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White Paper

Protecting Equipment from NEMP Damage

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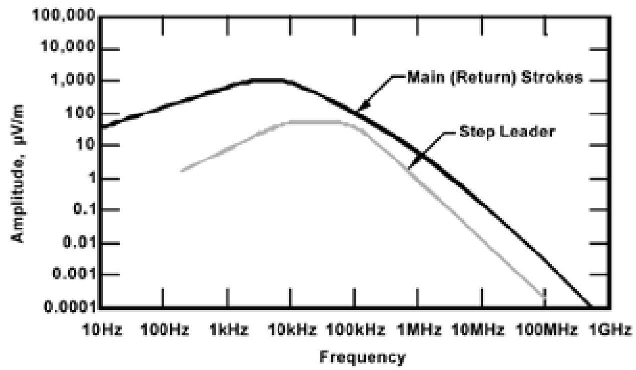
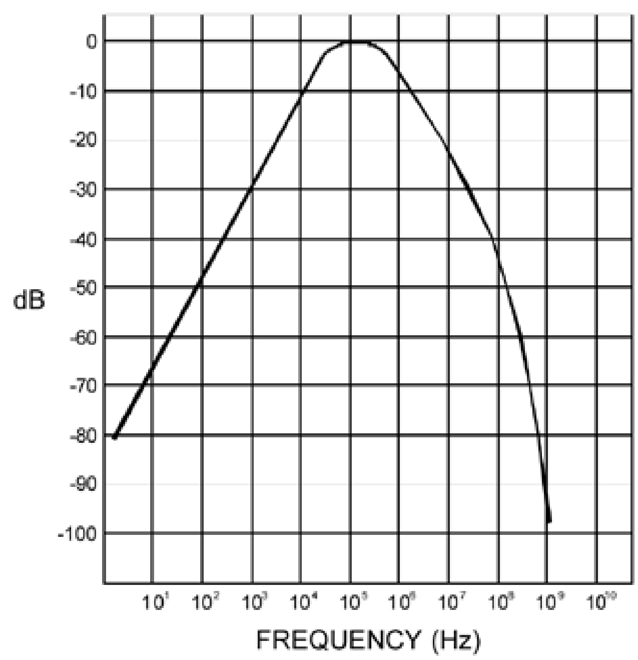
The sudden release of gamma rays (high energy rays) in a nuclear explosion will cause almost instant ionization (the removal of electrons from atoms) of the atmospheric gases that surround the detonation. Free electrons are driven outward. Gamma rays can travel great distances ionizing the atmosphere. This forced movement of electrons, which will again recombine with atmosphere atoms (Compton Recoil Effect), creates a pulsed electromagnetic field (EMP), or "Electromagnetic Pulse." This is also referred to as "Nuclear Electromagnetic Pulse" (NEMP). About 99% of the NEMP is radiated in a broad spectrum between 10kHz. and 100MHz. Most of the energy is at frequencies below 10MHz. For comparison, lightning's power density spectrum is from dc to 1 MHz (for the -3dB point).

The fast rise time of the radiated pulse (10 nanoseconds,) as well as its short duration (1.0 microsecond,) can cause any antenna to ring much like a direct lightning strike. The ringing amplitude would depend on the amount of captured energy. The antenna's capture area, its pattern relative to the blast, tuned frequency, and bandwidth, all affect the peak ringing voltage that will be present. This ringing voltage will attempt to propagate down the transmission line (open-balanced or coax unbalanced) to the equipment.



Amplitude spectra of the radiation component of lightning discharges.

Since the antenna impedance is not equal to the line's characteristic impedance over the entire NEMP spectrum, and the line may also collect NEMP energy. If additional shielding precautions are not taken, the energy could take the form of a complex waveform on the transmission line. Large voltages may be created due to line and antenna resonances. These high voltages can cause damage to unprotected equipment or cause arcing in the line or at the antenna. Cable shield grounding kits help prevent the lower-frequency components from being present on coax cable and may change the high-voltage resonance locations.



Cavity filters could increase NEMP damage. The small bandwidth (high Q) of the cavity causes larger ringing voltages to be present at the equipment than the equipment would receive if the cavity filters were not in-line. Quarter-wave shorting stub type protectors, depending on their "Q", may also worsen the effects.

Coaxial lightning arrestors with a 50ns response time are too slow for the NEMP ringing pulse for systems above 20MHz.

Nemp Protectors

Only NEMP coaxial units with a 1.0 to 7.0ns response should be considered for protection. NEMP protectors with dc continuity must have at least 10 feet of coax between the protector and the equipment. Since coax has a velocity of propagation factor, the NEMP rise time is delayed in reaching the equipment. This gives the protector time to operate. If this type of NEMP protector is placed directly on the equipment, a receiver (for example) would be required to develop an L di/dt voltage drop across its internal static drain inductor large enough to allow the protector to operate. The inductor value (which depends on the receiver frequency), the maximum current/voltage that the inductor can withstand, and the threshold of operation for the protector, will all determine the condition of the receiver after the NEMP event.

NEMP protectors that do not have dc continuity (dc blocked) will work on all equipment and do not need special precautions. They will work for lightning as well! Lightning radiates much like NEMP, but is more localized.

Type of Conductor	Rise Time (Sec)	Peak Voltage (Volts)	Peak Current (Amps)
Long Unshielded Wires (power lines, large antennas)	$10^{-8} - 10^{-7}$	$10^{5} - 5 \times 10^{6}$	$10^{3} - 10^{4}$
Unshielded Telephone and	$10^{-8} - 10^{-6}$	$100 - 10^{-4}$	1 - 100
AC Power Line at Wall Plug	$10^{-7} - 10^{-5}$	$10^{3} - 5 \times 10^{4}$	10 - 100
HF Antennas	$10^{-8} - 10^{-7}$	$10^{4} - 10^{6}$	$500 - 10^{4}$
VHF Antennas	$10^{-9} - 10^{-8}$	$10^{3} - 10^{5}$	$100 - 10^{3}$
UHF Antennas	$10^{-9} - 10^{-8}$	$100 - 10^{4}$	10 - 100
Shielded Cable	$10^{-6} - 10^{-4}$	1 - 100	0.1 - 50

Typical EMP energy collectors and responses.

Power Lines

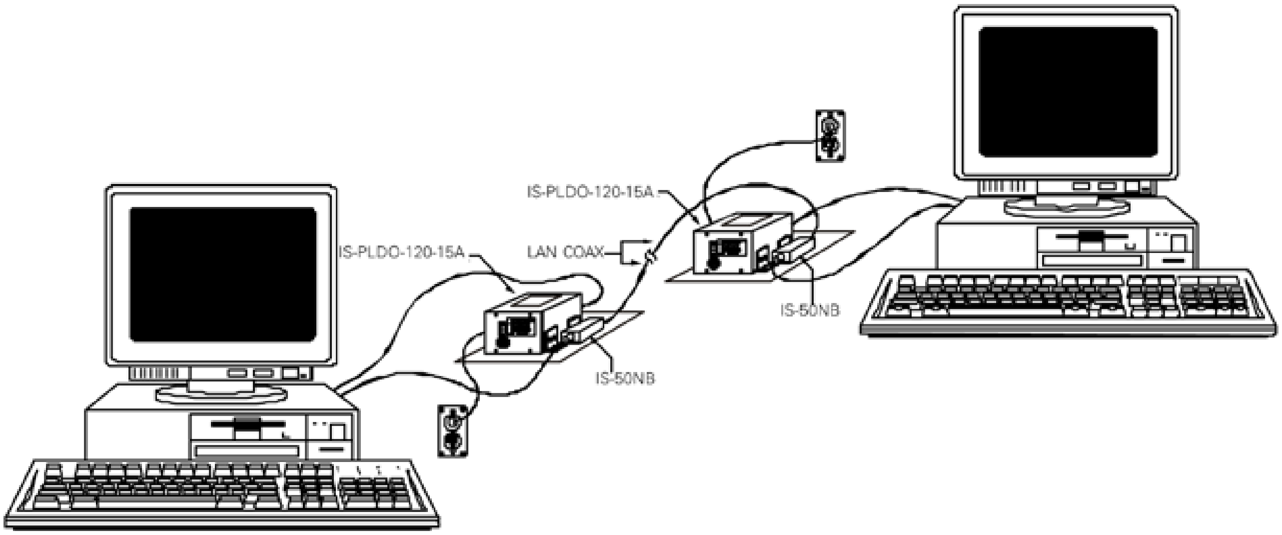
Utility lines act as a band-pass filter to the NEMP pulse. Transformers attenuate energy below 1MHz and capacitively couple energy to about 10MHz. Secondary ac power line protection with response times of 50ns and less should be used at or on the equipment.

Telephone/Control Lines

Twisted pair lines can couple some NEMP energy, but not as much as the coax or power lines. The higher inductance, smaller wire used for these applications limits the total energy delivered to the equipment.

NEMP does not have the same amount of energy as a direct lightning strike, it doesn’t last as long and usually doesn’t generate the high peak currents (20kA) of lightning. Rise times are a function of the coupling impedance to the unit under test, as well as the unit’s dynamic surge impedance.

All of the grounding techniques for lightning protection previously discussed apply to NEMP. Most importantly, long equipment interconnection lines can couple NEMP energy. Long lines will also have larger voltage drops across them because of the faster rise times involved (L di/dt). Extensive individual shielding of the inter-equipment wiring is necessary. The most cost-effective way to provide shielding for a room full of equipment is a screen room enclosure. The next most important part is to provide a ground system that will actually dissipate the fast NEMP pulse.



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

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