LIGHTNING PROTECTION

INTRODUCTION

Lightning is known to result from processes that cause charge accumulation between clouds and the earth. The potential can be as high as 300 megavolts. In fact, when a negatively charged cloud base is over a given point on the earth, the potential gradient at the earth's surface may be as high as -4000 volts/meter. This compares with a nominal fair weather value of only about -120 volts/meter.

The cloud-to-ground discharge known as lightning, however, cannot occur simply as a result of this potential difference. The reason is that air breakdown requires a gradient of about one megavolt/meter. Since cloud charges typically are at heights of one to six or more kilometers, a direct discharge cannot occur. Instead, the cloud emits small discharges of low luminosity which terminate on dust particles in the atmosphere. These discharges are called *leaders*.

Leaders carry part of the cloud's charge toward the earth in steps, hence the name *stepped leader*. The leader ionizes the air along its path. When one of the leaders has carried part of the cloud's charge to within 25 to 150 meters of the ground or a building, the field intensity, especially at any upward pointing metallic object on the ground, becomes great enough to produce corona. Air breakdown then occurs between the tip of the leader and the corona, resulting in the *first strike*, a flow of current between earth and cloud which typically peaks at about 20 kiloamperes. The result is an intensely ionized column of air having a diameter of about one centimeter and a visual corona sheath of one to three meters in diameter.

After the first strike, the drain of charges from the base of the cloud results in a redistribution of charge within the cloud. Often a second and third strike may occur as a result. A sequence of strikes occurring in rapid succession is called a *flash*. Figure 1 shows typical waveform parameters of a lightning pulse where it strikes the earth.

The distribution of lightning incidence over the surface of the earth is by no means uniform. Tropical areas tend to suffer more frequent storms. As a result of the radio noise that accompanies thunderstorm activity, tropical AM broadcasters often use frequencies higher than the usual 535-1605 kHz allocation. In the 2.3 to 2.5 MHz and 3.2 to 3.4 MHz bands which some tropical broadcasters use, thunderstorm noise tends to be less severe. Conversely, in relatively high latitudes such as those of Europe and northern Asia, much lower frequencies (150 to 285 kHz) can be used for radio broadcasting.

Tropical countries such as Indonesia suffer as many as 250 thunderstorm days per year, whereas mid-ocean locations such as Hawaii have only about five per year. Within the contiguous 48 states, Florida suffers the most storms, with about 95 thunderstorm days per year at Tampa. By contrast, California has an average of only 10 thunderstorm days per year.

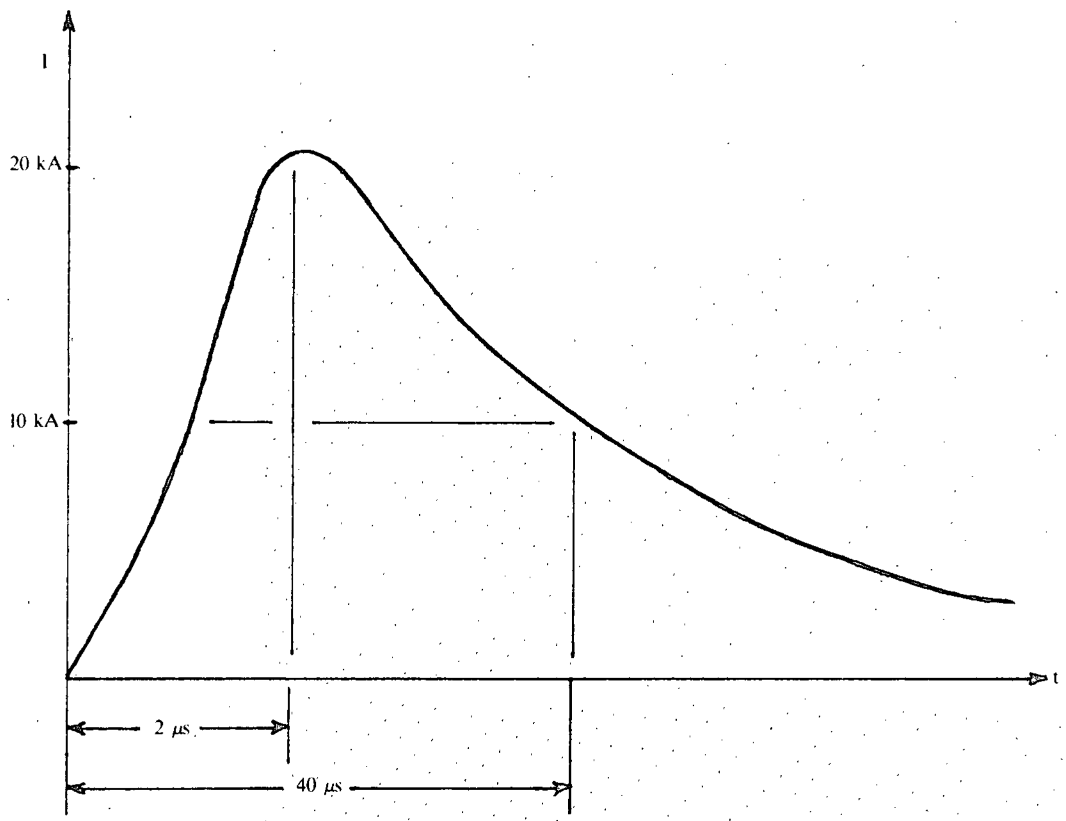

Figure 1. Parameters of Typical Lightning Pulse When It Strikes the Earth.

LIGHTNING PATHS TO EQUIPMENT

While radio equipment may suffer damage due to lightning being induced via the antenna system, and while data transmission equipment may suffer damage due to surges on telephone or other data lines, the most prevalent path to equipment is via the power line. A lightning pulse that has travelled down a power or telephone line for some distance will be attenuated to varying degrees and will be stretched out in time as a result of line series inductance and shunt capacitance. The $2\mu s$ rise time may be extended to $10\mu s$ or longer, and the $40\mu s$ decay time may be extended to as much as $1000\mu s$.

Surges on a 117-volt line may reach several kilovolts, with surges on the order of several hundred volts occurring frequently during a storm. Fortunately, many of these surges are brief enough, or attenuated enough, that they do no damage. However, one cannot count on this always being the case. The solution to this problem is discussed below.

Another mechanism by which lightning surges can damage equipment is earth potential difference. Figure 2 illustrates this problem. Current I results from lightning having struck the earth in the vicinity of Buildings A and B. Voltage difference (V_{AB}) results between points A and B, which are the locations at which the power neutrals entering Buildings A and B, respectively, are grounded. This is in accordance with the National Electrical Code. Accordingly, Data Transmitter A's output is derived from power referenced to ground at Point A, whereas Data Receiver B's circuits are referenced to ground at Point B. The result will be a surge along the data return line which will add to the input to Data Receiver B, possibly to the destruction of some of its circuits.

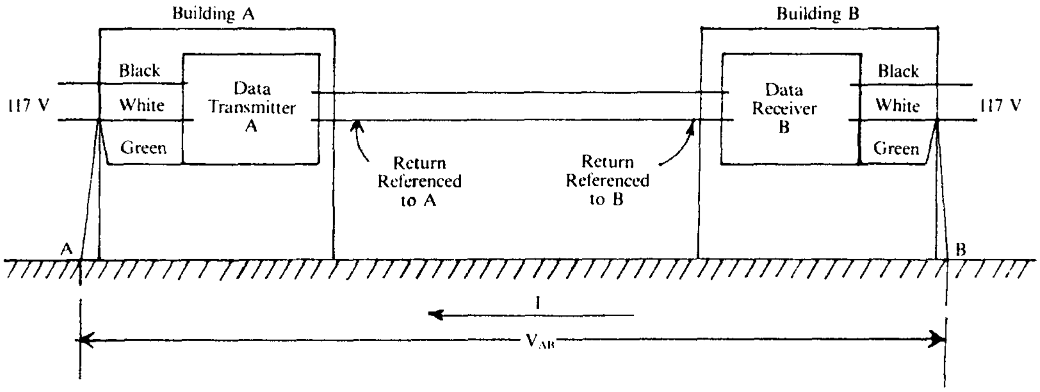

Figure 2. The Earth Potential Difference Problem

PROTECTION TECHNIQUES

Lightning will strike. However, chances for survival can be improved considerably by encouraging the strike to occur away from humans and equipment. This is done by providing a properly designed path for lightning and discouraging discharge paths through equipment.

The general protection of a building and its contents is achieved by a system of roof air terminals (lightning rods) and their interconnecting horizontal conductors, at least two downleads (#2 copper or #0 aluminum), either solid or stranded (U.S. codes), and ground rods providing a combined earth contact resistance of 25 ohms or less.

The protection of equipment is achieved through the use of surge suppressors of various types. For antenna leads, the coaxial gas tube is useful because of its low capacitance. For power leads, silicon transient suppressors are capable of fast responses (≃ one nanosecond) to lightning surges. Within buildings, metal oxide varistors (MOVs) should be installed at those outlets powering critical or easily damaged equipment. Such suppressors handle those surges that may have been induced into a building's wiring beyond the building entrance. Within equipment boxes, low-level semiconductor circuits can be protected using built-in diodes operating on the zener principle. Further protection can be obtained by introducing inductance into those leads in which lightning surges are to be inhibited. Such inductance can be obtained by tying knots in excess lengths of power cords, and by placing coils in series with telephone and data lines.

Surge suppressors are useful not only on power leads but also on data lines, in the solution of problems of the type depicted in Figure 2. However, the use of such surge suppressors still allows large potentials to be driven from one terminal to another, and an extensive network of suppressors actually may be required to maintain system safety. The entire problem of building potential differences can be avoided through the use of optical fiber data transmission between the buildings.

REFERENCES

Further information about lightning protection can be obtained from the following references:

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