# DESIGN OF A LOOP ANTENNA FOR LIGHTNING APPLICATION

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**PROJEK SARJANA MUDA II**

**Tajuk Projek** : Design of a Loop Antenna for Lightning Application

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Co-Supervisor's Name Dr. MOHD RIDUAN BIN AHMAD

Date : ……

*This Thesis is dedicated to*

To my parents for their support, prays and encouragement.

To my friends for their helps all the time.

To my lecturers for their guidance, time and knowledge.

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# ABSTRACT

Lightning is a type of natural phenomena. It is formed from an electrical discharge at the thundercloud. During the strikes, electromagnetic radiation will be formed. As we all know, nowadays the study about lightning has become growing, increasing and widening. Thus, lightning detection system has become the most demanded and needed for the researcher. For the common lightning detection system, there are two types of radiation that can be detected nowadays which is electric field (E-field) and magnetic field (B-field). For this project, it focuses on magnetic field (B-field) detection system. Loop antenna is the most suitable type of antenna to use for the magnetic field (B-field) detection system. This is because the direction of magnetic field (B-field) that emits is in horizontal axis based on Ampere-Maxwell's Law. Thus, the structure of the loop antenna is very suitable to capture the magnetic field (B-field). Therefore, this project aims to design and construct the loop antenna. Besides, for making the system more efficient, the buffer circuit also designed for act as the filter to filter the input frequency to the certain ranges. This project also intends to build a low cost loop antenna. After the construction process of the loop antenna and buffer circuit, the system was tested it capability for capturing magnetic field (B-field) produces from the 'electric fly swatter'. The 'electric fly swatter' has the same principle with lightning discharge. Last but not least, the result of magnetic field (B-field) waveform compared with the electric field (E-field) waveform which is from the existing A4 FR4 copper plate capacitive antenna to see the relationship between the direction of magnetic field (B-field) and electric field (E-field).

# ABSTRAK

Kilat adalah sejenis fenomena semula jadi. Ia terbentuk daripada nyahcas elektrik di awan petir. Semasa kilat, radiasi elektromagnet akan terbentuk. Seperti yang kita semua tahu, pada masa kini kajian tentang kilat telah menjadi semakin berkembang, meningkat dan meluas. Oleh itu, sistem pengesanan kilat telah menjadi yang paling dituntut dan diperlukan untuk para penyelidik. Untuk sistem pengesanan kilat biasa, terdapat dua jenis radiasi yang boleh dikesan yang merupakan medan elektrik dan medan magnet. Untuk projek ini, ia memberi tumpuan kepada sistem pengesanan medan magnet. Antena gelung adalah jenis yang paling sesuai antena untuk digunakan sebagai sistem pengesanan medan magnet. Ini kerana arah medan magnet yang terhasil adalah di paksi mendatar berdasarkan Undang-Undang Ampere-Maxwell. Oleh itu, struktur antena gelung adalah sangat sesuai untuk menangkap medan magnet. Oleh itu, projek ini bertujuan untuk mereka bentuk dan membina antena gelung. Selain itu, untuk membuat sistem yang lebih cekap, litar penampan juga direka untuk bertindak sebagai penapis untuk menapis frekuensi input kepada julat tertentu. Projek ini juga bertujuan untuk membina antena gelung kos rendah. Selepas proses pembinaan antena gelung dan litar penampan, sistem telah diuji keupayaan ia untuk menangkap medan magnet yang terhasil daripada 'pemukul lalat elektrik'. 'Pemukul lalat elektrik' mempunyai prinsip yang sama dengan proses nyahcas kilat. Akhir sekali, hasil daripada bentuk gelombang medan magnet akan dibandingkan dengan bentuk gelombang medan elektrik yang terhasil daripada antena A4 FR4 plat tembaga kapasitif yang sedia ada untuk melihat hubungan di antara arah medan magnet dan medan elektrik.

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| EM | - | Electromagnetic |
| -CG | - | Negative cloud-to-ground flash |
| +CG | - | Positive cloud-to-ground flash |
| IC | - | Intra-cloud |
| +NBE | - | Positive narrow-bipolar event |
| -NBE | - | Negative narrow-bipolar event |
| Fu | - | Upper frequency |
| FL | - | Lower frequency |
| E-field | - | Electric field |
| B-field | - | Magnetic field |
| ARES | - | Advanced Routing and Editing Software |
| CST | - | Computer Simulation Technology |
| EFS | - | Electric fly swatter |
| CH | - | Channel |
| N/S | - | North/South |
| W/E | - | West/East |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Lightning is a type of natural phenomena. It is formed from an electrical discharge at the thundercloud. During the strikes, electromagnetic radiation will be formed. This electrical discharge can happen inside the cloud (intra cloud), between the cloud (inter cloud) and cloud-to-ground (CG) [1]. Intra cloud and cloud-to-ground flash is common type of lightning. Intra cloud is type of lightning that occurs completely inside the cloud. For the inter cloud, this type of lightning occurs between two or more separates clouds and for CG, it occurs when lightning strikes the ground or a grounded object. Generally there are two types of intra cloud which is positive narrow bipolar event (+NBE) and negative narrow bipolar event (-NBE). For CG also there are two types of flash which is positive cloud-to-ground (+CG) and negative cloud-to-ground (-CG). When a lightning strike happens, the electromagnetic radiation will be generated in all frequency bands which are very low frequency (VLF), low frequency (LF), high frequency (HF) and very high frequency (VHF) which is across very wide spectra from

a few Hertz up to visible wavelength. These radiations are generated through the fast acceleration of charge [2].

## 1.2 Problem

Nowadays, the study about lightning has become growing, increasing and widening. Thus, lightning detection system has become the most demanded and needed for the researcher. For the common lightning detection system, there are two types of radiation that can be detected nowadays which is electric field (E-field) and magnetic field (B-field). For the B-field detection system, the market value is very high in term of cost. Therefore, there is needed to build a B-field detection system which low cost but still functioning as well as the existing detection system at the market.

## 1.3 Objectives

The main objective of this project is to design a loop antenna and also a buffer circuit. The loop antenna is used to detect magnetic field waveforms. For the buffer circuit, it is functioning to filter the output from the loop antenna within 30 Hz to 40 kHz.

## 1.4 Scopes

This project scopes consist 3 main parts. The first part deals with theoretical design of loop antenna and buffer circuit in simulation software. First, the decay time constant ($\tau$) for buffer circuit have been estimated. Correct values of decay time constant ensure that loop antenna systems operating at the right frequency. For simulation, Computer Simulation Technology (CST) has been used to simulate the loop antenna and Multisim have been used to simulate the buffer circuit and observed the output whether within the desired output response or not.

The second scope involves constructing, fabricating and calibrating the loop antenna, buffer circuit and transmission lines (coaxial cable). The loop antenna design is based on journal. Buffer circuit were fabricated on PCB and put inside metal boxes. The metal box acts as a shield from external interference.

The third scope deals with B-field recording from the 'electric fly swatter'(EFS). The waveform collection records B-field from every quadrant of the loop antenna. In this part of scope, first, we relate the shape of the waveforms (differences of waveform polarity for each quadrant of the loop antenna) with respect to the theoretical Amperes Maxwell's Law, Faraday's Law and Lenz's Law. Later on, a comparative study is conducted to analyse the wave polarity (from the existing A4 E-field antenna system with B-field loop antenna system).

## 1.5 Thesis Outline

The body of the contents in this thesis is divided into five chapters which are introduction, literature review, methodology, results and discussions, and conclusion and future work.

The first chapter briefly describes the background about the research work. Besides, this chapter also shows problem statement, objectives and the scopes of this project.

The second chapter covers important literature review related to this project. This chapter starts with the studies about Electromagnetic law such as Ampere-Maxwell's Law, Faraday's Law and Lenz's Law. Then, it continues with studies about the loop antenna and buffer circuit design.

The third chapter is about the methodology of the project. In this chapter, step taken, methods and process flow are shown.

The forth chapter is results and discussions. In this chapter will be analyzing the data based on the given scope and discussion about the result that observed.

The last chapter of this thesis is about the future work recommendation and conclusion about the overall achievement of this project.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Ampere- Maxwell's Law

The Ampere-Maxwell's Law states that an electric current or a changing electric flux through a surface produces a circulating magnetic field around any path that bounds that surface [3]. In other words, a magnetic field is produced along a path if any current is produces enclosed by the path or if the electric flux through any surface bounded by the path changes over time. If there is current source, it will produce E-field that same direction with current and perpendicular with the direction of circulating B-field within the same path.

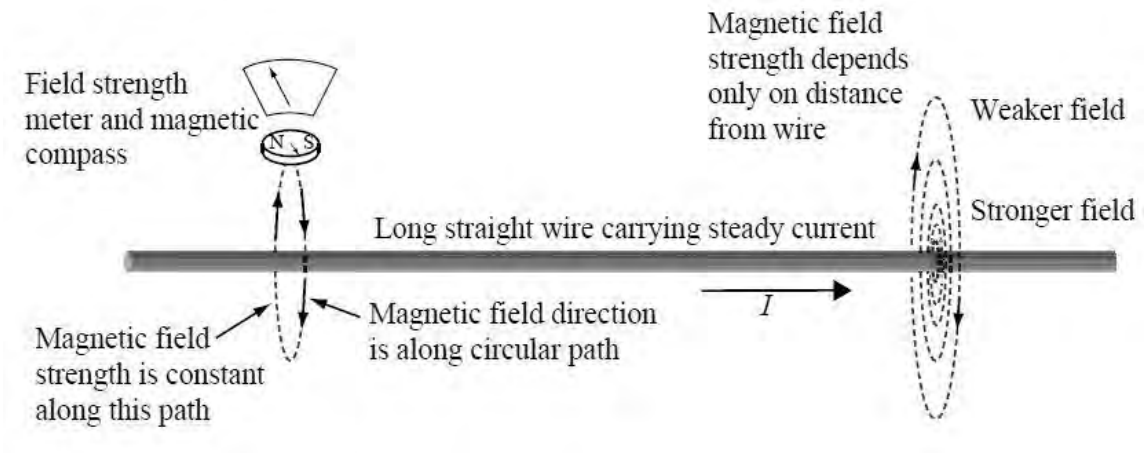


Figure 2.1: Ampere-Maxwell's Law (adapted from [3])

The direction of B-field can be determined by using Right Hand Grip Rule where the direction of current is used as reference.

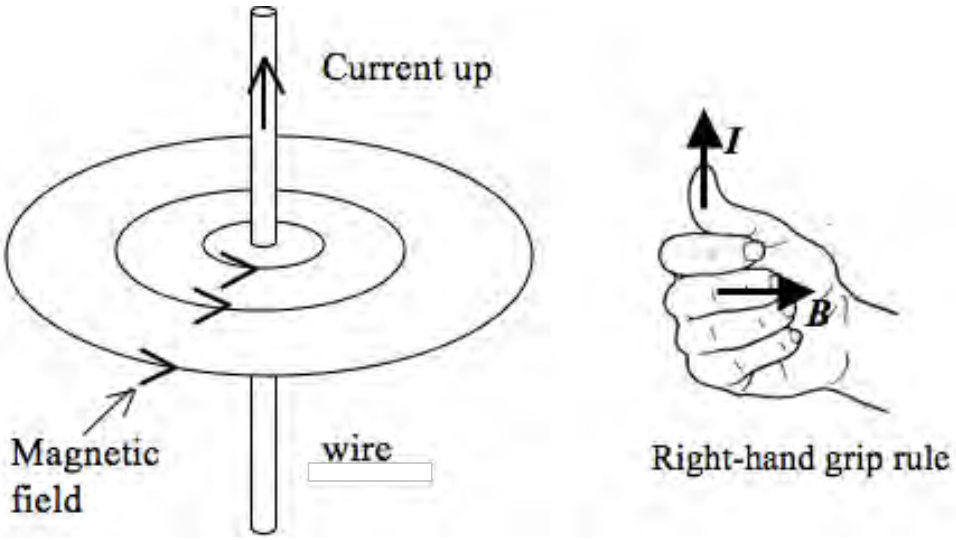


Figure 2.2: Direction of B-field and current