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LOCATION FACTOR AND ITS IMPACT ON ANTENNAE SAFETY WITH REFERENCE TO DIRECT LIGHTNING STRIKES.

Z. A. Hartono & I. Robiah
Lightning Research Sdn. Bhd.
457 Jalan B11, Taman Melawati,
53100 Kuala Lumpur, Malaysia
e-mail: hartono@pc.jaring.my

Abstract: The incidence of direct lightning strikes to TV and communication antennae have increased in recent years due to their indiscriminate installation on residential and commercial buildings. Recent studies have shown that the lightning discharge has preferred strike points (PSP) on buildings and structures by their unique geometry. This allows for a safer location for installing the antennae to avoid from being struck directly by lightning. The application of proprietary lightning air terminals do not provide any advantage since these devices have been declared as unscientific and unproven and their application is contrary to the provisions of international and national lightning protection standards. A brief comparison is also made with antennae protection techniques practiced in Japan.

Keywords

Air terminal, Franklin rod, active device, early streamer emission, protection cone.

I. INTRODUCTION

The advancement of television and other wireless telecommunication technologies have resulted in many types of antennae being mounted indiscriminately on the roofs of residential and commercial buildings. This has resulted in an increase in the number of reported lightning strikes to the antennae and collateral damages to equipment and services inside the building.

A survey of the antennae installations in Kuala Lumpur shows that no particular rules were applied as far as lightning safety is concerned. This may be due to a lack of specific guidelines on the safe installation of the antennae for the vendor or service provider to follow.

Recent studies have shown that the lightning flash is not as random as it was once thought to be. The location of the lightning strike attachment point on a building (i.e. its preferred strike point, PSP) has been found to be very predictable and they are normally identified from the damage left behind after the lightning strike had occurred. This information can be used to locate the installation of the antennae away from the PSPs and hence reduce the incidence and severity of the lightning damage.

The indiscriminate installation of the antennae is partly due to the long held mistaken belief that the proprietary lightning air terminals will provide an enhanced zone of protection on the roof. The claim has been shown to be scientifically unfounded by lightning research scientists and their effectiveness have never been proven nor published in peer reviewed scientific literature.

This fact was made very clear when several international organisations such as the International Conference on Large High Voltage Electric Systems (CIGRE), the International Conference on Lightning Protection (ICLP), the International Electrotechnical Commission (IEC) and the National Fire Protection Association International (NFPA) refused to recognise the non-conventional proprietary air terminal technology.

The methods proposed for the protection of the antennae can also be applied for other equipment such as surveillance cameras, spot lights etc.

II. LIGHTNING STRIKE LOCATION

A study conducted on buildings that have been struck by lightning in Kuala Lumpur has shown that lightning have PSPs that are dependent on the shape and height of the buildings [1]. This study has led to a better understanding of the lightning attachment process and will lead to an improvement in the design of the conventional lightning protection systems (i.e. those using the conventional lightning rods and copper strips).

For low buildings, such as homes and shops, the PSPs are commonly found on the highest parts of the buildings such as the top of the roofs and facades. It has been observed that the units at the far ends of a row of connected buildings of the same height have a higher probability of being struck by lightning [Fig. 1].

For tall buildings (i.e. above 50m in height), the PSPs are to be found mainly on the protruding corners on the flat or slanted roofs instead of the highest points. It has also been observed that the incidence of multiple strikes on the exact same location is more commonly found in tall buildings [Fig. 2].

The above suggests that an effective conventional lightning protection system can be designed by locating the Franklin rods exactly on the various PSPs that have been determined for a particular building. By this method, the lightning has a very good chance of attaching itself to the lightning rod instead of to the building fabric.

Fig. 1: A lightning damaged façade of a 10m high shop. Several other damaged façades could be found on nearby buildings of similar height.

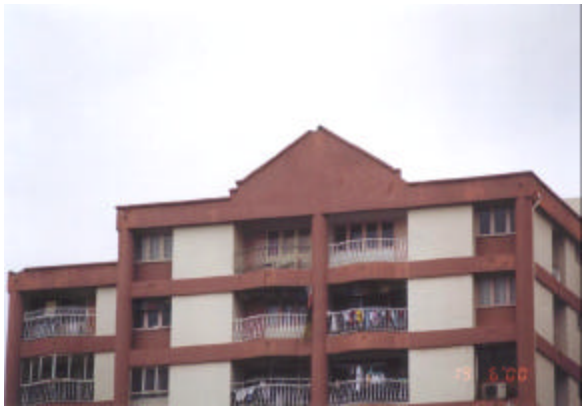

Fig.2: A highrise apartment building showing two typical lightning damaged locations (top of façade and corner on far left).

Since the PSPs for a building can be effectively identified, the antennae can be prevented from being struck by lightning by locating them some distance away from these points. This basic rule will result in a safe installation of the antennae and other equipment on the roof.

III. LIGHTNING AIR TERMINALS

An important component of any lightning protection system is the air terminal, a device that is installed on the upper parts of a building and is designed to be struck by lightning in order to protect the building. The conventional (or Franklin) air terminal has been in use for the past 250 years since its invention by Benjamin Franklin.

The air terminal technology has become the subject of a major controversy since the 1970s when non-conventional (i.e. proprietary) air terminals that lay claim to enhanced protection were introduced. Since lightning is known to cause major damages on the structure it struck, the question of public safety arise when the use of one or a limited number of proprietary air terminals is supposed to replace a much higher number of Franklin rods that are installed at predetermined locations on the building.

A. Non-conventional air terminals

The existing proprietary air terminals are classified under two broad categories:

1) Lightning eliminating air terminals, and
2) Lightning attracting air terminals.

Lightning eliminating air terminals

These air terminals were invented and introduced in the USA in the early 1970s. The principal claim of this technology is that the air terminal can discharge the thundercloud and hence eliminate the possibility of lightning striking on the facility it was installed on.

The air terminals were met by immediate failures when used by NASA and the USAF in 1974. The air terminals were actually photographed being struck by lightning at the above facilities on several occasions [2]. This led to a scientific enquiry that subsequently disproved the claims made by the inventor.

In spite of the above, the air terminal is still being sold in the USA on the basis that the end users are deemed to have understood and accepted the claims made for the air terminal when it is sold to them. It is also being sold in other countries, such as Malaysia, due to the lack of public information on the adverse performance of these air terminals in the USA.

Due to this, information pertaining to the performance of the lightning eliminating air terminals were recently published by the IEEE in 1998 [3].

Lightning attracting air terminals

The above air terminals relied on the fact that objects on the ground that are in the vicinity of the PSP emit streamers (i.e. streams of electrical charges) just moments before the main lightning discharge occurs. The lightning discharge is known to connect to only one of the many streamers emitted by ground-based objects to complete the discharge path to earth.

The air terminal, that is also known by such terms as “radioactive”, “active” or “early streamer emitting” (ESE) air terminal, claims to be able to emit the streamer earlier or faster than other nearby building parts can, hence ensuring that the lightning discharge is attracted to it instead of the building. However, this claim was found to be untrue from a number of recent scientific studies. Some of them are as follows :

1) In a high voltage laboratory test, the Franklin air terminal was struck by simulated lightning more frequently than the ESE air terminal that was placed near to it. [4]
2) In a field test carried out on several ESE and Franklin air terminals for over seven summer

seasons, the ESE air terminals were never struck by lightning while one type of Franklin air terminal was repeatedly struck by lightning.[5]

3) In a long term study of dozens of buildings that have each been equipped with one or more ESE air terminals, most of the buildings were found to have been struck by lightning, some with multiple strike points. [6]

Proposed standard for the ESE air terminal

Within the last decade, the vendors of the ESE air terminals attempted to establish a standard for their product through international technical organisations such as CIGRE, IEC and NFPA. Due to public safety interests, these organisations conducted a thorough investigation into the scientific claims made by the ESE vendors and found them to be unscientific and unproven.

In 1995, the above organisations issued several resolutions to reject the ESE air terminals and their stand on this issue have been followed by many other national standards bodies since then [7][8].

In the USA, the vendors proposed a separate standard for the ESE air terminal, the Draft NFPA781, but this was rejected by the NFPA in 1995. In May 2000, the NFPA again reconfirmed its stand not to issue the proposed Draft NFPA781 after conducting a major scientific review in 1999 that was participated by many interested parties from around the world, including the ICLP. [9][10][11]

As a result, the Franklin rod is the only air terminal that is currently recognised as scientific and proven by CIGRE, ICLP, NFPA, IEC and many other national standards.

B. Conventional air terminals

The Franklin rod has two basic versions, the sharp pointed version that is used in the USA and many countries around the world and the blunt tipped version that is used in some countries in Europe. Since its invention, there has not been any detailed study conducted on the shape of the rod and its effect on the attachment of the lightning discharge, until recently.

A study conducted by the Langmuir Laboratory of Atmospheric Research (USA) shows that the blunt tipped rod performed better than either the sharp pointed rod or the ESE air terminal under natural lightning conditions. After observing several of the above air terminals for seven summer seasons, they discovered that only the blunt tipped rod with a diameter of 19mm was struck by lightning. [12]

Their discovery also confirmed earlier findings that the sharp point, a main feature of the ESE air terminal, creates corona discharges that shield the terminal from being struck by lightning.

It is evident that a significant improvement can be made to the existing sharp pointed Franklin rods by converting the sharp points into those with a more rounded shape.

IV. SUMMARY OF OBSERVED DEFECTIVE LOCATION OF ANTENNAE

The following are some of the commonly observed errors in the installation of the antennae that were made by vendors and service providers:

Roof mounted terrestial and satellite TV antennae

A survey of the above installations shows that a significant number was installed at or very near to the PSPs on residential and commercial buildings. The following are some examples of erroneous antennae installation that placed them at risk to direct lightning strikes:

1) At or near to corners of rooftops of tall buildings [Fig. 3]

2) At or near to apex of facades [Fig. 4]

3) At or near to the protruding features of sloping roofs [Fig. 5]

This has resulted in many TV receivers being damaged by direct or indirect lightning strikes.

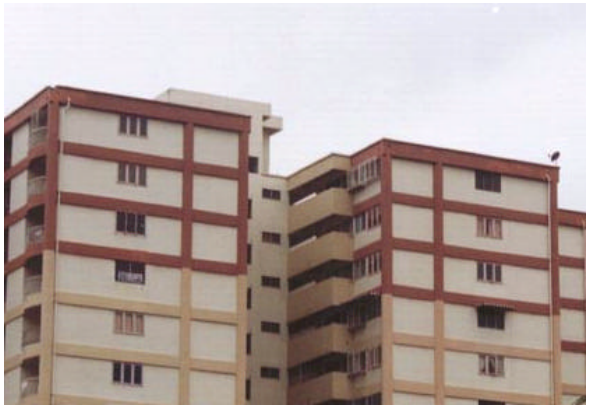

Fig. 3: A home satellite TV antenna installed on a PSP (far right) while a damaged PSP is shown on far left.

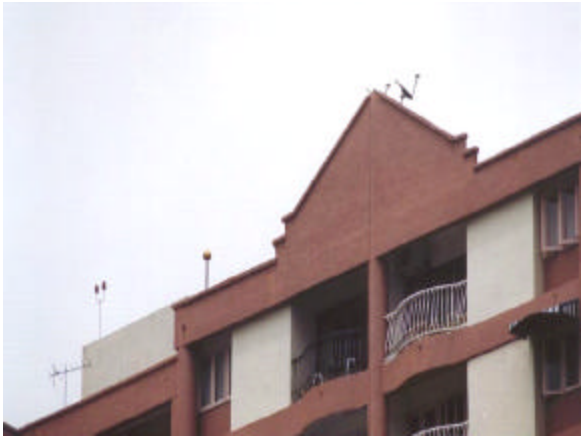

Fig. 4: Two home satellite TV antennae installed behind a façade that has been damaged by lightning.

Fig.5: A TV antenna installed close to a PSP, with an already damaged PSP nearby.

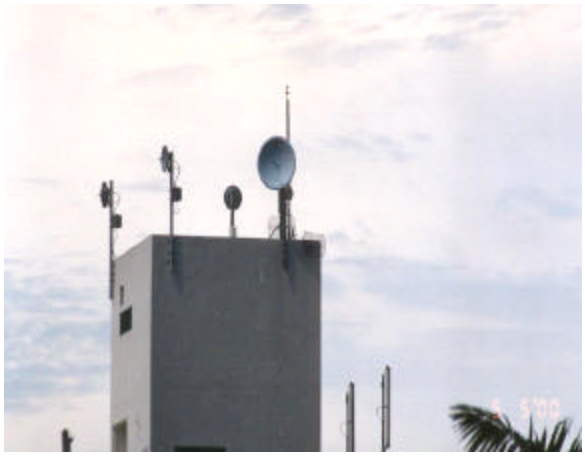

Fig. 6: Several microwave antennae installed on a roof that has been installed with a proprietary lightning air terminal.

Roof mounted satellite and microwave antennae.

With more businesses and service providers relying on private communication networks, the use of satellite receiving and microwave antennae has been on the increase. These antennae face the same problem since some of them have been installed at or near the PSPs. [Fig. 6]

The bigger business satellite receiving antenna also face an even higher risk of direct strike by lightning since many of them are installed on the rooftops of tall commercial buildings where multiple strikes to the PSPs have been documented.

Roof mounted cellular telephone antennae

By far, the installation of the cellular telephone antennae face the biggest risk since the majority of these installations are being installed right on the PSPs [Fig. 7]. This shows that in-depth understanding of the lightning strike behaviour are required by those who supervise or install the cellular systems to avoid making such errors.

In some cases, the only protection available for these antennae are proprietary air terminals that are normally installed at the center of the roof that is located several metres away. Some of these cellular antennae may have the Franklin rod installed on the individual mounting pole but they are now regarded as being ineffective since most or all of them are of the sharp pointed variant.

Mast mounted antennae

The antennae that are installed near the top of the mast are expected to have a higher probability of damage than those below them. This may be due to the lightning that can approach the top of the mast from numerous non-vertical trajectories.

These antennae can be effectively protected by installing slanted or horizontal air terminals above them in order to intercept the lightning discharge that approach the mast from a low trajectory. [13] This method has been applied with satisfactory results so far. [Fig. 8]

In some cases, the cellular antennae are mounted on horizontal metal extensions from the mast that emanate at or below the top. [Fig. 9] This practice may significantly increase their risk of being struck by lightning since the antennae is located beyond the safety zone afforded by the mast.

Fig. 7: Cellular phone system antennae installed on and close to the PSP with two proprietary air terminals installed nearby.

Fig.8: A radio system antennae installed near the top of the mast and protected between two simple triangular shaped horizontal air terminals.

Fig. 9: Cellular phone system antennae installed on horizontal extensions. The antennae face a higher risk of being struck by lightning in this case.

An air terminal, whether conventional or non-conventional, that is installed on the mast to protect the antennae is usually installed at the center of it and is technically defunct as far as protection is concerned. In many cases, the height of the air terminal above the antenna do not conform even to the basic "protection cone" design principles that are found in the national lightning protection standards.

V. ANTENNAE PROTECTION METHODS IN JAPAN: A BRIEF COMPARISON

In Japan, a nation that is steeped in safety practices and strict adherence to standards, the use of the conventional lightning air terminal is almost universal. It can be seen that the method of protecting the antennae in Japan is in stark contrast with those found in Malaysia.

Instead of using the normal (short) Franklin rods, the extended version of the Franklin rods is the favorite air terminal and they can be commonly seen on top of all types of buildings. They are used singly or in large numbers, depending on the importance of the building or equipment to be protected.

By using one or more of the extended Franklin rods at a particular location, the antennae and other roof-mounted equipment are protected using the standard "protection cone" concept. The extended Franklin rod is a much safer method than using the normal Franklin rod on the antennae or its mounting pole since the lightning discharge is kept well away from them, hence further reducing the possibility of interference being picked up by the antennae.

The logical and effective application of the extended Franklin air terminal is one of the reasons for the reported low incidence of damages due to direct lightning strikes in Japan. By following the Japanese example, it is expected that the lightning problem in Malaysia can be similarly reduced.

The following figures provide some examples on the use of the extended Franklin rods in Japan. [Figs. 10, 11 and 12].

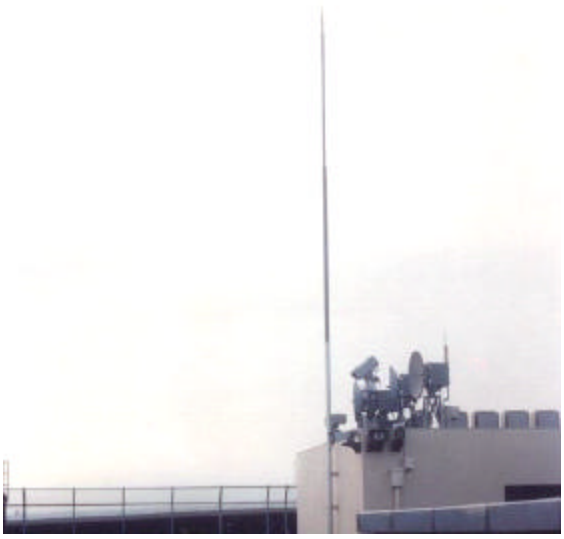

Fig. 10: A single extended Franklin rod used to protect a cluster of antennae on the roof of Narita Airport. The conventional lightning air terminal is widely used in Japan.

Fig. 11: Two extended Franklin rods being used to provide a corridor of protection for a number of antennae installed near and between them.

Fig. 12: Three extended Franklin rods being used to provide a wide area of protection for a large satellite antenna and several other antennae.

VI. CONCLUSIONS

The high incidence of lightning related damages to the antennae and associated equipment in Malaysia can be attributed to their indiscriminate installation at the PSPs. This practice seemed to be strongly influenced by the mistaken belief held by many technical professionals that the non-conventional lightning air terminal is able to provide a wide protection coverage, some up to 100m in radius, that include most of the PSPs on a building or structure.

With all the non-conventional lightning air terminals having been declared as unscientific and unproven since 1995, their application is deemed to have contravened the national and international standard on lightning protection. The antennae that have been installed in many parts of Malaysia, as previously described, are therefore deemed to be unprotected from direct lightning strikes. This account for the high incidence of lightning related damages that have been reported to the antennae.

It is apparent that this situation is the result of the following factors:

1) a lack of proper basic understanding of the lightning discharge attachment process and of the valid lightning protection methods
2) a lack of compliance to the provisions of the existing national and international lightning protection standards
3) a lack of restriction on the use and sale of the non-conventional lightning air terminals even though they have no scientific basis and is not field proven.

Due to the above factors, end users and service providers have to put up with unnecessary losses whenever an antenna and its associated system is damaged due to lightning. The solution to this costly, and potentially hazardous, problem is to ensure that the technical professionals concerned with the installation of the antennae are provided with adequate information about lightning and lightning protection from reliable scientific sources.

Currently, it is estimated that the majority of technical professionals obtained their information on lightning and lightning protection from the vendors of the non-conventional air terminals. This situation allows the vendors to provide a biased and non-scientific view of lightning protection technology on the unsuspecting technical professionals.

In addition to the above, a guideline on the proper methods of installing and protecting the antennae from lightning strikes need to be prepared as a technical reference for those concerned with its installation and maintenance. This will ensure a more uniform and safer method of installing the antennae that is highly relevant in a lightning prone region such as that found in Malaysia.

VII. REFERENCES

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