LIGHTNING LOCATING USING INTERFEROMETRY TECHNIQUE

AZIZAN BIN MOHD MAHARUDIN

A report submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical-Power)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JANUARY 2012

Dedicated, in thankful appreciation for support, encouragement and understandings to my family and to all my beloved friends.

ACKNOWLEDGEMENTS

In the name of ALLAH S.W.T., the Most Merciful and the Most Gracious

ABSTRACT

Study of lightning location is increased nowadays because of the high effect and hazard from lightning. Several techniques were developed to detect the lightning location. This project concentrates on the detection of a lightning location using the interferometry method. The system consists of four parallel plate antennas. Three of the antennas were placed at 14.5 meter apart to form two perpendicular base lines and the fourth is diagonally located at 75.58 meter distance away from antenna 2. The azimuth and elevation angle of the radiation source are determined by a set of three antennas, the fourth antenna is used to determine the exact position of the radiation source. The lightning signal was detected and recorded using Lecroy oscilloscope and the data obtained by all antennas were analyzed using the Matlab software. The system was controlled remotely using TeamViewer software to make work easy and more reliable. This project has detected only one lightning signal that can be analyzed. This situation happened because of the low probability of having a coincidence of lightning strike at location of the antennas. The result of the analysis is the azimuth and elevation angle and X-Y-Z location of the lightning signal detected. In general, the objective of present study was successfully achieved.

ABSTRAK

Pengajian berkenaan dengan lokasi kilat semakin meningkat pada masa kini disebabkan kesan kilat serta bahaya yang terhasil dari kilat. Beberapa teknik untuk mengesan lokasi kilat telah dicipta. Projek ini akan menekakan berkenaan pengesanan lokasi kilat menggunakan interferomtri teknik. Sistem ini menggunakan empat plat antena yang selari. Tiga antena telah diletakkan 14.5 m antara satu sama lain untuk membentuk dua garisan bersudut tepat dan antena ke-empat telah dipasang 75.58 m dari antena 2. Sudut azimuth dan ketinggian dari sumber radiasi diperolehi dari tiga antena yang berdekatan dan antena ke-empat berfungsi untuk menentukan lokasi X-Y-Z kilat. Signal dari kilat dikesan dan direkod menggunakan osiloskope Lecroy dan data yang diperolehi di analisis menggunakan perisian Matlab. Sistem pengesanan lokasi kilta ini menggunakan sistem kawalan jarak jauh menggunakan perisian TeamViewer untuk memudahkan kerja serta meningkatkan kebolehpercayaan sistem. Projek ini hanya dapat mengesan satu sumber dari kilat yang boleh dianalisis. Keadaan ini mungkin disebabkan lokasi antena yang dipasang dan kebarangkalian bilangan sambaran kilat dikawasan berkenaan. Keputusan dari analisis ialah sudut azimuth, sudut ketinggian dan koordinat X-Y-Z kilat. Umumnya, objektif projek ini telah dicapai.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGES
	DECLARATION OF THESIS	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENT	vii
	LIST OF TABLES	ix
	LIST OF FIGURES	x
	LIST OF ABBREVIATIONS	xii
	LIST OF SYMBOLS	xiii
	LIST OF APPENDICES	xiv
1	**INTRODUCTION**	1
	1.1 Background	1
	1.2 Objective of Project	2
	1.3 Scope of Project	2
	1.4 Report Outline	2
	1.6 Summary of Works	3
2	**LITERATURE REVIEW**	4
	2.1 Introduction	4
	2.2 Lightning Locating System	4

	2.2.1	Time of Arrival	5
	2.2.2	Interferometry	6
2.3		Interferometry foundation	7
	2.3.1	One dimensional interferometry system for lightning locating	7
	2.3.2	Two dimensional interferometry for lightning locating system	8
	2.3.3	Three Dimensional Interferometry for Lightning Locating System	10
3	**METHODOLOGY**		13
3.1		Introduction	13
3.2		Experimental Set-Up	13
	3.2.1	Antennas and its Location	14
	3.2.2	Access Performance of Protection Box	16
	3.2.3	Enhancement of Lightning Locating System Using Lecroy Oscilloscope	17
	3.2.4	Remote control system	18
3.3		Software Implementation	19
4	**RESULT AND DISCUSSION**		20
4.1		Introduction	20
4.2		Lightning Signal Detected	20
4.3		Azimuth, Elevation and X-Y-Z coordinate of lightning	27
5	**CONCLUSION AND RECOMMENDATION**		31
5.1		Introduction	31
5.2		Conclusion	31
5.2		Suggestion for further studies	32
REFERENCES			33
Appendix A			35

LIST OF TABLES

TABLE NO.	TITLE	PAGES
4.1.	Peak time of each channel and the delay time of Figure 4.2 to Figure 4.10	27
4.2	X-Y-Z, azimuth angle and elevation angle generated using Matlab for nine segments	27

LIST OF FIGURES

FIGURE NO.	TITLE	PAGES
2.1.	Three dimensional TOA technique for lightning locating	5
2.2.	Three dimensional interferometry system for lightning locating	6
2.3.	Relation between two antennas that receive radiation signal	7
2.4.	Baseline geometry of interferometry	8
2.5.	Determination of azimuth and elevation using trigonometry	8
2.6.	The baseline geometry for lightning locating using four antennas	11
2.7.	Schematic description of the geometry of two antenna and the position of radiation source	8
3.1.	Hardware connection for lightning locating	14
3.2.	(a) First, second and third antenna	14
3.2	(b) The fourth antenna	15
3.3.	Four antenna location looking from sky view by google earth	15
3.4.	protection box	16
3.5.	Lecroy oscilloscope	17
3.6.	The Lecroy oscilloscope additional function	18
3.7.	(a) TeamViewer software for remote control	19
3.7.	(b) Using computer to control the oscilloscope from other location	19
4.1.	The baseline geometry for lightning locating using four antennas	21
4.2.	First segment of lightning signal detected	22
4.3.	Second segment of lightning signal detected	22

4.4.	Third segment of lightning signal detected	23
4.5.	Fourth segment of lightning signal detected	23
4.6.	Fifth segment of lightning signal detected	24
4.7	Sixth segment of lightning signal detected	24
4.8.	Seventh segment of lightning signal detected	25
4.9.	Eigth segment of lightning signal detected	25
4.10	Nine segment of lightning signal detected	26
4.11	X-Y coordinate for lightning signal detected	28
4.12	X-Z coordinate for lightning signal detected	29
4.13	Three dimensional plot of X-Y-Z lightning location	30

LIST OF ABBREVIATIONS

TOA	Time Of Arrival
2D	2 Dimensional
3D	3 Dimensional
VHF	Very High Frequency
IVAT	Institute of High Voltage and High current
AC	Alternating Current
HV	High Voltage
UTM	Universiti Teknologi Malaysia

LIST OF SYMBOLS

θ	-	Angle
c	-	Speed of light = 3×10^8 m/s
Δt	-	Delay time
d	-	Distance between antenna
J	-	Length
M	-	Length
L	-	Length
α	-	Azimuth angle
β	-	Elevation angle
y	-	y - coordinate
Z	-	z - coordinate
$r1$	-	Length of radiation source
$r2$	-	Length of radiation source

LIST OF APPENDIX

APPENDIX	TITLE	PAGES
A	Matlab Programming	33

CHAPTER 1

INTRODUCTION

1.1 Background

Since the world began, at almost every minute, lightning occurs over the face of the earth. Lightning is one of the amazing and beautiful phenomena in the world. Lightning produces its own style of light which can occur from the cloud to cloud, or from cloud to earth. Lightning produces very high current that is powerful enough to dig deep holes on earth, easily cut trees, move a car hundreds of feet, set fire to homes, kills human being, and so forth. Besides that, in the power system, lightning is a single largest cause of fault. It creates transient, and outages which disrupt electric power service and it is also a major effect of electromagnetic interference for electronic system.

Malaysia is located at 1°7° N in latitude and 100° - 119° in longitude which is in area of high level lightning activities. Therefore, the information on thunderstorm occurrence and local lightning flash characteristics are required. The information allow utility to minimize outage time, improve services reliability, decrease public safety hazards and so forth. Besides that, the information can be used to determine the lightning protection level at that location which can provides reduction in cost for lightning protection.

There are various techniques used nowadays to locate lightning and to determine various parameters produced from lightning. Each technique provide its own claimed performances.

1.2 Objective of Project

The objectives of this project is to understand the interferometry technique related to lightning location, to enhance the existing lightning locating system and to determine the lighting location from the system.

1.3 Scope of Project

In order to achieve the objective of the project, there is one scope that has been outlined. The scopes of this project is focused on the interferometry lightning locating system using four antennas.

1.4 Report Outline

This report consists of five chapters. The first chapter discusses the objectives and scope of this project as well as the summary of works. While Chapter 2 discusses more on theories and literature reviews that have been studied related to the project. It discussed interferometry system for lightning location. In Chapter 3, the discussion will be on the methodology of this project. In Chapter 4, the results and discussion of the project are discussed. The last chapter focuses on the conclusion and recommendations for further studies.

1.6 Summary of Works

The project began with a study on the interferometry system and the requirements for lightning locating system. Then follow the performance checking and troubleshooting of the previously developed system was carried out. After the troubleshooting and improvement of the system, the experiment to detect the lightning location was conducted. The results from the experiments were used in the analysis using Matlab programming.

REFERENCES

1. H.D. Betz, U. Schuman and Pierre Laroche, *Lightning: Principles, instrument and applications review of modern lightning research*, Springer, 2009.

2. Kenneth L. Cummins and Martin J. Murphy, *An overview of lightning locating systems: History, Techniques, and data Uses, With an In-Depth Look at U.S NLDN*, IEEE transaction on electromagnetic compatibility, August 2009.

3. Redy Mardiana and Eprido Meiladi, *A technique for lightning reconstructions using short-baseline broadband time of arrival*, proceeding of the 14th asian conference on electrical discharge, November 2008.

4. T.Ushio, Y. Ota, M. Murakami, Z. Kawasaki, K. Matsuura, R. Mardiana, *Broaadband radio interferometer utilizing a sequential triggering technique for locating fasy moving electromagnetic sources emitted from lightning*, IEEE.

5. R. Mardiana and Z.I Kawasaki, *Lightning observation and positioning system by means of broadband interferometer*, IEEE conference, 1999.

6. Vernon Cooray, *The lightning flash*, IEEE power & Energy series, British Library, 2003.

7. Behnam Salimi, *Lightning Locating System Using Four-Antennas Time-of- Arrival Method,* Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 2011.

8. Saeed Vahabi Mashak, *Lightning Locating System By Using Time Of Arrival Technique And Three Broadband Antennas,* Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 2010.

9. Dongjie Chao, Xiushu Qie, Shu Duan, Jing Yang, and Yuejian Xuan, *Observations of VHF source radiated by lightning using short baseline technology*, 2010 Asia Pacific International Symposium of Electromagnetic Compability, 2010.