THE SIX POINT PROTECTION PLAN FOR LIGHTNING, SURGE PROTECTION AND GROUNDING FOR A RADIO OR TELECOMMUNICATIONS SITE

THE PROBLEM

Lightning and over-voltage transients are major problems for telecommunications carriers throughout Asia, particularly in the tropical regions with a higher lightning density. Lightning causes millions of dollars damage to cellular radio and telecommunications installations each year. Damage to telecommunications equipment in the US alone was estimated to US$1.0 billion annually, before including the loss of productivity from industrial and business downtime.

High energy over-voltage transients may be derived from direct lightning strikes to antenna towers or they may be conducted on power and telephone cables entering buildings and facilities. Induced transient over-voltages may also originate from near strikes due to capacitive or inductive coupling.

- Peak currents can exceed 200 kA with 10/350 µs waveshape (I.E.C. 61024-1).
- Current rise times vary between 0.1 - 100 µs.
- Multipulse surges are experienced in over 70 per cent of direct strike situations.
- Continuing currents of 200-500A lasting 1-2 seconds may also occur.

Wireless sites are particularly vulnerable to lightning and transients as they are sited in elevated locations for the best radio signal propagation. This means the towers are often located on mountain tops and on the top of tall buildings - where lightning is looking for the easiest path to ground! In addition to lightning surges, isolated stations at the end of long distribution lines are also prone to suffer equipment damage due to temporary over-voltages caused by switching surges or poor power supply regulation.

The first approximation to vulnerability to lightning damage is the number of “thunder days” experienced each year :

- Indonesia: 180-250
- Malaysia / Brunei: 180-200
- Singapore: 160-190
- Thailand: 120-170
- Philippines: 110-150
- Vietnam: 90-140
- Hong Kong, China : 80-100
- Darwin, Australia : 80-90

In Indonesia, one communications tower in West Java proved to be particularly susceptible to lightning strike. From the time of its construction in February 1993 until October 1995, the tower was struck by lightning on 34 occasions (on sixteen separate days) with massive equipment losses occurring on nine days.

SIX POINT PROTECTION PLAN

There is no single technology that can eliminate the risk of lightning and its transients. A holistic systems approach is required. From over 20 years experience in examining the nature and extent of damage created by lightning transients, ERICO has developed a comprehensive Six Point Plan to minimise exposure to damage.

The **Six Point Plan** recommends

1. *Capture the direct lightning strike* at a preferred point on purpose-designed air terminals;
2. *Conduct the lightning current to ground safely* via a purpose-designed downconductor system to minimise the dangers of side-flashing;
3. *Dissipate the energy into the ground* with minimal rise in ground potential through a low impedance grounding system;
4. *Eliminate earth loops and differentials* by creating an equipotential grounding plane under transient conditions;
5. *Protect equipment from surges and transients on power lines*; and
6. *Protect equipment from surges and transients on communications and signal lines* to prevent equipment damage and costly operational downtime.

Figure 1 shows a schematic representation of comprehensive lightning and surge protection for a typical cellular radio or telecommunications facility.

POINT 1: CAPTURE THE LIGHTNING STRIKE

The first point of the Six Point Plan involves capturing the lightning strike to a preferred point on purpose-designed air terminals.

In general, the most vulnerable point to direct strike is located at the highest point on a structure. This may be the metallic tower or the various antenna which may protrude above the tower top which are most susceptible. Large satellite antenna systems and their control equipment are typically vulnerable to direct strikes.
By correctly installing a purpose-designed air terminal on the top of the communications tower, direct lightning strikes can be attracted to a preferred point which is away from antennae and cabling to minimise the risk of damage to equipment from the direct force and energy of a lightning discharge.

A new air terminal design - the Dynasphere - intercepts lightning discharges at a preferred point ***earlier*** than conventional lightning protection techniques. This air terminal was developed from research into the formation of corona and space charge effects around grounded points during the millisecond time-frame prior to the development of lightning upward streamers.

The Dynasphere's floating sphere construction is passive on approach of a storm, and produces minimal corona. In the milliseconds prior to the approach of a lightning down leader it becomes active through capacitive coupling, it absorbs energy and assists in triggering an upward intercepting discharge to capture and control the main downleader. The Dynasphere is non-radioactive does not require external power sources or batteries.

Lightning can then be drawn to the downconductor system to enable the safe transfer of energy to ground.

POINT 2: CONDUCT THE LIGHTNING CURRENT TO GROUND SAFELY

Once the lightning has been captured at a preferred point, it is necessary to convey the discharge current safely to ground, and to minimise the conduction of lightning currents on ancillary conductors such as coaxial feeder cables as these can carry dangerous lightning energy directly to equipment racks.

ERICO has developed a purpose-designed, screened, downconductor cable to reduce the risk of "side-flashing and to contain the discharge to a central core conductor during a strike. In a radio base situation, ERICORE also reduces the risks associated with conducted currents entering equipment rooms via RF feeder cables.

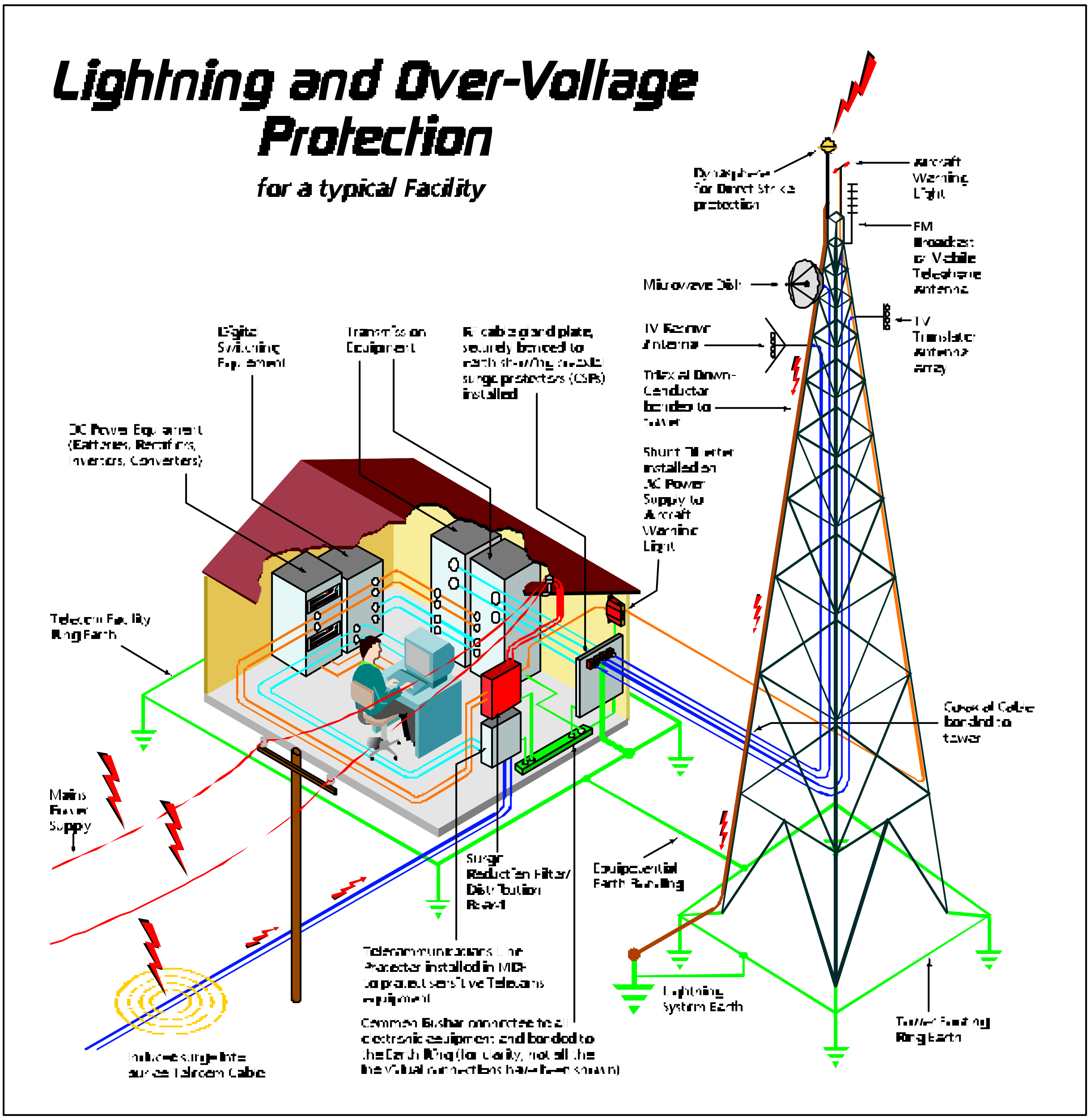

Figure 1 - Ideal grounding system for lightning and over-voltage protection

POINTS 3 AND 4: DISSIPATE THE ENERGY INTO THE GROUND AND ELIMINATE GROUND LOOPS AND DIFFERENTIALS

Once the energy is conducted to ground level, a low impedance ground is essential to dissipate the lightning energy into the earth mass as effectively as possible. The grounding systems for dedicated lightning protection terminals, tower footings and electronic equipment rooms or control centres are critical design elements.

It is also critical however, in the case of a cellular base station to create a constant reference ground plane that doesn't produce any interactive resonance with site signals. There must be complete and effective bonding of all metallic systems and equipment and interconnection into a single equipotential ground plane.

Attributes of an ideal grounding arrangement are considered in Figures 2 and 3 and below:

- Each grounding system (lightning, power, communications, antenna coaxial cable wave guides and equipment room) must be individually of high integrity, as well as being considered a component of an overall grounding network. Where separate grounds exist, they should be bonded together (especially under transient conditions). Bonding of all grounding systems is required by Code in the US.

- An interconnected ground ring should surround sensitive electronic equipment rooms, connecting the tower, power service ground, and other metallic elements at the facility. This system should also be connected to perimeter fencing ground ring surrounding the entire facility. (This will reduce the risk of potential gradients across the facility).

- The lightning protection ground should be directly bonded to the facility ground ring.

- The ground rings should be of substantial conductor size and buried approximately 900mm below the ground. Two-metre copper-clad or stainless steel ground rods should be cadweld to the ground ring at 3-4 metre intervals in the ring to ensure permanent reference grounding for the site.

- There should be a **"single"** point connection to the ground network from all equipment within a facility. Figure 2 shows an example of a well-designed grounding system with a "single" point connection of mains power and communications equipment ground wires to the ground ring. If a surge arrives at the facility via the mains power supply, the surge protection equipment will divert excessive energy to ground, and the telecommunications and lightning protection grounds would rise equipotentially with all other grounding / ground points as they are closely bonded together.

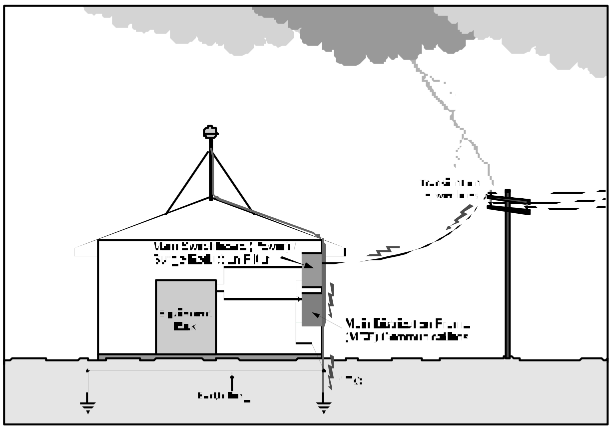

Figure 2 - Preferred grounding system

Figure 3 case shows a "non-preferred" system with multiple connection points to the ground-ring. Although adequate protection equipment on both the power and communications interfaces is provided, the separated electrical and communications grounds are located some distance apart (as shown by the parameter 'd'.) Regardless of the impedance of each individual ground, for a very short time the potential of the electrical ground will be higher than the communications' ground. As a result the excess energy has two potential paths to follow to reach the lower potential communications' ground, thus creating a dangerous 'earth loop' that will damage sensitive electronic equipment in the equipment room.

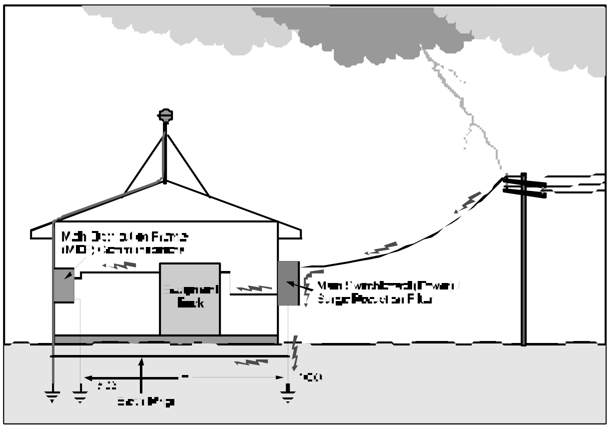

Figure 3 - "Non-ideal" grounding system - Currents in an earth loop can damage sensitive electronics through magnetic induction.

- The use of a pre-fabricated, low-impedance signal reference grid (SRG) grounding network inside a specialised shelter is highly recommended to create an equipotential plane for high frequency, low voltage digital signal installations which are highly susceptible to voltages differences as low as 1 volt.

- An effective grounding system is also important where towers are located on roof tops. Many cases have been observed where a single ground tape has been run some 10-20 floors down the side of a building to a single isolated ground rod. This is generally an inadequate arrangement. It is recommended that Signal Reference Grids are employed in such installations, and that the SRG, roof-top tower and lightning protection systems are bonded and integrated with all other building and utilities grounding systems in these cases.

A number of technologies are available, to assist in the construction of effective "best practice" ground grids or grounding systems.

- Special compounds can be used to improve (lower) practical grounding impedances at locations where the ground resistivity is high such as in rocky, sandy or mountainous areas with large particle soil sizes. In order to conform to various environmental standards, approved compounds are required to be non-leaching i.e. they must not release conductive ions to contaminate ground water or surrounding soil.

- Exothermic molecular bonding processes (copper-to-copper or alloys and copper-to-steel or alloys) for grounding and lightning protection systems provide
    - permanent, robust;
    - low-resistance;
    - corrosion-free connections;
    - that cannot loosen or weaken with age.

POINT 5: PROTECT EQUIPMENT FROM SURGES AND TRANSIENTS ON POWER LINES

Even if a structure is provided with an integrated direct strike protection system, there remains the risk that overvoltage transients may arrive via external cables.

High energy over-voltage transients can arise from capacitive and inductive coupling from nearby lightning strikes in addition to power switching and from irregular power distribution. Efficient clamping and filtering of power transients at the point-of-entry of power lines to facilities is essential to minimise the risk of physical equipment damage, loss of operations and economic loss.

Simple surge diverters installed at the mains switchboard may not provide adequate protection. In order to protect sensitive equipment, it is necessary to limit residual voltages to within the immunity level of the internal equipment. For equipment operating on a 230 V_{RMS} system, component damage may be result from transients with peak values as low as 700 V. Many manufacturers of battery chargers and rectifiers state a peak tolerance under 800 V.

Whilst some shunt-only devices can clamp at below the recommended voltages, they do little to limit the fast rising wavefront energy (dI/dt and dV/dt) prior to the onset of clamping.

Rates of current rise can be as high as 10 kA/µs (10^{10} A/s) from the initial discharge of lightning and an order of magnitude higher for subsequent restrikes in multiple strike lightning. These very high dI/dt and dV/dt values can induce destructive high voltages across components, leading to equipment damage and failure.

Suitably designed low pass filter technologies following the primary shunt diverter will reduce the peak residual voltage and dramatically reduce the rate of current and voltage rise reaching the equipment. Surge Reduction Filters (SRFs) and DINLINE filters (for sites of smaller current loads) provide multistage surge attenuation by clamping and then filtering transients on power lines.

Table 1 shows typical residual voltages and rates of change of voltage for various technologies.

This superior level of protection offered by Surge Reduction Filters means enhanced operational reliability for electronic and telecommunications equipment connected to mains power supplies downstream from the surge filter. Protection should also be installed on external power feeds (such as power supply lines to aircraft warning lights at the top of the tower) to protect against transients on subsidiary circuits.

POINT 6: PROTECT EQUIPMENT FROM SURGES AND TRANSIENTS ON COMMUNICATIONS LINES

Coaxial surge protector (CSP) devices are important to protect against transients tracking from towers directly to transmission and telemetry equipment via radio feeder (RF) cables. Although the purpose-designed downconductor confines the vast majority of the lightning current, some induction to coaxial feeder cables will occur with strikes to towers or as result of magnetic and capacitive coupling from the air channel component of a lightning strike.

CSPs are based on gas arrester devices housed in a chrome plated brass block. These devices are precision machined for impedance matching with the coaxial cable. They provide protection at typical power ratings of 50 W (continuous) and operate at frequencies up to 3 GHz. Typically, CSPs should be mounted directly into grounded bulkheads at the point of entry of feeder cables into the facility to provide maximum protection. Other installation arrangements are however possible.

Protection of land based telephone, signal and data lines into the radio facility may also be an issue for comprehensive protection. Transients up to 20 kA (8/20µs) injected onto telecommunications and signal lines can damage and destroy sensitive terminal equipment and lead to facility down time.

Telecommunications line protectors (TLPs) are designed to protect terminal and interface equipment from transients conducted on telecommunications lines.

- Single-stage, "gas arrester only" circuits provide cost-effective protection for less sensitive electro-mechanical or discrete component-type terminals and supplement circuits with "built-in" protection.
- Multistage stage protectors employing gas arrester primary and decoupled semi-conductor secondary protection stages can provide lower clamp (let-through) voltages than the single-stage protectors. These devices are suitable for the for more sensitive analog equipment and for PCM digital circuits operating at up to 8 Mbits/s or 12 MHz.

3 - SUMMARY

Direct lightning strikes and over-voltage transients create major equipment failures and cause downtime at telecommunications and radio sites where there is little or no purpose-designed protection fitted.

Analysis of damage has shown that no one protection device can provide lightning immunity. Comprehensive protection is provided only by employing an integrated Six Point Plan approach.

ERICO has over 20 years experience in examining the nature and extent of lightning and transient damage to equipment and are pleased to offer more detailed advice on lightning and transient protection solutions. Prevention is better than cure.

Technology	**Residual Voltage (V)**		**dV/dt applied to equipment**
	Applied Impulse 20 kA 8/20µs	**Applied Impulse 70 kA 8/20µs**	**at 20 kA 8/20µs (V/µs)**
32 mm "25kA" Block MOV	1,400 V	Failure	1400
60mm "70kA" Block MOV	1,050 V	1,500 V	1100
"135 kA" Shunt Movtec	790 V	1,100 V	700
SRF363F "135kA" Movtec Filter	510 V	700 V	25 to 40

Table 1 - Typical Residual Voltages and Rates of Change of Voltage