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Study of Electromagnetic Pulse Attack on Electronic Circuits and Hardening Strategies

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***Abstract*— Electromagnetic Pulses (EMP) attack on electronic circuits is a rising concern these days. Various electromagnetic weapons are mainly used for defense applications like Special Forces weapons and military weapons which have simple structure with huge vicious power. These electromagnetic weapons sustain enormous loss to the electronic circuit as well as system. This paper discusses about the electromagnetic pulse, damage effects of electromagnetic pulse and how to protect our electronics & electrical circuit from EM Pulse.**

Keywords—Electromagnetic Pulse, Electronics Circuits, Hardnening Strategies

I. INTRODUCTION

The first test of Electromagnetic Pulse was held in July 1945, the scientists had to shield their electronic equipment to protect it from bomb's explosion. During British nuclear tests in 1952-1953, many of the electronic circuits failed due to electromagnetic pulse attack.

In July 1962, the United States detonated a 1.44 megaton bomb, 250 miles above the Pacific Ocean. Starfish Prime was the first successful test of EM Pulse and this test was known as "Operation Fishbowl''. The results of Starfish Prime resulted in street lights being blown out, numerous burglar alarms being set off. In October 1962, the Soviet Union carried out and this process is known as "K Project". In this test the Soviet's 300 kiloton bomb was detonated over a large population concentration in Kazakhstan. This test proved that EMP has the ability to penetrate the ground, as it damaged 600 mile long underground power line thus, leading to power failure in Kazakhstan [1-3].

The reasoning behind the seriousness of the situation regarding an EM pulse attack is that EMP neutralizes anything with a microchip. These days our society and our life depend on automation in which the chips are manufacture on a silicon base. An EMP irreparably damages many critical systems as mentioned below:

- Food and water supplies are disrupted.
- Communications, transportation, and emergency services are severely hindered.
- Banking, finance, and energy sectors are crippled.
- Computers and electronic circuits are destroyed.

Interference in these sectors would seriously complicate and delay restoration efforts. It could take days, weeks, months, or even years to restore the impacted systems to their original performance, depending on the scale of the event.

II. WHAT IS EMP

An electromagnetic pulse (EMP) is the quick acceleration of charged particles which can produce high-intensity rupture of electromagnetic energy. Due to this huge EM energy our electrical network, communication and computer systems could be destroyed.

A transient electromagnetic energy is a short pulse and high powerful pulse which have the width of EM pulse in nanoseconds. These types of pulses may occur in radiated form and electric or magnetic field depending on the natural or artificial sources.

III. TYPES OF EMP

An EM Pulse occurs through different types of sources like natural, man-made, and military weapons which is a short-duration pulse of energy. All these types of sources generated as repetitive and regular pulse trains.

A. Natural EM Pulse:

Lightning Electromagnetic Pulse (LEMP) is a foremost natural source of EM energy. LEMP could produce enormous current of a few mega-amps and this huge current capable of producing harmful effect in manmade electronic circuit as well as electronic system [4-5]. Other natural EM source is ESD. Electrostatic Discharge (ESD) is created by contact and separation of two charged objects. ESD can harm electronic circuit by injecting a high voltage pulse [6-7].

B. Man-made EM Pulse:

Man-made EM radiation is more harmful for our health. Sources of these man-made electromagnetic radiation is Cooking devices, TV, Radio, Mobile Phones and Electric power cables. Frequently switching action of

digital electronics circuitry can produced pulse of train, even internal electrical contact rotation of electrical motors can produce a train of pulses [8]. Several kilovolts power flow in electric power cables and this huge power enough to destroy electronic equipment and circuit that is not sufficiently protected.

C. Military EM Pulse:

Nuclear Electromagnetic Pulse (NEMP) is a result of a nuclear detonation in the atmosphere and nuclear explosion produces gamma rays from the nuclear reaction with a rise time of nanoseconds [9-11]. These gamma rays travelling in atmosphere produce a flux of Compton retreat electrons that constitutes an electric current density. This current density produced the high power electromagnetic pulse. This pulse or EM radiation can affect our electrical system, sea and air etc.

According to the Scientists of International Electro technical Commission (IEC) Nuclear EMPs are classified into three components E1, E2 and E3. E1 is the fastest among all electromagnetic components and this EMP exists time duration for a microsecond as well as nanoseconds. E1 component is strong electric field that can quickly produce extremely high voltage in electrical conductor and hence this component destroys our electrical system, computers and communication equipment. E2 component of electromagnetic pulse is slower than E1component of electromagnetic pulse. The characteristics of E2 components are similar to lightning electromagnetic pulse and hence E2 component is the easiest to protect against. E3 component is the slowest among all electromagnetic components [12-15]. This type of pulse occurs from the Sun.

IV. DISTANCE TRAVELLED BY EM PULSE

TABLE I. EMP SOURCES AND APPROXIMATE MAXIMUM DISTANCES FOLLOW [29]

DEVICE DAMAGED	Nuclear Bomb	EMP Source	Lightning	Short Circuit
Radio with internal antenna	2.5 Mm	2 m	100 m	10 m
Computer network	2.5 Mm	6-10 m	1 Km	100 m
Car engine computer	2.5 Mm	2 m	5-10 m	5-10 m
Modern stereo	2.5 Mm	2 m	100 m	10 m
Radio or TV station	2.5 Mm	Unlikely	500	50
Switching DC power supply	2.5 Mm	4 m	500 m	200 m
Semiconductor controllers	2.5 Mm	Unlikely	500 m	200 m
New Technology light bulbs	2.5 Mm	2 m	500 m	200 m
Cellular phones	2.5 Mm	4 m	100 m	50 m
Cellular phone towers	2.5 Mm	Unlikely	50 m	20 m

Distance travelled by an EM Pulse depends on the cause of the EMP and the kind of equipment that is damaged. The EMP can arrive through power line or data cable.

1m = 3.28 ft	1ft = .3048 m
1Km = .621 mi	1 mi = 1.609 Km
1Mm = 621K mi	1Kmi = 1.609 Mm

V. EFFECT OF EMP ON ELECTRONIC CIRCUIT

An Electromagnetic Pulse (EMP) is a rupture of energy that destroys electronics circuit. EM Weapons can create the pulse of energy and that energy can cause the damage of electronics system. Two types of coupling modes occur- Front Door coupling and Back door coupling. In front door coupling EMP interfaces with front end electronic apparatus through such as antennas and destroys the semiconductor devices in transmission line like receiver and transmitter [16-18]. In Back door coupling EMP interfaces with back end electronic apparatus through such as data cables, wiring and power cables, and can harm to transmission devices like power supplies, data transmitter and receiver devices. The main target of any electromagnetic pulse is semiconductor devices. In BJT devices breakdown occurs due to the junction in reverse biased caused by the EM Pulse. Other effect of EM pulse is thermal damage in PN junction. In Field Effect Transistors devices like MOSFET a very high electric fields that gust through the Gate dielectric caused by the EM Pulse.

The waveform of a mixture of pulse explains how electromagnetic field strength or current changes with time. Pulses have a very sharp leading edge and achieve rapidly to their maximum level [19-20]. EMP energy travels through the wires and circuits in electronic devices. Complex circuits with more wiring tend to capture more energy. In a few nanoseconds, the EMP blasts **up to 50,000 volts** of energy in electronics circuit [21-22]. This pulse melts the circuit completely. Modern computer CPUs that require smaller pathways, are vulnerable.

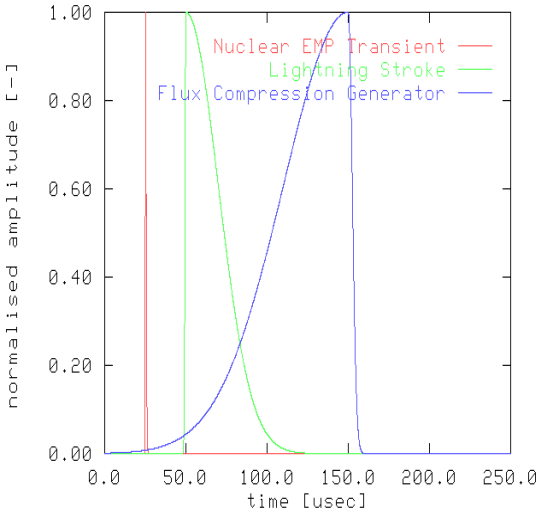

Fig. 1 Electromagnetic pulse shapes [30]

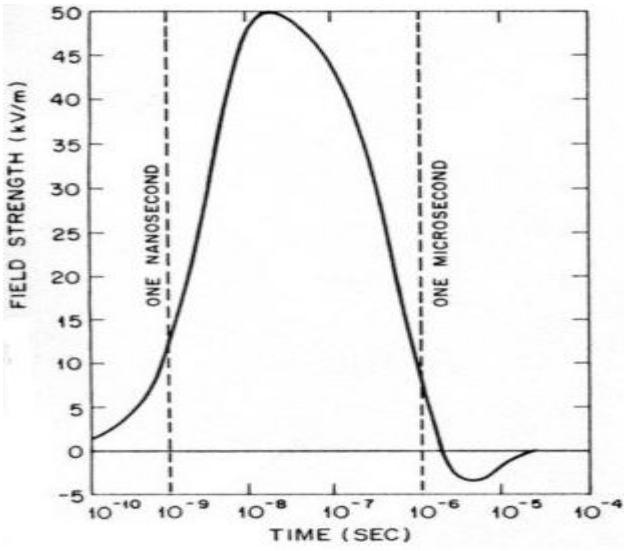

Fig. 2 Electromagnetic pulse strength [31]

The smaller connections which are closer to each other are easily broken, hence they melt quickly. The logic circuits inside the electronics system are also easily damaged by energy spikes. The energy rupture can even destroy unplugged electronics circuits. That is because the EMP energy travels like radio waves [28]. The effect of EM Pulse on the electronic system depends upon the type of attack and where you are in the energy-burst pattern. The electromagnetic energy produces huge currents in conductors that are part of electronic circuits connected to any electrical system or devices and due to these huge currents any electrical system suffer from following damages:

- The electromagnetic energy produced large currents in conductors which damage the device whether it is connected or not.
- If any conductors or components having current carrying capability are exceeded beyond a limit, it damages the device.
- Exceeding the limits of induced voltage and breakdown voltage of insulation, results in device damage.
- The voltage spikes penetrate through the metallic oxide gates in semiconductors thus, ruining them.

VI. HARDNENING STRATEGIES

- The various techniques to protect our electronics circuit from EM Pulse threat are electromagnetic shielding, proper layout of the circuit, adequate grounding and other protective devices [23]. The EM Shielding method consists of steel, soft iron or copper sheet which surrounds the system to be protected. The electromagnetic shielding of individual component is generally not possible due to complexity of the task. The shield should not be used as a ground or return conductor. The shield corners should be far away from sensitive apparatus or devices [24]. Apertures in shields should be avoided as far as possible. The circuit layout have following features like common ground points, intersystem wiring in tree format, avoiding loop layout, coupling to the other circuits and twisted cable pairs system. Fine grounding decreasing the vulnerability of a system from EMP threat. A common ground point is providing the circuit protection from electromagnetic pulse threat [25]. By using these entire component in electronic devices like Arresters, spark gaps, band pass filters, Amplitude limiters, circuit breakers and fuses we can protect our TV and radio antenna from EMP threat, even power line from the current surges.
- The main target of lightening electromagnetic pulse is antenna towers [26]. We can protect our communication channel equipment by using number of spark gaps are installed at the base of antenna tower station. When antenna is struck by lightning electromagnetic pulse then supporting guy wires also play important role and serve to bear most of the lightening EMP current to the ground.

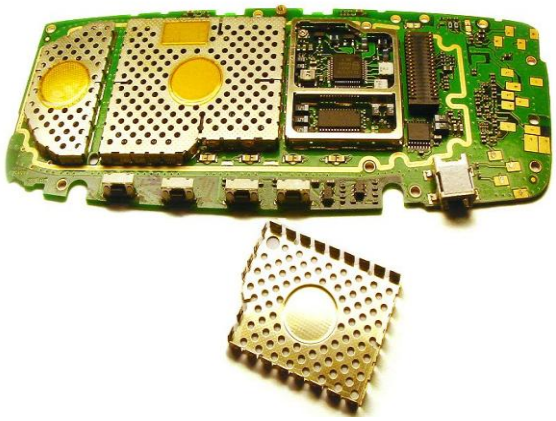

Fig. 3 Electromagnetic shielding [32]

- By using no of ground wires and modern lightening arresters of various types in electric power system we can protect our electrical system against lightening electromagnetic pulse.
- By providing electromagnetic shielding for complete building of telephone system in which number of repeaters and switching equipments are used hence we can protect our telephone system from electromagnetic pulse attack [27].

VII. CONCLUSION

Electromagnetic pulse of short duration with huge power has the potential to permanently destroy the electronic and electrical circuits. It incurs huge economic as well as human loss if electronic circuits of military weapons and Special Forces weapons are attacked by such EM pulses. Public Utility organizations which depend on automation controlled systems can suffer from damages due to these attacks which can trouble a whole town or the whole country. So, circuit designers need to take immediate steps for

preventing their circuits from electromagnetic pulse attack. In future research can be done on advance of hardening strategies to prevent circuits from EMP attacks.

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