Repeater Lightning Protection (by KT4AT)

Once the repeater is on the air, working reasonably well, the problem becomes to keep it this way. Among the leading causes of repeater failure, lightning strikes are way at the top. This article discusses lightning and lightning protection, as applied to the 145.15 machine. Although it is impossible to guarantee complete equipment protection, it is indeed possible to minimize the potentially disastrous effects of a strike.

We will start by doing a weird thing: establishing the number of times the repeater tower will be struck by lightning in an average year. The National Oceanic and Athmospheric Administration (NOAA) has determined that in the Greensboro area, there are on average 48 thunderstorm days per year. Empirical evidence shows that during those thunderstorm days, there will be a total of 16 lightning strikes per square kilometer, out of which, at this latitude, 25% will reach ground, or 4 strikes to ground per square kilometer. An object 300 feet high, like the repeater tower structure, has an equivalent area of 0.4 square kilometer. Therefore, we can expect the repeater tower to be struck 4 x 0.4, or 1.6 times per year. Rounding this result, the repeater will have to deal with three lightning strikes every two years on average. Not negligible an occurrence, is it ?

Objects less than 150 meters high above average surrounding terrain do not normally trigger lightning. The lightning mechanism is therefore purely statiscal and originates in the cloud itself. The negative charge in the cloud builds up until it is large enough to start a column of ionized air called a *pilot streamer*, which moves toward ground at 100 miles per hour for a distance of 150 to 200 feet. At this point, it will change direction, going down a path of easiest air ionization, progressing again 150 to 200 feet. The cycle repeats itself until it gets close enough to ground, where it triggers opposite streamers rising from the ground. The strike takes place when two streamers, one down from the cloud, and one up from the ground, meet. A sequence of return current flow from ground to cloud then takes place, cancelling the negative charge in the cloud. Regarding 145.15, the antenna is at the top of the tower, and is therefore the closest to the cloud. Probability is good that it will be the object struck. For this reason, the club will maintain a working replacement antenna in storage at all times. This is the price to pay to be on top.

People commonly consider a lightning strike as a DC current. This is not the case. As can be seen on Figure 1, a typical lightning strike is actually a succession of high current pulses. The first is always the highest, in the vicinity of

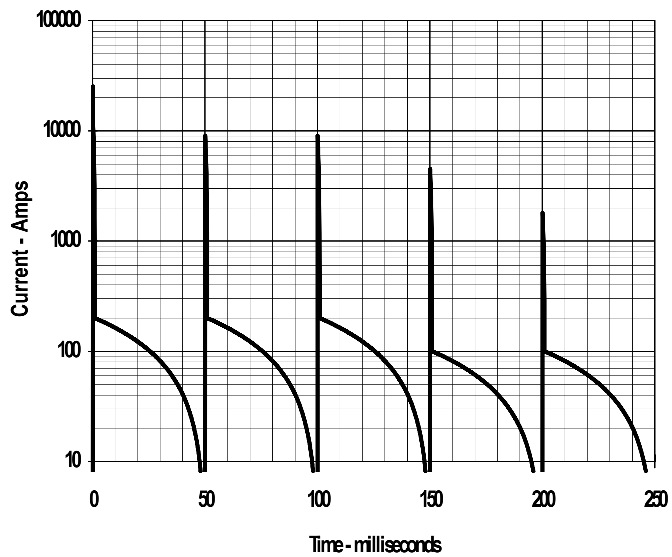

Figure 1 - Typical Lightning Strike

10 to 30 kA. Then 3 to 20 additional smaller pulses occur. This is what gives its flashing aspect to a strike. This phenomenon is due to various areas of the cloud discharging successively. On Figure 1, there are 5 of those pulses,

occuring within 250 ms. The first reaches 30 kA, the last 2 kA. In between pulses, there is also a tail current decreasing from 200 A to a few amps just before the next pulse occurs. We can see that, due to the quick rise and fall times of those pulses (in the microsecond range), they cannot be analyzed using DC methods. Rather, a transient analysis method need to be applied, involving impedances rather than resistances, that is the inductance of whatever carries that current is to be taken in account, not the resistance.

Another comment: those 30 kA WILL find their way somehow between the ground and the cloud. If your cabinet full of radio equipment is in the current path, you LOSE. The disastrous effects of sending 30 kA through a cabinet-full of electronics are two folds. One is melt-down, as part of that current may flow through conductors nowhere big enough to survive it. The other effect is breakdown, as that current may flow through impedances that will develop voltages across them, those voltages being way higher than what those impedances can sustain. In any case, the result will be a dead machine.

Is there a way we can structure the repeater installation so that the cabinet is not in the way of those current pulses ? Figure 2 shows such an arrangement, called the Ground-High Floating arrangement, which is standard for radio stations. In the case of a strike, the current will go down the tower legs and the feedline. The shield of the feedline is bonded to the tower leg at the point where this feedline leaves the tower (Point B). Most of the current will follow that path to ground along the tower leg. At the entrance point to the shack (Point C), there is a metal bulkhead, with another path to ground. And, inside the shack, the radio cabinet is standing on insulators. This time, there can be no current flowing through the cabinet to ground, as this cabinet is isolated from that ground. Therefore, the part of the current which left the tower along with the feedline will find its way through the bulkhead ground. A last point: there is a need to equalize potentials between the shield and the inner feedline conductor at the bulkhead. This is because a fair amount of current will come down on the center conductor, and cannot escape. Also, the velocity coefficient inside the feedline is different than on the shield. This means that the outside pulse will arrive at the bulkhead before the inside pulse, creating a voltage differential there. This is the role of the gas tube (Polyphaser) to equalize those potentials (those tubes conduct above 600 V, and turn on very fast, shorting inside and outside potentials). The net results are that (a) there is no current flowing through the cabinet, and (b) instead the cabinet will be "floating" in voltage above ground. Care must be taken to reference all grounds to that bulkhead, for power line, telephone line, etc..., so no additional path to ground exists. This is how 145.15 is arranged. The duplexer is inserted into an insulating wooden box, and the station cabinet is on wooden stands as well. A Polyphaser at the entrance bulkhead is used to equalize inside and outside feedline potentials.

A last interesting point. We have seen that during a strike, the cabinet will actually "float" in voltage above ground. How much voltage is it going to rise by ? Let's take an 20 kA event, rising in 2 us. Tower leg, feedline, and bulkhead ground bar inductances are as shown on Figure 3. Those would be typical values for a site like 145.15, 300 feet high, with a 7/8 inch feedline. This example assumes there would be only one feedline coming down the tower, which is incorrect. Computing the series and parallel inductances, then applying V = L di/dt yields a pulse of 4430 Volts to ground on the cabinet and duplexer. Do not visit that site during thunderstorms. Even less touch the cabinet and/or duplexer during same.

KT4AT - KT4AT@compuserve.com

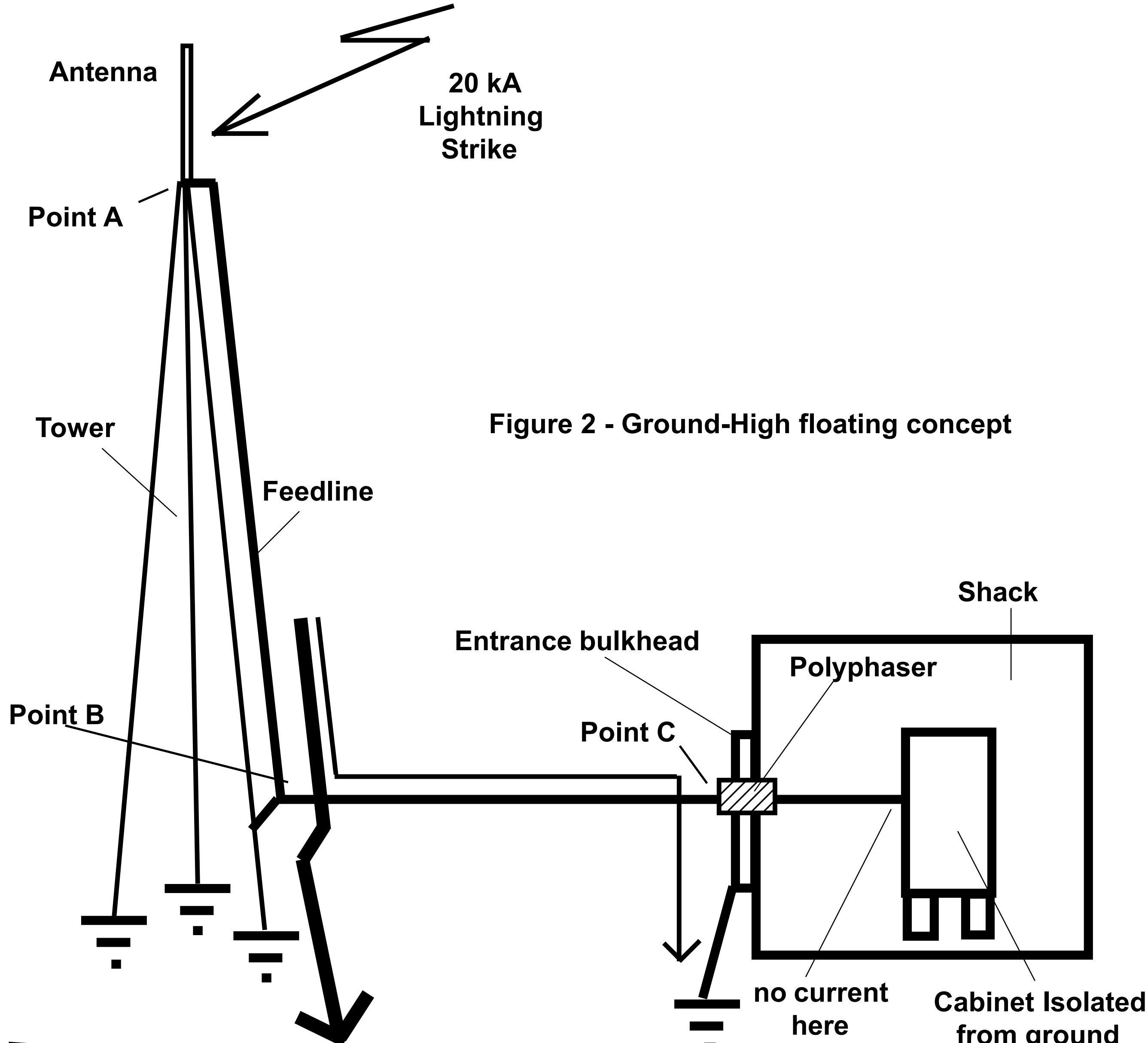

Figure 2 - Ground-High floating concept

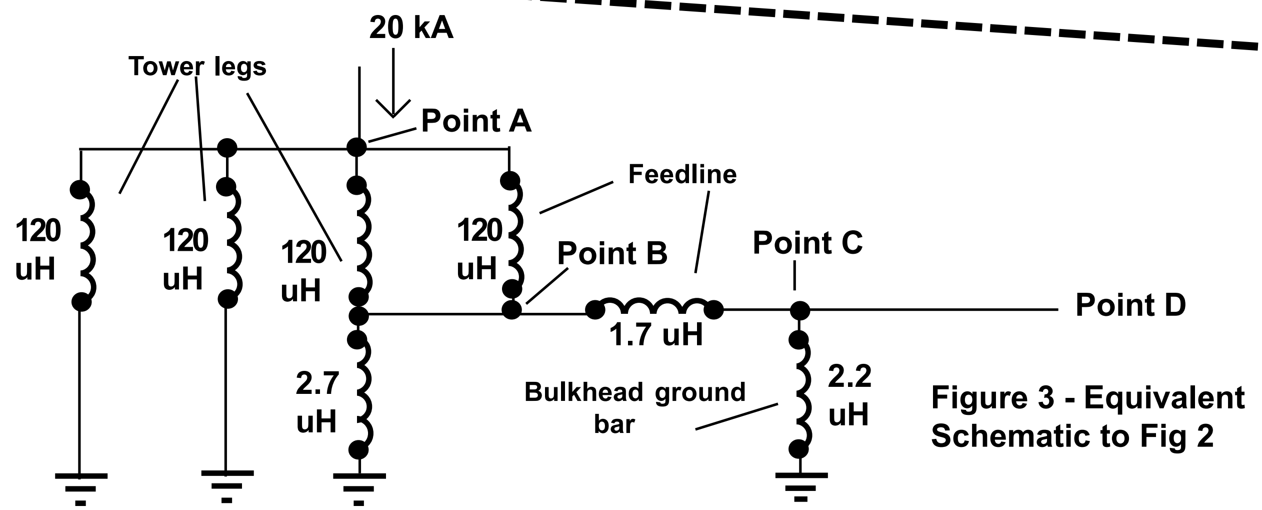

Figure 3 - Equivalent Schematic to Fig 2