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# Lightning

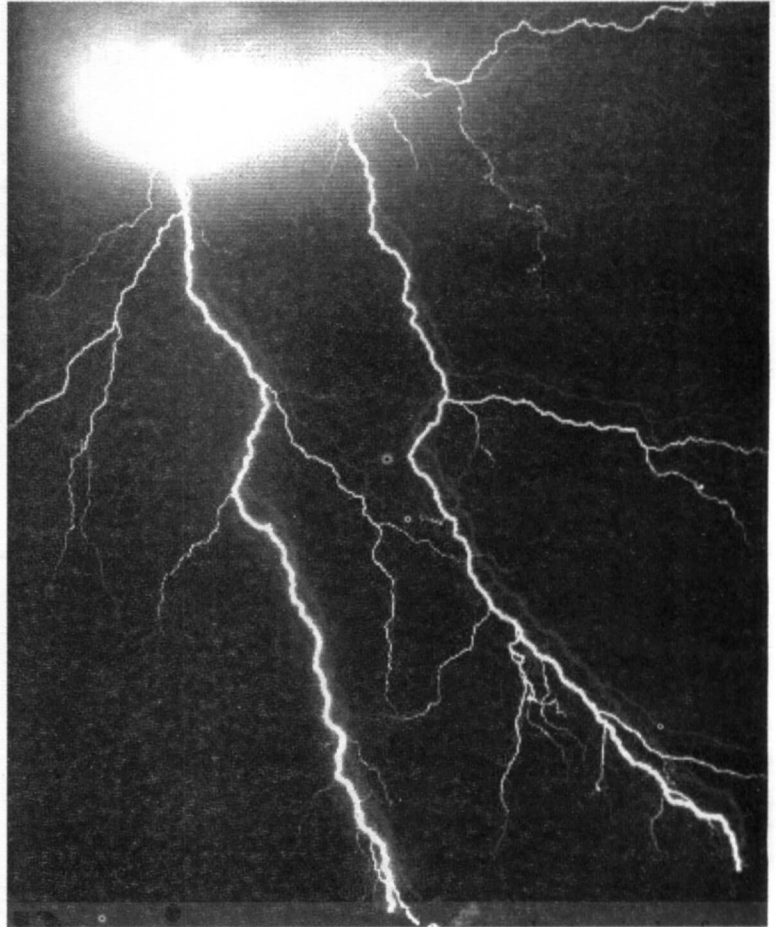
The glazing momentary brightness followed by the monstrous bellowing that occurs naturally in the atmosphere is termed lightning and thunder. It was treated as a powerful divine deity by the people of many civilisations for thousands of years. For an example, ancient Greeks believed that a Cretan called Lasios was struck by lightning hurled by Zeus for attempting to ravish Demeter, the goddess of Com. According to the Vedic mythology of India, Indra, the god of earth, conquered innumerable human and demon enemies, and killed the dragon Virtra, who had prevented the monsoon from breaking, by means of the power of lightning and thunder.

It is apparent that people of these ancient civilisations knew that lightning possesses a massive power that is beyond their comprehension. The lightning and thunder gods still continue in the popular beliefs of Eastern Europeans as St. Elijah, of Latin Americans as Santiago and of Nigerian Yoruba tribe as Shango, the thrower of thunderbolts. In Sri Lanka too, there are many beliefs and folk stories related to lightning although our people do not worship lightning in the capacity of a god. The ways that people look at lightning as a phenomenon are sometimes beneficial for them to have protection from lightning while in some cases they are extremely hazardous.

As a number of persons have been killed and millions of Rupees worth properties including very expensive electronic equipment were destroyed during the last few years in Sri Lanka due to lightning, now it is a good time for us to look at the basic concepts and safety of lightning.

## *What is lightning ?*

A lightning flash originates inside a cloud, several kilometers above the ground level. Except for ball lightning, which is a very rare phenomenon that we will discuss later, lightning is simply an electric spark between a cloud and ground, between two clouds or between two parts of a cloud. The spark that jumps between the ends of two wires, which are connected to



## Basics, Safety, and Protection

the terminals of a car battery, is a very basic form of lightning.

Lightning has been reported to occur in various types of clouds, in smoke emission of volcanic eruptions, in

sandstorms, in the dust-mushroom created by nuclear explosions etc. However, in tropics lightning is basically associated with a special type of cloud named Cumulonimbus cloud is given in Figure 1. A large source of positive charge is located towards the top of the cloud while a similar negative charge source is located at the lower part. At the very bottom a small positive charge pocket is located.

When the breakdown stress between the negative charge source and the positive charge pocket exceeds a certain

limit a sparking takes place between the negative charge centre and the positive pocket, thus forming a conducting

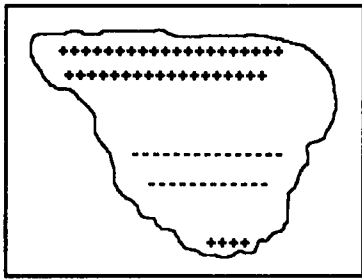


Figure 1: A simple charge structure of a Cumulonimbus Cloud. A large positive charge source at the top; Similar negative charge towards the lower part and a small positive charge pocket at the bottom.

channel. Sometimes when the negative charge source is sufficiently large the so about  $10^5$  m/s. This channel is termed the stepped leader. When the stepped leader is about 50 - 100 meters above, earthbound objects in the vicinity (eg. trees, buildings, human beings, animals etc.) start sending upward channels of opposite charge to meet the downward channel from the cloud. One of these upward channels succeeds in meeting the downward channel first. Subsequently a large current will flow through the object, which takes the earth potential to cloud (bringing negative charge into ground) is termed the return stroke is followed by several leaders that come along the already formed channel, without stepping. They are termed dart leaders and each of them is number of times. This gives the flickering effect of a lightning flash. The combination of the stepped leader, return stroke, dart leaders and subsequent strokes is termed a lightning flash. A lightning flash lasts for about 0.5 seconds. The above description is diagrammatically shown in Figure 2. In the first return stroke the current drained into ground has a typical peak current of 30 kA, however extreme values of over 250 kA have also been recorded. The inrush of this large current along the channel raise the atmospheric temperature up to about 40,000 K, which is almost 8 times greater that the temperature of the surface of the sun.

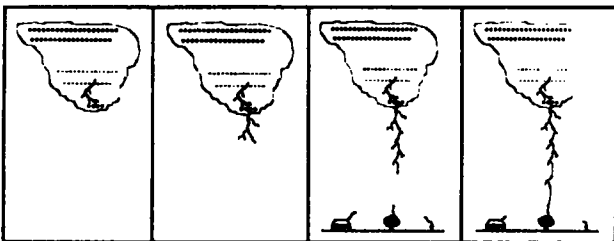


Figure 2 : The breakdown initiated inside the cloud sends a negative stepped leader which will be followed by a return stroke.

The lightning described above is called a negative ground flash as it brings negative charge to ground. Sometimes the channel may come from the upper positive charge centre which is termed a positive ground flash (Figure 3). They drive larger currents into earth than their negative counter part. Records reveal that the peak current of a positive lightning may be as high as 500 kA. They contains long continuing currents which have values over 1 kA flowing for a long period (Several hundreds of milliseconds). These long lasting currents may cause forest fires and severe explosions. Fortunately the percentage of positive lightning in tropics is only about 5% of the total ground flashes.

Except in the cases of aviation industry and high altitude in installations nobody paid attention to the protection against cloud flashes, until the development of digital communication. Cloud flashes generate bursts of pulses which are very similar in temporal characteristics to that used in date line communication. Therefore, they can

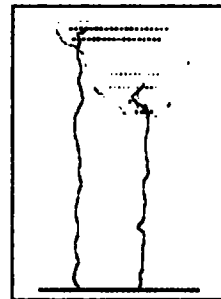


Figure 3 A positive lightning that emerges from the upper positive charge source and a negative lightning that comes from the negative charge source.

generate wrong information in such systems. Cloud flashes may occur within the cloud (intra-cloud flashes), between two clouds (inter-cloud flashes) or from cloud to air (cloud-to-air discharges). The Figure 4 depicts the three types.

If the number of branches at the ground termination is large then the lightning is termed "Fork Lightning". A recent study in Florida reveals that more than 60% of the ground flashes have multi-point ground terminations.

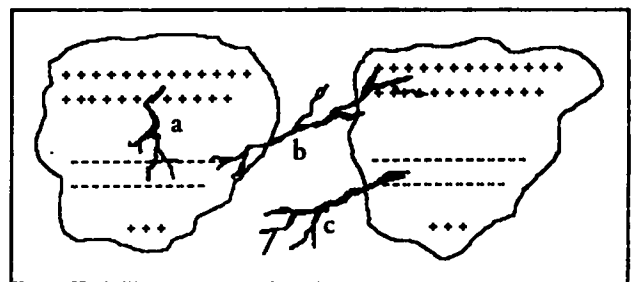
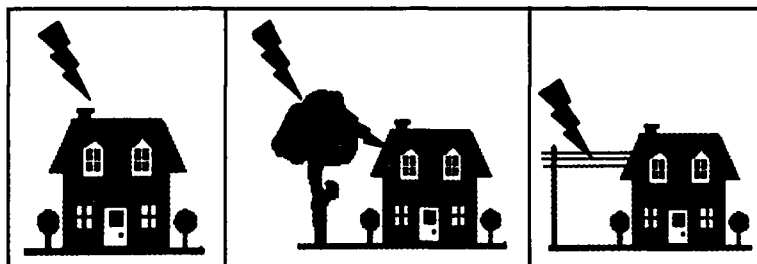


Figure 4 : There types of cloud flashes  
a. Intra-cloud flash  
b. Inter-cloud flash and  
c. cloud to air discharge

### **How does lightning cause damages ?**

Lightning may cause damages to people, buildings and equipment in three ways. If a person or a building is a tall protrusion in a certain landscape, it may be the object that sends the first upward channel that meets the downward stream of charge from the cloud. When a building attracts a downward lightning leader (direct strike) or attract a part of a lightning flash that hit another structure in the near proximity (side flash), it will get the maximum damage (Figure 5). The enormous current involved with the lightning flash may destroy the entire power and communication networks in a building including all the equipment connected to the networks. The high temperature resulted by both the current that flows in the lines and the sparks that jump in between different parts of the building may trigger fires that will completely burn out the installation. Direct lightning (or side flashes) cause damages at a very rapid rate so that once a building is lightning struck, it is very unlikely



**Figure 5 : Ways of lightning current interacting with buildings**

- a. direct strike
- b. Side flash
- c. through service lines.

that one can prevent the damages to the equipment and human injuries (still one can prevent the spreading of the fire by acting quickly).

The second mode of getting lightning currents into an installation is through the service lines such as power, communication and cable TV (Figure 5.) Once lightning strikes a service line, fractions of the lightning current enter all the nearby buildings and may destroy all the equipments that are plugged into the system. The lightning current may also injure the users of equipments connected to service lines. This mode of intrusion of the lightning current causes less damages than a direct strike, yet service lines are subjected to lightning strikes much more frequently than buildings themselves.

The lightning current that flows from cloud - to ground is a good emitter of electromagnetic radiations. Thus once a lightning hit a nearby object (e.g. about 500 m) even your building is exposed to a strong dose of electromagnetic radiation. When this radiation passes

through electronic equipments such as computers, medical equipments, security and defence etc. The sophisticated parts of them can be destroyed. This may happen even when the equipments are unplugged from service lines. However, the chances of ordinary electrical equipments getting damaged due to such radiation is very slim.

### **Lightning protection**

The above three modes of lightning threats can be eliminated by three types of lightning protection systems. A person who seeks lightning protection should clearly understand this difference.

### **Building Protection**

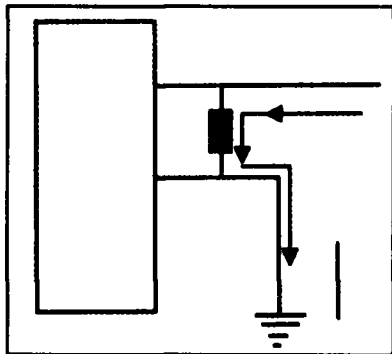
In the commercial language a building protection system is referred to a network that is meant to protect a building from direct lightning strikes and side flashes. An ordinary building protection system consists of one or several sharp pointed rods (or a mesh of metal strips/wires) installed at the roof of the building (called air termination), several metal stripes or metal wires from roof to base (down conductors) and one or several conducting rods buried in the ground (earth conductors). The down conductors ) and one or several conducting rods buried in the ground (earth conductors). The down conductor system connects the air termination to the earth conductors. When a downward channel comes

from a cloud, the air termination sends an upward channel much faster than the other parts of the building thus the lightning is attracted to one of the rods (or to the metallic mesh). Then the lightning current is safely passed in to earth through the rest of the system. Thus, instead of repelling a lightning channel, a lightning protection system attracts that. However, as the lightning current is safely driven into earth the building will not be damaged. The above system is called the "Franklin Rod System", named after Benjamin Franklin who first proposed lightning rods in 1749.

It should be clearly understood that the protection of high-risk structures needs special designs in contrast to low-risk structures irrespective of the type of protection system selected. High-risk structures include explosive industries, industries of toxic chemicals, military bases with ammunition and explosive stores, high voltage lines and power plants, oil refineries, nuclear plants etc. Typically for these high-risk structures, tall masts or overhead grounded shield wires located above the structure to be protected are designed. Here, the idea is to collect the lightning above the structure, not directly on it so that any risk of interaction of the lightning current

with the risky areas of the structure or with dangerous substances is completely excluded.

With the above-described system your building is protected only from direct strikes and probably from side flashes. Still your building can be penetrated by lightning currents that propagate along service lines (power, telecommunication etc.) There are special devices (surge diverters or surge suppressors), which prevent these current impulses from entering your building. A surge diverter is connected at the entrance of the service line to the installation. At high level of protection they are connected at the power socket of each electrical or electronic equipments as well. Under normal operation the surge diverter does not interfere with the line signals. In the case of a lightning invasion it provides a convenient path for the lightning current to divert into the earth without permitting it entering into the building or the equipment (Figure 6). Surge suppressors, which have to be connected to protect power lines, communication lines and data lines, are different from one another. Make sure that you go for a reputed brand of surge suppressors, as



**Figure 6 :** A surge diverter safely pass the lightning current to earth. Thus the equipment to the left is protected from large current surge.

the performance of such a device is difficult to be predicted unless it has a proven laboratory test report.

The sophisticated electronics in a building can also be damaged by radiation, which will be emitted from the lightning flash. Electromagnetic radiation propagates in free space. This radiation can be prevented from entering the building by taking suitable protection measures. The typical method of radiation prevention is to screen the building with a conductive material so that the

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building becomes a "Faraday Cage". As it is very costly and unnecessary to screen the whole building it is recommended to take safety measures only to compartments of the building where sophisticated electronics are installed (such as computer rooms, medical theatres and scanning rooms, control chambers of power plants, airports, military bases, and communication bases etc.) Design and implementation of protection systems that prevent the intrusion of undesired

electromagnetic impulses through both radiation and conduction is termed Electromagnetic Compatibility (EMC). This newly emerged concept of electromagnetic protection is a huge business in many developed countries but rather unheard to the Sri Lankans. Hence for an interested entrepreneur a tremendous opportunity is opened in the industry of EMC in Sri Lanka.

With all these system still nobody can guarantee you 100% protection from lightning. The company, which provides lightning protection, will give a certain level of protection (by a percentage) related to the system you buy. The cost of the system depends on the level of protection. For an example a nuclear power plant or a store of explosives and ammunitions may need a level of protection of about 99.99% (a highly expensive system) while that of 75% may be acceptable for an ordinary house.

### ***Fire balls our of the sky***

Sometimes people have observed balls of fire emerging from the sky in overcast conditions. They are now termed ball lightning. These fireballs are reported as having a size varying from that of a peanut to greater than that of a football. Their colour varies from pale yellow to glittering red. It has been seen that ball lightning moves at walking passes over some one's body the flesh and skin along the path will be burnt to ash while the person get no feeling of heat. Despite all these observations, still the scientists have failed to come up with a concrete explanation for a ball lightning. There are several theories put forward in this respect. At present, those are being discussed and reviewed by the scientific community. Nobody has yet succeeded in giving ball-lightning protection at any level.

## ***Lightning safety of human beings and animals***

It is dangerous to be the tallest protrusion of a landscape during thunderstorm conditions. If you are a tall protrusion in a certain landscape your body may be the object that sends the first upward channel that meets the downward stream of charge from the cloud. Thus in thunderstorm conditions it is advisable to avoid standing in playgrounds, seashore, paddy fields, open boats on rivers or sea, roads with no structures beside or swimming in open waters etc. One should also refrain from hiking, working on roofs, on the top of buildings under construction, on telecommunication, radio and television towers (even if the structures are lightning protected) etc.

If you are caught up outdoors in an intense thunderstorm never get shelter under a tree. The large current that flows along the trunk of a tree as a result of a lightning strike may decide to jump into your head and reach the ground through your body when you stand nearby. This is termed a side flash. A majority of lightning victims have been struck while getting shelter under trees. Thus, the number one rule of lightning protection of living beings is not to get shelter under trees or any other tall structures when lightning strikes around.

Caught up outdoors in an lightning storm one should not lie down flat. If you lay down flat in a thunderstorm a lightning that strikes ground nearby may send a current through the soil, which may enter your body from head and leave from the feet thus damaging many of the vital internal organs. Thus, the international standards recommend that the best position to be in such a condition is to squat down on your feet and to rest the head on the knees.

***A single lightning may kill more than one. In 1998, 11 players of a football team in the Africa state of Congo were killed by a single lightning strike. Also, when there are several people under a tree, several side flashes may leap out of the tree (once the tree is lightning struck) either killing or injuring all of them. Even in Sri Lanka, a few years ago, a single lightning killed five people on the same place in Moneragala as those people were getting shelter from a thin drizzle, under a tree.***

Some people believe that a person with wet clothes is safe from being hit by lightning. There is no scientific base behind this belief. However, if the person is lightning struck then the wet clothes will give him some protection. The lightning current always takes the best conducting (least resistive) path. When a person is wet his external body becomes a good conductor thus if he is lightning struck the

current will prefer to flow outside the body instead of flowing internally. Thus the person will escape with some skin burns instead of getting damages to vital organs inside the body. Similarly a person wearing a metal necklace following an external path, then to the lower abdomen and flows into earth, thus avoiding the brain and the heart.

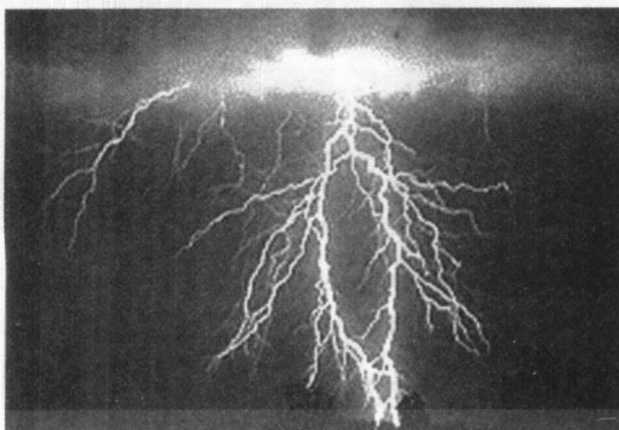
Another wrong belief is that once a person or a structure is struck by lightning he or it will not be struck again. Although it is rare, there are structures and even people who have been lightning struck several times. There is no scientific reason why one should get immunity to lightning once he is struck.

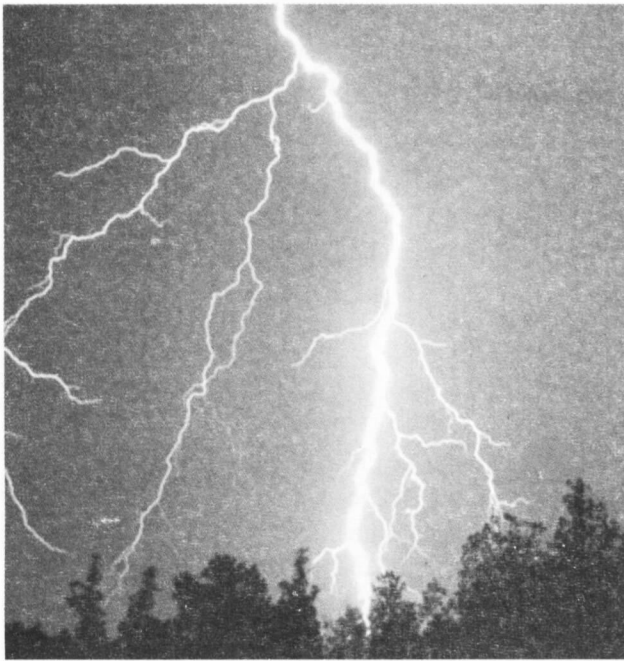
One can not avoid lightning strikes or escape unharmed even when struck by lightning if he wears rubber footwear or plastic raincoats. In contrast to the situation that a person touches a live electric wire, the insulation of rubber, plastic or any fabric cover is not sufficient at all to give you any lightning protection.

A person struck by lightning does not carry a charge in his body for several minutes, so it is not dangerous to touch him immediately after the strike. The electrical charge injected into a person by a lightning current is drained into earth within a fraction of a second. Hence, the lightning victim should be attended immediately and first aid should be given.

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It is a high risk to use the telephone during thunderstorm periods. There is a high chance of lightning striking telephone and power lines which run miles over the open





fields. Once lightning strikes the telephone network, large waves of current will propagate to the nearby subscribers through the lines. A person who uses the telephone during such an instant may be injured or even killed by this large current.

Electrical equipments are not safe if they are only kept switched off during thunderstorm periods. The lightning current, which may propagate through power cables, can easily jump across the open switches and enter the equipment. Thus, it is highly advisable to disconnect your electrical households such as phones, fax machines, computers, TVs etc., from the power line (unplug them) during thunderstorm periods. TV antenna cables should also be disconnected from the telephone network. When you go away for few days during the thunderstorm season it is better to disconnect all the electrical items at home. It is also a high risk to repair electrical networks (house wiring etc.) during thunderstorm periods.

It might be dangerous to use a needle (sewing) during a period when lightning is striking nearby. Sharp and pointed metallic objects attract lightning more than blunt and smooth objects do. Thus if the house is lightning struck, theoretically, there is a chance that the needle would get a side flash from walls, power lines etc. However, we do not know to what extent a tiny needle is capable of attracting a side flash.

Some people in our country throw out a metal rod during a lightning period. One cannot see any scientific reasoning behind this act. However, a metal rod kept close to the wall or especially a power line, metallic drain pipe etc. may attract a side flash if the building is lightning struck. Such a side flash cause fires and explosions. However, in order to get rid of such an

accident one has to throw out all the metallic objects out of the house which is not very practical.

According to observations at individual records and damage record of industries and other service providers (bank, mobile phone services etc., there are certain small areas in the country, which receive a high density of lightning compared to the neighbouring areas. Many of these areas are not located in specific geographical conditions that favour high rate of lightning strikes (located at high altitude, isolated hills etc.,) However, we need to conduct a thorough research in order to give reasons for this observation, as our current knowledge does not help to give a reasonable explanation. To name a few of these areas reported are Matugama, Horana, Avissavella, Kalutara, Bulathsinghala, Waliveriya, Gampaha, Nittambuwa and Pilimathalawa.

One may get lightning even in the absence of rain. Rain usually falls from the base of the thundercloud. Sometimes, due to the high wing shear the upper part of the cloud will spread in a large region while the lower part (base) is localised in a comparatively small region. Lightning may emanate from that dispersed upper part, thus the point at which the lightning strikes ground may be tens of kilometers away from the rain. In addition lightning may also emerge from sandstorms, dust clouds of volcanic eruptions and nuclear explosions and forest fire smokes. All these are rainless lightning.

Compared to others, coconut trees are prone to high rate of lightning strikes. There may be few reasons for this observation. Being a tall tree and having leaves with sharp edges and pointed ends a coconut tree may be the object in a certain landscape that send the first channel to meet the down coming channel from the cloud. In addition, being the most abundant tree in the country, coconut trees will obviously have a high probability of getting lightning strikes.

Lightning has a good side as well. Due to the extremely hot conditions imposed by a lightning flash Oxygen and Nitrogen of air combine together to form Nitrous Oxides. These nitrogenous compounds dissolve in rainwater and reach ground to fertilise the soil.

### ***Beyond our knowledge of Science***

Most of the ancient temples in Sri Lanka are built either in flat terrain of the dry zone (thus for a large area, the only protrusion of the ground is the Dagaba) or on top of hard rocks. Still there are very few reports on these tall structures struck by lightning. There are similar situations all over the world that can not be explained properly using the current level of scientific knowledge.

***Chandima Gomes***

*Ph D, CEng, MIEE, MInstP  
Department of Physics, University of  
Colombo*