



# White Paper

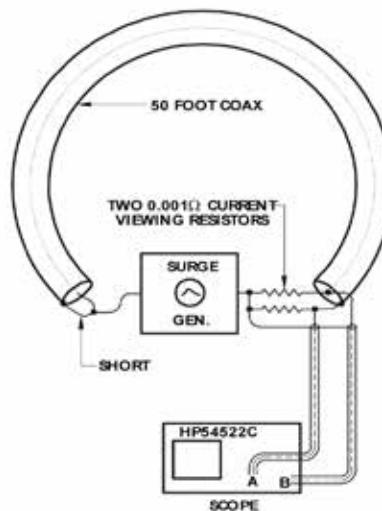
## Coaxial Cable Protection

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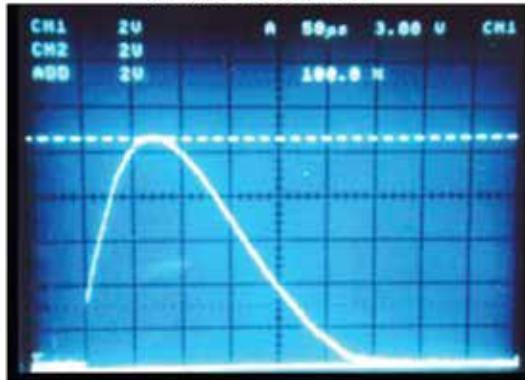
### Why is coaxial cable protection needed?

Skin effect is a physical phenomenon that relates to the limited penetration into a conductor of a RF signal, according to its frequency. This effect is present in coax cable, keeping the RF signal inside and any coupled outside interference on the shield's outer surface. The effect begins to fall apart as the frequency is lowered and the penetration, which is a gradient, begins to mix the shield's outside interference energy with the desired inside energy. A ground loop, which imparts 60 Hz onto a desired signal, is due to dissimilar ground potentials causing ac current flow between points on the coax shield and is low enough in frequency to couple energy through to the center conductor. With lightning, the main frequency range is dc to about 1 MHz (-3dB). This is in the range that affects the coax transfer impedance. The thicker the shield material, the less the effect to these low frequency currents.

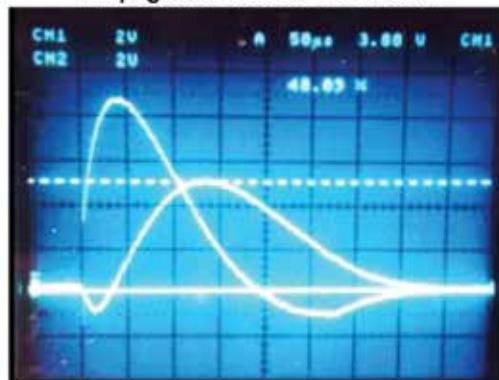
A test was performed on 51-feet (15.5 m) of 1/2-inch (13 mm) coax, where the center conductor to the shield on one end was shorted, simulating a shunt-fed antenna. (see catalog page 29) A fast rise time pulse was applied to the shorted end and the resulting voltage was viewed across the .001 ohm resistors at the far end. These current viewing resistors went to separate channels on a digital storage scope. The velocity factor / inductance of the shield caused its pulse to arrive first. The center conductor had more inductance, and a capacitive relationship through the dielectric to the shield, so the pulse was spread out in time. The total energy (area under the curves) was the same for both the shield and the center conductor.



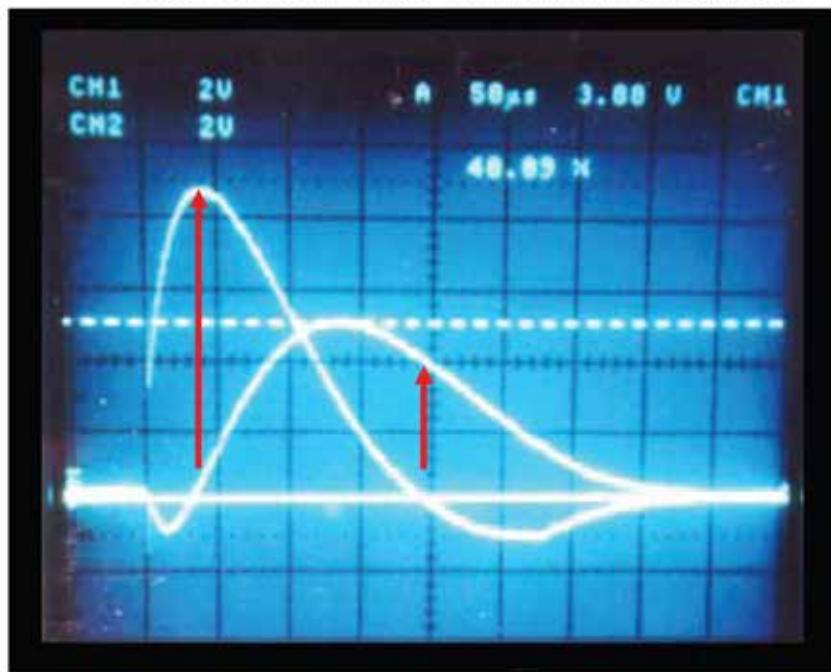
Pulse at Shorted End



Propagation caused Differential



## Center Conductor "Surge" Delay can damage equipment



The left arrow indicates the area when the shield is elevated referenced to the center conductor. Current can flow from coax cable shield through unprotected equipment inputs back to the center pin during this time.

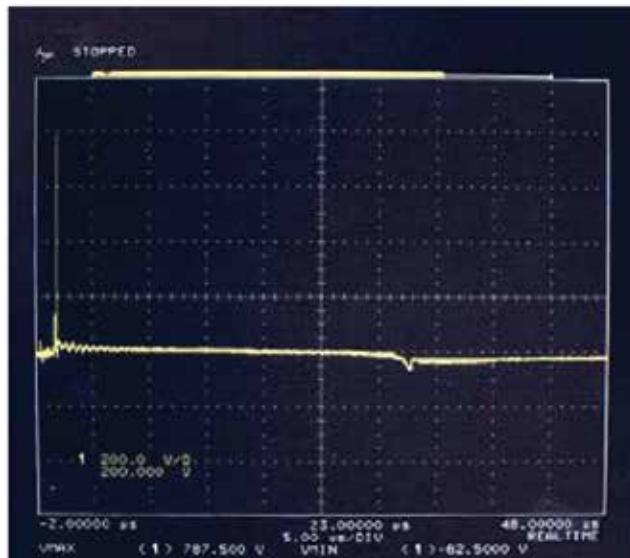
The right arrow indicates area when the center conductor elevates referenced to the decreasing potential on the shield. Current can flow from coax cable center conductor through unprotected equipment inputs back to the shield. This phenomenon is common to unbalanced cable (coax cable). Coaxial cable could be considered a low pass filter. The center conductor will "roll off" higher frequencies compared to the shield.

When struck by lightning, the tower acts like a voltage divider. For a few nanoseconds, there will be a high peak voltage at the top referenced to zero voltage at the base. Current will then flow through the tower and all attached conductors. The rise time and amount of current directed toward the equipment will be determined by the strike characteristics, how high the coaxial cable shields are grounded to the tower before they turn towards a building, the inductance of the tower with coaxial cables, the series inductance of the coaxial cables turning to enter the building/cabinet, and the parallel inductance of the building / cabinet entry conductors to ground.

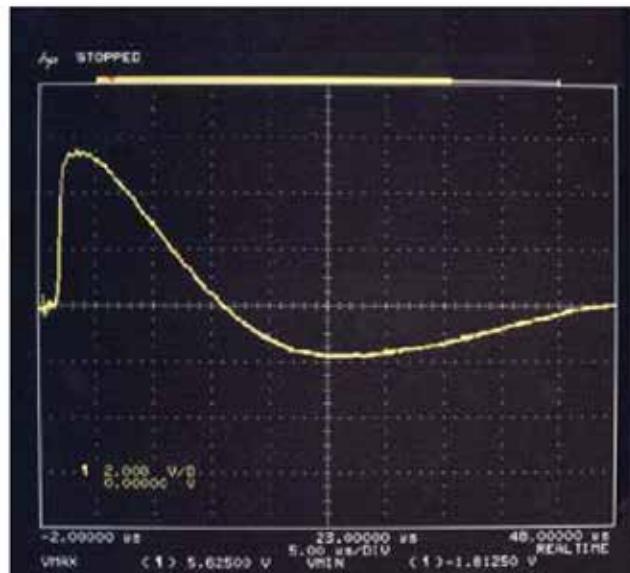
A gas tube lightning protector can be considered a very fast switch. Whenever a given threshold voltage is exceeded across the "switch" it will turn "on" and handle a large current pulse for a short duration. When the voltage falls back below the turn on threshold, the "switch" will "open" again allowing the protected circuit to resume normal operation. There are many protector designs with both parallel and series components, each intended for a specific application.

RF protectors are designed for a direct connection to earth ground. The inductance of the earth ground conductor causes an  $L \frac{di}{dt}$  voltage drop between the protector case and the lightning energy's intended path towards ground. This voltage drop is additive and reduces the protector's effectiveness. There is no zero impedance ground conductor (yet) for site ground use.

Lightning protectors with dc continuity, such as, simple gas tubes, and 1/4 wave coaxial stubs, cannot divert this strike voltage differential without sharing some of it with the equipment. This “sharing” for straight through dc continuity gas tube protectors, occurs during the time period between zero volts and when the threshold for turn-on has been achieved. Expect a short high voltage “spike” to occur at the output before the gas in the tube ionizes and becomes conductive (a short duration 800 to 1kV peak occurs with a 6kV/3kA, 8/20 s waveform test pulse, and the arrestor output connected to a 50 ohm load). This high peak voltage goes to the equipment causing arcing, degrading capacitive inputs, or creating damaging current flow in shunted inputs.



**Straight through Gas Tube with dc continuity**



**Quarter wave stub with dc continuity**

For Quarter wave coaxial stubs, from 2GHz down, the inductance of the stub will still allow considerable voltage to be presented to the equipment input (+ 9Vpk, - 4Vpk ringing for the entire test pulse waveform) measured for a 900MHz 1/4 wave stub with a 3kA 8/20 s test waveform and the stub output terminated in to a 50 ohm load). A higher peak voltage will be present if the equipment has internal capacitive coupling to the center conductor of the coax line and could cause arcing at the input. If it is inductive, such as the input of a shunt fed repeater duplexer, the lower frequency voltages are immediately converted to a current. In this case, all dc continuity type arrestors would be relatively useless in stopping the surge current since a gas tube arrestor would never turn on (without a minimum one meter jumper cable) and the 1/4 wave stub would share surge current with the equipment.

Since the quarter wave stub can only divide the low frequency and dc current, a significant portion flows towards the equipment input. How much flows toward the equipment is dependent on the grounding conductor attached to the stub and the length of the coax jumper to the equipment. Since all conductors are also inductors, the length / size /shape of the grounding conductor will set the peak voltage at the protector (it will vary as the stroke current varies), and the coax jumper will impede the current. A worst case would be a long, small sized grounding conductor with a short coax jumper. DC Blocking solves both the above problems.

Quarter Wave Stubs are a bandpass filter with spread of approximately +/- 15% of center frequency at -3dB points. What if we could design a dc blocked rf bandpass filter with a frequency range of 800 – 2300 MHz, an insertion loss of 0.1 dB, and less than 1.1:1 SWR over the entire frequency range?

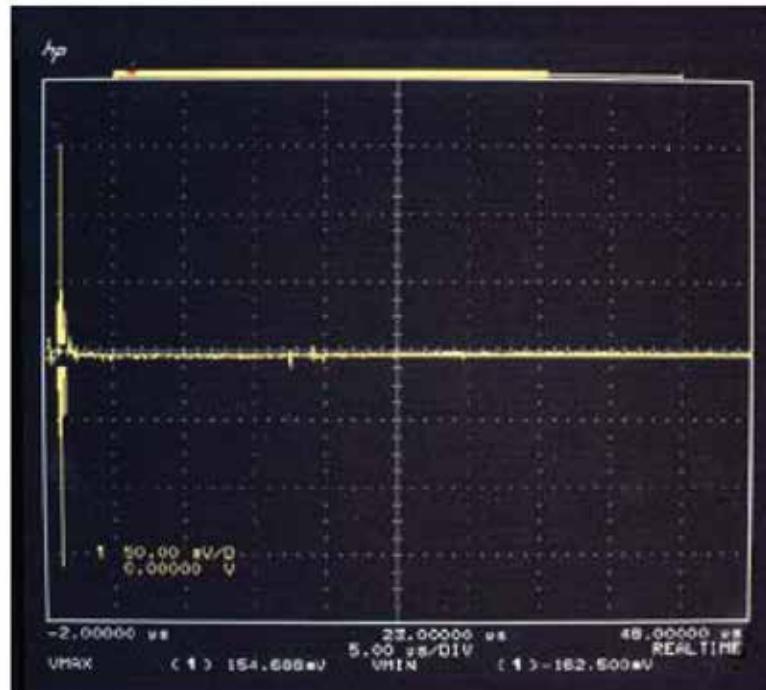
PolyPhaser's "SX" series protectors use a laser cut spiral inductor on the surge side, effectively grounding the dc and low frequency lightning components, while allowing the desired frequency range to pass through a flat plate series capacitor to the equipment side (dc blocked, low "Q", wide bandpass).

Typical let-through voltages are less than 500 millivolts peak with the above tested product at 318 millivolts peak. Product frequency ranges (at this writing) are from 700 MHz - 6 GHz, consult web site product section or factory for latest specifications.

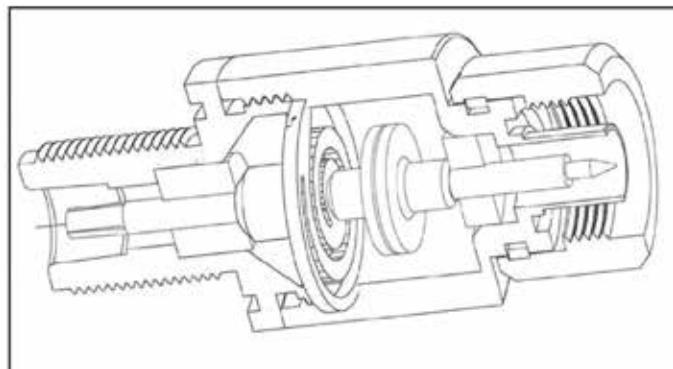
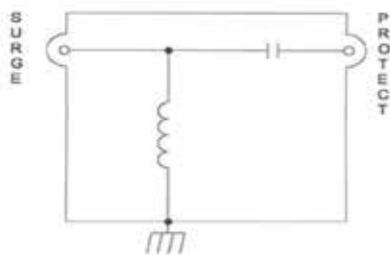
**SX Series Protectors**



**SX lets through 318 Millivolts Peak**



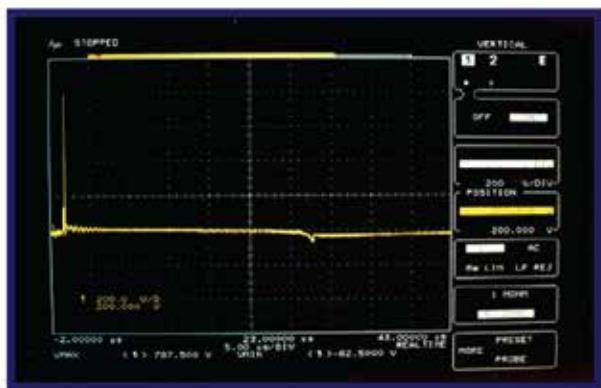
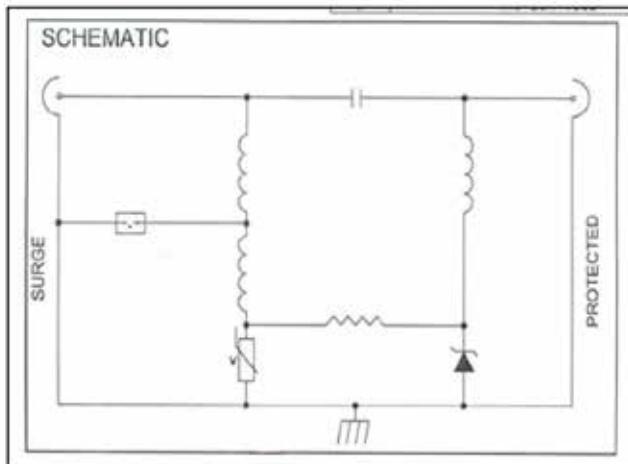
**SCHEMATIC**



## Tower Mounted Data Links and Receiver Preamps

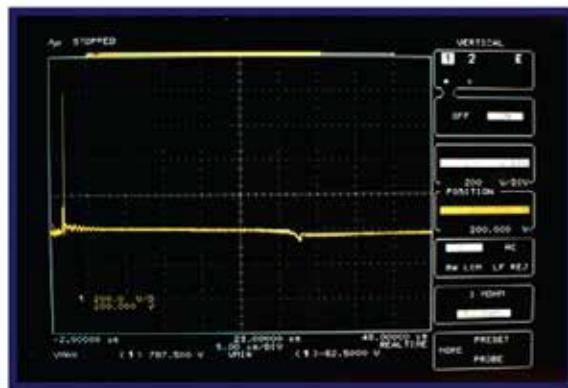
During a lightning strike, the circuitry between the elevated potential tower “ground” in the tower mounted equipment and any isolated outbound conductor (e.g. coax cable center conductor) will be damaged or destroyed unless a lower impedance path from the elevated “ground” to the outbound conductor is established.

**PolyPhaser’s “GX” series protectors** are a dc blocked rf path, with isolated and protected low voltage injector, pick-off, or pass through dc for tower top electronics. A series of protectors designed for receive only from 30-400MHz and power handling transmit/receive protectors from 400 -1200MHz and 800-2500Mhz are available. There is also a “bias T” (dc injector / pick off) that includes rf and dc protection.



**PolyPhaser Device (12Vdc, 2A):**  
Vmax: +16.57 /-2.50 Volts

Surge wave form:  
3 kA @ 8/20  $\mu$ -sec. Surge source impedance: 2 Ohm



**Straight Gastube Device:**  
Vmax: +707.5/-62.5 Volts

Now that the tower mounted equipment is protected, what is to be done with the energy applied to the outbound coaxial cable center conductor from the low impedance path provided by the tower mounted protector? If there is a protector at the top of the cable, there must be a protector at the bottom to provide another low impedance path to the site ground for the energy switched to the center conductor by the top mounted protector!

Tower Mounted Protector Installation (DAS Series, 3GPP and AISG compatible shown)

The DAS Series protectors are a lightning protector, a Bias-T layer-one coaxial modem, and an integrated RS-485 interface combined into a single package.

A Distributed Antenna System (DAS) Is an antenna system used to optimize coverage when existing cellular isar architecture is inadequate and / or when traffic density is.

DAS 3GDAS systems are often designed to optimize coverage where traffic patterns change several times a day. RETA's (Remote Electrical Tilt Antennas) are used to change the beam orientation for more efficient signal coverage. The change to the antenna system can be done from the network operations center, or at the BTS. It is accomplished through a control system that is defined by the AISGP/3G

#### Surge Current Ratings for Lightning Protectors

Surge current ratings on coax lightning protectors are like horsepower ratings for cars. Is more better? Some manufacturers point to a 50kA rating and say the protector will take multiple strikes at 50 kA before failure. Although this is interesting, you might also ask how much energy (with a 50 kA strike) does the protector let through to your equipment? If they tell you, beware, any quantitative answer is suspect! The standard test for our coax protectors is a 6kV/3kA 8/20 microsecond waveform pulse, with the output connector terminated to a 50 Ohm resistive load. The let through energy is calculated from the peak voltage/current and integrated pulse width across the load. How would they know what the throughput is at 50kA?

Although it is interesting to know how many tens of kiloamps it takes to destroy the protector, it is better to know the protector's throughput energy to the equipment with a standard 6kV3kA 8/20uS pulse.



Please contact us for questions or further information on this topic.

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