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Skinflint Lightning Arrestors

Great protection on the cheap.

Who needs coax high voltage impulse (EMP) protection? You can bet you do, if you expect to keep that expensive low loss coax cable usable after a harmful electrical event. And this is not to mention what would happen to those super-sensitive field effect transistors (FETs) in the front ends of the new solid state transceivers.

It is good common practice to provide outer shield coax grounding at the base of a tower so that if a near miss lightning strike occurs, proper safety precautions are observed. However, there is the problem of the 2,000 volt breakdown between the inner conductor and shield of the coax cable. By the time the breakdown occurs, any equipment left connected to it in the ham shack would have suffered substantial degrading, if not outright destruction. It is a costly problem for everyone concerned.

The first thing to be considered is the basic three classes of coax cable. The large 4,000 volt breakdown types, such as RG-213, RG-8, RG-17, and so on, are relatively expensive in today's marketplace. Then there are the smaller cables used by hams who anticipate running output powers of 600 watts (continuous) or less. Quite a cost savings can be realized with such cable, along with the very flexible nature of the product. These cables are the 1000 volt breakdown types such as RG-58, RG-59, RG-8X, and so-forth. Then there is the third type, such as RG-6, RG-174, special Teflon low loss, and so on. These types have breakdown voltage specifications of, typically, 700 volts and in some cases 200 volts. Obviously, these are to be used in the UHF/VHF ranges such as 145 MHz and 432 MHz; however, high SWR in the range of 3:1 can produce breakdown very easily in these types.

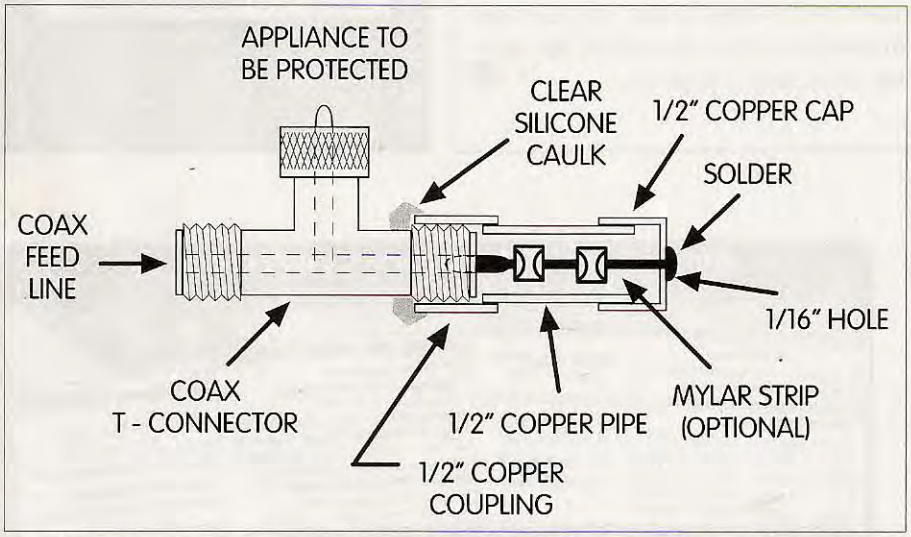

Fig. 1. *Gas discharge coax lightning arrestor. Notes: (1) Ensure that gas devices do not short center conductor to shell. A piece of Mylar can be inserted. (2) Use clear silicone caulk around housing to make the moistureproof connection. (3) Two 350 V gas discharge spark gaps (700 V breakdown). Ensure centered, or use a piece of Mylar drafting material as an insulator (1 µS 700 V response). (4) Specifications — 20,000 A surge current, 10^{10} ohm insulation resistance, 1 pF capacitance, 1 mS response (100 V/µS).*

As can be seen, the buildup of EMP (electromagnetic pulse) between the inter and outer shield of coax can happen in just microseconds even with a near miss of lightning. If a strike *does* occur, it is probable that the tower will be the arrestor, and maybe you will not lose the rotor and rotor cable. Arresting of the rotor cable will occur at earth ground. Take the rotor cable and ensure that it is taped securely to the tower leg before descending down to

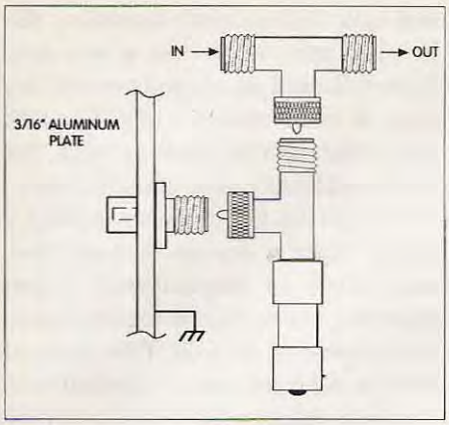

Fig. 2. *Gas and gap assembly (full protection). Notes: (1) Gas discharge to protect sensitive FET devices in today's transceivers (IGFET dual gate). 700 VDC and overclamping, 10,000 amp 1 uS response. Clamping of static voltage buildup on antenna also. (2) Impulse voltages exceeding approximately 2000 VDC. Spark gap device 0.25" gap, hard clamp for near-miss lightning strike protection, for coax cable RG-213, RG-8, RG-17, etc. (3) Most transceivers have a 56 ohm 2 watt resistor across the SO-239 antenna connector to bleed off static voltage buildups.*

the earth ground. This usually will provide your best chance of surviving a near miss.

The coax cable is yet another problem. The near miss lighting strike will hit the antenna and run down the coax via the shield until it finds a low resistance path to earth ground. Well, maybe you will lose fifty feet or so of coax if you have a good earth ground at the base of the tower.

The worst case is a near miss which does not run to earth ground but instead stays on the center conductor of the coax. This is a real problem, since it will mess up your nice expensive solid state equipment, should it be attached, and possibly burn "punch through" holes between the inner conductor and the shield of the coax, through the insulation material. Usually this will happen in several places along the coax until it reaches earth ground level and arrests itself.

Now, you are saying OK, what do I do to provide inexpensive protection from this problem? There are many home-made remedies, including the shorting of coax at the station when not in use.

However, I have the feeling that if any of nature's fury is ever headed my way, it can be kept outside at the base of the tower and I will sustain minimum damage. It is always a good rule of thumb to keep the tower at least 50 feet away from any structure, and well grounded to earth. A good system of center conductor protection for coax cable is going to be described here.

The first thing to consider is how fast the response is to EMP. Any device responding after about five microseconds is probably too late. I like the numbers one microsecond and 700 volts. If a device can clamp off at those parameters, it is likely that the cable will survive and it is probable that the transceiver FET will do OK, just in case you forgot to disconnect from the antenna system.

The following information is provided so that you can home-brew your own inexpensive devices with

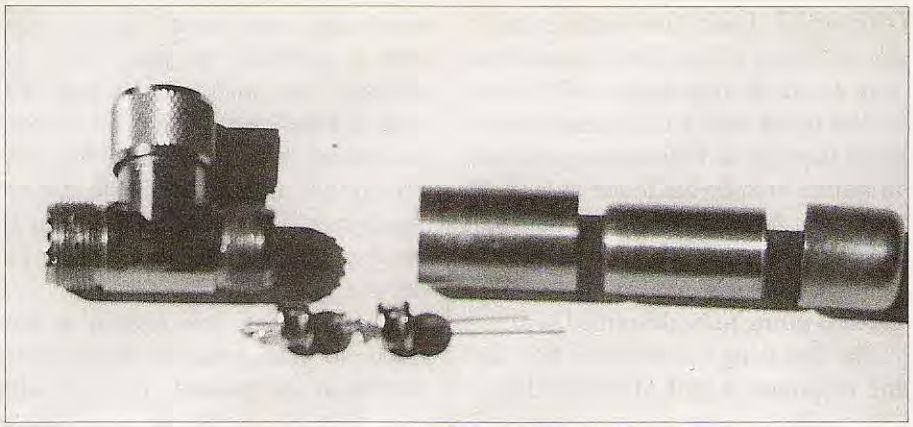

Photo A. *Gas discharge EMP arrestor parts laid out for assembly.*

components available from the sources given.

Another important thing to note is the incoming 120 VAC power input source. This electrical service requires that neutral and ground be connected to earth ground at the circuit breaker box that powers your residence. This National Electrical code requirement provides a nice earth ground for your ham shack equipment unless disconnected. In most cases, we just do not electrically disconnect at the ham shack when we finish operating. The coax shield is now grounded via the residence earth ground and the tower base ground, which is usually a considerable distance apart. This sets up a naturally bad situation for ham equipment destruction. I recommend some type of coax disconnect system in the shack which can be quickly engaged. A relay which disconnects the coax from equipment when not in use can be devised. Now, at least you have a chance of surviving. In any case, these are the three rules I recommend to provide some degree of protection.

Quantity	Description	Cost	Source
1	UHF coax T connector	$2.45	Hosfelt #552A
2	Siemens B1A350	$5.60	Mouser #444-GT350L
1	0.5" copper pipe coupling	$0.15	Local
1	0.5" copper pipe 1" long	$0.10	Local
1	0.5" copper pipe cap	$0.20	Local
	Total	$8.50	

Table 1. *Gas discharge arrestor parts list.*

Make your ham shack an island when not in use!

My three rules for survival are:

1. Ground the coax shield at the base of the tower at least 50 feet from entry to the shack and disconnect when not in use.

2. Adhere to National Electrical Code (NEMAL) rules in residential homes regarding the AC power source. Both neutral and buss ground returns go to the circuit breaker box and then directly to the earth ground rod at the box. Disconnect AC power when not in use.

3. Use a gas discharge device to provide 700 volts and less than one microsecond clamping and breakdown between the center conductor and shield of the coax cable at base of tower and RF earth ground.

Now, let's look at a little history on the "gas discharge" device, which is sometimes referred to as a "comm-gap" device. They are available in four or five different breakdown voltages, and all respond in the one microsecond range. They are similar to a neon lamp bulb. There are at least three manufacturers of these devices. One of these manufacturers retails the devices via Mouser Electronics under a catalog number of #444-GT-350-L; this is a Siemens stock number of B1A350 with a cost of $2.80 each. Sometimes you can find these devices at flea markets for $1.00 each if you are lucky. This source comes from the OEM folks who have production over-runs that filter into the flea market arena.

Since we now have SO-239 and PL-259 UHF-type coax connectors that have Teflon center insulators, this is what most of us use now-a-days. Some folks still use old and new military types of the N connector UG-21 and the like, which can be made to work, but with considerably more effort involved.

Now let us get down to making a couple of these devices. A small, one-inch length of one-half-inch copper plumbing water pipe is used to house the comm-gap devices. This piece of pipe is soldered into a one-half-inch copper coupling which will fit over the UHF coax T connector. Now fit the one-half-inch copper pipe end cap over the pipe and solder in place. Drill a small, one-sixteenth-inch hole into the center of the cap so that the wire lead of the comm-gap will pass through. This completes the housing, and we can move on to the attachment.

Twist together one lead of each comm-gap device to provide a good mechanical coupling, and solder. Clip the excess leads and prepare one lead of the assembly for insertion into the female center pin of the T connector. Usually, a needle-nose pliers is all that is needed to make a small loop which fits tightly into the connector. Solder this connection as quickly as possible to minimize the heat to the center pin of the connector.

Now, push the copper pipe assembly over the pair of comm-gap devices, taking the remaining lead through the cap hole until the assembly is in place. Bend the lead and trim and solder to the copper cap end. Take an ohmmeter and check continuity between the center and outside case of the coax T connector. No shorts should exist. A little silicone RTV (clear caulk) can be used to provide a seal.

Let's check for continuity between the T connector outside case and the

Quantity	Description	Cost
1	UHF SO-239 coax receptacle	$0.75
1	0.5" copper pipe cap	$0.25
1	UHF T coax connector, or a gas discharge device	$2.45
	Total	$3.45

Table 2. *Spark gap parts list.*

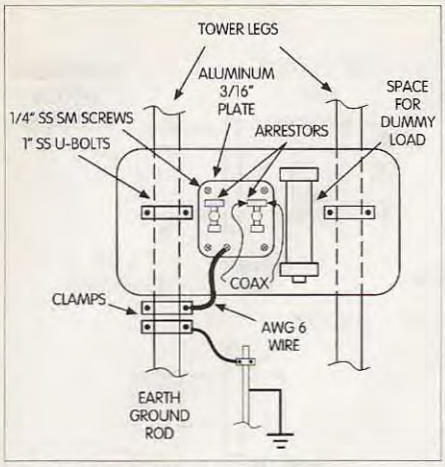

Fig. 3. Tower plate installation.

copper end cap. Continuity must exist. When attaching to the associated SO-239 connector on the antenna or tower base, ensure that the cap is facing up and the coax cable is coming out from the sides. This ensures that moisture will not be able to seep inside of the arrestor housing. You have just made a 700 volt one microsecond EMP device, for under $8.50, which should provide adequate protection.

A quick look in your favorite ham publication will make you aware of the cost of commercial versions in the $50 range. These devices have no frequency or RF power limitations. The usable SWR range is about 7:1, which is well beyond any usable antenna system specification. If you are over 3:1, you just do not have a usable system!

Spark gap lightning arrestor

Now that we have the EMP protection between the center conductor and shield of the coax taken care of, it is time to consider the direct lightning strike possibility. This means catastrophic breakdown and failure of gas discharge and coax cable. We need to ensure that most of the strike will be conducted directly to the earth ground system. Remember, we want the shortest and straightest path to earth ground.

The spark gap will ensure that voltages exceeding 2,000 volts for a period beyond the one millisecond time frame will have a direct path to earth ground. This can be done with a one-quarter-inch air gap between the shield and center conductor. Here's how I do this at this QTH.

See the **Fig. 4 (b)** side view for the assembly details. This is done simply by using a good SO-239 coax receptacle, UHF-type, with the Teflon center insulator and the nickel or silver plated shell. Purchase a one-half-inch copper pipe cap from the local hardware store. Attach it to the back of this SO-239 with clear 100% silicone caulk. Ensure that there is continuity between the copper cap and SO-239 shell. Allow time for drying, and then mount to an aluminum ground plate as follows.

Quantity	Description
1	24" x 12" x 3/4" CDX ply, coated with shellac and spray enamel paint
4	1/4" x 1/2"L SS sheet metal screws
2	1-1/4" x 2" SS U-bolts
2	Gas discharge spark gaps
3	Ground rod clamps
1	8' ground rod
1	#6 AWG lug and bolt
2	1' #6 AWG solid copper wire
1	3/16" thick 8" x 8" aluminum plate

Table 3. Tower plate parts list.

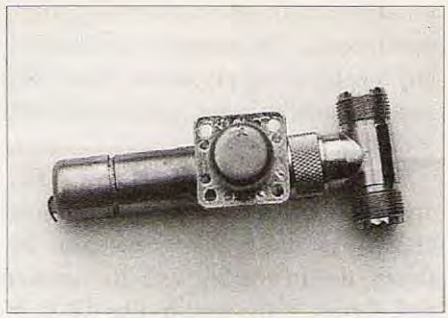

***Photo B.** Final assembly — gas discharge EMP arrestor and spark gap unit.*

At this QTH, we use a 24- x 12-inch 0.75-inch-thick CDX plywood piece which has a couple of coats of shellac and a couple of coats of enamel paint to provide a tower base mounting system. I use a small piece of three-sixteenths-inch-thick aluminum stock to mount all the coax connections on, and then one-quarter-inch stainless sheet metal screws in the four corners to mount to the plywood base. This assembly is then mounted to the two tower legs with U-bolts (stainless are good!) to provide a really nice looking transition point.

On this aluminum plate, mount a copper lug with AWG #6 or better solid copper wire to a leg of the tower. I always use anti-oxide grease (copper

to aluminum) when matching these two metals. The grease is available at any electrical supply house. You could use aluminum wire and avoid this problem.

Then purchase an electrical NEC-approved ground rod and two ground clamps to make the connection between the tower leg and the ground rod. Again, make sure to use AWG #6 or larger solid copper wire. Also, if the tower is not aluminum, ensure wire connects to both of the ground clamps.

Now you have a good, safe RF ground for your radio station. This is NOT to be connected to the electrical grid power system. Keep electrical power and RF grounds separate if AC power neutral and ground returns are tied together. Current traveling on the return neutral may like your RF ground better than its own, and real trouble begins.

For the experts, yes, I am aware of the National Electrical Code and its safety issues. A ground rod in the earth is considered to be an acceptable and required safety ground by the NEC.

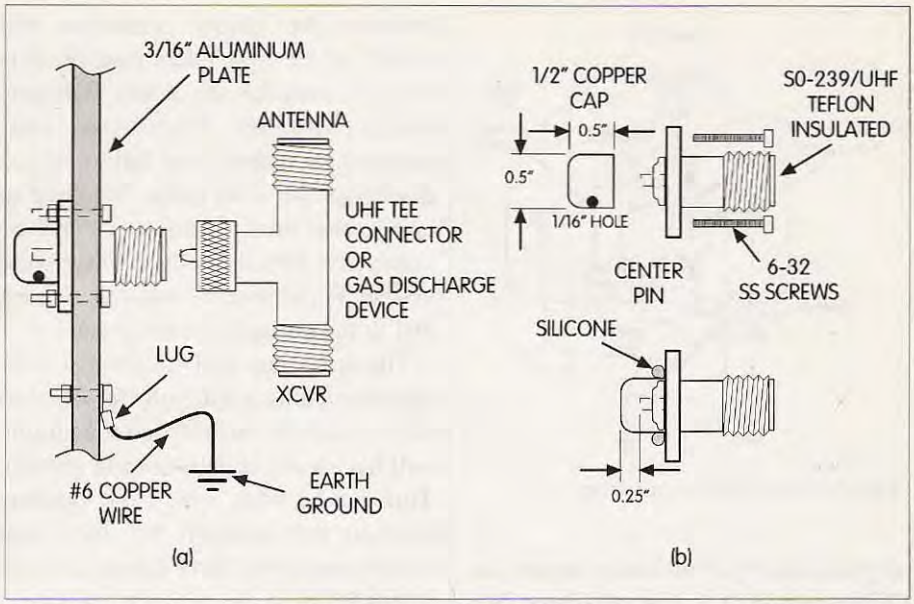

Fig. 4. (a) Spark gap lightning arrestor assembly. (b) Construction details. Notes: (1) SO-239 is silver or nickel plate. (2) Copper plumbing 1/2" cap. Small 1/16" vent hole in bottom side (face ground). (3) Physical earth grounding.

The use of one for AC power and three for antennas is an example of the inconsistencies. It is recommended that an AC switch and relays be used to disconnect and isolate your power source when the station is not in use. Unplug your station!

It is a good idea to put a large MOV device across the 120 VAC source to ensure that the ills of the power grid do not eat your expensive electronics when you are using your station.

Use common sense!

Now, you have gas discharge devices for static voltage buildup problems and near miss lightning strikes, and a spark gap device for the really wild things that nature can send your way. The required safety and earth ground requirements have been met with the tower base aluminum plate assembly, and we are now interested in how the coax cables are to attach to all of this.

Well, the UHF T connector takes care of all of that. Just cut the coax cable and attach a UHF-type PL-259 male plug to each end, and attach to the two female ends of the T connector. Please use a good grade of PVC electrical tape to weatherproof the PL-259s. You are now both safe and efficient. Play it safe!

Sources

Mouser
958 N. Main St.
Mansfield TX 76063
1 (800) 346-6873
(Fax) 1 (817) 483-6899
[www.mouser.com]

Hosfelt
270 Sunset Blvd.
Steubenville OH 43952-1158
1 (800) 524-5414
(Fax) 1 (800) 524-5414

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