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STUDY OF EXO NUCLEAR ELECTROMAGNETIC PULSE (NEMP) AND ITS EFFECT ON AIRCRAFT EQUIPMENT

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ABSRTRACT

In this review, the main effects on aircraft components of exo atmospheric NEMP are discussed. The main NEMP features to obtain the frequency distribution, electric current and voltage densities on the different parts of aircraft are noted. some proposals to protect aircraft electronic equipments are discussed. Assessment of use of small antennas is important for protection. The use of radars operating in S and X bands is advised. Separation of surface of aircraft and common earth of its electronic equipment is advised.

KEY WORDS

Protection, NEMP, Aircraft.

INTRODUCTION

Exo atmospheric pulse means that the explosion is at high altitude outside earth's atmosphere of at least 30 Km but the maximum effects occur at burst height between 40-400 Km where the yield is high. The mechanism for its formation was discussed in[1-4].

The very high produced fields by NEMP may cause permanent or transient damage for different unprotected components of aircraft like cables, signal equipments, circuit breakers, microcomputers, magnetic cores, logic elements, computers, active and passive electronic components, digital processing systems and memory units. Some components burn out especially which is sensitive for energies $10^{-9} - 10^{-2}$ jouls like audio transistors, switching transistors and integrated circuits. The energy received and the resulted damage depends on the effected area and the band width of antenna system. Communication systems operating in medium to ultra high frequency could be severely damaged. Radars operating in S and X band which have small antennas will be less affected [1,2,5].

PULSE CHARACTERISTICS

Figure (1) shows the pulse shape of NEMP exo atmospheric burst. The NEMP field reaches 45 KV m^{-1} (0.9 E_0) in about 10 nanosecond (the rise time) and reaches maximum value of 50 KV m^{-1} (E_0) during about 20 nanosecond with magnetic field of order 260 Am^{-1} . the field reaches 25 KV m^{-1} (0.5 E_0) after about 200 nanoseconds and 0.1 E_0 after about 600 nanosecond and terminates at about 1 microsecond.

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The assumed NEMP wave form may be represented by the following function[6]

$$f(t) = \begin{cases} C_1 t^2 e^{-C_2 t} & 0 < t < 10 \text{ ns} \\ C_3 t^2 + C_4 t + C_5 & 10 < t < 30 \text{ ns} \\ C_6 t + C_7 & 30 < t < 70 \text{ ns} \\ C_8 t^2 + C_9 t + C_{10} & 70 < t < 110 \text{ ns} \\ C_{11} e^{-C_{12} t} & 110 < t < 200 \text{ ns} \end{cases}$$

Where C_1= 0.0738, C_2=0.2, C_3= -3×10^{-4}, C_4= 6×10^{-3}, C_5= 0.97, C_6= -1.2×10^{-2}, C_7= 1.24,C_8= 8.106×10^{-5}, C_9=-2.335×10^{-2}, C_{10}= 1.637, C_{11}=9878.0, C_{12}=0.111 and t is measured in nanosecond.

Figure (2) shows that 90% of the energy is contained in the $10^4 - 10^7$ Hz:. The instantaneous peak power density is very high whose value is about 6 MW m^{-2} [1-6].

In endo atmospheric burst, the duration of pulse is much longer and of order of 1 millisecond. Its peak energy density is much larger and of order of 1 KJ m^{-2} . in exo atmospheric burst, the energy density is much less and of order of 1 J m^{-2}. The intensity of the electric field depends very little on the yield of the nuclear weapon and represented by the following formula :

$$E= 10^4 \times 1 / R^{3/2}$$

Where R represents the distance from center of burst in Km and E is the electric field in volts/m.

ANALYSIS OF SURFACE CURRENT AND CHARGE DENSITIES FOR AIRCRAFTS

The surface current and charge densities were computed on the surface of fuselage except in the vicinity of intersection of the wings and fuselage[7]. Fast Fourier transform (FFT) algorithm was applied to the solution in the frequency domain to obtain the early time NEMP response. High frequency components were obtained using geometrical theory of diffraction (GTD) which gave the contributions from the reflected and edge-diffracted fields from the wings plus those diffracted from curved surface of fuselage[8]. To predict NEMP response on metal structures of the aircraft, simulators were made. Modeling using computers my perform theoretical evaluations and analysis systems for NEMP effects, frequency field for antenna and induced currents and voltages.

The surface current and charge density induced of the aircraft is performed by GTD theory in both frequency and time domain. The frequency dependence of the current density on the shadow side is completely different from that occurring on the illuminated side for frequencies about the fundamental resonance of the aircraft[7,8].

PROPOSALS FOR PROTECTION OF AIRCRAFT AGAINST NEMP

The protection depends on utilization of external surface as a shield for reducing and filtering electromagnetic radiation. It is important to utilize special cables surrounded by good earthing to filter the induced disturbances. High magnetic case prevents the entry of electric and magnetic fields created by NEMP. Faraday cage is important to dampen the magnetic field. Filtering of incoming frequencies is accomplished by mounting across the wall to maintain the radio-electric integrity of the shielded room. This can be aided by welding light copper network with all parts of aircraft with special attention to openings to maintain the effectiveness of the shielded enclosure. The dimension of nonconductive openings should be minimized. The components are connected carefully together by good conducting metal or painted by graphite. The internal ground loops must be prevented to carry bypassed NEMP transients. This shield can be connected to one pole of separate battery and isolated from the general ground of the rest of electronic equipment of aircraft. Signal amplitude limitors protect highly sensitive electronic devices[9,10].

Special power cables can be utilized for power mains protection according to the phase (single or 3 phase), if the power is DC or AC and the range of volts and value of current. For radio-frequency telecommunication lines protection, there are two types of high frequency protection systems. For frequencies <25 MHz, the protection is treated as wire protection using low capacity components by a coaxial assembly. For frequencies >25 MHz, special cables has developed. They act as an open circuit with respect to antenna frequencies and as a short circuit with respect to frequencies of disturbances. Sometimes a coaxial surge arrester is located. Over-tension arrestor contains spark gap with lower limit response time and silicone carbide resistor. Spark gaps on RF antenna transition lines that operate in NEMP spectrum must be used[11].

Metallic casings of electrical and non-electrical apparatus, switching panels, water pumps, gas and oil pumps, conducting cable sheathes and ventilation ducts must be protected against NEMP by their good connection to earth. Copper, aluminum and iron can be utilized or faraday cage. Between the flanges it is necessary to insert copper braid strips. At non-flight duration the aircraft must be kept in special shelter equipped by well earthed faraday cage[12]. The net weight of the prepared measures should be taken in considerations.

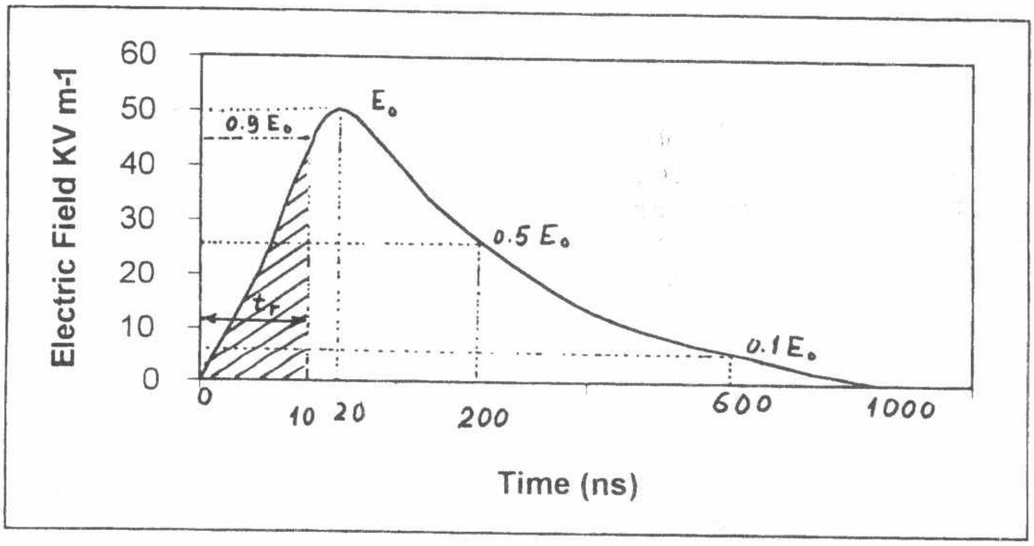

Fig.1. NEMP from exo atmospheric burst

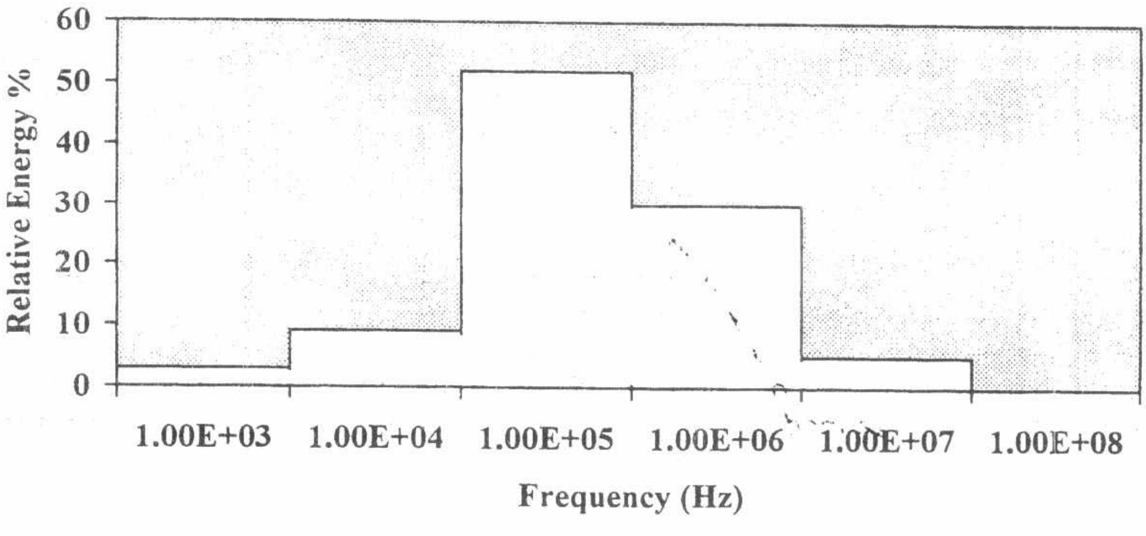

Fig 2. Relative energy frequency relationship

REFERENCES

[1]Mc Naught L.W., Nuclear Weapons and Their Effect, UK Brassey's Deffence Publishers, London 1984.

[2]Bin C. and Bihua Z., A Study of The Underground EMP Environment of High Altitude Nuclear Explosion, Int. Sympos. On Electromag. Compat., Sendai, Japan, 16-20 May , pp.97, 1994

[3]Delaballe J., High Altitude NEMP Hardening of Power Stations (Generating Sets) Methodology and Industrial Consequences , 15th Inter. Telecom. Energy Conf. , Vol. 2, Paris, France, pp. 157,27-30 Sept. 1993.

[4]Ginzburg N.S., Novozhilova Yu. V. and Sergeev A.S., Superradiance of Ensembles of Classical Electron-Oscillsators as a Method for Generation of Ultra Short EMP, 15th Inter Free Electron Laser Conference, TheHague, 23-27 Aug. 1993.

[5]Gut S.J., The Swiss EMP Concept of General Defence, IEEE Antennas and Propagation Society Newsletter, 29(6), pp. 5, 1987.

[6]Longmire C., On Electromagnetic Pulse Produced By Nuclear Explosion, IEEE Trans. on Electromag. Compat., Vol. EMC-20, No.1 ,pp. 3, 1978.

[7]Hwang Y.M., Peters L. and Burnside W.D., Surface Current and Charge Density Induced on Aircraft, IEEE Trans. on Electromag. Compat., Vol. EMC-20, No.1 ,pp. 141, 1978.

[8]Taylor C., External Introduction of The Nuclear EMP with Aircrafts and Missiles, , IEEE Trans. on Electromag. Compat., Vol. EMC-20, No.1 ,pp. 64, 1978.

[9]Jeruchim M.C., Techniques For Estimating The Bit Error Rate in The Simulation of Digital Communication Systems, , IEEE Journal on Selected Areas in Comm., Vol. SAC-2, No. 1, Jan. pp. 153-170, 1984.

[10]Marin L., Castillo J.P. and Lee K.S.H.,IEEE Trans. on Electromag. Compat., Vol. EMC-20, No.1 ,pp. 141, 1978.

[11]Lee K.S.H., Kliu T. and Marin L.,EMP Response of Aircraft Antennas, , IEEE Trans. on Electromag. Compat., Vol. EMC-20, No.1 ,pp. 94, 1978.

[12]Protection Against NEMP, AL CATEL,Les Cables De Lyon, EMP Protection,France, 1994.