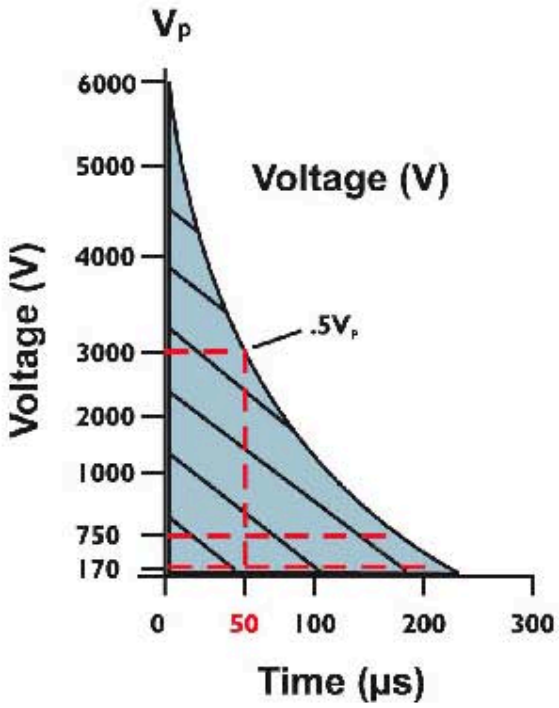
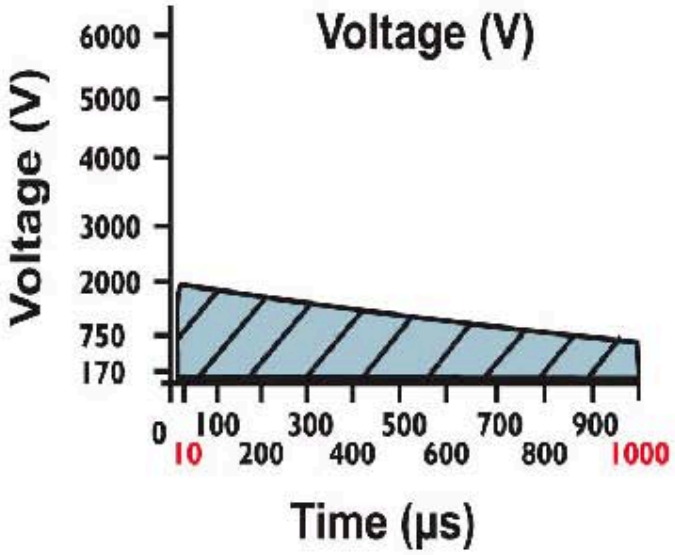
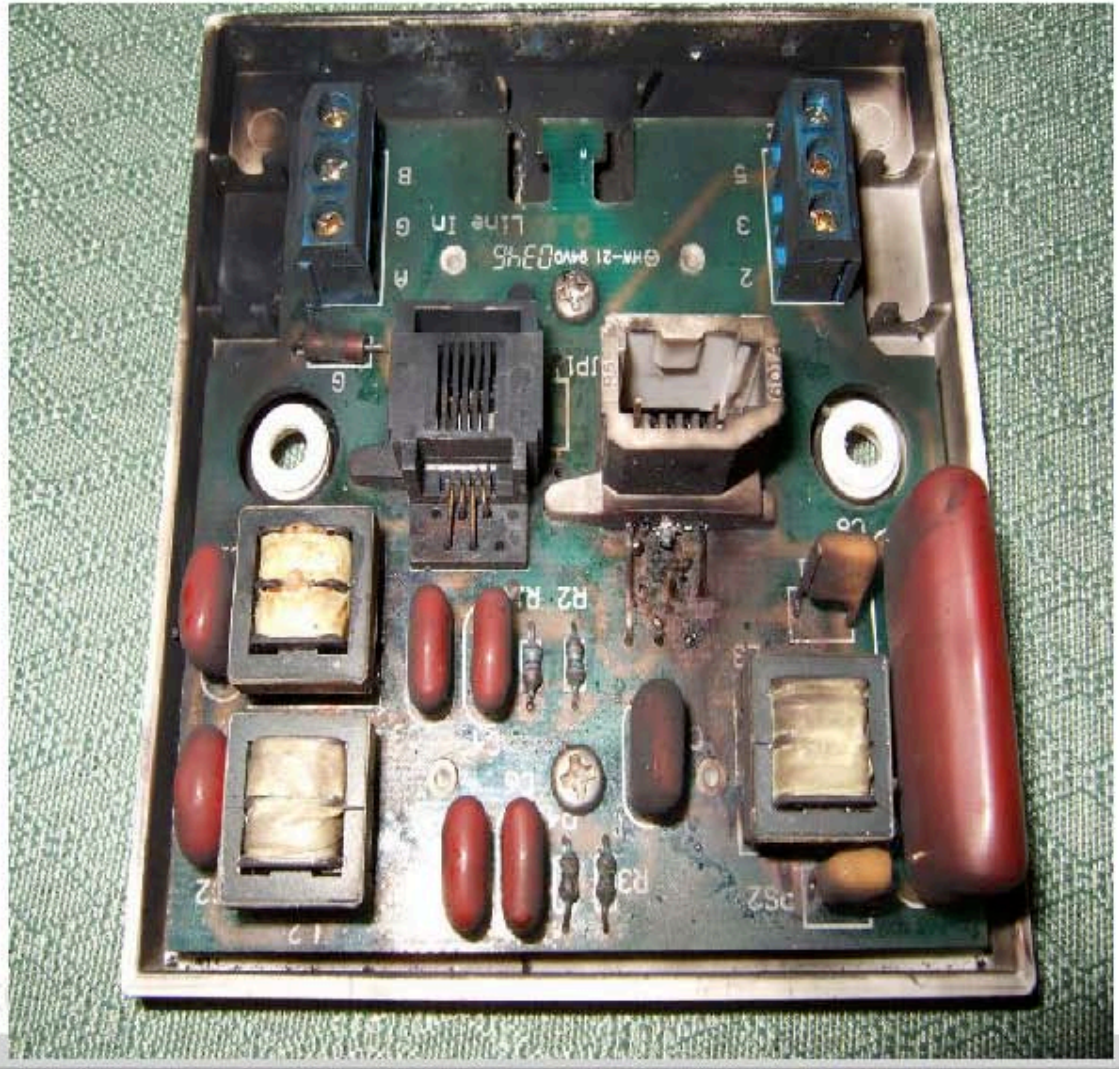
Surge waveforms 8x20 and 10x1000

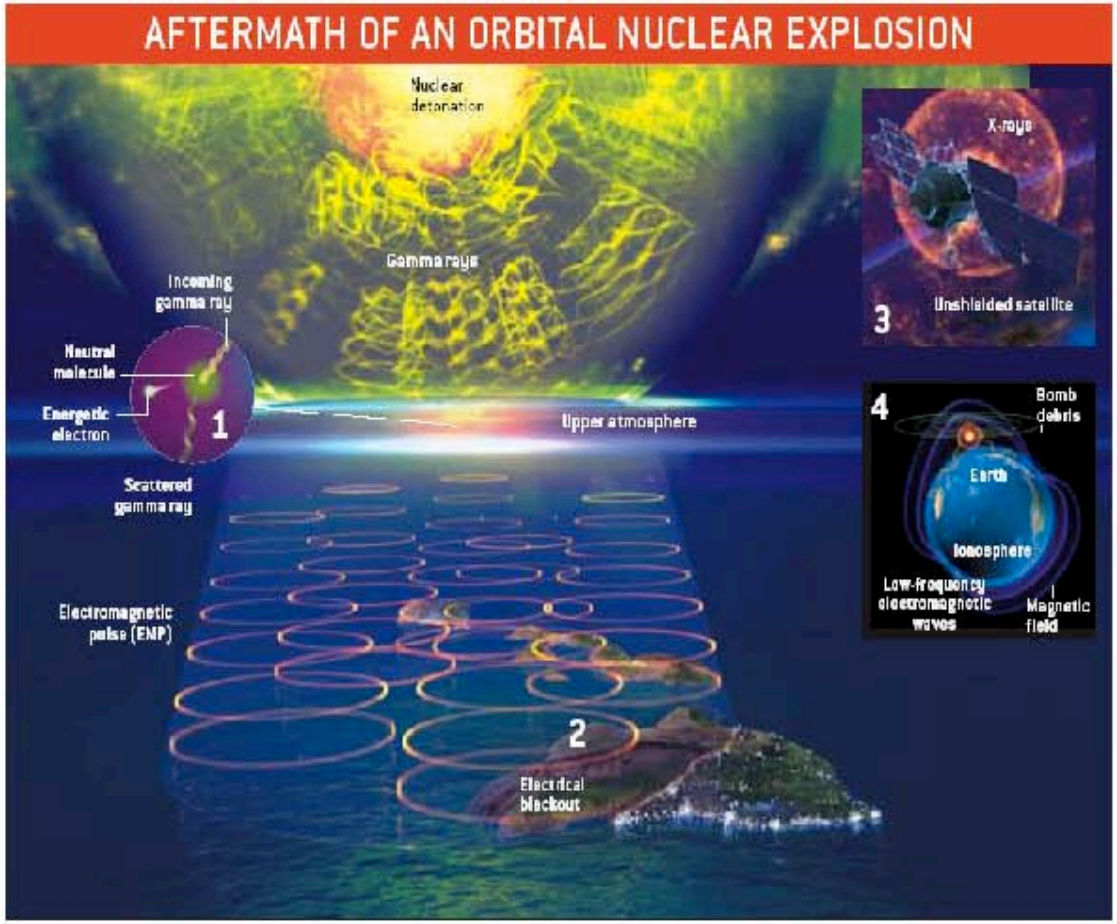




Transient Damaged



Operation Starfish Prime - EMP



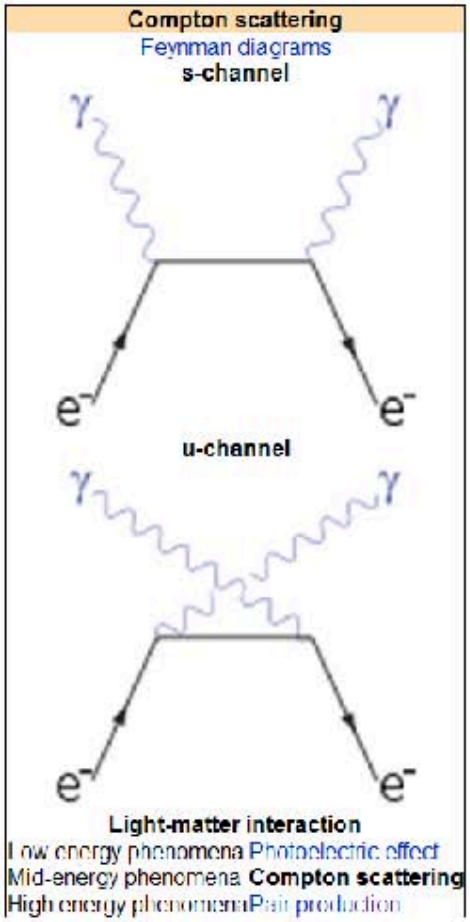
On July 9, 1962, a high-altitude nuclear test named *Starfish Prime* was conducted by the United States military above Johnston Island in the Pacific Ocean. Its unexpected electromagnetic pulse (EMP) effects caused disruptions in electrical systems and equipment in Honolulu 700 miles away. The EMP shut down long-distance telephone calls and disabled three satellites in low earth orbit. It was later learned a total of seven satellites were damaged by knocking out their solar arrays or electronics.

Operation Starfish - EMP

In physics, **Compton scattering** is a type of scattering that X-rays and gamma rays undergo in matter. The inelastic scattering of photons in matter results in a decrease in energy (increase in wavelength) of an X-ray or gamma ray photon, called the **Compton effect**. Part of the energy of the X/gamma ray is transferred to a scattering electron, which recoils and is ejected from its atom, and the rest of the energy is taken by the scattered, "degraded" photon.

Inverse Compton scattering also exists, where the photon gains energy (decreasing in wavelength) upon interaction with matter. Since the wavelength of the scattered light is different from the incident radiation, Compton scattering is an example of inelastic scattering, but the origin of the effect can be considered as an elastic collision between a photon and an electron. The amount the wavelength changes by is called the **Compton shift**. Although nuclear compton scattering exists[1], Compton scattering usually refers to the interaction involving only the electrons of an atom. The Compton effect was observed by Arthur Holly Compton in 1923 at Washington University in St. Louis and further verified by his graduate student Y. H. Woo in the years following. Compton earned the 1927 Nobel Prize in Physics for the discovery.

The effect is important because it demonstrates that light cannot be explained purely as a wave phenomenon. Thomson scattering, the classical theory of an electromagnetic wave scattered by charged particles, cannot explain low intensity shifts in wavelength (Classically, light of sufficient intensity for the electric field to accelerate a charged particle to a relativistic speed will cause radiation-pressure recoil and an associated Doppler shift of the scattered light[2], but the effect would become arbitrarily small at sufficiently low light intensities regardless of wavelength.) Light must behave as if it consists of particles in order to explain the low-intensity Compton scattering. Compton's experiment convinced physicists that light can behave as a stream of particle-like objects (quanta) whose energy is proportional to the frequency.



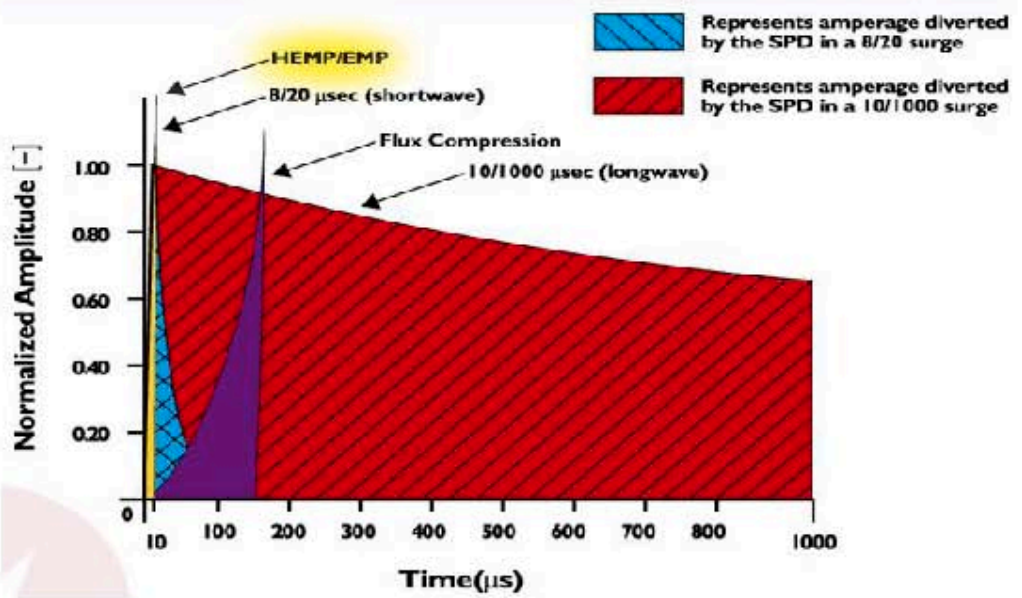
The interaction between electrons and high energy photons (comparable to the rest energy of the electron, 511 keV) results in the electron being given part of the energy (making it recoil), and a photon containing the remaining energy being emitted in a different direction from the original, so that the overall momentum of the system is conserved. If the photon still has enough energy left, the process may be repeated. In this scenario, the electron is treated as free or loosely bound. Experimental verification of momentum conservation in individual Compton scattering processes by Bothe and Geiger as well as by Compton and Simon has been important in disproving the BKS theory.

EMP - Pulse and wave shape

• E1 (20/550ns, 300kV, 5kA) fast pulse that must be attenuated down to allow only 10A past the filter into a 10ohm load.

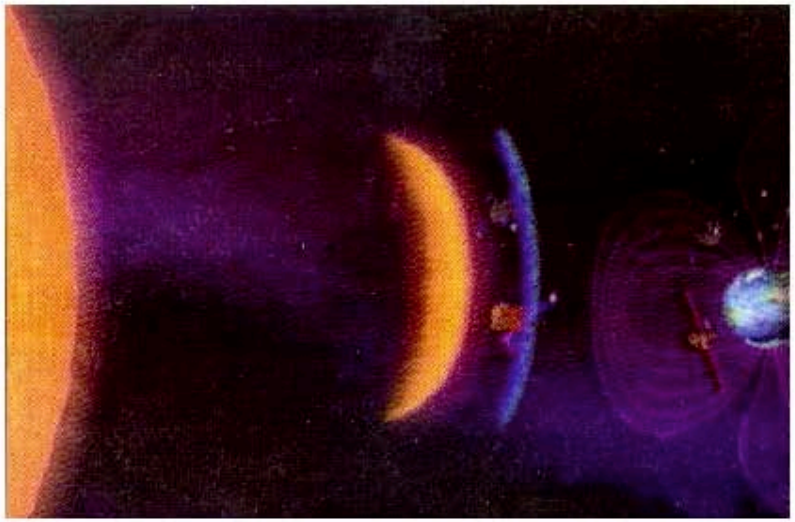
• E2 (1.5us / 3000us, 2500V, 250A) pulses which are much like the IEEE C62.45 8/20us and 10/1000us surge pulses.

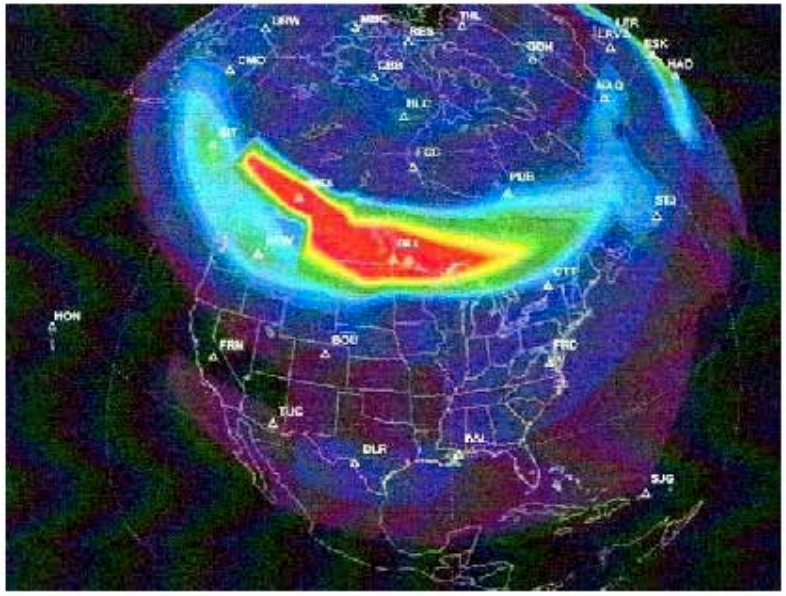
• E3 pulse is defined more like a continuous overvoltage condition like the UL1449 Overvoltage Fault Tests and is a much longer pulse. The .2 second rise by 20 second duration E3 pulse is only applicable to exposed connections from long power line and telephone wire lines.



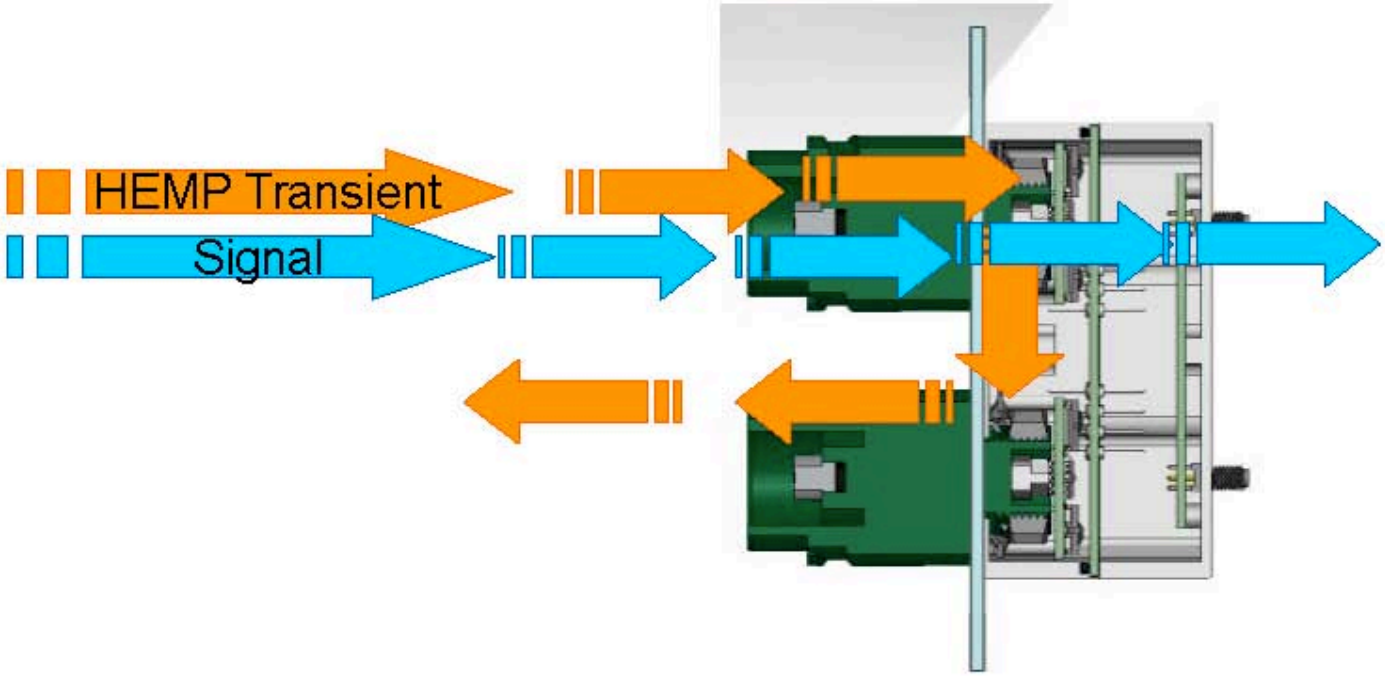
Solar Flares

- According to a report of the National Academy of Sciences, a severe geomagnetic storm could cause economic damage of $1 to $2 trillion (10 to 20 times that of Hurricane Katrina) in the first year, with 4 to 10 years until full recovery.
- One hundred fifty years ago the world's only electrical system – the telegraph network – was destroyed, after British astronomer Richard Carrington observed an unusually **severe solar flare.**
- In a recently published NASA study on severe space weather, scientists concluded that such Carrington-class solar flares occur about once per century. The report warns that a severe flare could occur any time, causing long duration, catastrophic failure of our vital electric infrastructures.
- March 1989 (Quebec) – Solar flare takes down Quebec utility.
  - Knocked out power to 6 million people in 92 seconds.



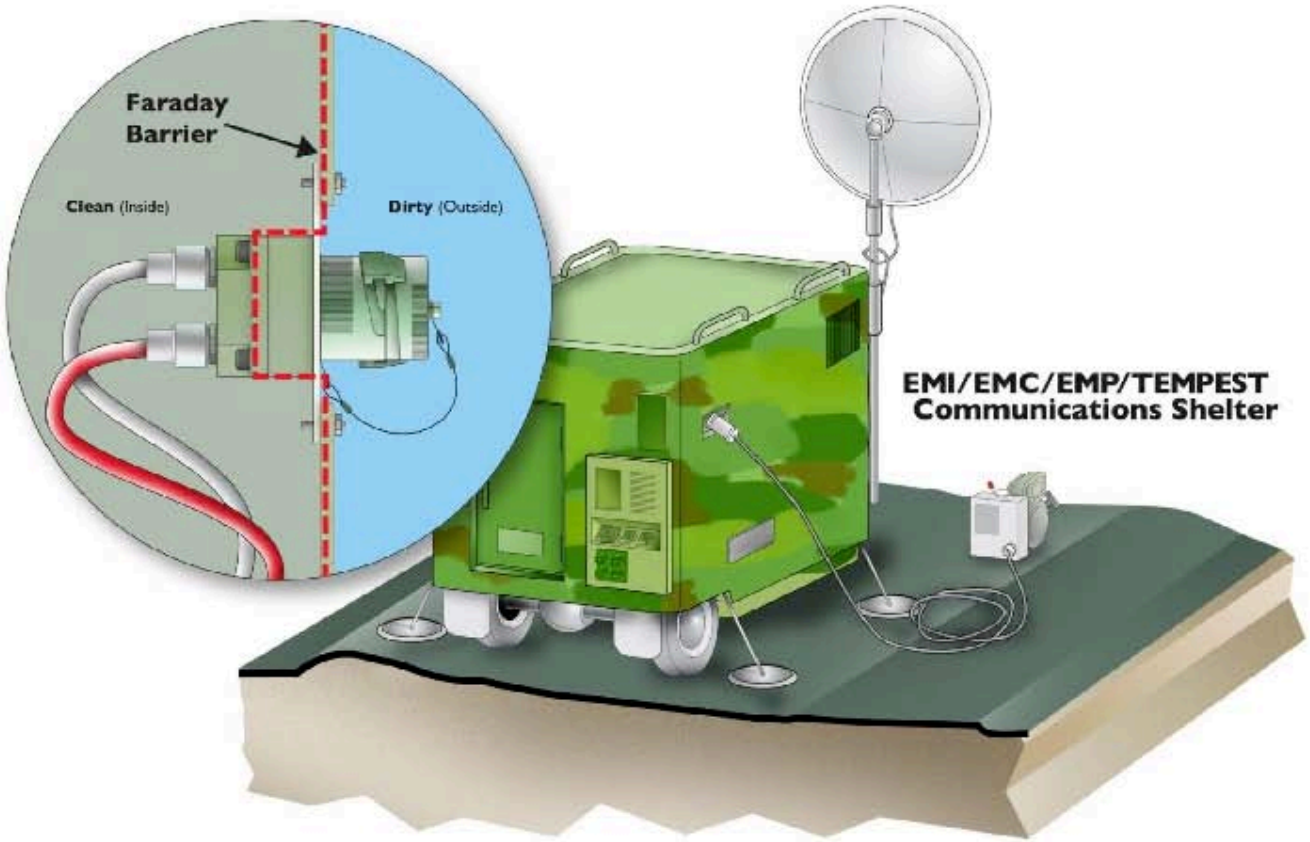


EMP filtering goal



- Grounding – TPM Mounted Directly to Faraday Cage Ground Structure
- Shielding – Mounting Method Maintains Integrity of Faraday Cage
- Filtering – Designed to Minimize Impact on Differential Operating
- Signals while Maximizing Attenuation of Common Mode Threats
- Transient Suppression – GDTs, MOVs & SASDs

EMP Protection



EMP Protection: Transtector Components are a Crucial Element of the System Solution

Practical Applications

(Please Consult Your Transtector Representative for Grounding and Wiring Instructions)

PANEL/CABINET PROTECTION
- APEX
- SPDC
- MCP

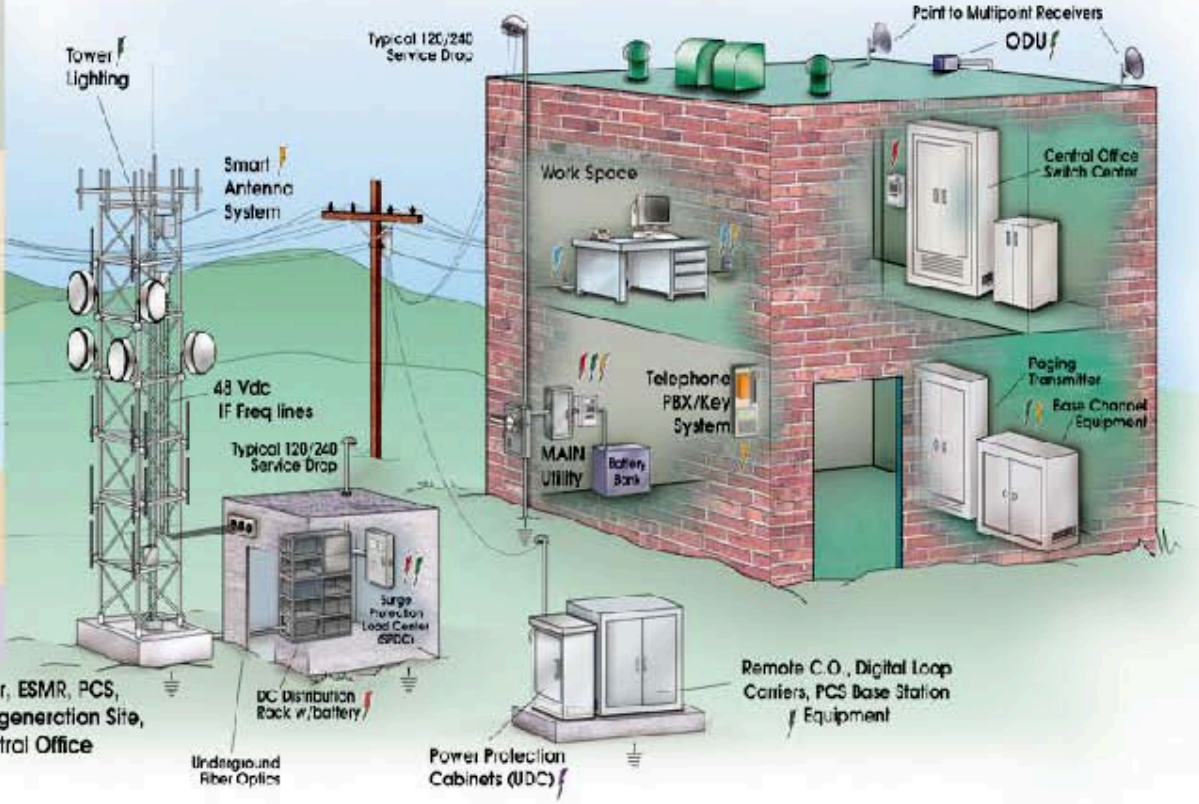
AC Hardwire PROTECTION
- MCP
- SLIMLINE 120V
- DR/AC Series
- DPS2UA
- RMPS20AT

Phone/Cable PROTECTION
- TSJB/B/4B/4BL
- TS.4B CLT
- FSP4000 MC
- TSP2500 Series
- LMP4
- PMB600

High Speed Data PROTECTION
- MPE
- TCP
- DLP
- TSJ45

DC Hardwire PROTECTION
- CB Series
- DCB Series
- DR/DC Series

Load Center PROTECTION
- UDC



Surge Protection

E1 & E2 Mitigation

Distribution panel / Load Center

Dual ATS Switches with voltage monitor

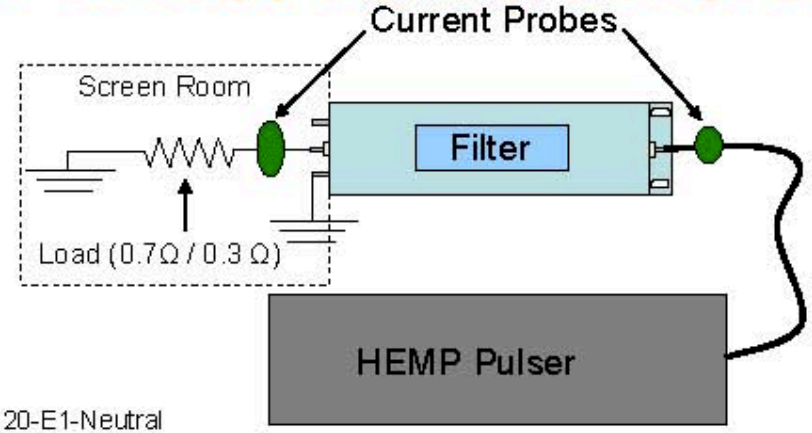
Mil-STD-188-125

- The 188-125 Family of Standards Define all Aspects of the Construction and Validation of HEMP Hardened C4I Facilities
  - Appendix A – Shielding Effectiveness (SE)
  - Appendix B – Pulse Current Injection (PCI)
    - Early Time HEMP (E1) Waveform – 20/500ns
    - Intermediate Time HEMP (E2) Waveform – 1.5/3000µs
    - Late Time HEMP (E3) Waveform – 1000A for 60s
  - Appendix C – Continuous Wave Immersion (CWI)

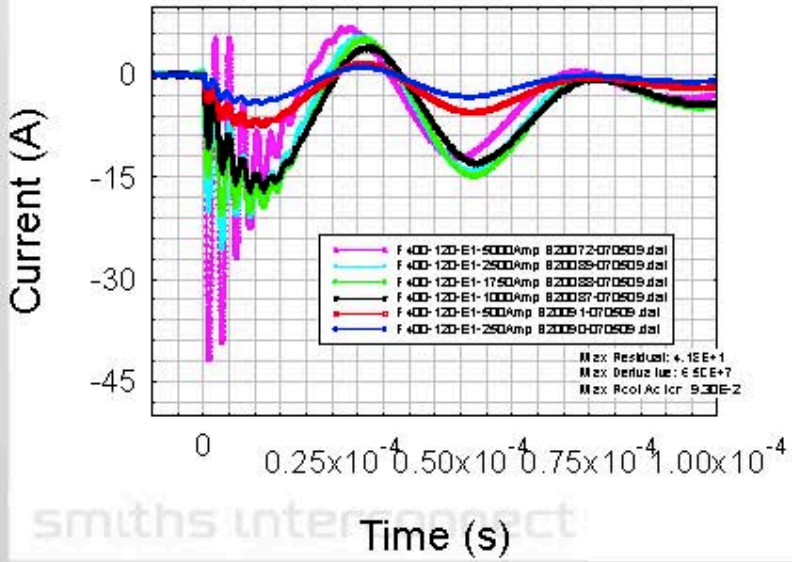
MIL-STD-188-125 Appendix B, PCI Testing

- Early Time HEMP Waveform (E1), 20/500ns
  - 60Ω Generator Impedance
  - Maximum Drive Current (Per Pin) = 2500A
  - Very High Voltage is Required !
  - Pass/Fail Determined by Analysis of Residual Norms Measured Across a Resistive Test Load
    - Peak Current (10A Max for Power, 0.1A Max for Data)
    - Peak Rate of Rise (1E7 A/s)
    - Peak Root Action (1.6E-1 A*s^0.5 for Power, 1.6E-3 A*s^0.5 for Data)

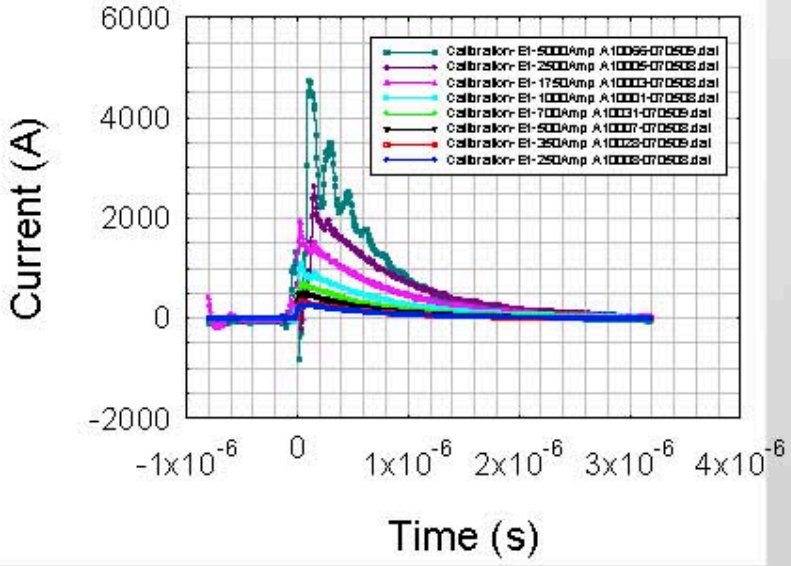
MIL-STD-188-125 Appendix B, PCI (Cont'd)



F400-120-E1-Neutral



Calibration-E1



MIL-STD-188-125 Appendix B PCI Testing (Cont'd)

HEMP E1 Testing @ SARA Inc. - Colorado Springs