitive antennae with high sensitivity are designed. Compact stacked method is used in capacitive antennae by increasing the copper plate layer in between the parallel plate antennae. Performance analysis had been done by using CST software. The hardware is built and test in real-time raining event. The results are compared and shown that the parallel plate capacitive antennae (two FR4 board in square size) perform better than compact stacked capacitive antennae.

ABSTRAK

Antena adalah komponen terdahulu dalam sistem pengesanan kilat. Antena yang berkesan dan cekap sangat penting untuk mengesan kejadian kilat yang sensitif. Oleh itu, kejadian ini perlu untuk meningkatkan dan menilai prestasi antena baru untuk menambahbaikkan sistem pengesanan kilat lebih berkesan. Antena kapasitif adalah bahagian utama dalam penyelidikan ini untuk mengesan dan menilai bentuk gelombang isyarat sama ada jenis kilat berlaku pada masa itu. Terdapat dua jenis antena yang digunakan dalam sistem pengesanan kilat yang merupakan antena kapasitif untuk mengesan medan elektrik dan antena gelung untuk mengesan medan magnet. Kedua-dua antena berada dalam saiz besar dan tidak mudah alih telah menyebabkan ketidakselesaan. Oleh itu, antena mudah alih dengan sensitiviti yang tinggi perlu direka bentuk. Kaedah yang disusun padat dan rapat digunakan untuk antena kapasitif dengan meningkatkan lapisan keping tembaga di antara antena kepingan tembaga sejajar. Antena gelung meningkat dengan bilangan lilitan antena. Analisis prestasi dengan menggunakan perisian CST. Perkakasan dibina dan diuji dalam acara hujan waktu sebenar. Hasil dibandingkan dan ditunjukkan bahawa antena kapasitif plat selari (dua papan FR4 dalam size persegi) berfungsi lebih baik daripada antena kapasitid yang disusun padat.

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LIST OF SYMBOLS AND ABBREVIATIONS

E-field	:	Electric field
B-field	:	Magnetic field
CST	:	Computer Simulation Technology
Hz	:	Hertz
EMF	:	Electromagnetic field

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CHAPTER 1

INTRODUCTION

1.1 Background

Lightning phenomena happens around the environment within us and it is an electrostatic discharge inside the thunderstorm [1]. Due to the tripolar structure of the thundercloud, lightning is either occurring between cloud to ground, between cloud or in different regions of cloud. Electromagnetic radiation from the lightning can cover large frequency spectrum from Hz to GHz. For example, the effects of lightning strike can kill one person in few seconds. Therefore, it is important to have a lightning detection system to detect the thunderstorm and lightning to prevent the losses like the malfunction of the control automation machinery in industries in Malaysia.

This design idea starts with the formation and types of lightning. The most common sources of lightning are the electric charge separated in ordinary thunderstorm clouds (cumulonimbus). There are three main types of lightning which are cloud-to-ground lightning, cloud-to-cloud lightning and cloud-to-air lightning. The cloud-to-ground lightning has been studied more than other lightning forms. This is because the practical of cloud-to-ground lightning is interesting and the lightning channels below cloud level are more easily to be photographed and studied with optical instruments. There are a lot of studies and researches to be referred before carrying out this project. Most of the titles are about the basic lightning concepts, electric and magnetic field properties, Maxwell equations, antennae design, buffer circuit etc. Research on The Lightning Discharge has explained about negative and positive cloud-to-ground lightning. Negative cloud-to-ground (CG) lightning is a discharge between cloud and ground. It starts in the cloud and eventually brings to earth tens of coulombs of negative cloud charge. Positive CG lightning is a lightning discharge between cloud and ground initiated by a downward-moving which is a positively-charged leader. Negative CGs is more common than positive CGs. This is because negative CG lightning strikes can be identified visually and in photographs by their distinctive downward branching.

Besides, there are reviews about the electromagnetic fields which are emitted by lightning flashes. Electromagnetic fields are emitted by lightning flashes following the rule of the Maxwell's equations and allow us to predict and measure accordingly both slow varying fields and fast varying fields. Lightning is a result of discharge phenomenon when the cloud is charged electrically to a point of reaching electric field breakdown threshold to allow the discharge process to occur. Then, the electric charges from the cloud are not brought down to the ground immediately. This process

will create a very long conducting channel where current would flow. According to Ampere's law, a current carrying conductor emits magnetic field. At the same time, Maxwell-Ampere's law stated that a current carrying conductor emits not only magnetic field but also electric field at the same time, perpendicular to each other and travel at the speed of light. In other words, a changing electric field induces a magnetic field.

On the other hand, loop antenna for this project was inspired from the E.Philip Krider and R.Carl Noggle which is from their "Broadband Antenna System for Lightning Magnetic Fields" journal. For their project, a single loop antenna was improved into two loops of 93Ω coaxial cable which is constructed perpendicular to each other. It intends to detect the total horizontal of magnetic field produced from the lightning strike because of previous single loop antenna is not efficient. This is because the lightning channel might be not parallel the single loop antenna which is cause the external magnetic flux may not go through the loop completely.

In general, electromagnetic fields are emitted during the lightning strike. Current will produce when the lightning strike occurs due to the movement of the electron. Since there are electrons moving, current produced. By applying right hand grip rule, we can also determine whether magnetic field curling clockwise or counter clockwise. To measure magnetic field (B), loop antenna is the most suitable antenna. When lightning strike at a point, direction of the B field propagates in the circular form. Therefore, we can state that the lightning strike is the current flow. From the concept of right-hand grip rule, B field will circulate along the direction of the current flow when it flows in a direction either upward or downwards.

A conductive copper ring with small gap is placed to detect magnetic field according to Faraday's law. Faraday's law state that changing of magnetic flux will

hit the surface of the loop surface induced electric field (emf) in the opposite direction. The emf is then channel through the antenna and further to the buffer circuit. On the other hand, from the formula, we can conclude that the bigger the cross-sectional area of the loop, the greater the magnetic field, the greater the output voltage.

At the ends of both capacitive and loop antennas, detected magnetic field will channel to the buffer circuit to filter the frequency range emits by the lightning strike and to minimize the noise. For the whole system of this project, the buffer circuit is attached with the antennae and then connected to the PicoScope. The buffer circuit acts as band pass filter for the signal processing. Band pass filter is a type of filter that passes the frequencies within the certain range and reject the frequencies that out of the range. To construct a buffer circuit, there are several components that need to be consisted in the circuit. The main components that consist are IC, resistor and capacitor. The high-speed buffer amplifier is chosen to use to isolate the high input impedance of the antenna. Besides that, it also provides enough power to drive the signal from antenna to the oscilloscope. The amplifier inside can isolate the high impedance of the antenna hence it can offer enough power to drive the signal from the antenna to recording unit through the coaxial cable. The recording unit can be used in showing the waveform of electric and magnetic fields of lightning is PicoScope. The output of the buffer circuits will be inputted into the PicoScope 4000 series. PicoScope will acts as the digitizer where it will convert analogue signal to digital signal.

1.2 Problem Statement

According to US National Lightning Safety institute records, a Malaysian lightning expert said that Malaysia experienced an average of 180 to 260 thunderstorm days a year, after Indonesia (322) and Columbia (275 to 320). From this statement, we can observe that Malaysia is the country that has third highest lightning activities in the world. There are some problems that are always facing by Malaysians. Therefore, what we need is a system that is able to provide accurate lightning data information to avoid human injuries and deaths due to its extremely high current and voltage surge. A 10 years retrospective study (1996-2005) was conducted at University Hospital Kuala Lumpur (20 cases) also including cases during last 3 years from Hospital Tengku Ampuan Rahimah, Klang (7 cases) from the autopsy reports at Forensic Pathology Units of these 2 hospitals. Both these hospitals are attached to University of Malaya. Lightning strike could affect the electrical and communication networks which will cause damage of equipment. It could cause data losses to the server and malfunctioning of control system of machinery in factories. Since Malaysia has bought live lightning tracker, we could able to detect the thunderstorm and lightning. It gives convenient to all the Malaysian to avoid fatalities caused by lightning and prevent the server's data losses and malfunctioning of control automation machinery in factories. However, the price of buying the lightning detection system from foreign country is too expensive. In UTeM, we have our own built lightning detection system. However, the current available lightning system is using single plate capacitive antenna and two single loop antennae. Capacitive antenna which is in A3 size that is used for the detection of the electric field of the electromagnetic field that caused by the emission of lightning. Loop antennae which is in single loop and the position is fixed at x and y axis in order to detect the magnetic field of electromagnetic field of emission of lightning. Therefore, the current antennae have lower sensitivity and radiation pattern.

This had been caused the performance of the antennae decreased. In general, the higher the sensitivity of the antennae, the better the performance of the antennae, the more accurate the results and data obtained. Therefore, in order to increase the sensitivity of lightning tracker, there are some efforts need to be carried out.

1.3 Objective

a) To increase the sensitivity of capacitive antennae
b) To design A3 size, box size and compact stacked capacitive antennae in CST software
c) To analyse and evaluate performance of new antennae using both CST software and hardware setup

1.4 Scope

The scope of research consists of the whole complete lightning detection system. The hardware parts include electric field sensor (capacitive antenna), buffer circuit, PicoScope, computer as a display on waveform detection. In order to build this portable and user-friendly system, this project deal with theoretical design and analysing the performance of capacitive antenna systems in simulation software and hardware fabrication.

First, capacitive antennae are designed using Computer Simulation Technology (CST) and undergo Printed Circuit Board (PCB) manufacturing and fabrication. This project is more focus on designing and developing more sensitive antennae which

enable accurate data obtained. For capacitive antenna, stacked form parallel plate antenna is decided to design to see the effect of the stacked capacitive antennae result. The project requires to do CST simulation and figure out the increment in stack number of the copper plate whether it will fulfil the design specification. Once the antennae system had done, all of them are connected to buffer circuit. The buffer circuit is designed by using Proteus 8 Professional software. It then fabricates and solders to form a complete buffer circuit board. PicoScope is used to perform the waveform of the electric field detect by the antennae. For the computer, it is connected from PicoScope to display the waveform of lightning event occur in Melaka area to analyse the type of the lightning.

1.5 Thesis Structure

The body of the content in this project is divided into five chapters. Chapter included are introduction, background study, methodology, result and discussion and conclusion. For the introduction part, the contents include background, problem statement, objective, scope and the project structure of the project.

For the background study part which is the second chapter of the project. This chapter begins with the formation and types of lightning events. There are some explanations of the how the formation of lightning flashes and the theories of the electromagnetic field emission of the lightning event. After that, it continues with the researches about the design pattern of the antennae. Then, there are some discussions about antennae fabrications with different parameters and how the wave propagations