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Lightning and EMP Protection Devices

Introduction

M/A-COM has developed a unique series of Lightning and EMP protection devices for use in cellular infrastructure including GSM, DCS 1800, and PCS 1900 systems. These devices are designed to offer the cellular operator protection against EMP (electro-magnetic pulses) caused by lightning strikes. Direct or even near strikes produce fast rising electric fields within micro-seconds. These fields generate high voltage pulses through unprotected antennas and transmission lines which lead to the primary communication equipment. High voltage pulses can cause extensive damage leading to costly repairs as well as significant loss of service to subscribers. These protective devices come in two different categories: surge protectors and quarter wave stub tuners. The intent of this application note is to comprehensively explain how the devices work, the electrical parameters of each system, and how to choose the device best suited to your application.

Surge Protectors

These devices incorporate Gas Discharge Tube (GDT) technology. A GDT is a hermetically sealed tube containing an inert gas. The tube is inserted in the side of the device through an easily accessible weather sealed port. During normal operation the tube is inactive. When an installation is struck by lightning, a high voltage impulse will appear on the coaxial line. As the impulse amplitude rises, a level is reached where the impulse surpasses the dynamic voltage threshold of the tube and the electrodes arc over to discharge the energy to ground. Prior to activation of the tube, there will be a short period of time where energy will be present on the line. This RESIDUAL PULSE is equal to the dynamic voltage threshold of the tube. The maximum impulse voltage a tube can handle without discharging is referred to as the IMPULSE SPARKOVER VOLTAGE. This capacity of the GDT is quoted as follows:

Characteristic	Symbol	Definition	Impulse	Typical Value
Impulse sparkover voltage	U_{zdyn}	Dynamic voltage threshold	1kV/µS	650V

In the case of the above chart, the voltage will rise at one kilovolt per microsecond and the tube will fire after 650 nanoseconds. During activation a small percentage of voltage (called ARC VOLTAGE) will still pass through. This will be approximately 20 volts. When the pulse subsides, the tube again becomes inactive leaving a small RESIDUAL VOLTAGE on the line. A direct lightning strike results in an impulse current of high amplitude. The capability of a device to protect a system is defined as the IMPULSE DISCHARGE CURRENT rating. This is defined as the peak current of an impulse which the device can withstand ten times (5 at each polarity at fixed intervals) without affecting the device. MAXIMUM IMPULSE DISCHARGE CURRENT is the peak current of an impulse the device can withstand once.

Surge protectors are often used in applications requiring a standing DC line voltage. This is typical in applications with mast top electronics. The maximum voltage capacity of a surge protector prior to it surpassing the static voltage threshold and discharging it to ground is defined as its D.C. SPARKOVER VOLTAGE. This capacity is quoted as follows:

Characteristic	Symbol	Definition	Impulse	Typical Value
d.c. sparkover voltage	U_{zstat}	Static voltage threshold	n/a	230V

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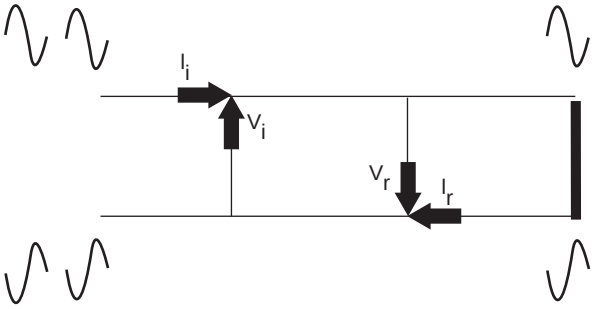
In these applications it is important to select a device that will assure the tube can return to its inactive state after the passage of a surge. This feature of the Surge protector is known as the HOLDOVER VOLTAGE. If the device continues to conduct, the protected line will be short circuited and the tube will heat up (GLOW MODE). If left in this state, the tube can overheat and destruct. GDT's have a finite life span which is inversely proportional to the energy dissipated. At extremes it is possible to reach a level where the tube is unable to discharge all the energy and is destroyed. It is therefore necessary to schedule routine maintenance checks and periodically replace the tube within the surge protector.

Surge protectors offer excellent lightning protection for broadband systems and are usable up to 2.5 GHz. Standard interfaces include 7-16, N, and SMA. Configurations include straight and bulkhead mounted adapters which allows for ease of assimilation into existing systems.

Quarter Wave Stub Tuners

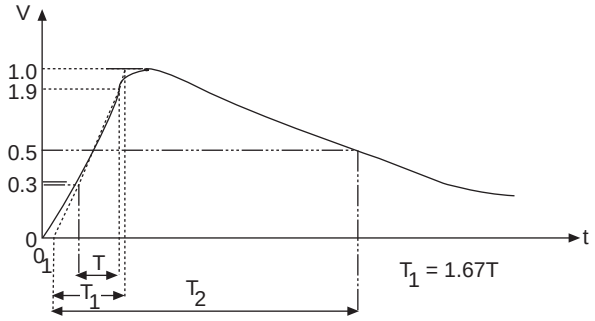
These devices are three port coaxial connectors. The third port extending from the main through path is terminated in a short circuit at a pre-determined distance calculated to be exactly one quarter wavelength at the desired center frequency (see graph).

λ/4 SHORTING STUB BASICS

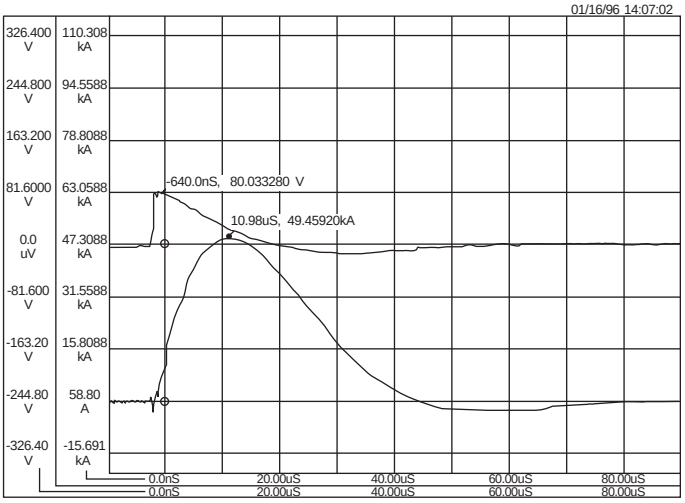


Unlike surge protectors, this design eliminates concerns about residual pulse, sparkover voltage and residual voltage ensuring greater protection for sensitive electronic equipment. As opposed to surge protectors, stub tuners will absorb lightning strikes without need for replacing components. These devices yield very low VSWR and feature high attenuation within a relatively narrow pass-band (+/- 70 MHz) but are application specific. Stub tuners also pass energy in bands that are harmonically related to the fundamental center frequency. The graphs below show a typical test impulse and the response of a stub tuner.

TYPICAL TEST IMPULSE



TYPICAL λ/4 TEST RESPONSE



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Stub tuners are classified into two broad categories- simple and broadband. The simple stub tuner exhibits a V-shaped response on the VSWR vs. frequency plot. The trough of the V is designed to occur at the required Fo and the bandwidth is restricted to approximately 8%. The broadband tuner employs extra RF techniques, similar to multiple cavity filtering, which increase the effective bandwidth by approximately 20%.

M/A-COM offers a wide variety of stub tuners for the most popular frequency bands to facilitate purchase without need for custom design and manufacturing. Designs exist for GSM, PCS 1900, DCS 1800 frequencies with standard industry interfaces including SMA, 7-16, and type "N". Configurations include cable assemblies, cabled connectors, and adapters for ease of assimilation into existing systems. Stub tuners are maintenance free since they incorporate no active components though it is recommended that a check of the stub tuner affixment be made following heavy discharges at an installation.

Selection of a Lightning Protection Device

Below are the basic advantages and limitations for both types of protection to use in the proper selection for your application:

Surge Protectors

Advantages

- Broadband
- Allows DC bias on the transmission line. (critical for applications using mast top electronics.)
- No harmonic passband
- Ease of retrofitting antenna sights
- GDT easily accessible for replacement

Limitations

- Routine maintenance recommended
- 2.5 GHZ maximum frequency
- Initial pass-through voltage

λ/4 Stub Tuners

Advantages

- Low VSWR in passband
- Minimal maintenance
- Pass - through voltage eliminated
- No sparkover or residual voltage concerns
- Ease of retro-fitting antenna sights

Limitations

- Frequency specific
- Harmonic passband
- Does not allow DC bias on transmission line

Glossary of Terms

Arc Voltage - voltage that continues to pass through a surge protector during activation of GDT (approx. 20 volts)

D.C. Sparkover Voltage - defined as the maximum voltage across a device before it discharges the energy to ground when subjected to a slowly rising voltage ramp. A rate of rise of 100V/s is usually chosen for testing purposes.

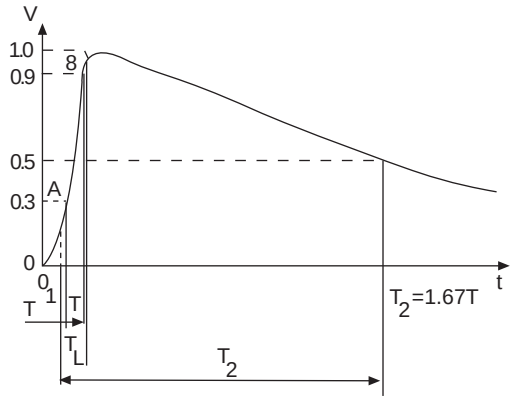
Gas Discharge Tube (GDT) - hermetically sealed device containing an inert gas.

Glow Mode - condition in which the GDT continues to conduct after an impulse passed. Characterized by a visible glow in the device caused by over-heating.

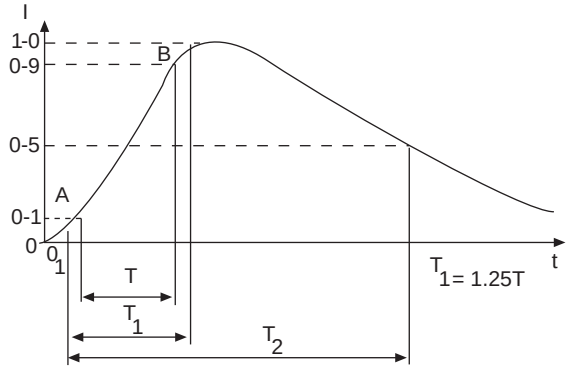
Voltage Hold Over - refers to the maximum line voltage at which recovery of the GDT to its inactive state will take place within a specified period period of time (normally 150ms) after an induced lightning pulse (normally 10/1000ms) has been applied.

Impulse Discharge Current - defined as the peak current of an impulse which a GDT can withstand ten times (5 at each polarity) without affecting the device.

Impulse Sparkover Voltage - defined as the maximum level of voltage across a device before it discharges the energy to ground when subjected to a voltage impulse. The three common waveform profiles used to determine this capacity are:



Impulse Discharge Current - is defined as the peak current of an impulse which the device can withstand ten times (5 of each polarity at fixed time intervals) without substantially affecting device performance. The test normally used to determine this capacity uses the 8/20ms waveform as depicted below where T1=8ms and T2=20ms.



Maximum Discharge Current - defined as the peak current of an impulse which the device can withstand once without substantially affecting device performance.

Residual Impulse - defined as the voltage that will pass through the device prior to activation of the GDT.

Residual Voltage - defined as the small amount of voltage left on the line after an impulse passes

Frequently Asked Questions

1) If lightning rods are installed in an antenna site is additional protection required?

Yes. Lightning is highly unpredictable and can strike locations other than the lightning rod. When lightning does strike a rod, there are still secondary pulses which installations should be protected against in key areas.

2) Where should lightning protection be positioned within the cellular infrastructure?

Normally protection is installed at the junctions where the transmission line joins the antenna and where the cable joins the base station electronics. Lightning protection needs to be tailored to the particular infrastructure. The type of devices used and locations depend on the sensitivity of the electronics and their location within the infrastructure (i.e. mast-top electronics vs. standard base station location).

3) What is the shelf life of a replacement GDT?

The typical shelf life of a replacement GDT is 5 years. This enables the maintenance provider to inventory GDTs for routine maintenance and insures a speedy return to service in case of severe lightning strikes.

4) When should a GDT be replaced within the surge protector?

GDTs are capable of withstanding multiple strikes of varying intensity dependent on the specification of the device. However, there are no outward signs of how many strikes a GDT has absorbed. Routine replacement should be scheduled based on the frequency and magnitude of storms in the area of the site.

5) Will lightning protectors contribute to inter-modulation ?

There is always potential for intermodulation when a device is placed in an RF transmission line between the antenna and the filter. M/A-COM has taken precautions to manufacture these devices using non-ferrous materials and to provide a superior plating finish to ensure this condition is minimized.

6) Can existing antenna sites be retrofitted with lightning protection?

These products can be easily retrofitted into existing systems. M/A-COM supplies protection devices to be cabled as complete cable assemblies or as adapters. All of these are available with standard RF interfaces including N, 7-16, and SMA.

The above information gives the basic guidelines for determining which protection system is correct for your application. Please contact M/A-COM's Global Application Engineering team for additional specifications of this exciting new product line. M/A-COM is continuing to work on new and innovative products for the wireless market to complement our complete line of quality coaxial RF connectors and cable assemblies. M/A-COM is ISO-9001 certified so you can be assured that these new protection devices will meet the same high standards for performance and workmanship as you have come to expect from the leader in RF/Microwave interconnect products.

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