MULTI-STATION SHORT BASELINE LIGHTNING MONITORING SYSTEM

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Abstract: Lightning is a natural phenomenon where the charges generate due to cloud, air movement or other turbulence atmospheric condition. The lightning can occur between cloud to cloud, cloud to air and cloud to ground. The lightning strike gives a big impact in our daily life such as it will kill people and animal, interruption on transmission line; destroy the building and other electrical equipment. These problems can be managed by using Lightning Detection System and the location method to detect and locate the lightning strike. This paper introduced the multi-station short baseline of VHF using Time-of-Arrival (TOA) method. A NI-DAQ 6212 was used to connect the antennas to the personal computer for display and data storage by using LabVIEW. The azimuth and elevation angle was calculated to determine the location of lightning stroke.

I. INTRODUCTION

Lightning is a natural phenomenon that is of great concern to mankind and industry because of the detrimental impact on human safety, hazard and equipment failure due to AC main power conducting electrical transient. The lightning discharges produce energetic electromagnetic radiation. The quest of lightning distance can be solved by means of multi-station or single station techniques. Multi-station technique is the most accurate compare to the single station and several systems have been developed in the past decades [1].

Lightning VHF radiation source location system has been developed and applied widely. Many studies were done by several researchers that used Time-of-Arrival (TOA) method and this method was successful for lightning location studies. This method also can provide accurate locations at long ranges and if the antennas are properly sited, the systematic errors are minimal [2].

According to [4], three detection technologies and location method was introduced that employ network of radiation field sensors. There are three technologies, the first is very low frequency (VLF), low frequency (LF), and the last is very high frequency (VHF). C. Dongjie et al [2] present the method that they used to measure the location of the lightning strike. TOA technique has been used to locate lightning radiation sources. However, to give perfect reconstruction of lightning discharge, the interferometer method was introduced. This method could be classified as narrowband and broadband interferometer. A new type lightning location system uses short baseline TOA technique was developed.

Multi-station has been setup for lightning detection system in short radius. The signals that come from the lightning strike will be capture by antennas and monitor from the personal computer. The signal then will filter, save and estimate the azimuth and elevation angles by using LabVIEW software.

II. TIME-OF-ARRIVAL METHOD

Time-of-Arrival (TOA) also known as time of flight (ToF) is the travel time of a radio signal from a single transmitter to a remote single receiver. The relation between light speed in vacuum and the carrier frequency of a signal, the time is a measure for the distance between transmitter and receiver. Time-of-Arrival always uses the absolute time of arrival at a certain base station rather than the measured time difference between departing from one and arriving at the other station [5]. The distance can be directly calculated from the time of arrival as signals travel with known velocity [6]. Time-of-Arrival (TOA) data from two base stations will narrow a position to a circle; data from third base station is required to resolve the precise position to a single point [7].

A method for locating lightning that is based on measurements of the Time-of-Arrival of a radio pulse at several stations that are synchronized has been described by [8]. A constant difference in the arrival time at two stations define a hyperbola, and multiple stations provide multiple hyperbolas whose intersections define a source location. Wideband TOA receiver that is suitable for locating lightning sources at medium and long ranges using the hyperbolic method has been developed by [9].

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II. METHODOLOGY

VHF short baseline broadband was used as a method to locate the position of the source of VHF impulse. Fig. 1 shows that the simplest short baseline consists of three separate antennas. The distance between each antenna is 10m. The system employed three broadband circulate flat antennas having diameter of 30cm each. The antennas were connected to a NI-DAQ 6212 through coaxial cable.

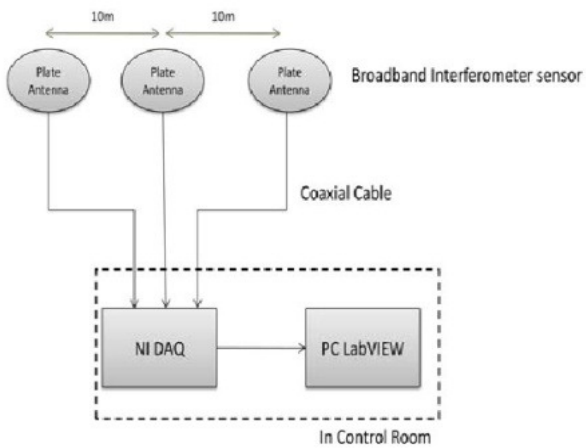


Figure 1 Multi-station short baseline

In order to determine the azimuth and elevation angle, the third antenna is added. The first and second antennas will be the first baseline while the second and third antennas will be the second baseline. These two baselines are perpendicular to each other. Figure 2 shows the geometry of the perpendicular baseline antennas.

The localized multi-station short baseline lightning alarm system is made up of three broadband antennas. The antennas have been installed in a chosen area at the Blok 1, FKEE. Figure 3 and 4 shows where the position of antennas has been installed.

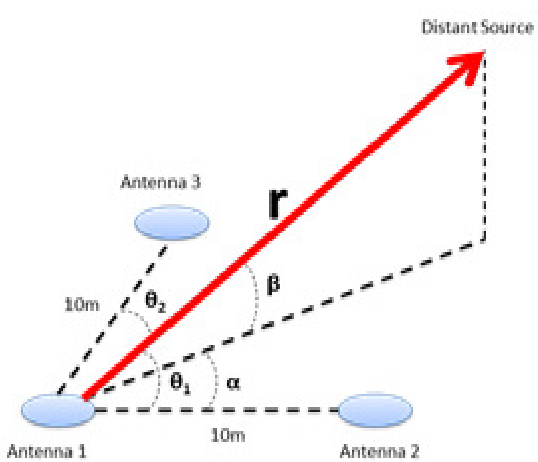


Figure 2 Baseline geometry of the short baseline broadband

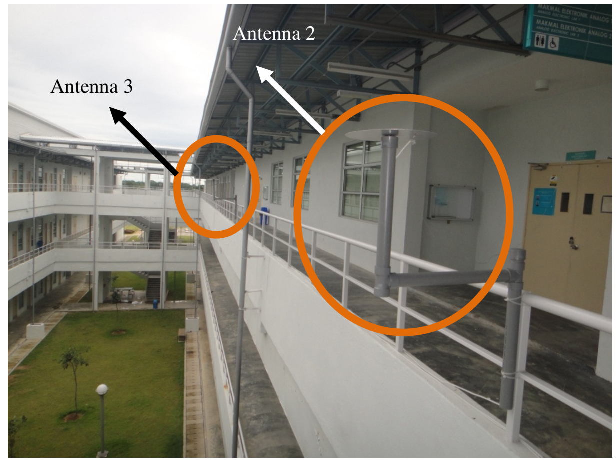


Figure 3 Position of antennas 2 and 3

Figure 4 Position of antenna 1

III. RESULTS AND DISCUSSION

At this part, we will explain more about the data from a cloud to ground lightning strike which was detected by the plate antennas. Figure 5 shows a typical signal captured when lightning occur. From this figure, we can see that the difference of time delay for each signal.

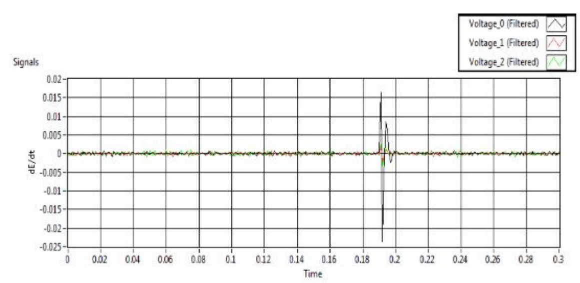


Figure 5 Lightning electromagnetic signal (dE/dt)

According to a simple geometry model that has been developed in Figure 2, three antennas are used to determine the angle of azimuth and elevation by the formulation as follows [3].

$$\alpha = \tan^{-1}\left(\frac{\Delta t_2}{\Delta t_1}\right) \tag{1}$$

$$\beta = \cos^{-1}\left(\frac{\Delta t_2}{dSin\alpha}\right).C \tag{2}$$

Where α is the azimuth angle of radiation source, β is the elevation angle and C is speed of light

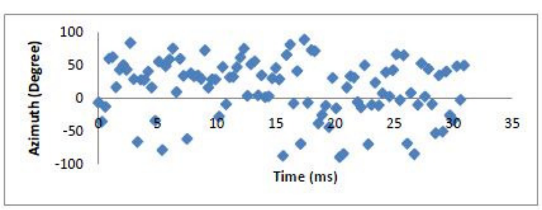
In this experiment, the plate antennas triggered the highest and lowest of the signal radiation. The strength of the signal radiation is dependent on the distance of lightning strike from the baseline. When the lightning data (dE/dt) is high, the distance of lightning strike is closer to the baseline and so on. Table 1 shows the value of electromagnetic signal (dE/dt) at certain time for antennas 1 on 2nd May 2012.

Table 1 Electromagnetic signal data analysis on 2nd May 2012

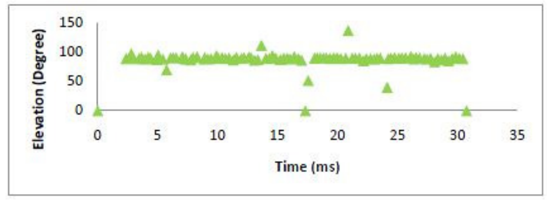
Time	Electromagnetic Signal (dE/dt)
12.03 am	0.00152
12.05 am	0.00221
12.08 am	0.00162
12.10 am	0.00158
12.13 am	0.00151
12.14 am	0.00182
12.17 am	0.00710
12.19 am	0.00600
12.22 am	-0.00411
12.24 am	-0.00800
12.29 am	-0.00900
2.06 pm	-0.10000
2.07 pm	-0.00620
2.08 pm	0.30000
2.09 pm	0.06200
2.10 pm	-0.50000
2.21 pm	-0.25000
2.30 pm	-0.10000

From table above, there are ten data in positive discharge while only eight data in negative discharge. The highest value of dE/dt was 0.3 where it occurs at 2.08 pm and the lowest value was -0.5 at 2.10 pm. The other data is almost same which is in range between -0.009 to 0.0020.

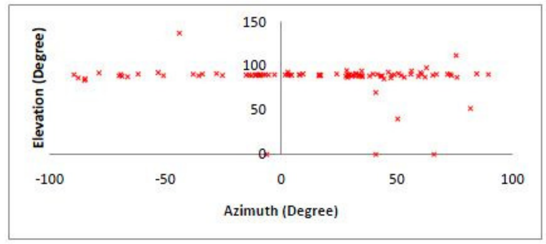
Figure 6 shows time waveforms and radiation source location during the flash.



(a)



(b)



(c)

Figure 6 Radiation during a multi stroke CG flash at 14.15 pm on 2nd May 2012. (a) Azimuth angle versus time, (b) Elevation angle versus time, (c) Radiation source locations

It was obvious that the flash initiated in the cloud. The traditional atmospheric sign convection was adopted to present an electric field change. So, an abrupt negative change means that positive charges are lowered from the cloud to the ground. In this meaning, Figure 4 (a) and (b) is discriminated both negative and positive CG strokes. Both of figures show the activity during 30ms.

The Boltek LD-250 has been installed in Blok 1 FKEE building last year. This lightning detector puts a live lightning map on personal computer. Within millisecond of a lightning strike the detector beeps and the computer will display the strike location. The LD-250's direction finding antenna measures lightning strike direction while the LD-250's receiver estimates distance from received signal strength. Advanced signal processing in software improves distance accuracy, reducing the effects of strike-to-strike variations in strike energy.

The LD-250can warns of both close and severe thunderstorm. If a storm is detected closer than a preset distance or the strike rate exceeds a preset limit, the LD-250 sounds its internal alarm and activities the computers alarm tone or WAV file notification.

Lightning data was obtained from the LD-250's panel for the period between 2.00 pm to 2.30 pm on 2nd May 2012. The data was for a region 3.2 km radius from FKEE. This is shown in Figure 7. Figure 9 shows the summary of the data obtained.

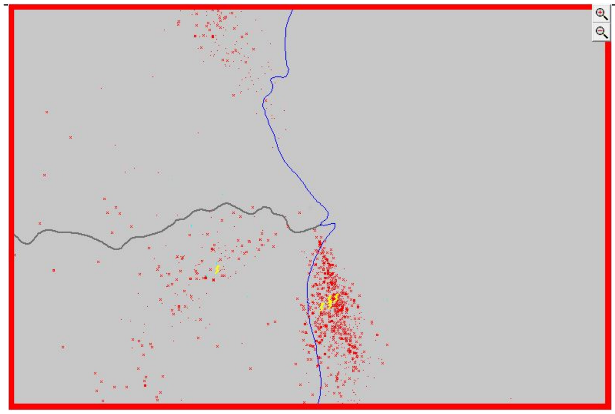


Figure 7 Lightning activity detected by Boltek LD-250 for a region within 3.2 km radius from FKEE building

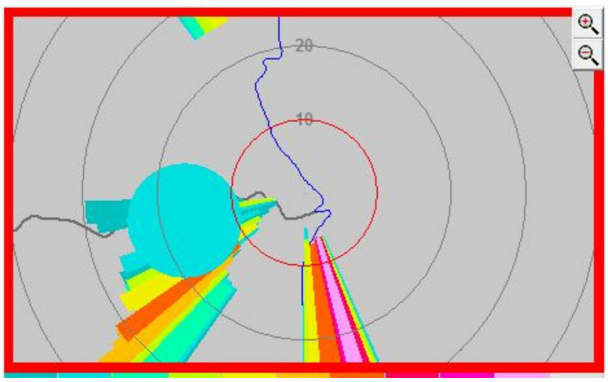


Figure 8 Summary of lightning activities

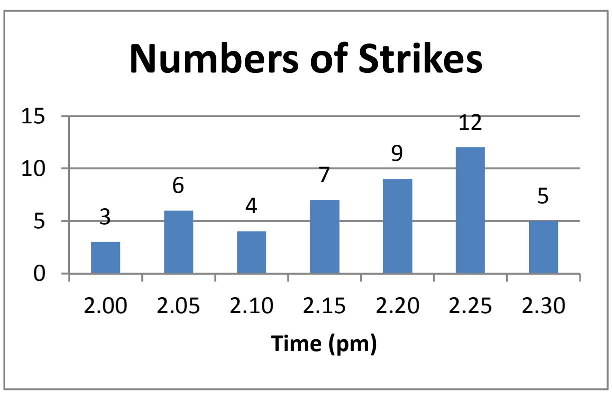


Figure 9 Lightning strikes distribution on 2nd May 2012 at 2.00 pm till 2.30 pm detected by LD-250 for a region within 3.2 km from FKEE building

Figure 10 shows the comparison of the lightning strikes recorded by Boltek LD-250 and multi-station short baseline lightning alarm system. Five strikes were recorded by multi-station short baseline (MSSB) at 2.00 pm and 3 strikes were recorded by LD-250 at same time. At 2.20 pm, nine strikes were recorded by LD-250 while there are no strikes recorded by the MSSB antennas. As a whole, the total of lightning strikes detected by LD-250 is 46 strikes and 30 lightning strikes were detected by MSSB.

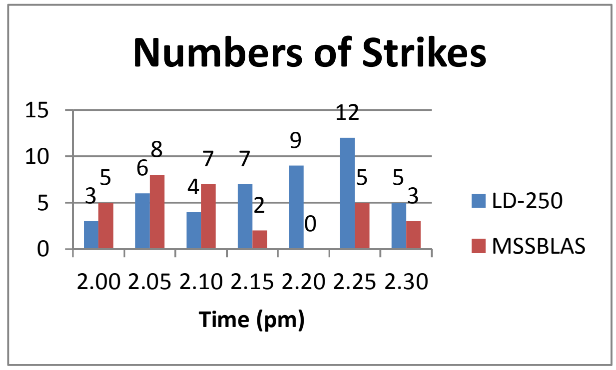


Figure 10 A comparison of lightning strikes recorded by LD-250 and MSSB

In summary, the above data gives early results for the purpose of comparison between the LD-250 lightning detector and MSSB.

IV. CONCLUSION

This paper describes a short baseline lightning location system (LLS) using time-of-arrival (TOA) technique. This technique was performed into two dimensional.

From the analysis of CG multi stroke, we can conclude that the system works well. The system will be improved after this by increased the high speed of the DAQ so that it can be longer time to record.

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