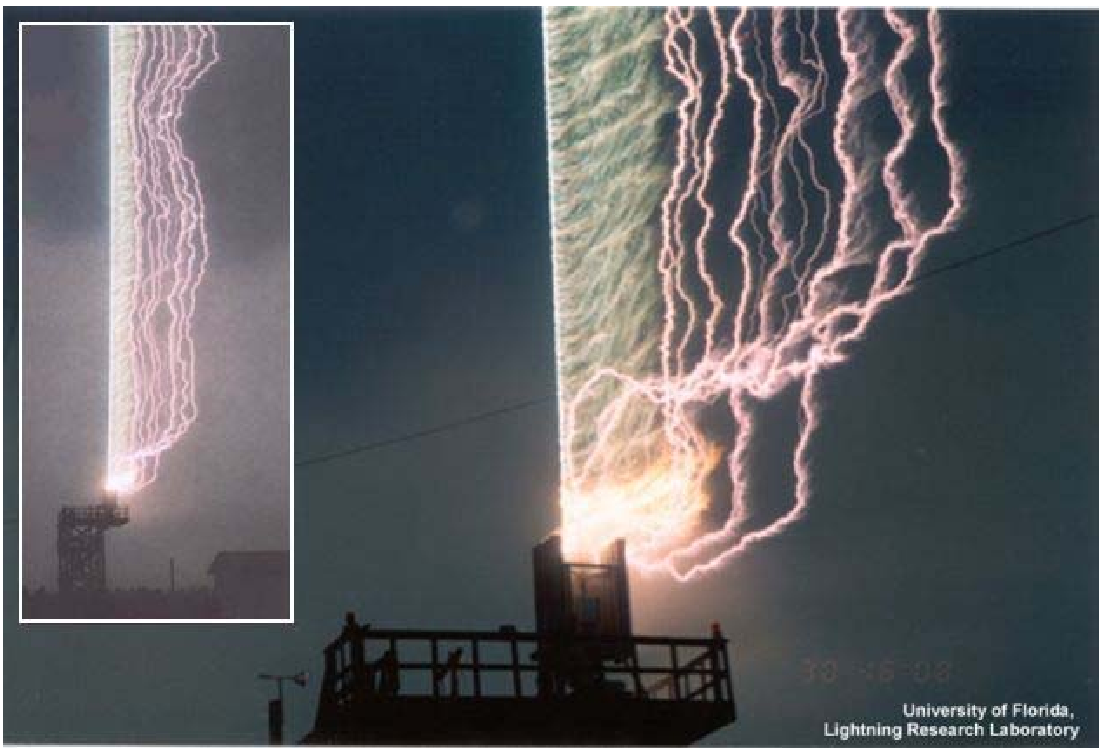
Acknowledgements

The information in this article was compiled from (literally) dozens of sources on the internet & elsewhere. To list them all individually would take up a significant amount of space in OTN so I'd like to take the alternative option of thanking everyone who has put any information about thunderstorms & lightning (or the folklore surrounding it) onto the internet or into print.

I do have to specifically thank two sources though.

Jerry Kerr, from Lightning Eliminators and Consultants Inc, Colorado, for permission to use illustrations of their DAS and CCGR systems.

Dr Uman, from University of Florida's International Center for Lightning Research, for permission to use the following photo on the cover of OTNews.



It looks pretty spectacular, doesn’t it?

What you are seeing is lightning striking the trailing wire of a rocket deliberately fired up into a storm to attract a strike. The straight luminous line is the triggering wire. The luminous channels blown sideways and separated by the wind are subsequent dart leader/return stroke combinations originating in the thundercloud charge.

In addition to bright flashes of visible light and a lot of noise lightning produces intense bursts of radiation believed to be X-rays. The discovery illustrates another of Nature's many ways of generating high-energy particles, of which X-rays are one type, and also how little we actually have to learn about lightning.

LIGHTNING

by G3ZPF

A close encounter of the 'burnt' kind

I have always had a healthy respect for lightning. The elevated nature of my parents' house saw to that. Over the years we were witness to some really spectacular lightning displays. When I obtained my licence in my late teens, the presence of aerials over the roof sharpened my awareness even more. The coax feeder of my HF aerial had its braid connected to earth just outside the timber window-frame by a length of 30A twin & earth, with all 3 strands in parallel. The arrival of a really impressive storm would be indicated by the intermittent 'click' of the static spark between the centre connector & outer. On one occasion I somewhat foolishly decided to see if I could use my new camera to capture a lightning bolt on film. Luckily, as it turned out, the storm abated & I moved away from the window to do some reading.

Fig1: Cloud-to-ground and cloud-to-cloud lightning strokes during a night-time storm

A few minutes later there was a huge 'bang' and everything went white. Bear in mind I was facing away from the window at the time. The intensity of the flash was far more than just a bright light behind me. Both retinas briefly registered peak white for the whole of their area. It probably only took a couple of seconds for sight & hearing to return, but it seemed far longer.

The coax connector on the wooden window-frame had 'gone', along with the corner of the window-frame itself. The burned stump at the end of the coax was hanging outside. Part of the charge had then (judging by the burn marks) travelled along the bottom of the net curtain, then jumped to the nearest mains socket and gone to ground. Taking all the fuses with it. The audible bang had been so severe that the light-bulb in my room was broken.

Subsequent investigation revealed the 30A twin and earth to be in a sorry state, and the leg of the aerial that went down the garden had 'gone'. Later I found a number of sections of the wire (curiously all of them were around 12" long) with molten ends, scattered across the garden.

Although I only heard one bang, the rest of the family downstairs heard two. The first accompanied the appearance of what they described as a 'large fireball' just above the aluminium greenhouse, and the second was definitely from upstairs in my room.

This sequence tail end of a storm followed by one 'last blast' that does real damage turns out to be a known event, so don't be too quick to turn the TV back on when you think the storm has passed. One of my mother's neighbours did just that. Before he got back to his seat his TV exploded.

Thunderstorms

As most people are vaguely aware, there are two main types of thunderstorms in the UK. A 'frontal' storm precedes the arrival of a cold front. The sudden upward displacement of warm air by the incoming cold air triggers the storm. These storms tend to be violent but short-lived, because of the rapid transit of the "squall line" over the ground.

The more common type is that which appears on a summer afternoon and rumbles on for quite some time. They are also caused by rapidly rising warm air, but without assistance from an incoming cold front, just summer heat over warm, moist, ground. Because there is little or no wind, the thermals are quite concentrated and give rise to the classic anvil shaped cloud formations sometimes referred to as a 'thunderhead', but more correctly as 'cumulo-nimbus'. Large storms can contain more than one 'thunderhead'.

Both storm types collect electrical charge from friction within the turbulent air. The charge distributes itself vertically through the storm centre with the top of the storm being positive.

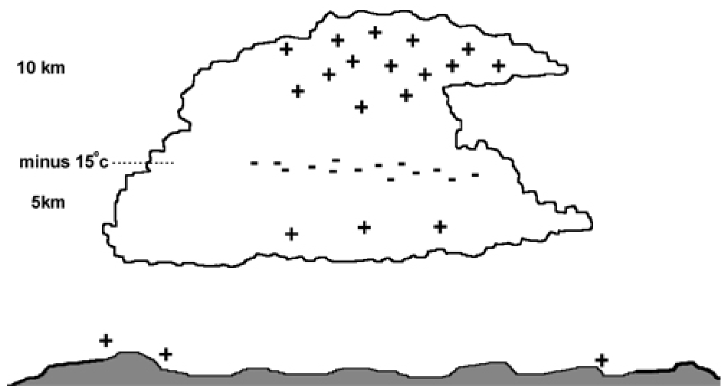


Fig 2 Charge distribution within a thundercloud.

There are other sources of natural lightning that I was previously unaware of, although thankfully not likely to occur in the UK. The ash clouds from an erupting volcano can often generate enough charge to form lightning, but to be honest I think anyone near enough to see it would have more pressing matters to attend to. Large forest fires can generate enough dust to create a sufficient static charge too, but again I think most people will be too preoccupied to notice.

A brief history of lightning research

Early experiments with electricity using Leyden Jars prompted a number of people to suggest that small sparks were of the same nature as lightning. Famously, Benjamin Franklin tested the hypothesis by flying a kite in a thunderstorm. Less famously, he had initially intended to use the spire of a church being erected in Philadelphia at the time, but became frustrated by the delay in its completion and chose to use a kite instead. By the time of the kite flying, French scientists had conducted similar experiments but because the original idea of using a high object + spark gap had been his; Franklin is generally credited as being the first. Except in France, presumably.

In June 1752 Franklin raised his kite, assisted by his son. On his end of the string was a key, tied to a post with a silk thread. After a while, Franklin noticed the fibres on the string stretching out. Intrigued, he moved closer. As he brought his hand close to the key a spark jumped across the gap. The rain had soaked the string and made it conductive. Luckily the amount of charge built up at that point was only enough to give Franklin a fright. Had he left it any longer before approaching the string, the consequences could have been fatal.

Oblivious to the magnitude of the power they were investigating, Franklin's experience prompted a number of people to replicate the experiment. Predictably there were a number of fatalities, one of the most famous being Professor Richman, of St Petersburg. During his experiment a 'ball of lightning' appeared. He was killed outright, his clothes burned, his shoes blown apart, and the door of his room ripped from its hinges. That kind of thing could really ruin your day.

I was amazed to discover that during the 1700's it was widely believed that ringing church bells during a thunderstorm would protect the community against lightning. Church bells were inscribed with the words *Fulgura Frango*, or "I break the lightning". The sound from the ringing of church bells was said to ward off the evil spirits associated with the lightning, and actually cause the lightning to disperse. This belief persisted despite records indicating that more than 300 church towers were struck by lightning, and 103 bell ringers were killed on duty, over a thirty-three year period in the mid 1700's. We must have been slow learners back then.

As a result of his kite experiment, Franklin went on to develop the lightning rod but instead of plaudits from a grateful population he was blamed for the "year without a summer". Briefly, it is now know that dust from a series of volcanic eruptions in 1816 lowered temperatures worldwide. The greatest effect seems to have been in the American northeast where frost killed off pretty well all crops that had been planted and two large snowstorms in June killed off a significant portion of the population in that area. Many historians believe these events prompted the rapid settlement of the American mid-west. Europe, still recovering from the Napoleonic wars, had its share of troubles too. The "wet, ungenial summer" of 1816 forced Mary Shelley, John Polidori, and friends to spend their Swiss holiday indoors. During this time Shelley wrote "Frankenstein", and Polidori wrote "The Vampyre". In addition, the high levels of ash in the atmosphere produced spectacular sunsets, and these are a feature in many Turner paintings of the time.

How strange that a natural disaster could simultaneously cause such real hardship and such classics of art and literature. For his part Franklin was to shoulder the suspicion that his introduction of lightning rods had changed the weather until 1920 when climatologists finally determined the real cause of the 1816 weather, and identified similar events in other centuries.

The mechanics behind the formation of lightning

Separation of positive and negative charges within a cloud is a prerequisite for lightning formation. The exact mechanism by which this happens is still the subject of debate. One popular theory is that falling droplets of rain & ice become electrically polarised as they fall through the atmosphere's natural electric field, whilst another suggests that colliding ice particles become charged by electrostatic induction.

Recent studies claim that the numbers simply don't add up for either of those scenarios and that most thunderheads cannot generate enough charge separation to form a lightning discharge without external assistance. Prime candidate for the 'assistant' are cosmic rays entering the earth's atmosphere and producing an extremely energetic electron by ionisation. This produces a cascade effect of fast moving electrons within the thundercloud, elevating charge levels to the point where a discharge can occur.

Cosmic rays are known to strike every square metre of the atmosphere thousands of times each second, so there are plenty of 'assistants' available but there is still speculation about the exact mechanisms involved. Clearly science is still some way from a definitive understanding.

Whatever the formation mechanism, the opposing charges are driven apart and energy is stored in the electronic field between them. Positively charged crystals rise to the top, with negatively charged crystals and hailstones falling to the middle and bottom of the cloud layer. The conditions are then suitable for cloud-to-cloud lightning to form. Cloud-to-ground lightning is actually far less common, but being more spectacular is more frequently noticed. Clouds that do not produce enough ice crystals often fail to gain enough charge separation for lightning to form.

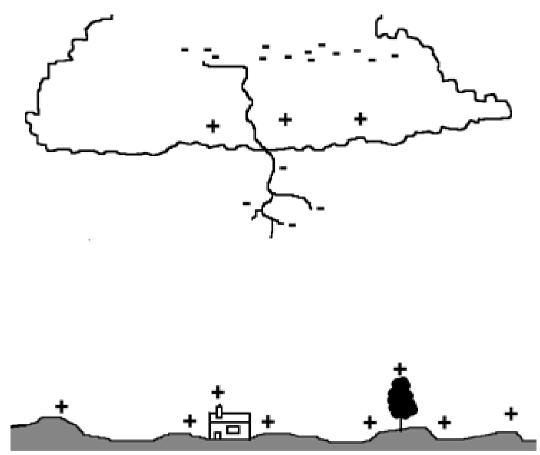


Fig 3 Stepped leader breaks out of cloud

For cloud-to-ground lightning to form, an additional process is required. Positive charges form on the ground below the clouds, causing electrical energy to be stored in the air between. These charges can spread for some distance around the storm, but are concentrated in vertical objects such as trees or tall buildings. A bolt of lightning usually begins when an invisible, negatively charged, 'stepped leader' breaks out of the cloud. **(FIG 3)**.

These ‘steps’ are of similar length; typically around 20 metres but sometimes over 100 metres depending on the charge in the storm cloud and the current in the stroke. Each step brings the cloud base potential down by the step length, resulting in another packet of ionised air allowing the leader to continue its downward progression. More than one packet may be targeted for the leader, but not all alternatives find subsequent targets so they fizzle out, leaving one to continue its downward path.

When the stepped leader reaches a point around one step distance from the earth (or from an earth-bound facility) a “strike zone” is established. The strike zone is hemispherical in shape, with a radius of one step length. The electric field within the strike zone is now so high that it creates upward moving ‘streamers’ **(FIG 4)** from earthbound objects within the zone.

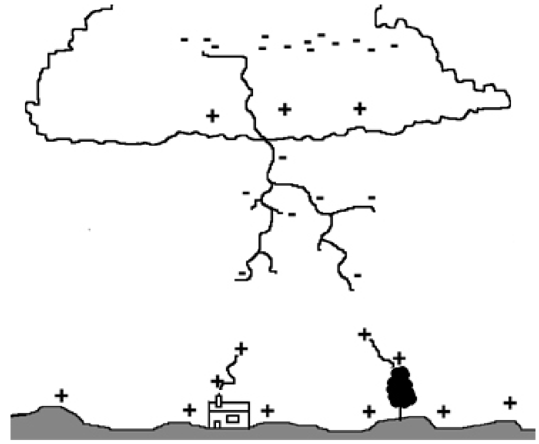


FIG 4 Stepped leader establishes a ‘strike zone’ and streamers move upwards from likely targets.

The first streamer that reaches the end of the stepped leader completes the circuit. **(FIG 5)**

When the leader and streamer meet the current increases vastly, as the energy stored in the e-field between cloud and ground is drawn into the conductive filament. The region of high current travels back up the streamer into the cloud **(FIG 6)**.

This ‘return stroke’ is what we actually see as "lightning" so, contrary to popular opinion, the bolt of lightning travels up, not down. It is several inches in diameter, surrounded by about a four-inch thick sleeve of superheated air, carrying a charge of 20,000 to 200,000 amperes. Superheating of the surrounding air, causes it to expand violently, which we hear as thunder. When it completes its path to the cloud, negative charges within the cloud are neutralised **(Fig 7)**.

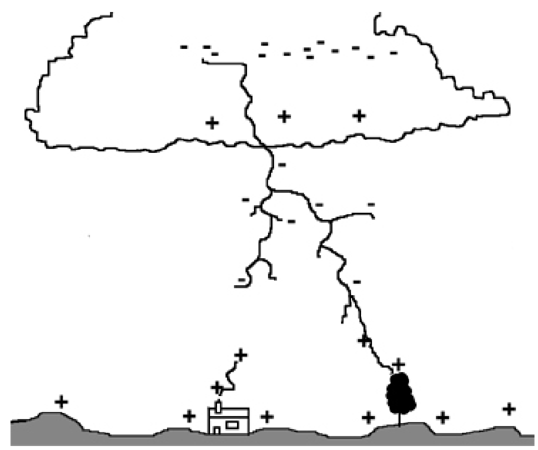


Fig 5 One streamer joins with stepped leader and completes the circuit.

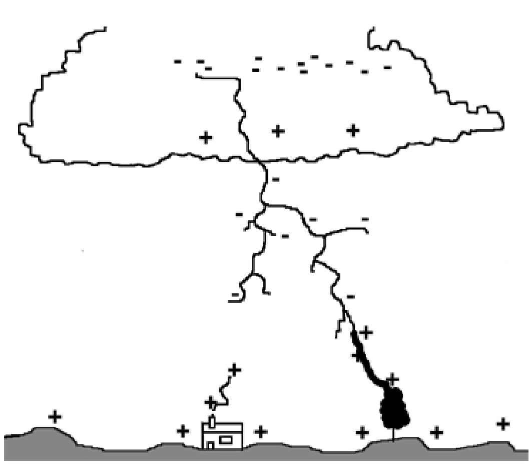


FIG 6 High current starts to track upwards towards the cloud.

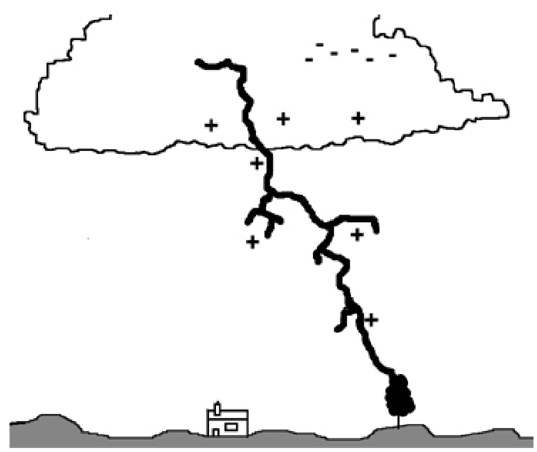


Fig 7 The return stroke reaches the source of the stepped leader and neutralises local charges.

Because the light and sound are generated simultaneously, but travel at different speeds, you can time the interval between them to roughly estimate how far away the bolt of lighting is. The lightning is approximately one kilometre distant for every 3 second interval (one mile for every 5 seconds) between the flash and the crash.

Most strikes only last a quarter of a second, but sometimes several strokes travel up and down the same leader, forming a flickering effect. When multiple strokes along the same stepped leader happen, sometimes a connection is made to a different upward streamer on successive strokes. This gives rise to a display of 'forked lightning', although strictly speaking lightning never forks. The effect is caused by persistence of vision in the human eye making two or more distinct strokes look like a single event.

Positive lightning

The previous section described 'negative' lightning. This accounts for over 95% of all lightning, but there is another form of lightning. In around 5% of cases, the stepped leader forms at the positively charged cloud top with a negatively charged streamer coming up from the ground to meet it. **(FIG 8)**.

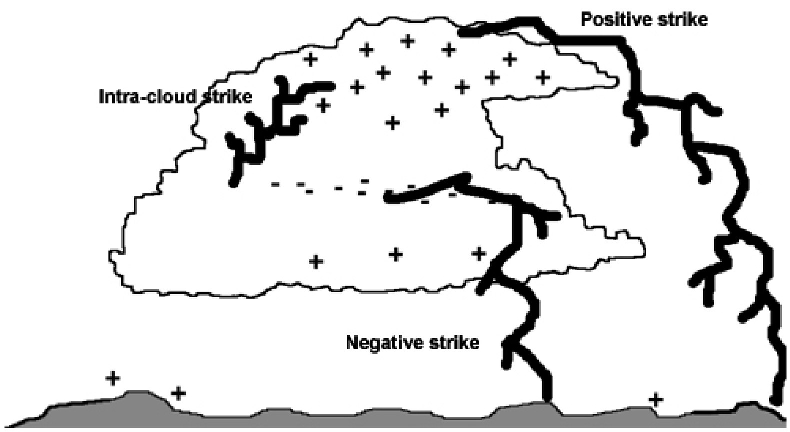


Fig 8 Main types of lightning stroke

The overall effect is a transfer of positive charges to the ground, hence this phenomenon being referred to as 'positive' lightning. This form of lightning carries around 10 times more power than the more common form. The bolts last almost 10 times as long, and can strike several miles from the storm centre. Think about this. You can be struck by lightning whilst the storm is still some distance away. This event is presumably the source of the expression "a bolt from the blue".

Because of their higher power, positive lightning strikes are considerably more destructive. Somewhat worryingly for regular fliers, aircraft are not designed to withstand such strikes because their existence was unknown at the time standards were set. Positive lightning is now thought to be responsible for many forest fires, and has been shown to trigger lightning in the upper atmosphere. It tends to occur at the end of a thunderstorm; the 'last blast' I referred to earlier. Statistics suggest an average 'positive' lightning strike carries a current of 300 kiloAmps, at a voltage of 1gigaVolt. A side-effect of 'positive' strikes is the generation of ELF and VLF radio waves.

Hailstones

You will undoubtedly have noticed that some thunderstorms drop hail as well as rain. Hail forms when strong updrafts carry water droplets high enough in a thunderstorm to freeze. A strong updraft allows hailstones to grow large enough to reach the ground. Once hailstones grow large enough to begin falling despite the updraft that's been holding them up, they hurtle toward the ground as fast as 90 mph. Small ones often melt before reaching the ground, but the larger ones reach the ground and can cause extensive damage to crops and vehicles caught in the storm. Most hailstones that make it to the ground have melted away to something quite tiny, but stones weighing more than a pound have been recorded in some countries.

The thunderstorm we had in the midlands last week produced hailstones so large that they left a number of dents in the roof of my car. One week on (in the grip of another) with all radios & computers disconnected from the mains, their aerials, and the telephone line, I am grateful for the battery in my elderly laptop making it possible to make a start on this piece.

I know of a couple of people left crying into their beer because the static generated by a storm 'fried' their modem, so it pays to disconnect it from the telephone line during a thunderstorm. Some people earth their aerials during a storm, while others prefer to leave them floating. If you subscribe to the latter school of thought, don't forget to short them to earth briefly, before re-connecting the rig because a sizeable charge can build up on them during a storm.

Other lightning types

In addition to the two main types (positive and negative) there are numerous sub-classifications.

Intra cloud : The most common form. Discharge takes place entirely within one cloud. Commonly referred to as 'sheet lightning' because it lights up the cloud, and surrounding area of sky with what looks like a 'sheet' of light.

Anvil crawler : A special type of intra-cloud lightning, where discharges travel up the outside of the cloud, branching out at the top of the 'anvil'.

Anvil lightning : A special form of 'positive' lightning. The stepped leader starts out horizontally until finally veering towards the ground. These usually occur several miles ahead of the main storm.

Bead lightning : A normal (negative) cloud-to-ground strike, but with higher than normal luminosity. When the discharge fades it leaves behind a brief 'string of beads' effect.

Cloud-to-Cloud lightning : In large storms, where a discharge takes place between two entirely separate 'thunderheads'.

Ribbon lightning : Occurs in storms with strong cross-winds and multiple return strokes. Each successive stroke is blown slightly sideways from the previous one, creating a ribbon effect. A spectacular example of this is shown on the cover. That lightning strike was artificially triggered, by launching a small rocket with attached wire upwards into a storm. The left-hand edge of the ribbon is perfectly straight, where the strike came down the cable. Subsequent strokes displaced to the right by the strong wind are more irregular.

Ball lightning : An extremely rare event. For a long time the phenomenon was treated as a myth or hoax. Witness accounts vary widely, and are often contradictory. Some researchers suggest that this is because several different phenomena are being incorrectly grouped together. The discharges are red to yellow in colour and seem to float in the air. Despite their name can be spherical, ovoid, tear-drop, or rod-like in shape. The longest dimension observed is between 15 and 40 cm, although clearly that has to be a guesstimate as no-one in their right mind would get close enough to use a ruler.

Some reports indicate the discharge appears to be attracted to an object, whilst others report it moving randomly. After being visible for a few seconds the discharge either disperses, is absorbed into an object or (rarely) vanishes with an explosion.

Sightings on the wingtips of ww2 bombers gave rise to them being called "foo fighters". More recently ball lightning has been reported floating down the aisle of an airliner. Bet there was a rush for the loo afterwards!

Despite extensive surveys of several thousand witness accounts, and the study of numerous photographs, no explanation for ball lightning can be deduced. Attempts to create similar events in a laboratory have produced superficially similar phenomena, but there is no evidence that a true replica of the natural event has ever been created artificially.

Upper atmosphere lightning : I was rather surprised (given their location) that this was observed as far back as 1886, although obviously it is only in recent years that the technology became available for thorough investigation. There are three main classifications. Sprites, Elves, and Jets.

Sprites are reddish-orange flashes that occur high above the cumulo-nimbus cloud of a thunderstorm. They occur within 100milliseconds of a 'positive' cloud-to-ground strike, although they can be up to 50km distant from it. They usually occur as a cluster of vertical discharges extending from 40 to 47 miles above the earth, lasting for around 17 milliseconds. Preceded by a halo that forms due to local heating and ionisation, they are accompanied by VLF emissions.

Jets, or blue-jets, extend from the top of a 'thunderhead' in a narrow cone extending up to 30 miles above the earth. Brighter than sprites and, as their name suggests, blue in colour. First recorded on video during a 1989 Shuttle mission.

Elves, are a faint red flattened glow which rapidly expands to around 250 miles in diameter. They last only for around 1 millisecond and occur about 60 miles above the earth, directly over thunderstorms. The light is generated by excitation of nitrogen molecules due to electron collisions resulting from the EMP caused by a 'positive' lightning bolt.

Lightning Protection

It goes without saying that lightning is not something you want to tangle with, but given the inescapable presence of it on a regular basis, what measures can be taken to minimise the consequences of a strike.

Superficially, the figures do not look too encouraging. There are reckoned to be around 2000 thunderstorms in progress around the world at any one time. These result in 30 to 100 ground strikes every second, or about 5 million each day. Scary huh?

Well, like most statistics, it pays to study the detail. For the UK it has been determined that there are likely to be 10 days in a year when a thunderstorm is in your vicinity. By which they mean within audible range, not necessarily overhead. Statistical evidence that indicates an 'average' storm produces 10 to 15 ground strikes, and that the storm is around 4 square kilometres. A stationary 'average' storm in an 'average' year would thus produce 2.5 ground strikes per square kilometre, but storms are not stationary. During its life of 30 to 60 mins, this 'average' storm would (on average) be travelling at 50 km/hr so its ground strikes would be spread over an area of 100 square kilometres.

We are already knee-deep in 'averages', so I'll cut to the chase. The statistics ultimately determine the chance of a ground strike hitting an 'average' domestic property being 1 strike every 500 years. This gives an entirely different (though equally valid) perspective to the 5 million strikes/day worldwide, doesn't it? Even allowing for 'blips' in the statistics, the odds of disaster are quite low, but don't lose sight of the fact that statistical events are not synchronised with your lifestyle. That 1 in 500 year event can happen the day after you move into your new house.

Anyone with an aerial mast tempts providence by putting up a tall conductor at pretty near earth potential. Still, if it is tall enough to enclose your property within a 'cone of protection' a mast is easier to replace than the roof of your house.

RadCom (Jan 1984) outlined a simple technique that allegedly offers 93% protection to your aerials & house, from a direct strike. It consists of a 50mm dia mast, 5 metres higher than any other part of your installation, with a short rod on top. All joints should be electrically sound, and protected against corrosion. The base should be connected to a 15 mm earth rod, 2.5 metres long. In addition to providing a cone of protection some 20m in diameter, you can gamma match the pole and use it as an aerial.

Do not be lulled into a false sense of *absolute* security by the 'cone of protection' mentioned previously. I well remember a trip around the Sutton Coldfield transmitting station many years ago. Tom Douglas (G3BA) mentioned that when the 900ft mast was proposed, the 'cone of protection' offered by the mast to local dwellings formed part of the charm offensive. The elevated landscape had seen more than its share of lightning strikes in the past, and the residents were duly mollified. Unfortunately, a few months into service, a lightning bolt completely ignored the mast & ripped the roof off a house well within the 'cone of protection'. It hasn't happened since, and the mast has taken multiple strikes over the years, but it serves to reinforce the feeling that "if its got your name on it, then sooner or later….."

Spark-gap dischargers are something you can either pay an awful lot of money for, or which you can make yourself. For open wire feeders something made from a strip of PCB should suffice, and a number of similar diagrams have appeared over the years. **(FIG 9)** shows one suitable for open wire feeders.

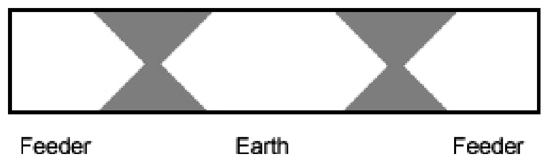


Fig 9 A spark discharger for open wire feeders made from a strip of Printed Circuit Board.

A similar, but physically different, arrangement can be arranged for coaxial feeders. The idea is to ensure that your mast, not your feeders, look like a grounded lightning conductor to a storm.

For coaxial lines there are two basic types of arrestor. The cheapest is nothing more than a spark gap inside a back-to-back connector, whilst similar looking ones containing a gas discharge tube cost around 10 times the price. **(Fig 10)**. The cheap ones actually earth the braid of the coax, and in my experience whilst the PL259 variety seem OK at HF, when I tried one for a 70MHz antenna feed, the VSWR was rather high. Some gas discharge types have to be completely replaced after a strike, whilst others have replaceable gas units.

Fig 10

Simple arrestor

Gas discharge arrestor

Attract or Prevent

Commercial facilities have their risk of lightning strike expressed either as the "Keraunic number" (lightning days per year) or the "isokeraunic level". I was somewhat surprised to find that there are 2 options for dealing with lightning. Either use a conventional lightning rod to attract the strike towards a specific structure, and conduct the strike to ground, or use a charge transfer system to discourage the strike happening. To be strictly correct there is a 3rd technique, called passive protection, whereby you effectively form a rudimentary Faraday cage around the structure to provide numerous paths to earth, but personally I see this as a variation on the standard lightning rod.

Lightning rods being commodity items, it was inevitable that the marketing men would be looking to improve on it. The result is the 'ESE' or Early Streamer Emitter **(Fig 11)**. These are claimed to speed up the process of ionisation that it will saturate earlier than other potential targets and cast a streamer upwards much further than a normal lightning rod. The combination of these claimed features should mean that it is definitely the chosen target of a lightning bolt.

Fig 11 Early Streamer Emitter

It is common practice for lightning rods to have a sharp point at the top, but according to a recent field study a rod with a rounded or spherical end is better. Researchers in New Mexico tested sharp and blunt rods, together with early streamer emitters. After 7 years on a mountain none of the sharp rods or 'early streamer emitters' had been struck once, but the rounded rods had been struck numerous times. Although sharp tipped rods do get struck when no blunt ones are nearby, the conclusion was that blunt rods are far more effective.An additional, though unmentioned, conclusion would seem to be that early streamer emitters do not perform as advertised. They have apparently yet to be accepted by the BSI.

I was quite surprised to find that there are systems designed to discourage lightning. Rather than accept the inevitable, and target the strike to a favoured point & then deal with it, you use a Dissipation Array System (DAS) to prevent a strike. Lightning strikes are the process of neutralising the potential between the cloud and earth. To prevent a strike to a given area, a system must be able to reduce the potential between the site and the storm cloud so that the potential difference never gets high enough for a lightning strike to terminate within the protected area. In other words, the system must release (by leakage) the charge induced in the area of concern to a level where a lightning strike is impractical.

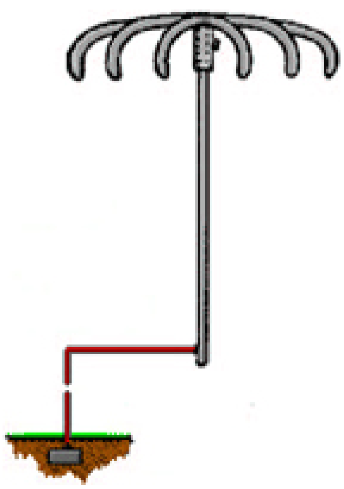


Fig 12 Nikola Tesla's lightning rod

Apparently, some research suggests that much of the storm's energy is dissipated by natural dissipation. The ionisation produced by trees, grass, fences, and man-made objects that are earthed and exposed to the electrostatic field created by a storm. The dissipation array effectively works by increasing the number of ionisation points from the single one of a lightning rod to something that looks (to the storm) like thousands of them. That way the charge dissipates as quickly as it builds up, so a lightning bolt can never form.

This is, in effect, what Benjamin Franklin originally proposed, but to get a lightning rod high enough to actually be inside a storm cloud was impractical so he opted for short rods on tall structures. Nikola Tesla was granted a patent on a different form of lightning rod because he was able to demonstrate that a single point actually increased the risk of a strike. **Fig 12** shows Tesla's patent. Looks like a standard lightning rod with a capacity hat on top. This makes me wonder whether a multi-element HF yagi on top of a tower would actually form a DAS array by accident.

The modern DAS systems comprise a huge, mesh, capacity hat on the top of a tower or tall structure, in conjunction with something called a 'spline ball' (metal spheres with numerous spikes) down the sides. An essential part of the overall protection is an effective earthing system, **(fig 13)**. The marketing men have been busy here too. Earthing system is such a boring concept. Think “ground charge collector” instead.

To me, hoping to persuade the lightning to go elsewhere, as opposed to accepting the inevitable and allowing for it, seemed to be a somewhat naive (and expensive) approach but after reading the literature more thoroughly I can see instances where it has merit.

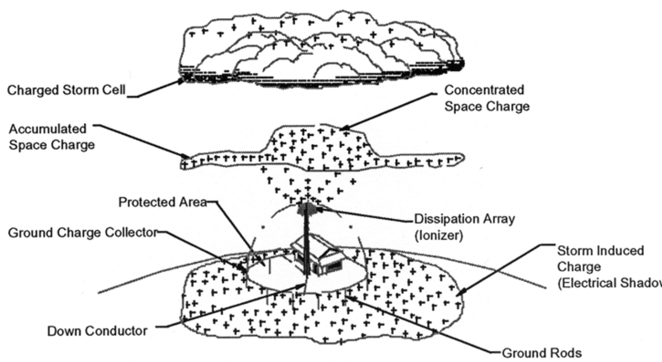


Fig 13 A Dissipation Array System
Lightning Eliminators and Consultants Inc. Colorado.

When lightning does strike, it generates an EMP (electro-magnetic pulse) and can also cause power surges in power lines. In communication facilities you really don’t want these around, so a DAS system that reduces the chance of a strike is worth having. If push comes to shove and an extreme storm gets the better of the system, then the tall structure carrying the DAS will carry the strike to earth anyway. This is only going to be worthwhile in isolated sites. There isn’t much point in reducing the likelihood of a strike on your facility if it is going to hit the guy right next door & generate surges and EMP anyway.

Earth systems
To be fully effective, any lightning protection system must be efficiently earthed. In Fig 12 the system appears to be a circle of copper wire, buried some 250mm below the surface, with individual earth rods spaced at 10 metres around the circumference. The literature does suggest that a grid of interconnecting wires (in other words an earth mat) is also beneficial. Many amateurs will already have an reasonable earth system, especially those using LF verticals with extensive radial systems. The literature indicates that despite the high current passing through the lightning rod, currents experienced in earth systems rarely exceed 0.5A so our existing RF earth should be able to cope.

To increase the efficiency of earth rods, the Chemically Charged Ground Rod (CCGR) has been developed. The LEC version is illustrated in **Fig 14**.

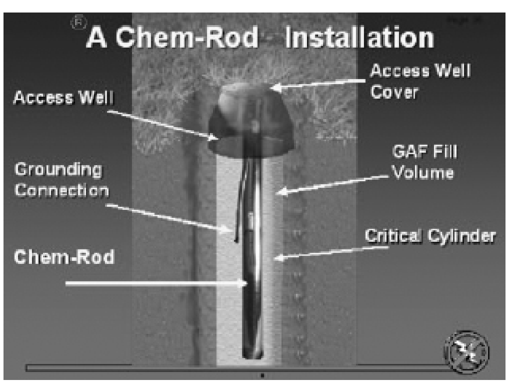


Fig 14 Chemically Charged Ground Rod

The perforated 50mm tube is filled with “metallic salt”. Moisture from rainwater form a solution, which seeps out into the surrounding soil. This lowers the soil resistivity, hence increasing the efficiency. The rods are said to take about 10 weeks to reach their design ‘resistivity’, which thereafter continues to drop off at a slower rate for the next 6 months or more, depending on soil porosity. Details are sketchy, but I assume this requires topping up of the “metallic salts” and the presence of an access cover seems to support that view.

The area of backfill material, and the material used for backfill, around the rod performs a function too. The ‘cylinder’ of backfill material is required to be between 12” and 24” diameter. Again, details of composition are sketchy. They refer to ‘clay-based mixtures’ and ‘carbon-based mixtures’. The latter stated as being better, but more expensive.

I'm not aware of any reference to these devices in the amateur press, but for people unable to install extensive radial systems under vertical aerials, or even for general RF use, these CCGR may be worth experimenting with if more details were available. If anyone has experience with them, perhaps in a professional situation, I would be most interested to know.

Your life in your hands

The title for this section was actually the title of an article by G3FEW (our illustrious editor) in the July 1984 edition of Practical Wireless. Good advice never ages, so the relevant part will be repeated here. The arrangement shown in **Fig 15** for earthing a coax down-lead, suggested by Ted, is exactly the same as the one I had in use at the time of my "close encounter".

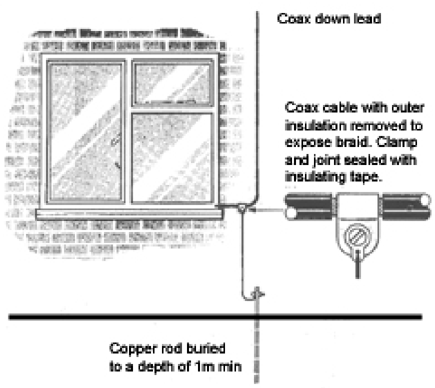


Fig 15 Earthing coax braid at entry to building to minimise strike damage.

Despite the damage done to my window frame at the time of that strike, there is little doubt in my mind that it prevented the majority of the strike entering the building and causing extensive damage. In my case, the earth strap was actually fixed right at the window frame, so moving it slightly away may have saved the wooden frame from damage. As Ted said in his original article, there is little you can do about a huge direct strike but some very simple precautions can minimise the damage caused by lesser ones.

Even in the absence of a strike, static charges can build up on aerials to levels which would damage RF sections of a receiver so it always pays to earth aerials even when thunderstorms are some distance away.

At my current QTH, the aluminium mast attached to the rear gable of my bungalow has a length of 30A twin & earth from its base to an earth rod. At the point where the coax down-leads from my W3DZZ and 4m vertical turn away from the mast and through the brickwork, they have their braids earthed to the same lead. Should the mast be struck, then most of the charge should carry straight on down into the ground, with only a small portion of it possibly coming along the coax into the shack. As I always disconnect my aerials from my rigs when not in use, the consequences of this should not be expensive.

Although I disconnect my electronics from the mains whenever a thunderstorm is about, there will be times when you are not at home to do this. Surge protection strips for equipment mains leads (which often incorporate one for your telephone line too) are a relatively inexpensive method of protecting against voltage surges caused by thunderstorms. Some of them have RFI filtering too, which helps stop general mains noise.

Lightning injuries

Nearly 2000 people each year are injured by lightning strikes, of whom up to a third may die. Injuries result from 3 factors. Electrical damage, intense heat, and the mechanical energy generated by the strike. While sudden death is common from the huge voltage of a lightning strike, survivors fare better than victims of conventional electrical shock.

People may be hit in several ways. In a direct hit the charge strikes the victim first. Somewhat surprisingly, if the victim's skin resistance is high enough, most of the current will flash around the skin or clothing to the ground. Whilst you would probably expect a direct strike to turn someone to ash, the outcome is often surprisingly benign. Splash strikes occur when lightning effectively bounces off a nearby object and hits the victim en-route to the ground. Again the victim's injuries can sometimes be surprisingly small.

Ground strikes, where the bolt hits the ground near a victim, can be very nasty. The charge is conducted through the victim via their feet. You would think having both feet on the ground would make you safe, but it is not necessarily so, due to an effect called 'step potential'.

When a lightning bolt forms, there is a significant voltage present at its junction with the ground. This voltage tapers off in all directions, but the rate of change is such that if you happen to be standing with your feet apart, and sideways-on to the strike, the potential difference between your two feet can be disasterously high. Cows fare pretty badly in this respect, for two reasons. Firstly, the distance between their front and back legs is significant. Secondly, they tend to huddle together during a storm. In effect the 'step' is not between the legs of the individual cows, but between the legs of the cow nearest the strike, and those of the animal furthest away. The charge passes through the bodies of animals in contact.

For those of a morbid disposition, photographic photographs of entire herds being wiped out in this way can be found on the internet.

If caught out in a thunderstorm (on a golf course perhaps) the one place you definitely do **not** want to shelter is under a tree. If you feel the hairs on your head start to rise, this is an indication that you are in a strike zone and a 'streamer' has formed from you (fig 4 refers). Do not be tempted to throw yourself flat on the ground. The step potential from a nearby strike would be fatal. Instead, crouch down. Feet together. Head on knees. Arms wrapped around legs. For fairly obvious reasons this posture is known as the 'desperation position'. Incidentally, wet clothing means you are actually **less** likely to be injured if struck. Most of the charge conducts through the wet fabric.

If a ditch is available, that is the place to head for. Or a car. Despite the petrol tank full of fuel, a car (not a soft-top) is a surprisingly safe place to be, thanks to the 'Faraday cage' effect. I saw a recent "Top Gear" feature where one of the presenters sat inside a VW golf that was deliberately struck by artificially generated lightning. Not only did he survive unscathed but also, after a brief flurry of confusion on the dashboard, so did all the car electronics. Just keep your hands away from anything metal.

In rare cases even if the streamer that forms from a victim fails to 'connect', injury (or death) can result. There is eye-witness evidence that in addition to the victim sensing the static charge, a "zzzzt" sound was heard by others nearby, just prior to the victim collapsing.

Surprisingly, victims may not die instantly. Indeed, several reports mention them collapsing "in slow motion" and speaking a few words after the event, even if they then die. This means that prompt CPR can mean the difference between life and death in many cases. Many apparently lifeless victims may have suffered cardiac arrest, but surprisingly little other damage. In other cases the mechanical force from the explosion can cause a lack of consciousness.

Fulgurites

And finally, a curiosity to end with. I'd never heard of Fulgurites before. When a lightning stroke occurs over dry, sandy, soil the intense heating caused by the electrical current passing down into the soil fuses the sand. **(Fig 16)**. At the same time vapourisation of any moisture in the soil causes the molten material to be expanded into a tube with a diameter of over an inch, but with extremely thin walls. Fulgurites of over 5ft in length have been recovered.

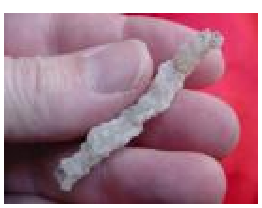


Fig 16 A Fulgurite

There is some research being done in the US where a lightning strike is deliberately 'triggered' (as per the cover photo) and earthed through a selection of materials. One of the theories being tested is the production of "Buckminster Fullerines", alternatively known as "buckyballs". These are carbon-60 molecules shaped like a geodesic dome, of interest to physicists. I can see the commercial attraction of utilising the 'free' energy in a lightning bolt, but I still question the sanity of people who go out of their way to get struck by natural lightning.