Strong Electromagnetic Impulse Generation

Pyda Daniel
Wroclaw University of Science
27 Wybrzeze Wyspianskiego
Wroclaw, Poland

Abstract - **Electromagnetic fields can have not only disturbing but also damaging influence on equipment. There are many ways to generate such electromagnetic field. In this paper some of electromagnetic field generators will be introduced and how dangerous such field is for today electric and electronic equipment.**

I. Introduction

The fact that an electromagnetic pulse is produced by a nuclear explosion was known since the earliest days of nuclear weapons testing, but the magnitude of the EMP and the significance of its effects were realized very slowly.

In July, 1962, a 1.44 megaton united states nuclear test in space, 400 km. Above the mid-pacific ocean, called the starfish prime test demonstrated to nuclear scientists that the magnitude and effects of a high altitude nuclear explosion were much larger than had been previously calculated. Starfish prime also made those effects known to the public by causing electrical damage in Hawaii, more than 800 miles away from the detonation point, knocking out about 300 streetlights, setting off numerous burglar alarms and damaging a telephone company microwave link.

The EMP damage of the starfish prime test was quickly repaired because of the ruggedness (compared to today) of the electrical and electronic infrastructure of Hawaii in 1962. Realization of the potential impacts of EMP became more apparent to some scientists and engineers during the 1970s as more sensitive solid-state electronics began to come into widespread use.

The larger scientific community became aware of the significance of the EMP problem after a series of three articles was published about nuclear electromagnetic pulse in 1981 by William broad in the weekly publication *science*.

The relatively small magnitude of the starfish prime EMP in Hawaii (about 5,700 volts/meter) and the relatively small amount of damage done (for example, only 1 to 3 percent of streetlights extinguished) led some scientists to believe, in the early days of EMP research, that the problem might not be as significant as was later realized. Newer calculations showed that if the starfish prime warhead had been detonated over the northern continental united states, the magnitude of the EMP would have been much larger (22,000 to 30,000 volts/meter) because of the greater strength of the earth's magnetic field over the united states, as well as the different orientation of the Earth's magnetic field at high latitudes. These new calculations, combined with the accelerating reliance on EMP-sensitive microelectronics, heightened awareness that the EMP threat could be a very significant problem.

In 1962, the Soviet Union also performed a series of three EMP-producing nuclear tests in space over Kazakhstan called "the k project". Although these weapons were much smaller (300 kilotons) than the starfish prime test, since those tests were done over a populated large land mass (and also at a location where the earth's magnetic field was greater), the damage caused by the resulting EMP was reportedly much greater than in the starfish prime nuclear test. The geomagnetic storm-like E3 pulse even induced an electrical current surge in a long underground power line that caused a fire in the power plant in the city of Karagandy. After the collapse of the soviet union, the level of this damage was communicated informally to scientists in the united states. Formal documentation of some of the EMP damage in Kazakhstan exists but is still sparse in the open scientific literature.

II. Characteristic

The case of a nuclear electromagnetic pulse differs from other kinds of electromagnetic pulse (EMP) in being a complex electromagnetic multi-pulse. The complex multi-pulse is usually described in terms of 3 components, and these 3 components have been defined as such by the international standards commission called the International Electrotechnical Commission (IEC).

The 3 components of nuclear EMP, as defined by the IEC, are called E1, E2 and E3.

The **E1** pulse is a very fast pulse that generates very high voltages. E1 is the component that can destroy computers and communications equipment and is too fast for ordinary lightning protectors.

The **E2** component of the pulse many similarities to the electromagnetic pulses produced by lightning. Because of the similarities to lightning-caused pulses and the widespread use of lightning protection technology, the E2 pulse is generally considered to be the easiest to protect against.

The **E3** component of the pulse is a very slow pulse, lasting tens to hundreds of seconds, that is caused by the nuclear detonation heaving the earth's magnetic field out of the way, followed by the restoration of the magnetic field to its

natural place. The E3 component has similarities to a geomagnetic storm caused by a very severe solar flare.

III. Explosion on Earth surface

During the case of a nuclear explosion on Earth surface (Fig.1) the symmetry conditions aren't preserved. We can treat earth as a perfect absorber for γ radiation and current conductor. Because of that un symmetry a current vertical component is forming which generates an electromagnetic field like vertical monopole. Electromagnetic energy is been radiated beyond deposition region.

The conditions of electromagnetic impulse propagation are in accordance with theory of wave propagation near Earth. Some of electrons that propagates radial from place of explosion returns to this place through ionized magnetic paths in air and Earth. Therefore current circles are forming and produce strong azimuth magnetic field. The electric field made during the explosion is very high but it decreasing quite fast, at first inversely proportional to power third of distance. In bigger distances from influence area we engage to so called far zone and field decrease inversely proportional to distance from explosion place. The range of influence for electromagnetic field generated in such conditions is relatively small reaching several kilometers. Typical on Earth nuclear explosion electromagnetic impulse shape is shown on (Fig.2).

Main parameters of electromagnetic impulse can be shown as below:

- impulse increasing time < 5ms
- impulse lasting time < 200ns
- E < 40kV/m
- H < 200A/m

IV. Explosion in atmosphere

During the case of a nuclear explosion in atmosphere (Fig.3) equivalent electric dipole is been formulating, what is caused by atmosphere inhomogeneity, which is a radiation producer. Some of this radiation is been reflected from Earth surface and interfere with direct radiation explosion electric field has lower intensity than the on Earth explosion field.

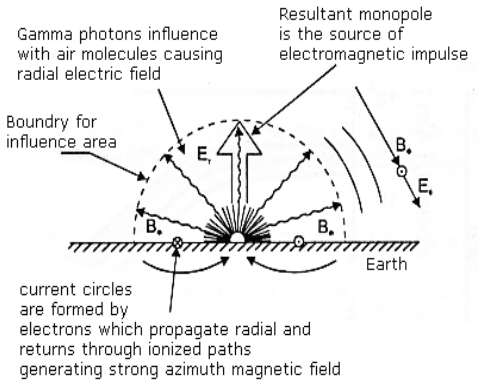

Figure 1. Nuclear explosion on Earth surface

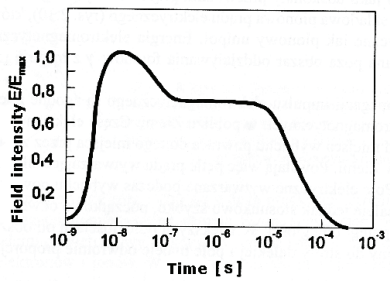

Figure 2. Earth nuclear explosion electromagnetic impulse shape

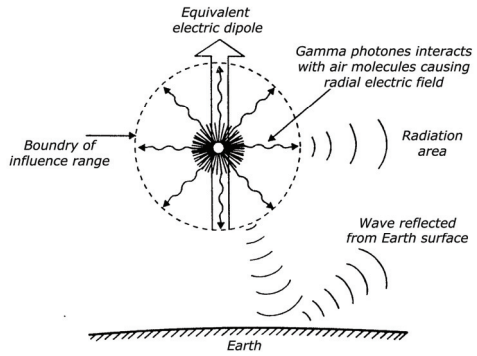

Figure 3. The in atmosphere explosion

Main parameters of electromagnetic impulse can be shown as below:

- impulse increasing time < 50μs
- impulse lasting time < 100μs
- E < 10kV/m
- H < 50A/m

V. Explosion in great altitude

During the case of a nuclear explosion in great altitude (Fig.4), recoil electrons are produced only when photons γ reaches the thicker parts of atmosphere. These electrons are deflect by Earth magnetic field producing crosswise directed electric current, which is the source of electromagnetic radiation propagating radial from hot spot. Such rising electromagnetic impulse (HEMP – High Altitude EMP) has great range (Fig.5).

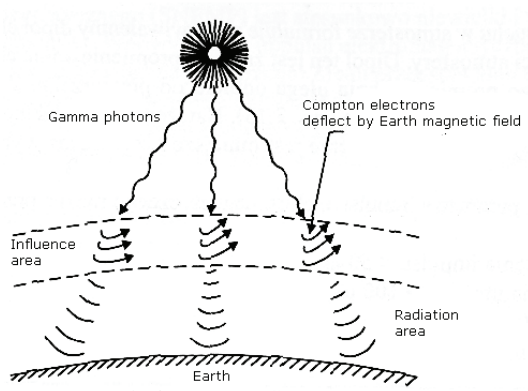

Figure 4. Nuclear explosion in great altitude

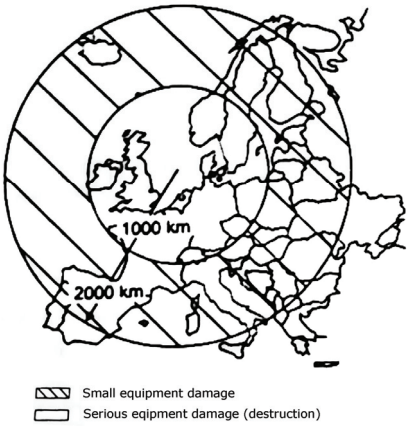

Figure 5. Nuclear explosion in great altitude damage range

Main parameters of electromagnetic impulse can be shown as below:

- impulse increasing time < 10ms
- impulse lasting time < 100ns
- E < 100kV/m
- H < 300A/m

Parameters and maintenance of electromagnetic produced during nuclear explosion in great altitude are base for determine parameters and time run for conventional disturbance (test signal), recommended by many standards to perform tests for equipment sensitivity for electromagnetic field.

VI. Non-nuclear electromagnetic impulse

Non-nuclear electromagnetic pulse (NNEMP) (Fig.6-7) is an electromagnetic pulse generated without use of nuclear weapons. There are a number of devices that can achieve this objective, ranging from a large low-inductance capacitor bank discharged into a single-loop antenna or a microwave generator to an explosively pumped flux compression generator. To achieve the frequency characteristics of the pulse needed for optimal coupling into the target, wave-shaping circuits and/or microwave generators are added between the pulse source and the antenna. A vacuum tube particularly suitable for microwave conversion of high energy pulses is the vircator.

Figure 6. A right front view of a Boeing E-4 advanced airborne command post (AABNCP) on the electromagnetic pulse (EMP) simulator for testing.

Figure 7. USS Estocin (FFG-15) moored near the Electro Magnetic Pulse Radiation Environmental Simulator for Ships I (EMPRESS I) facility. (Antennae at top of image)

NNEMP generators can be carried as a payload of bombs and cruise missiles, allowing construction of electromagnetic bombs with diminished mechanical, thermal and ionizing radiation effects and without the political consequences of deploying nuclear weapons.

NNEMP generators also include large structures built to generate EMP for testing of electronics to determine how well it survives EMP. In addition, the use of ultra-wideband radars can generate EMP in areas immediately adjacent to the radar; this phenomenon is only partly understood.

Information about the EMP simulators used by the United States during the later part of the Cold War is now in papers under the care of the SUMMA Foundation, which is now hosted at the University of New Mexico.

The SUMMA Foundation web site includes documentation about the huge wooden Trestle simulator in New Mexico, which was the world's largest EMP simulator which used a specialized version of a Marx generator.

VII. Example of vircator generator

(Fig.8) A vircator (VIRtual CAthode OscillatOR) is a microwave generator that is capable of generating brief pulses of tunable, narrow band microwaves at very high power levels. A typical vircator is built inside an evacuated resonant cavity or waveguide. An electrode at one end injects an intense electron beam, such as from a Marx generator or a flux compression generator. The electrons are attracted to a thin anode, such as an aluminized PET film, that is connected to the grounded waveguide body.

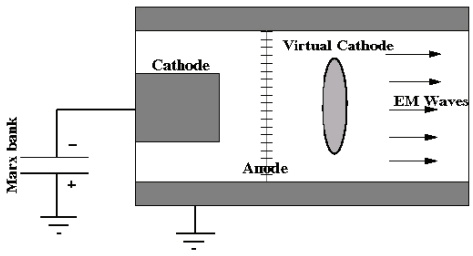

Figure 6. A right front view of a Boeing E-4 advanced airborne command post (AABNCP) on the electromagnetic pulse (EMP) simulator for testing.

The unit is surrounded by a magnet. Due to the intensity of the electron beam, many electrons pass through the anode into the region beyond it, forming a virtual cathode. The electron beam must be intense enough to exceed the space charge limiting current in that region, causing oscillations that generate microwaves. The frequency, efficiency and other characteristics of the emitted beam depend on the precise physical configuration and operating parameters.

Vircators have been used as electromagnetic pulse generators and for generating X-rays. Power levels on the order of 10^{10} to 10^{12} watts are possible.

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