An Analysis of Manual and Autoanalysis for Submicrosecond Parameters in the Typical First Return Stroke

by Muhammad Akmal Bahari

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Article Info

Article history:

Received Oct 1, 2018
Revised Dec 10, 2018
Accepted Jan 25, 2019

Keywords:

First keyword
Second keyword
Third keyword
Fourth keyword
Fifth keyword

ABSTRACT (10 PT)

The mechanism on how Lightning Detection system (LDS) operated never been exposed by manufacturer since it was too confidential. Under the above scenario motivated our team to explore the issue above by using MATLAB to program the software based on the Features Extraction for recognizing the parameters in the first return stroke and compare the measurement between the programmed software (autoanalysis) and the manual analysis. This paper is a modification based on a previous work regarding autoanalysis of zero-crossing time and initial peak of return stroke using Features Extraction programming technique. Further, the parameter on rising time of initial peak is added in this autoanalysis programming technique. Finally, the manual analysis using wavestudio viewer (Lecroy product) of those two lightning parameters is compared with autoanalysis programmed. This study found that the programmed software can produce similar result with the manual analysis hence proved the reliability of this software.

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1. INTRODUCTION

Lightning has been an interesting phenomenon to discover. From Benjamin Franklin times until recently, many investigations were conducted to uncover the mysteries lies behind this phenomenon. The lightning is immense electrical energy which occurs less than a second. There are thousands of amperes released when the lightning struck [1]. The lightning brought damages towards electrical appliance, the electrical distribution power system and many more [2]–[5].

The investigation and reports by researchers in Sweden and Malaysia, for instance [6], [7] showed the potential effect of a thunder-to-tempest variation on electric fields generated by lightning flashes using a single station measurement to be useful as a ground truth [4 – 6]. In addition, the technique considered it to be an important tool to electrical engineers and scientists, [1],[6],[7] as it made a lot of progress towards the investigator in understanding the possible effects of deleterious lightning field connections with various objects, particularly for a sensitive electronic device. Thus, various lightning location systems built to measure the lightning. The investigation helps an electrical engineer who involves in designing the electrical protection unit to design their equipment to withstand the damages from the lightning.

Four types of geolocation techniques, known as time of arrival, direction, optical imagery and combined special techniques, were discussed [8],[9]. Lightning geolocations techniques were described. As discussed, arrival time is a technique for the simultaneous use of multiple sensors when measuring the time of the particular characteristic of a lightning event electromagnetic wave form. To geolocate the lightning event, at least four sensors were necessary, as well as the determination of its time, latitude, and longitude. Sensors in the long-range lightning finding system could measure the propagation of the lightning electromagnetic influenced by Earth-ionosphere waveguide over thousands of kilometres [10],[11]. This strategy is based on the notion that lightning Very Low Frequency (VLF) waves propagate through the ionosphere with dispersion, causing higher frequency components to arrive before lower frequency components, as mentioned in [10],[12]. Second, magnetic direction finding (MDF) is used for very low frequency (VLF) range, whereas broadband interferometry is used for very high frequency (VHF) range. [13],[14] used VLF interferometry in the study to improve direction finding accuracy, while [11] and [15] used VHF interferometry. MDF is defined as a technique that employs two orthogonal loop antennas to measure the magnetic field waveform produced by a lightning event. [15 – 18] explained that the azimuth of a lightning event could be calculated by measuring each loop.

Generally, a direction vector joining a sensor location and a lightning location can be achieved by the peak proportion amplitude of the electromagnetic waveform produced by an illumination event. Simultaneously intercepted vectors from two or more sensors identify an event site with lightning [17]. In addition, magnet directional finding can be employed when two or more sensors simultaneously intercept can calculate the time, latitude and longitude of a flash event. Two or more three-axis magnetic field sensors are required to determine the altitude for a lightning event [18],[19]. Each sensor needs to have three orthogonal loop antennas to calculate the altitude and the capability to measure the azimuth and elevation angles of a reported lightning event [20]. VHF interferometry is another method to find direction. A lightning system that uses sensors that have been built into a variety of antennas. Like the MDF technique, lightning event location measurements were conducted simultaneously with two or more sensors to determine the location of the lightning event. An azimuth information is provided by the derivation of the time of arrival (phases difference) from the VHF signals associated with the lightning events among individual sensor antennas. The measurement utilizing magnetic direction finding, on the other hand, suffers from local site inaccuracies. To acquire absolute angle estimation, these errors must be taken into account. As the distance from the detector grows, the constant angle error becomes more linear. Using at least three sensors with sensor direction vectors intersecting at a right angle is the simplest way to reduce constant angle error.

Thirdly, an optical imaging is a satellite-based lightning detection technology that uses the radiation emitted by clouds to geolocate photographs captured from space. The cloud top could measure cloud-to-ground and intracloud lightning flashes [21],[22]. Optical imaging can also be used to establish time, latitude, and longitude. Optical imaging cannot, however, be utilized to determine the altitude of a lightning strike's site. The fourth lightning locating system employs a variety of techniques, including integrated and unique ones. Combining time of arrival and magnetic direction finding, or broadband VHF interferometry and optical imaging, are two examples of integrated approaches. The time of arrival and magnetic direction-finding techniques were used together for the first time to build a lightning locating system. When employing the combined methodology given by [9], more sensors are required to establish the geolocation of a lightning incident. Furthermore, broadband VHF interferometry and optical imaging were used in the second combined and unique methodology. According to [23], in the low-Earth orbiting satellite-based lightning locating system, a two antennas system was employed to predict a direction of arrival together with optical imagery to geolocate a lightning occurrence. The benefit of using this strategy was that it reduced local site error. The position of a lightning strike event can be obtained more accurate and reliable [24].

There are four different types of lightning locating systems. Arrival time, direction finding, optical imaging, and combination and special procedures are all available. The three forms of stand-alone lightning locating systems are time of arrival, direction finding, and optical imaging. In comparison to stand-alone lightning locating systems, the combined and customized methodologies provided a more reliable lightning locating system. Although there are several lightning locating systems in the world, the lightning analysis system is inadequate. When analyzing lightning data, all of the systems rely on manual measurement [25],[26].

This research compares the analysis between the manual analysis by using Wavestudio viewer software provided by LeCroy and the programming software that based on Features Extraction technique to discover the reliability of the programming measurement to measure the duration of the zero-crossing and the duration of the rising time. This study is a modification of previous work by [17],[18] regarding on autoanalysis of first return stroke based zero-crossing time of the initial peak using Features Extraction programming technique. Furthermore, in this paper the parameter on rising time of initial peak of first return stroke is added in this autoanalysis programming technique. Finally, the manual analysis (using wavestudio viewer from Lecroy product) of those two lightning parameters is compared with autoanalysis programmed of submicrosecond parameters in the typical first return stroke. The contribution of this research is useful for initial development towards the automation of the lightning location system in this world. There are many lightning location systems have this study focused on to compare the measurement of the parameters lies in the first return stroke. The parameters in which we focused on are the duration of the zero-crossing and the duration of the rising time.

2. Data and Methodology

In this study, the 32 typical lightning data were analysed. The data of the lightning obtained from the measurement setup consist of the parallel-plate antenna, buffer circuit and the oscilloscope. The typical lightning analysed by using two methods. The first method was using manual measurement. The second method was by using the programming method. The programmed software to measure the duration of the lightning zero-crossing and the duration of the rising time was built. The algorithm in the programmed software was tested to ensure the measurement was reliable. The programmed software was tested by running several iterations with many threshold values. Previous researchers discovered the range of the threshold values chosen for the duration of the zero-crossing detection were starting from 35μs until 70μs. The threshold value selected which gives the most accurate measurement was 40μs.

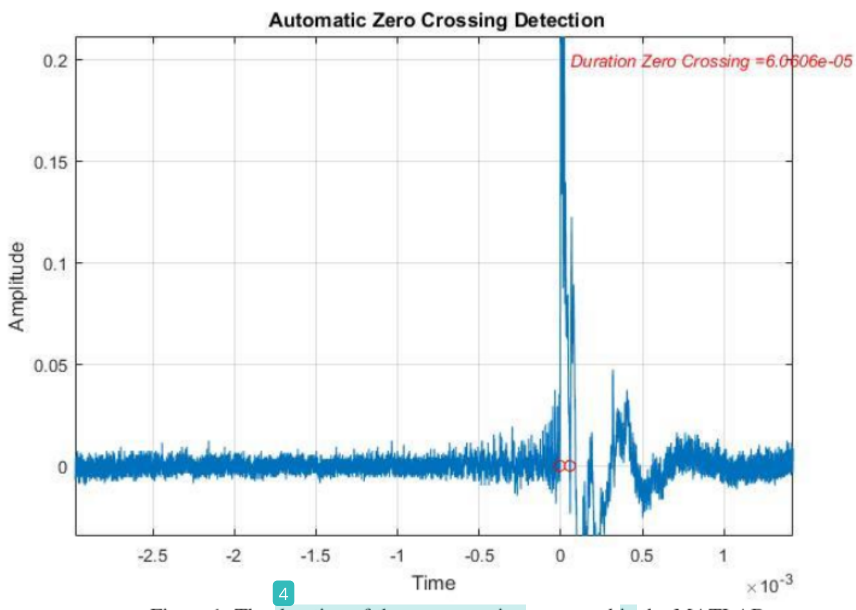

Figure 1: The duration of the zero-crossing measured in the MATLAB.

This study chose 40μs as the appropriate threshold value to utilise in the algorithm to measure the duration of the zero-crossing in the first return stroke to avoid false detection [6],[7].

$$t0\ (k-1) - t0\ (k) > 0.00004 \quad (1)$$

The equation (1) above shows a part of the algorithm involves in this research. The t0 (k-1) is the time of the amplitude at the end of the zero-crossing time duration while the t0 (k) is the time of the amplitudes at the start of the zero-crossing duration. The value of 0.00004 is the threshold value of 40μs for the zero-crossing detection [6] and [7].

$$ynorm\,(k + 210) > 0.5 \quad (2)$$

The equation (2) used for rising time detection. This research uses this equation in the algorithm to find the rising time of the first return strokes. The *ynorm* variable it a variable which contain information about the value of the sample amplitudes. If the samples amplitudes reach more than 0.5 the samples are marked as a potential first return stroke amplitude. The sample of time is 210 was used to simplify the detection processes of the rising time. The algorithm ignores all the first 210 samples to ensure accurate first return stroke could be detected. Finally, this study suggested that a value of 0.5 is the minimum value to recognise the first return stroke.

3. Result and Analysis

Table 1: The comparison measurement between the programmed software and manual measurement.

Means	Measurement			
	Rising Time		Zero Crossing	
	Manual	Software	Manual	Software
Geometric	5.0μs	4.6μs	62.3μs	63.1μs
Arithmetic	5.4μs	4.7μs	64.1μs	64.9μs

The geometric mean and arithmetic mean of 32 typical ground flashes were examined in this study. Whereby, the difference between manual and software measurement was computed and observed. All of the methods produced the same reading between the manual and programmed software measures, as shown in Table 1. Table 1 illustrates that the data generated by the coded software is reliable.

Table 2: The comparison of measurement for the duration of the zero-crossing.

	Location	Zero Crossing Time
Lin and co-workers [25]	Florida	54.0μs
Cooray & Lundquist. [23]	Sweden	49.0μs
Haddad and co-workers [24]	Florida	89.0μs
Wooi and co-workers, [22]	Malaysia	50.7μs
This study -Manual	Malaysia	64.1μs
This study -Software	Malaysia	64.9μs

The arithmetic mean zero crossing detection for typical ground flashes for human and software calculation is 64.1μs and 64.9μs, respectively. The arithmetic mean difference between the human calculation and the software calculation is 0.01μs. To put it another way, the percentage is reasonable and acceptable.

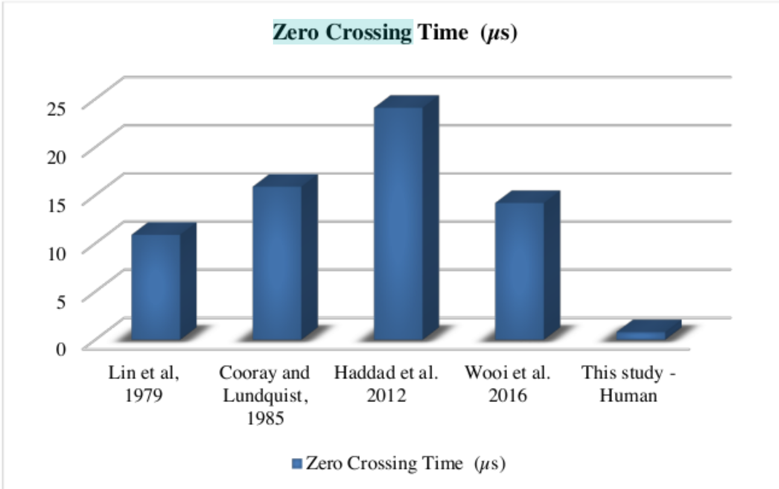

Figure 2: The duration of the zero-crossing compared with the previous studies

The data in this software measurement study are more than 14.2µs (50.7µs), [21] as much as 15.9µs (49.0µs) and [24] as 10.9µs (54µs). Comparison to the previous researchers is more important in this study than [19]. There is only [22] which recorded an arithmetic mean that is 24.1µs higher than the value recorded in this study, for zeros crossing times at (89µs).

Furthermore, [22] measured the length of zero-crossing to be nearly 0.25µs longer than the software measurement in this investigation. According to [26] and [19], the duration of the zero-crossing rises as a result of the increased current moment and charges to be neutralised in the initial return stroke in a lightning event. The researchers present the geometric mean for both human and software measurement. In software measurements, the geometric mean for zero-crossing duration is 63.1µs, but in human measurements, the geometric mean is 62.3µs. In the geometric computation, the predicted error margin is 0.01µs.

The geometric mean, on the other hand, was presented in [19]. In Malaysia, the geometric mean for zero-crossing duration was 41 seconds, according to their analysis. The geometric mean for human measurements of zero-crossing duration is 62.3µs, while the software measurement is 63.1µs, according to this study. The geometric mean derived in this investigation differed somewhat from that provided by [19]. According to the findings of this investigation, the difference in value is less than 18µs. For both investigations, the geometric mean shows a difference of less than 36%. The difference in value between [22] and [24] on the other hand, was almost double. Even though the measurements were taken in the same location, various thunderstorms and cloud activity may have caused the results to differ.

Table 3: The measurement comparison for the duration of the rising time.

Research	Location	Year	10-90 % Rise Time
Master et al.	Florida	1984	2.6µs
Rakov & Uman.	General	2003	5.0µs
Wooi et al.	Malaysia	2016	3.9µs
This research/study - Software	Malaysia	2020	4.7µs
This research/study - Manual	Malaysia	2020	5.4µs

The data of calculated arithmetic and geometric mean for the fast transition of the lightning events are recorded and the fast transition value is compared with the value from previous researches as stated in the table 3. In this investigation, the highest arithmetic mean of quick transition was 5.4µs, which was measured by humans. In comparison to other researchers, this value is the highest. Master et al. (1984) in Florida measured the shortest fast transition time at 2.6µs. Furthermore, Master et al. (1984) had the shortest rapid transition time of all the researchers, at only 2.6μs. In general, [13] indicated that the arithmetic value of a quick transition was 5μs, which is quite close to the value found in this study.

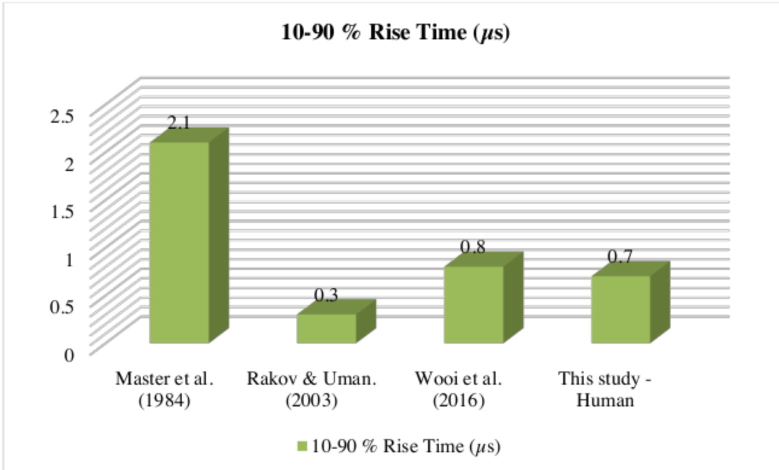

Figure 3: The duration of the rising time compared with the previous studies

For fast transition, a comparison is made between software analysis (autoanalysis) and manual analysis (using LeCroy software, Wave Studio). For software measurement, the arithmetic mean is 4.7μs, but for manual analysis, the arithmetic mean is 5.4μs. The arithmetic means differ by 0.7μs. The fast transition values for typical ground flashes differ by around 0.12μs between human and software measurement. This value indicates that employing a different method, the same data generated a different result. The 4.7μs of autoanalysis (this study) was compared to prior measurements by Master et al. (1984), Rakov and Uman (2003), and Wooi et al. (2003). The arithmetic means from all previous researchers have an average value of 3.8μs. It was discovered that autoanalysis is closer to the average (3.8μs). Meanwhile, the software measurement had a 0.19μs discrepancy, and the manual analysis had a 0.30μs discrepancy, which is 0.11μs greater than the software measurement, which were both judged modest and equivalent. Based on the results of the comparison, it was determined that the arithmetic methods employing software measurement for fast transition detection in this study is appropriate and reliable. It will be interesting and enhance more understanding on auto-analysis study if one can consider this type of analysis by considering the uncommon lightning mechanism such as attempted leader as reported by [7],[27] and common lightning flashes such as reported by [27–32].

4. Conclusion

This study was conducted to compare the analysis of the parameters of lightning between manual analysis and the autoanalysis operated by the developing software using the algorithm created in this study. The result from the comparison have found remarkably similar result. Hence proved that the accuracy of the software is reliable. However, the equation in the algorithm cannot detect the zero-crossing duration less than 40μs. In future, research should be carried out on the case of zero crossing less than 40μs. Further, the analysis work should also consider the case of final stepped leader pulse that associated on the abrupt of the initial first return stroke because the effect of this pulse may alter the zero-crossing pulse.

Acknowledgment

The authors would like to thank all staff in Fakulti Teknologi Kejuruteraan Elektrik& Elektronik and CRIM in UTeM for their facilities, support and co-operation during our measurement campaign. This work fully utilized the equipments from the funding by Ministary of Education Malaysia (MOE) under ERGS/2013/FKE/TK02/UTEM/03/01 and FRGS/2/2014/TK03/FTK/03/F00248.

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