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EMP & Its Protection–An Overview

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Abstract: *An electromagnetic pulse (EMP), (also known as transient electromagnetic disturbance), is short burst of electromagnetic energy. Its shortness means that it would always be spread over a rage of frequencies. Such a pulse may occur in the form of a radiated electric or magnetic field. It can be man-made or natural. Normally the highest frequencies are present in the nuclear EMP burst. Minor EMP can cause low level of electrical noise or interference. Whereas large EMP can damage electrical equipment or disrupting its function, that can lead to electrical fire. Now our aim is to minimize the effect of EMP to the electronics components. This can be done using a thick conducting material coating, around the component such as aluminum foil. Then the foil would be grounded, so as to pass the EMP to ground.*

1. INTRODUCTION

Electromagnetic pulse (EMP), is a short burst of electromagnetic energy. It also known as transient electromagnetic disturbance. Such a pulse may occur in the form of radiated electric or magnetic field or conducted electric current depending on the source and may be natural or man-made. EMP interference is generally damaging to electronics equipment. The management of EMP effects is an important branch in Electromagnetic Compatibility (EMC) engineering.

1.1 General Characteristics of EMP

Pulses of EMP are generally characterized by:-

- **Type of energy**

These include electric field, magnetic field, electromagnetic radiation and electrical conduction. In general electromagnetic radiation is more prominent.

- **Frequency range**

EMP generally contains frequency range from zero Hz to the upper limit, depending upon the source. Highest frequencies are present in Nuclear EMP (NEMP). They generally continue up to optical and ionizing ranges.

- **Pulse waveforms**

Real pulses tend to be quite complicated, so simplified models are used. These include describing it through rectangular pulse or double exponential pulse or damped sine wave.

1.2 Types of EMP

They are broadly divide into 3 categories Natural EMP, man-made EMP and military EMP.

- **Natural EMP**

Natural EMP includes lightening electromagnetic pulse (LEMP) and electrostatic discharge (ESD). ESD occurs due to charred bodies coming into contact or in close ranges.

- **Man-Made EMP**

Man-made EMP includes:-
- Switching action of electrical circuitry.
- Continual switching of digital circuitry.
- Power line surges.

Power line surges can be of several KV enough to damage electronics equipment.

Switching pulse can cause sharp change in the flow of electricity. This sharp change is also a form of EMP. The amplitude is usually small and signal is generally treated as “noise”.

- **Military EMP**

These are divided into 2 categories.
- Nuclear EMP (NEMP)
- Non-nuclear EMP (NNEMP)

NNEMP is generated without the use of nuclear technology. The electromagnetic pulse from the NNEMP come directly from the bomb itself, while the nuclear weapon generate EMP as its secondary effect. Device that can achieve this objectives include a large low inductance capacitor bank discharged into a single loop antenna, a microwave generator and an explosively pumped flux compression generator.

NNEMP generator can be easily carried as a payload of bombs, cruise missiles and drones.

The range of NNEMP weapon is much less than nuclear EMP. NNEMP allows finer discrimination of target.

NEMP is an abrupt pulse of electromagnetic radiation from a nuclear explosion. High altitude nuclear EMP (HEMP) a category of NEMP. It generated when nuclear detonation occurs at high altitude (typically over 100 KM). HEMP device produces the EMP as its primary damage mechanism.

A high altitude nuclear detonation produces an immediate flux of gamma rays from the nuclear reaction within the device. These photons in turn produce high energy free electrons by Compton scattering. These electrons are then trapped in earth's electromagnetic field, giving rise to an oscillating electric current. This is asymmetric in general and give rise to EMP.

NEMP pulse consists of three components.

- E1 component:-

It is very fast component of NEMP. It can induce very high voltage in electrical conductor. Field strength is approximately 50KV/V. Its magnitude typically decrease to half of its peak value within 200ns. The strength of pulse is somewhat dependent up on the altitude of detonation.

- E2 component:-

E2 component of NEMP is very similar to lightening pulse. It is generated by scattered gamma rays and inelastic gamma rays produced by weapon neutrons. It also known as intermediate pulse, which last from about one microsecond to 1 second after the beginning of EMP. It is generally considered the easiest to protect.

- E3 component:-

It is a very slow pulse lasting tens to hundreds of second. It is caused by the nuclear detonation heaving the earth's magnetic field out of the way, followed by the restoration of earth's magnetic field to its normal place. It is commonly refer to as "solar EMP".

2. HISTORICAL GENERATION OF EMP

Many test were carried out to study EMP and its effect. Out of them most significant were Starfish prime (conducted by USA) and soviet test 184.

Starfish prime was the name of the operation that involved detonating a nuclear warhead 400KM above mid Pacific Ocean. Its effect, as electrical damage can be seen at 1445KM away in Hawaii. The test was carried in month July, 1962.

Soviet also performed the similar tests on EMP. There most prominent test was, "test 184" which occurred over Kazakhstan. The test occurred in 1962.

3. EMP EFFECTS

Minor EMP events and especially pulse trains, can cause low level of electrical noise or interference which affect the operation of susceptible device.

Higher level of EMP can induce spark for e.g. when refueling a gasoline engine vehicle.

Large EMP can induce high current and voltage amounting to the damage of electrical equipment or disrupting its function.

Very large EMP can damage objects such as aircraft. There indirect effect can cause electrical fire, which are caused by overheating.

General effects on aircraft can damage the vital electronics systems.

In NEMP, there components can have different effects. There effect are briefly described as follows:-

- Effect of E1 component:-

It can destroy computer and communication and it changes too quickly for ordinary surge protectors to provide effective protection against it. Although there can be fast acting surge protectors that can block the E1 pulse. There are special transient protectors that are fast enough to suppress nuclear EMP.

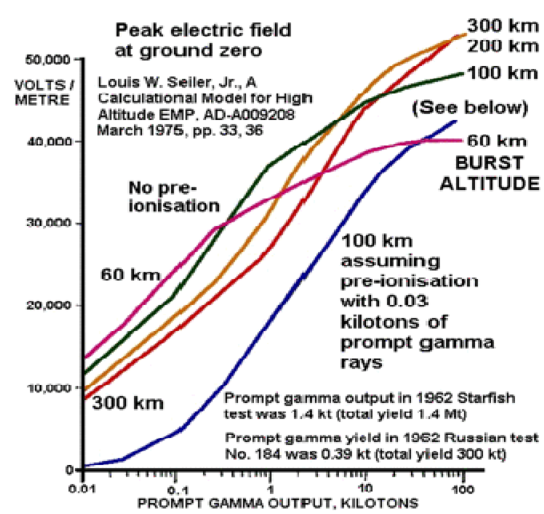
- Effect of E2 pulse:-

The damaging effect of E2 pulse is similar to the lighting pulse. The most significant risk is synergistic, because of the E2 component follows a small fractional of a second after the first component insult, which has the ability to destroy the many protective and control features. The energy associated with the second component thus may be allowed to pass into and damage systems.

- Effect of E3 pulse.

It is like a geomagnetic storm. It can produce geomagnetic ally induced currents in long electrical conductors, damaging components such as power line transformers.

The effect of NEMP would increase as the detonation altitude will increase.



Typical HEMP curve, explaining how the peak EMP on the ground varies with weapon yield and burst altitude. (Photo above)

E.g. effect of EMP on electronic circuits (Photo above)

4. MITIGATION OF EMP

An EMP can cause minor to major damage to electronics circuits. Our life –sustaining critical infrastructure such as communication networks, energy networks and food and water distribution networks could also break down. Fortunately, protecting electronics and critical infrastructure against an EMP is doable. It involves enclosing every electronic component in shielding that block out the electromagnetic pulse. Such shielding is designed to prevent electromagnetic pulse to enter or exit the device. With the help of shielding a protector circuit can also be used. Shield should be made up of robust materials and they should protect the device especially cords, cables and wires that connect devices to external entities such as power supplies or networks. Cables and wires act as antennas through which an EMP travels directly into a device.

There are many ways to protect the device.

E.g. tailor hardening, which is cost effective way of hardening. In this method, only the most vulnerable elements and circuits are redesigned to be more rugged. The more rugged elements will able to bear much higher currents. But this method has shown some unpredictable failures in testing. Still it may be used to make existing systems less vulnerable.

Vacuum tubes (valve) can be used to increase the ruggedness of the electronics circuits. In general vacuum tubes based equipment is generally much less vulnerable to nuclear EMP than newer solid state equipment. But other component in vacuum tube circuitry can be damaged by EMP. Solid state circuits can also be designed to be more robust. E.g. solid state PRC-77 VHF man packable 2-way radio.

Metallic shielding can also be used. In this shield are made up of continuous piece of metal. A metal enclosure generally does not shield the interior because of the small holes that are likely to exist. Therefore, this type of shielding often contains additional elements to create barrier. Commonly a fractional of a millimeter of a supply adequate protection. This shield must completely surround the device to harden.

Generally for metal hardening aluminum foil is used. Aluminum foil is widely used for thermal insulation (barrier reflectivity), heat exchangers (heat conduction) and cable liners (barrier and electrical conductivity). It can also be used in EMP shielding.

The shielding effectiveness of aluminum foil depends upon the type of incident field, the thickness of the foil and the frequency (which determines the skin depth). Shielding effectiveness is usually broken down into reflection loss (the energy that bounces of the shield rather penetrates it) and an absorption loss (the energy that is dissipated within the shield).

Although aluminum is non-magnetic, but it is good conductor, so even a thin sheet reflects almost all of an incident electromagnetic wave. At frequencies more than 100 MHz, the field is attenuated by more than 80dB (less than 10^{-8} of the power gets through).

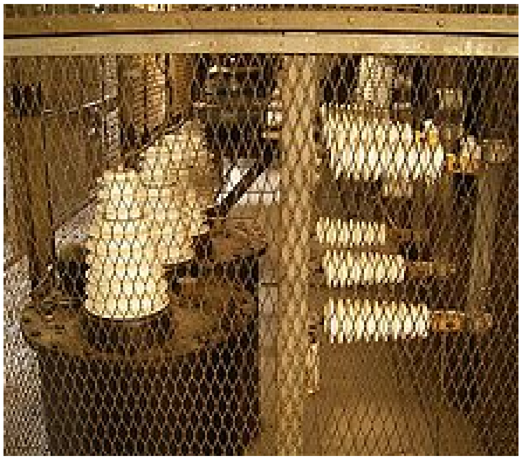
But thin sheets of aluminum are not very effective at attenuating low-frequency magnetic field. The shielding efficiency is dependent upon the skin depth. A field travelling through 1 skin depth will lose about 63% of its energy. Thin shields have internal reflection that reduce the shielding effectiveness.

For effective shielding from a magnetic field, the shield should be several skin depths thick.

Aluminum foil is about 1mil (25µm). A thickness of 10mils (250µm, ten times thicker) offer less than 1dB o shielding at 1 KHz, about 8dB at 10 KHz and about 25dB at 100 KHz.

Faraday cage can also be used in metallic shielding. It is an enclosure formed by conductive material. Such an enclosure blocks external static electricity through the mesh, providing constant voltage on all sides of the enclosure. Since the difference in the voltage is the measure of the electric potential, no current flows. A faraday cage operates because an external static electric field causes the electric charges within the cage conducting material to be distributed such that they cancel the fields in the cage's interior.

A faraday cage can be best understood as an approximation to an ideal hollow conductor. Externally and internally applied electromagnetic fields produce forces on the charge carriers (usually electrons) within the conductor, the charges are redistributed accordingly (that is electric currents are generated), once the charges have rearranged so as to cancel the applied field inside, the current stop.



E.g. Faraday shield at Art Nouveau power plant in Heimbach, Germany (Photo above)

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