# Protect Your **Network**

System designers should keep these parameters in mind when choosing lightning and grounding equipment for communications sites.

**By Bogdan (Bogey) Klobassa and Ken R. Rand**

More than 2,000 thunderstorms are active throughout the world at any given time, producing about 100 lightning flashes per second, any one of which can destroy a radio system that isn't properly protected. As we become more dependent on computers and communications networks, protection from system disruptions is essential. Understanding the principles behind a lightning event helps users properly design system protection.

As heated air migrates upward into a freezing region, it creates within the thundercloud constant collisions among ice particles driven by rising and falling air columns, causing static charge buildup. The static charge becomes sufficiently large to cause the air to break down. An initial small charge called a step leader breaks out, seeking an ideal cloud-to-cloud or cloud-to-earth path. Once this path is established, the main series of strokes follow.

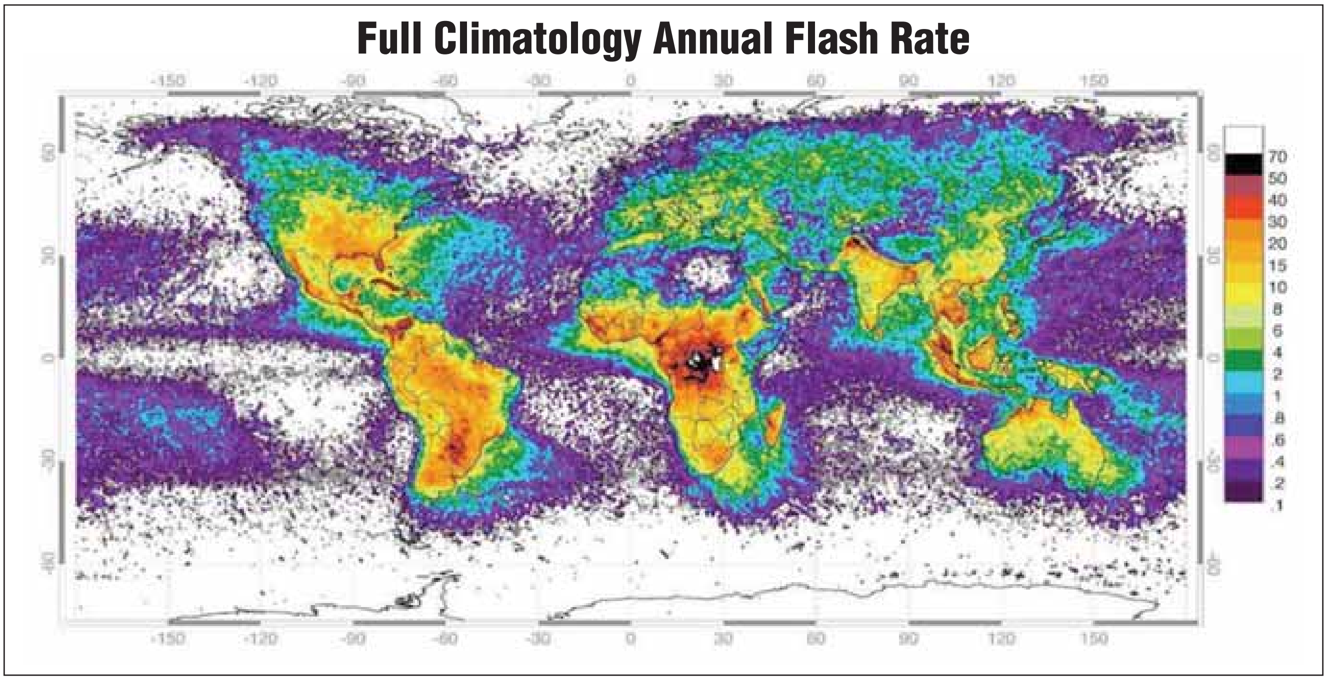
### Statistical Nature of Lightning

The most basic forms of lightning are cloud-to-cloud, intra-cloud and cloud-to-ground. There are positive and negative forms of this event. The step leader polarity determines positive or negative characteristics of lightning. To understand the statistical nature of the event, system designers must evaluate these parameters:

The current wave shape. This specific wave shape consists of rate of current rise to peak value (front time) and the current duration at 50 percent of the rate of rise (time to half value). This current wave shape consists of the di/dt high frequency component, as well as the DC content. To provide specific frequencies associated with this wave shape, Fourier analysis should be performed. Taking into account the 1 – 10 microsecond (μs) rise times, the event could be characterized as DC-1 MHz.

The peak current analysis. International research data compiled during the past 40 years captures values and distribution parameters of these lightning currents. Looking at 50 percent distribution, the typical event will carry peak currents in the 10 – 50 kiloampere (kA) range. While planning for site protection, these values are helpful in analyzing protection needs for grounding design, as well as determining ratings for protectors applied on all input/output (I/O) ports.

A lightning event can have as many as 30 additional lower current return strokes based on the impedance of the conductive channel and the charged cloud's ability to migrate electrons to the discharge area. A typical lightning event might have two or three low energy return strokes. Total energy conducted through the struck object




Global distribution of lightning from April 1995 through February 2003 from the combined observations of two NASA instruments.

will be elevated as the number of return strokes increases.

Continuing current. Any one of multiple return strokes can have the pulse decay extended from 35 to 550 milliseconds. During this extended time, continuing lightning currents can cause damage to equipment that might have survived the initial series of short, high-current pulses. The long-duration DC surge following a fast rise time event will be reduced only by the DC resistance of the cables. There can be from 30 to 1,000 amps delivered to the coaxial cable entry panel for 35 – 550 milliseconds. Proper entry panel grounding is essential.

Current rise time. The rate of rise time to peak lightning current ranges from a fraction of a microsecond to about 10 µs. Understanding this parameter is important once one observes the inductive voltage drop associated with the rate of current rise. By taking into account the lightning peak current, its rise time and inductance of the tower with RF coaxial cables, it's easy to determine how much differential voltage will be present. Let's assume 20 kA peak lightning current with 2 µs rise time conducted by a 150-foot tower with approximate inductance of 50 micro Henry (µH). The $V_p = -L di/dt$ formula becomes handy. The calculated total inductive voltage drop across the tower will amount to about 500 kilovolts (kV). This voltage will be responsible for flashover among towers, cables and grounding jumpers and can destroy coaxial cable insulation.

## Site Grounding Principles

Coaxial cables, and the tower with all other service entries into the communications shelter, present a low impedance preferred lightning path to ground through individual circuits. In all cases of proper grounding, bonding and protection techniques offer alternative paths for damaging currents. The earth referenced as ground is the electrical return for lightning strike energy. It is nature's balance for a continuing sequence of natural phenomena.

Why is a lightning ground system different from an AC power ground? A lightning ground system at a communications site should disperse large amounts of electrons from a strike over a wide area with minimum ground potential rise (GPR). GPR means any difference in voltage within the strike's local sphere of influence (step potential). Properly designed and implemented lightning ground systems should be capable of doing this quickly (fast transient response). By spreading electrons over a wide area, the step potential for any smaller given area would be reduced. The speed, or transient response of the ground system, would be dependent on the geometry and combined inductance of the below-grade conductive components and the resistivity/conductivity of the soil "shunting" those components. The lower the inductance of the system components and soil resistivity, the lower the impedance at higher frequencies, and the faster the ground system could disperse electrons. A lightning ground system is an excellent AC power ground. An AC power ground might not be a good lightning ground.

Strike energy going to the tower base and energy through the coaxial cables to the entry panel ground can saturate a ground system and elevate potential throughout the site referenced to the outside world. AC power lines, telephone, data, control and alarm lines all represent paths to a lower potential for incoming strike energy. Critical equipment might be between the strike energy and a lower potential current return path.

One or two ground rods for a residence, a ground loop around a commercial building, or a loop and three ground rods around the base of a communications tower might meet electrical code, but will not disperse the strike energy quickly enough to keep the GPR low. Effort and money spent upfront on proper grounding will reduce downtime and equipment damage. Much attention should be dedicated to design, implementation, maintenance and integrity of the site grounding system. All lightning protection devices, regardless of the technology used in their designs, rely primarily on the low impedance return path to ground while conducting surge current and controlling differential voltage to protect equipment. It applies without exceptions to RF, DC, AC, telecommunications, data and telemetry services entering any communications site.

**A typical lightning event might have two or three low energy return strokes. Total energy conducted through the struck object will be elevated as the number of return strokes increases.**

## Ground Testing

How do I know if I have a good lightning ground? The first thing is to find and inspect it. If it's a minimum installation to meet code, it may not be good enough. There are ground resistance testers available to provide a measurement value. For example, a residential ground is acceptable at 20 ohms, and 5 ohms is good enough to be considered an adequate tower ground measurement.

There are two types of ground testers. The first is the traditional fall of potential tester where three or four rods are driven into the earth, connected back to the tester, and a calibrated AC current (100 – 300 Hz) is passed between them in ways to facilitate the kind of measurement required. The returned data is interpolated into a value called ohm-m or ohm-cm.

After the ground system is designed using the four-stake resistivity measurement method, performance after construction can be verified by using the three-stake fall of potential (FOP) measurement below. Ground resistance is the meter reading when rod three is at 0.618 the distance of rods one to two, and the graph flattens.

There is also the clamp-on on-ground tester that couples AC energy into each ground rod or system of rods and radials and calculates a reading directly in ohms based on the timing and wave shape of the reflected energy. Although the fall of potential measurement with driven rods is considered more accurate, the clamp-on device is easier to use and shows results close to the FOP tester.

Most measuring devices use an AC source current in the low frequency range to calculate the earth impedance of the grounding component or system. So the returned measurement is the impedance at specific frequencies between 100 – 300 Hz. This is a useful measurement for an AC power company or an electrician, but a communications technician should regard these measurements with suspicion.

Although lightning is a DC current event, the fast change from no current to peak current will cause a dv/dt voltage drop across any conductor. Direct and magnetic field coupled damage can be severe. The strike event delivers energy into a ground system that, unless properly designed with a fast transient response, will quickly saturate, causing a rapid rise in GPR even though it might measure 5 ohms with a ground tester.

## Evaluating a Ground System

Consider the lightning grounding system as an RF circuit. Ground rods have a series inductance bridged by earth's resistance. Connecting ground rods along buried conductors (radials) presents a series inductance bridged by earth resistance with additional ground rods along the radial's length. The additional ground rods can be considered in parallel, all bridged by earth's resistance. Multiple radials with ground rods are all electrically in parallel to further reduce inductance. Multiple buried conductors (radials and rods) with attention to geometry and materials will net a good reading on a ground resistance tester and have an enhanced transient response as well.

The best way to prevent lightning-caused coaxial shield currents from reaching equipment is to limit them from entering the building. This may be accomplished by installing, on the inside of the building, a continuous panel bonded to the ground system or a panel with large surface conducting strap(s). The large surface area strap is necessary to provide a low inductance path to ground for the entry panel's surge energy, as well as provide for the high frequency component of the strike energy. Each coaxial line as it enters the building is attached to the panel with a protector/feed through or an additional ground kit before connecting to a protector.

A recommended entry system would provide a continuous surface area single point ground plate from the coaxial cable entry to the ground system. This continuous surface area ground plate:

- Keeps inductance low;
- Minimizes inductive voltage drop during lightning event;
- Improves master ground bar (MGB) performance;
- Provides a low impedance single point ground by design, not installation;
- Makes provisions for grounding of all RF protectors on bulkhead, increasing protector performance; and
- Accommodates installation of additional surge protectors for DC, data, telephone and telemetry with reference to the same single point ground.

## Proper Operation of Protection Devices

The effectiveness of lightning and surge suppression devices used to protect wireless networks depends on a low impedance ground return path for conducting surge currents to limit differential voltages. Times-Protect RF lightning protectors are designed to handle high surge currents with minimal energy and voltage throughput to the protected equipment. Installed on the bulkhead with no added ground lead inductance, they limit the protection voltages to the lowest industry recognized benchmarks.

The added inductance through a 1.5-foot grounding wire adds about 500 volts to the surge delivered to the protected equipment by a lightning strike. The Times-Protect RF bulkhead addresses this concern because the RF protectors are installed on the bulkhead without the need for additional grounding jumpers — grounding is achieved by the flange mount. Other services can be routed through the bulkhead, grounded and protected, capitalizing on the single point ground.

A lightning protection system for a wireless communications site is a scientifically based, common sense integrated set of the following:

**Grounding Design Measurements.** Ground system design based on targeted FOP impedance using soil ohm-m resistivity measurements, depth/length of radials, and length/diameter of rods and how many of each, all configured to Institute of Electrical and Electronics Engineers (IEEE) ground system design parameters. To ensure a fast-transient low-impedance earth ground response, multiple rods and radials should be chosen to reach targeted FOP impedance.

**Tower to Entry Port Coaxial Cable.** Bend away from tower toward equipment shelter at lowest practical height above ground. Do not connect tower cable tray to entry port. Only active RF, DC, data and tower lighting should complete the tower to entry panel circuit.

**Entry Panel.** Provides coaxial cable connector termination, lightning protectors and a low inductance, large surface area conductor to a single point ground connection. The entry panel is the last chance to reduce damaging incoming currents from the tower or coaxial cables.

**Lightning Protectors.** Install lightning protectors on all circuits subject to damaging currents. All protectors should be bonded to the site single point ground. ■

## More Information

For more graphs, drawings and further explanation, visit the Times-Protect brochure at www.timesmicrowave.com

Bogdan (Bogey) Klobassa and Ken R. Rand with Times Microwave Systems support the wireless industry in lightning protection, grounding, power quality and risk management. Both have contributed to the Motorola R-56 and multiple IEEE standards development. They conduct engineering seminars on lightning protection and grounding solutions for wireless networks. E-mail comments to bogdan.klobassa@timesmicro.com.

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