

## Lightning Air Terminal Collection Volume Assessment: A New Technique and Device

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### Abstract

For buildings, structures and facilities a Lightning Protection System (LPS) is very important. There are some components that affect the effectiveness of LPS. One of the components is the lightning air terminal. With reference to the facilities requiring lightning protection the position, the apparent height, and the angle of protection of lightning air terminals determines the collection volume (CV) of the protected area. The CV of direct strike lightning air terminals can change because of the facility is affected by natural disasters such as seismic tremor and flood. If such natural disasters do happen, there are possibilities that the facilities will not be fully protected from direct lightning strikes. The building and structure could be misalignment after the seismic tremor and flood related to earth movement. So for the safety of equipment and personnel, lightning protection system efficacy assurance is necessary. Therefore, there should be a technique and device to monitor the variation of collection volume afforded by every lightning air terminal on buildings and structures after the occurrence of a natural disaster. This paper presents a new technique as well as a new device to monitor the collection volume variation. A part of the device was obtained from a recycled moveable television antenna. This approach is not only practical, portable and cost effective but also incorporating the idea of environmental protection and recycling of used plastic materials.

**Keywords:** lightning, lightning protection system, collection volume, seismic, flood

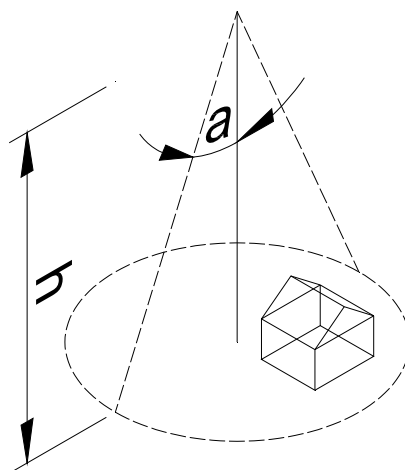
### 1. Introduction

The protection of a structure against a direct lightning strike is a significant step in any comprehensive lightning protection system (LPS). One of the key components of any direct-strike protection system is the lightning rod or air terminal placed on the structure [1]-[3]. In determining the location of the lightning air terminal, there are two related and equally important aspects that must also be measured i.e., protection area afforded by each air terminal and positioning of the air terminals on the structure to achieve the desired interception efficiency [4]-[6].

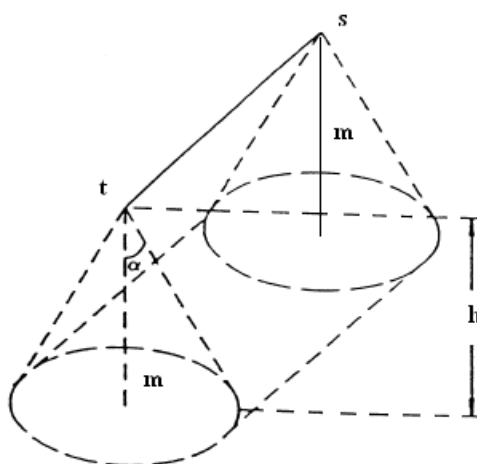
On most turnkey projects involving petroleum facilities, and electrical transmission and distribution network main intake LPS are based on Cone of Protection / Protection Angle Method, IEC 62305 [7]. Cone of Protection is the creation of virtual 3-D cone with its apex point is at the top most point of the standing mast or monopole or vertical rod whether is standing independently or supported by a building structure. The virtual lightning collection volume is shown in Figure 1 and

Figure 2.

Nowadays natural disasters such as flood and earthquakes have been frequently occurred in some certain areas [8]-[11]. These conditions will change the condition of land and building in the affected areas hence the ground level following the flood and earthquakes occurred could heave or dwindle [12]-[14]. If the ground level changes then the lightning air terminal protective angle which is calculated in regarding the land and building before the disaster take place become not reliable anymore to provide a appropriate protection [15]-[16]. Since, the displacement indirectly changes the entire height of the installed lightning air terminal.



(a)



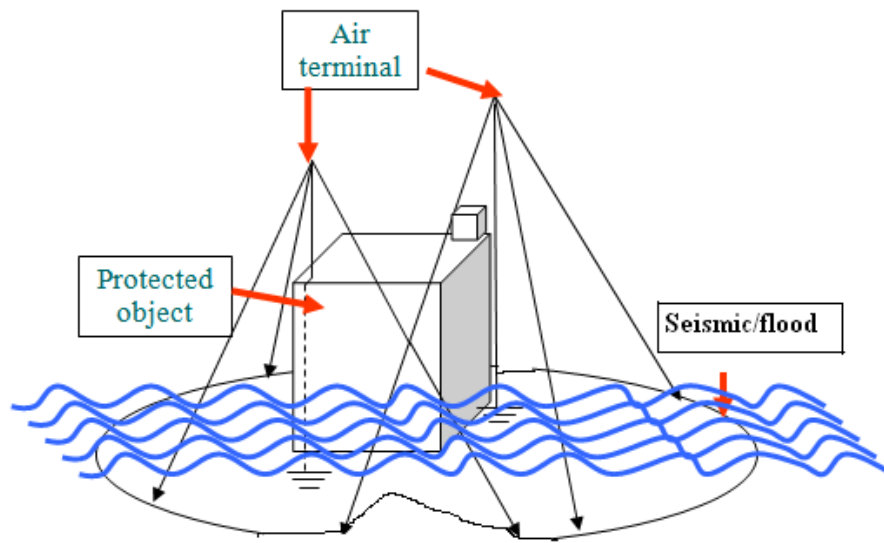
(b)

Figure 1. Protection Angle: (a) facility protected by a vertical lightning rod air terminal,  $a$ , is the protective angle; (b) protected by a wire air termination or horizontal metallic conductor indicated by  $ts$  for a pair of standing mast  $m$  of its equivalent of height  $h$

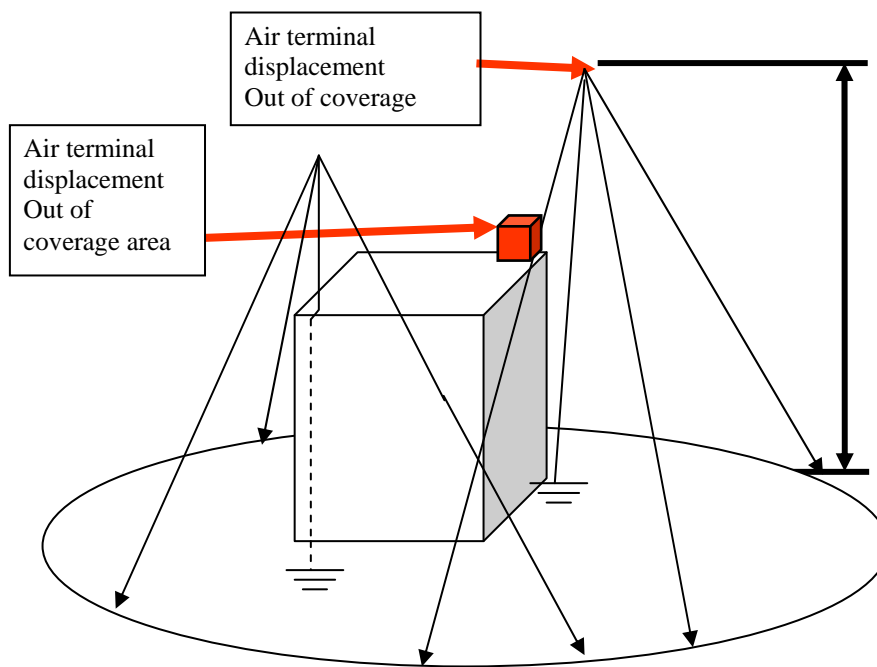
The regeneration of volume of protection by laser beam based on Figure 1 can be a mean to check the building orientation and misalignment due to seismic activities and flood impact.

Figure 2 shows the collection volumes generated from a pair of air terminal. In

Figure 2(b) the environmental displacement due to the seismic activities and flood results misalignment of the lightning collection volume. This in time bring about some part of the facility expose to lightning direct strike. In another word the probability of lightning to strike that part of concern is higher compared to other parts. If this scenario involves petroleum or other inflammable and explosive items, the consequents of a direct strike is very fatal [17]-[20].



(a)



(b)

Figure 2. The cone volume of protection generated from a pair of air terminal. (a) Prior to seismic/flood impact; (b) The misalignment of the collection volume result in certain segment of facility expose to lightning direct strike

Visual inspection could be carried out but of course there are some drawbacks. Therefore there should be a device to cater any responsible personnel to observe any changing of lightning air terminal protective angle on the facilities of concern. This paper presents a new technique and device to monitor the lightning air terminal protection angle. By using this approach any dynamic of protection angle can be monitored at all time.

## 2. Research Method

Few aspects of design have been considered in the development of the device i.e. (i) various angles of protection as per requirement based on the standard concerning lightning protection, (ii) horizontal displacement due to vertical placement of the instrument when attach to the test lightning rod, (iii) rotation of the shaft affixed laser pointer, and (iv) recording the laser focus image before and after the occurrence of a natural disaster. Figure 3 shows the device and the technique general flowchart is shown in

Figure 4 describes the whole activities involving the use of the device.

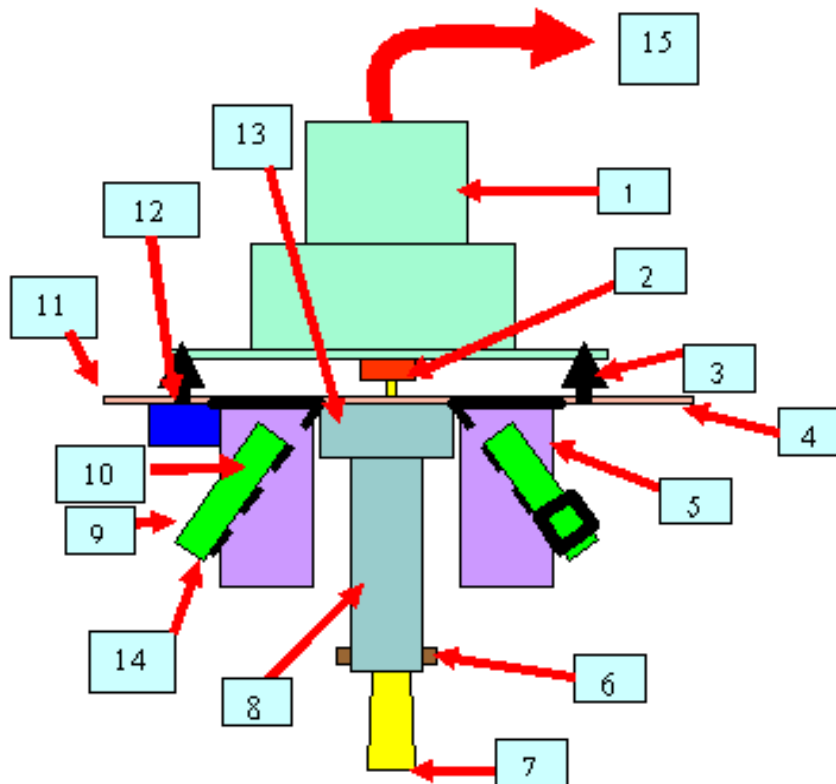


Figure 3. The various parts and component to make up the device:

- 1) Main chassis – Remote control;
- 2) Shaft Driver – Hollow copper rod;
- 3) Screw – M3 Screw with nut;
- 4) Main Platform – Acrylic board;
- 5) Angle Shifter – Aluminium block;
- 6) Stabilizer – Screws;
- 7) Air terminal;
- 8) Air terminal holder – PVC pipe;
- 9) Laser beam holder – Pipe Clip;
- 10) Laser Indicator – Laser beam;
- 11) Switch;
- 12) Battery slot;
- 13) PVC coupling;
- 14) Shifter base – Pad locks;
- 15) Connector to antenna modem

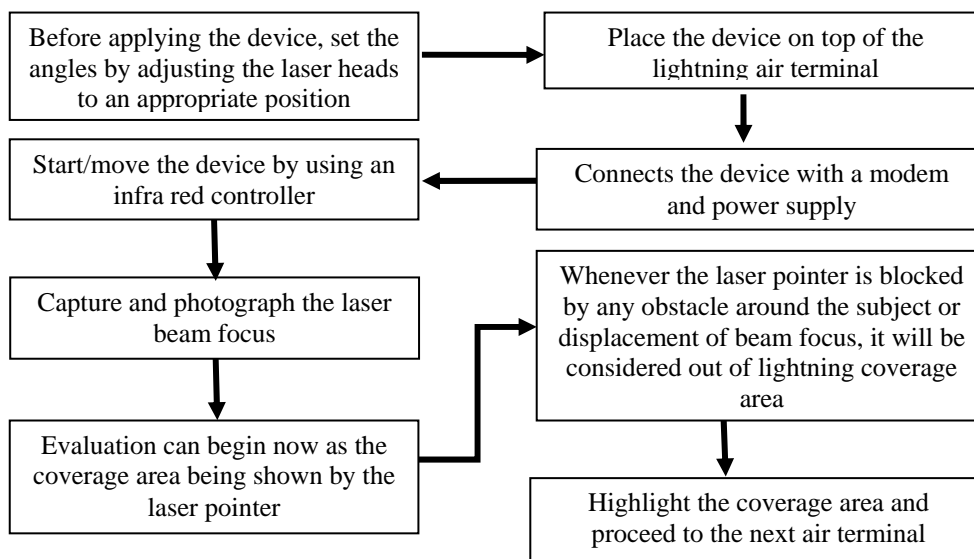


Figure 4. System functionality flowchart

The sensitivity and resolution of the laser beam images captured is very critical to determine the severity of seismic impact and flood displacement forces to the facilities. The camera should be an infra-red type that can record the low luminosity laser beam and they should continuously record the images while the instrument is used. The recorded images will be preserved for future reference.

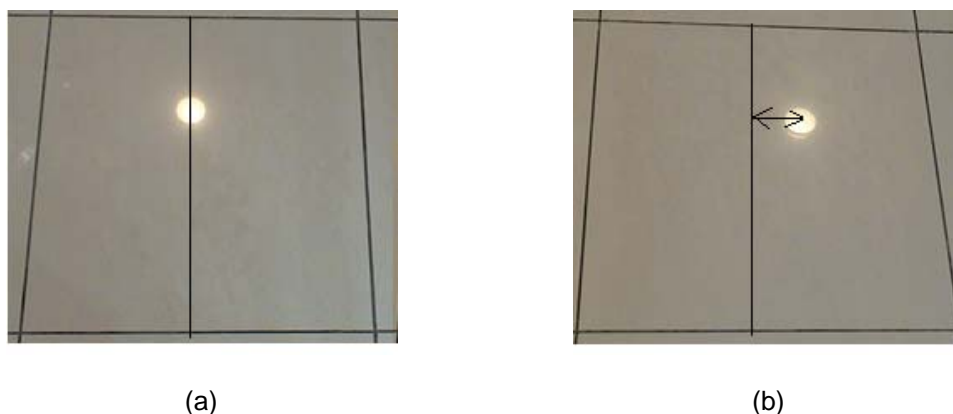


Figure 5. The image was recorded by using a camera which was affixed at the same position. (a) The previous image of laser beam focus and (b) The later image of the laser recorded where there was misalignment has taken place

A systematic error is derived from the elevated positioning of the device which is placed on top of the lightning air terminal as shown in **Error! Reference source not found.**. This fact is seemingly unavoidable except when the laser pointer placement is the same point of the apex of the air terminal and the device is designed as such which is very thin and slim. But at this point of time, the length of the device is quite sizable however if the actual air terminal is of substantial height, the integrated error compounded due to this on the image captured by the camera is relatively neglected. Another source of error could be also emerged if the lightning air

terminal is tilted. In **Error! Reference source not found.**, the fractional comparison between  $Y$  and  $h_{actual}$  and also  $x' - x$  with  $h'_{field}$  is very small. Thus the slight image displacement captured by the camera can be neglected and assume quite correct.

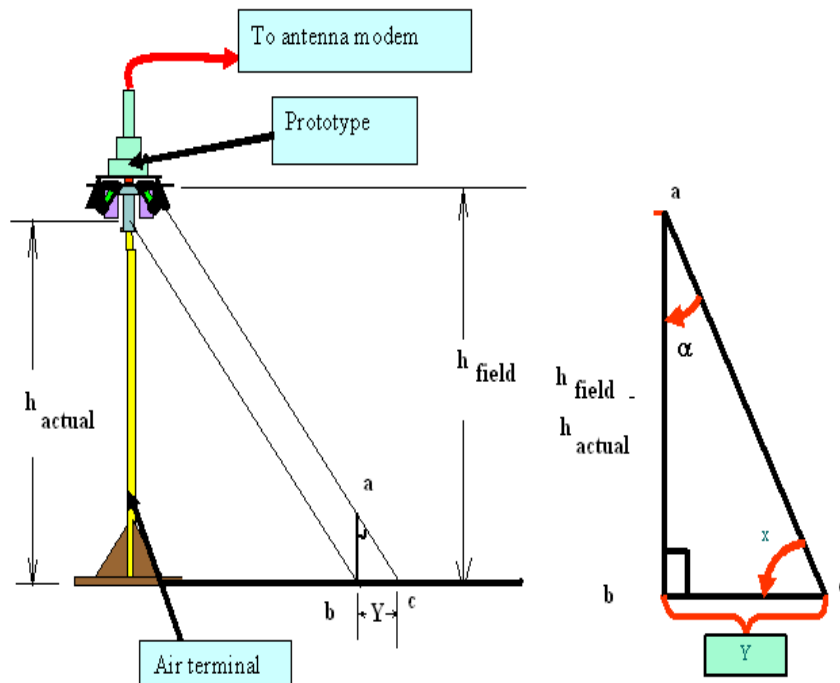


Figure 6. Slight error being introduced to the measurement

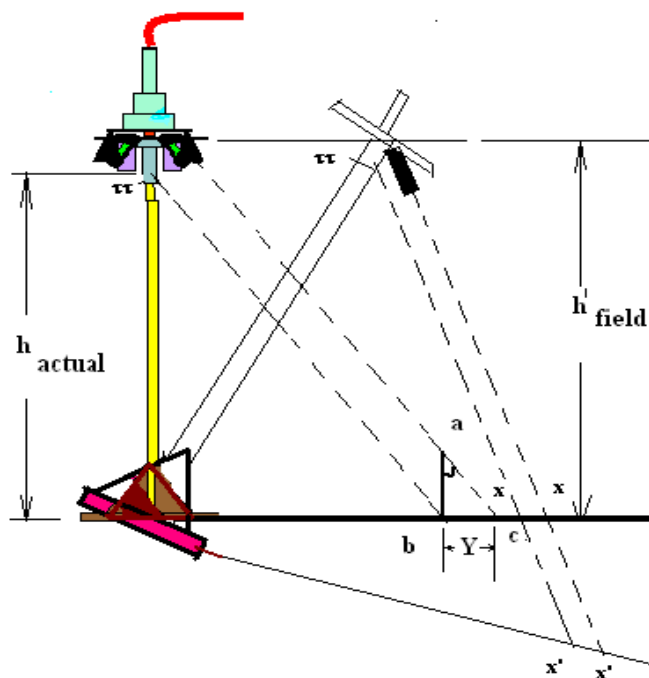


Figure 7. The error involve in the tilting of building which correspondingly tilt the lightning air terminal

### 3. Discussions

The need to evaluate the adequacy of lightning protection is gaining more importance when an occurrence of seismic activities and also flood. The fact these natural disasters can create environmental displacement which subsequently affects the building structures and other structures –involving the several of form utilities – especially when considering the petroleum facilities and power utilities. Taking for granted that seismic activities in this region will not adversely affect the facilities is not acceptable in relation to international professional practices and taking too much risk when involving with petroleum industries. So the invention of this technique and device is rather timely assisting building maintenance personnel to audit the buildings lightning protection system adequacy and with some form of analysis can provide certain forms of assessment of degree of seismic impact on infrastructure facilities. It is a common scenario in wide application of laser for measurement such as temperature, distance and others. Thus making the usage of laser beams for the determination of lightning collection volume variation is good method. The additional height being introduced to the air terminal which is subjected to test measurement due to the size of the device, introduce a degree of error to the resultant lightning collection volume generated by the laser beam.

### 4. Conclusion

In this paper, a new technique has been introduced. A new device has been also designed and constructed which makes possible to re-evaluate the shielding angle of a lightning rod and subsequently the lightning collection volume variation. The testing showed that this technique can be straightforwardly applied and produced a good result.

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