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MISSILE'S GUIDANCE HEAD ANTI-NUCLEAR ELECTROMAGNETIC PULSE REINFORCEMENT

by

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Missile's guidance head anti nuclear electromagnetic pulse reinforcement

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Abstract: In the nuclear weapon family, following A-bombs and H-bombs, some countries developed and produced some other kinds of nuclear weapons, the nuclear electromagnetic pulse bomb is one of them. This kind of nuclear bomb is mainly used to interfere or damage un-reinforced electric and electronic systems. Un-reinforced missile guidance heads also could be damaged.

So, this paper simply introduces the generation and main characteristics of the nuclear electromagnetic pulse, the damaging mechanism of the nuclear electromagnetic pulse to the guidance head, and the response of electronic devices to the nuclear electromagnetic pulse, at last introduces the guidance head's defense method to the nuclear electromagnetic pulse.

Keyword: nuclear electromagnetic pulse, nuclear electromagnetic pulse damaging mechanism, anti nuclear electromagnetic pulse reinforce

The electromagnetic pulse produced by a nuclear weapon explosion is called nuclear electromagnetic pulse (NEMP). It is mainly formed by the irradiation after nuclear explosions and the Compton collision among media around the nuclear explosion, it is a kind of transient electromagnetic field.

The excitation of NEMP to the missile is similar to the excitation of the electromagnetic wave to antennas. It induces very high voltage and very strong current in the missile, this voltage and current are transmitted into the missile's interior, cause temporary or permanent damaging effects to the electronic devices in the guidance head. Therefore, it is necessary to reinforce the guidance head to anti NEMP.

1. The nuclear electromagnetic pulse effect

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1.1 NEMP

The explosion of nuclear weapons can be approximately divided into high altitude explosion, low altitude explosion and ground explosion. The explosion height of high altitude nuclear explosions is from dozens of kilometers to several hundreds kilometers. The ground explosion is the nuclear explosion on the earth surface or near the earth surface. These explosions all produce NEMP. To a great extent, the characteristic of NEMP is determined by the nuclear weapon equivalent mass and nuclear explosion height.

If the gamma ray produced by the nuclear explosion directly acts on the guidance head, it will excite electrons inside the guidance head, thus producing electromagnetic field in the guidance head, this is called internal electromagnetic pulse (IEMP). When the high altitude nuclear explosion happens, due to the very long distance of nuclear irradiation, it will cover very large areas, when the air defense missile and ballistic missile and other aircraft fly through the area of strong gamma ray dosage, the guidance heads interior will create IEMP, it will interfere with or damage the guidance head.

1.2 The main characteristics of NEMP

1.2.1 Field intensity

The field intensity of the electromagnetic pulse (EMP) produced by air explosion radiation is determined by the equivalent mass, explosion height (because of the density gradient of the atmosphere, the effect of height is asymmetrical) of the nuclear explosion and the asymmetry [1] due to the weapons (including auxiliary equipment, shell case or launching vehicle). For the low frequency EMP produced by the difference of air density, at a random specified time t, the radiation electronic field E(t) that is observed is :

$$E(t) = \frac{r_0}{r} E_0(t) \sin\theta \qquad (v/m)$$

#1

where, r is the distance to the explosion center outside the source area

$r0$ is the radius of the source area

If we compute $E0(t)$ under specific conditions using $r0 = 0.32 \ln Q + 0.48$ (Km), $E0(t)$ is usually from dozens of Volts per meter to several hundreds volts per meter.

In the ground explosion, the radiation electronic field peak values at the source area's boundary along the earth's surface direction is 10 ~ 100 times bigger than that of the air explosion of the same equivalent. The peak value irradiation electronic field along the earth's surface direction changes with the distance r:

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$$E = \frac{r_0}{r} E_0$$

#1

where, E0 is the peak value radiation field intensity at the source area's radius r0, it is usually several thousand volts per meter.

The relationship between the range and explosion height of NEMP is showed in table 1 and figure 1. Figure 1 shows the electronic field peak value changing at different places on the earth's surface where the explosion height is 100 ~ 500 Km, equivalent mass is 100 Kt, explosion center's projected point is in the area of north latitude 30°~60°

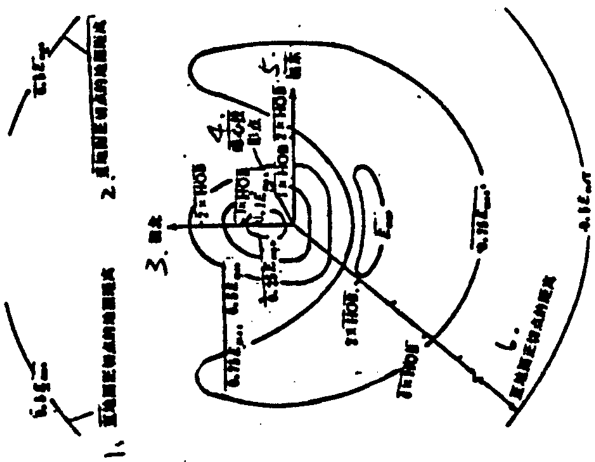

Figure 1. The electronic field peak value changing at different places on the earth's surface in high altitude nuclear explosions.

Key:
1. The ground distance to the ground surface's tangent point
2. The ground distance to the ground surface's tangent point
3. magnetic field north 4. explosion center's projected point
5. magnetic field east 6. The distance to the ground surface's tangent point

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The low frequency field (10 ~ 20 KHz) of NEMP is very strong, approximately $10^4 \sim 10^5$V/m [2]; but because the high frequency field is absorbed and there is a rapid decrease in the transmission period, in the not far distance, the field intensity is possibly very small.

Table 1. The range of the nuclear electromagnetic pulse of different heights

1. 爆炸高度(km)	100	150	200	300	400	500
2. 从爆心"看"到地球的半径(km)	1120	1370	1580	1923	2250	2450

Key: 1. explosion height (Km) 2. the earth's radius viewed from the explosion center

The NEMP's spectrum is from 1Hz to more than 300 MHz [3], shown in figure 2. Usually, NEMP's main frequency produced by H-bomb explosions is around 7 ~ 8. 0 MHz; in the A-bomb explosion, about 95% of the main frequency is around 15. 25 ~ 18. 99 MHz, the spectra are different according to the explosion center distance [4]. The distance increases, the field intensity's high frequency energy loss is larger than that of the low frequency energy, so in the far area, the spectrum distributes below 100 KHz.

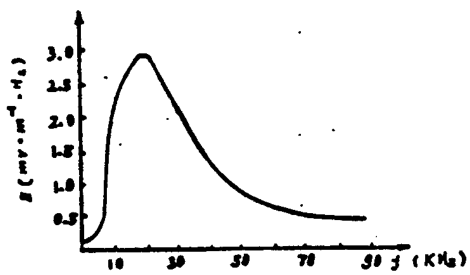

Figure 2. The spectrum distribution of the nuclear electromagnetic pulse

The spectrum can usually be divided into three areas: 1) source area: if the pulse width is 0. 1 ~ 0. 2 μs, the energy mainly concentrates in the range below 5 ~ 10 KHz; if the leading edge is 0. 01 μs, the upper limit of the spectrum is about 100 KHz; 2) transition area: the energy mainly concentrates in the range from several hundred Hz to 150 KHz,

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3) radiation area: the energy mainly concentrates in the range from several hundred Hz to 50 KHz, the peak value appears around 10 ~ 20 KHz [5].

In brief, the leading edge of NEMP is steep, in the 10^{-8} second period of gamma ray radiation, it rises from 0 to the maximum of about $5X10^5$v/m, the pulse width is about 10 ~ 30 μs, the field intensity can reach 100 ampere * turn / meter. Figure 3 shows the comparison of NEMP and lightning and radar pulse.

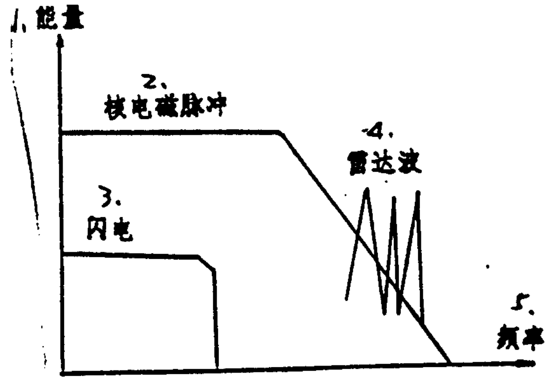

Figure 3. The comparison of NEMP and lightning and radar pulse
Key: 1. energy 2. nuclear electromagnetic pulse 3. lightning
4. radar wave 5. frequency

1. 3 The mechanism of how NEMP damages the missile's guidance head

The coupling of the guidance head to the NEMP can be divided in three ways: electronic induced coupling, magnetic induced coupling and resistance coupling. The electronic induced coupling produces induced current on the conductor's surface. The magnetic induced coupling appears in the conductors that form the closed loop, in this loop, it causes current flow. The form of the loop can be invisible or radome connected conductors. The resistance coupling appears when the conductor immerses in the conducting media, such as the air of electronic ions, it produces induced current. From these factors, we can say that all conductors can get energy from NEMP field by coupling. In this circumstance, the missile's cover, guidance head's shell become the NEMP energy collectors.

Because the spectrum of NEMP is very wide, there always exists a part of the energy that can be effectively

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absorbed by coupling. Usually, the larger the missile's area, the longer the missile, the more energy would be collected. The energy collected by the missile is converted into strong current and very high voltage, thus the electronic devices inside the guidance head could be badly damaged and cannot work normally.

1. 4 The nuclear electromagnetic pulse response of electronic devices

NEMP has a temporary effect or permanent effect on the electronic devices. The permanent effect causes permanent damage, the devices cannot work without repair.

What kind of effect can be produced depends on the energy threshold of the damage, it usually relates to the following aspects: how much energy the electronic devices collect, the quantity that the sensitive and easily damaged devices get, and the sensitivity of the devices or the circuits themselves.

The devices that easily generate permanent effects are: the semiconductor node of semiconductor devices (especially high frequency transistor, integrated circuit and microwave diode), integrated circuits, especially large scale integrated circuit, insulated radio frequency cable, power supply cable, rated power or very low voltage electronic devices, and precise devices, etc. The minimum energies in Joule which cause permanent damage to some devices are shown in table 2.

Table 2. The minimum energies in Joule cause permanent damage to some devices

1.名称	2.最低焦耳能量*	3.故障	4.说明
2N36	4×10^{-2}	5.烧毁	6.锗声频晶体管
2N3528	3×10^{-3}	7.烧毁	8.硅可控整流器
9.继电器	1×10^{-1}	10.接点熔焊	11.西格马(IIF)1A 继电器
12.集成电路	4×10^{-10}	13.电路失灵	14.西凡尼亚 J—K 触发单块集成电路(SF50)
15.磁芯	2×10^{-9}	16.接线抹擦	17.布罗快速计算机磁芯存贮器(FC2001)
18.放大器	4×10^{-11}	19.干扰	

Key: 1. Name 2. minimum energy in Joule 3. damage 4. description 5. burn down 6. germanium voice frequency transistor 7. burn down 8. silicon controlled rectifier 9. relay 10. connection point desoldered 11. Sigma (IIF) 1A relay 12. integrated circuit 13. circuit malfunction 14. Sylvania J-K flip-flop single integrated circuit (SF50) 15. magnetic core 16. wire smearing 17. Burroughs high speed computer magnetic core memory (FC2001) 18. amplifier 19. interference

* NEMP's damaging effect on electronic devices can be indicated by "minimum energy in Joule"

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The devices or components that easily generate transient effects include: low power or high speed digital processing system, the wired connected memory, and flight control system, etc.

2. Anti electromagnetic pulse reinforcement

From above descriptions we know that the missile's guidance head must have anti NEMP reinforcement. There are many methods of reinforcement, before reinforcement, the effect of each reinforcement should be considered.

The degree of the reinforcement should depend on the total tactical and technical index of anti NEMP. According to this index, each subsystem of the guidance head should be considered, then determine which devices in the subsystem should be reinforced and the reinforcement index that they should have, and which devices need not be reinforced.

The total index depends on the NEMP environment that the guidance head is in. Some people think, 5×10^4v/m is the standard NEMP environment.

In addition, the reinforced guidance head should: 1) be able to endure the testing; 2) during the effective life time of the guidance head, this kind of reinforcement can be kept and maintained.

2.1 shielding

Shielding is an effective method to reduce the NEMP environment level. Shielding can be divided into static shielding, magnetostatic shielding and electromagnetic shielding.

2.1.1 Static shielding

The static shielding is mainly to isolate the electric power wire. One of the important ways is to connect the shielding unit to the earth, maintain the earth's electric potential of the shielding unit.

2.1.2 Magnetostatic shielding

The magnetostatic shielding can compress the magnetic field lines in the range of the shielding unit's thickness, thus producing the effect of magnetostatic shielding. The crack or aperture of magnetostatic shielding should not cut off the magnetic field lines, otherwise the shielding effect would be reduced. If the shielding unit is connected to the earth, this method also has the effect of static shielding. The magnetic field intensity of NEMP can reach 100 ampere * turn / meter. If the frequency is lower than 100 KHz, the magnetic shielding is relatively

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difficult. The shielding performance can only be realized by experiment.

2.1.3 Electromagnetic shielding

The principle of electromagnetic shielding depends on the energy reflecting loss of the high frequency electromagnetic wave on the shielding unit's surface and the high frequency energy's whirlpool loss within the shielding unit's thickness. In fact, the electromagnetic shielding is the summation of reflecting loss, absorbing loss, and the correction term causing multiple reflecting (when the absorbing loss is small, this term cannot be ignored).

In addition, the circuit layout inside the guidance head should avoid loop circuit layout (figure 4a), and should employ the tree layout as shown in figure 4b, thus avoiding latent "loop antenna", causing magnetic coupling and absorbing NEMP energy.

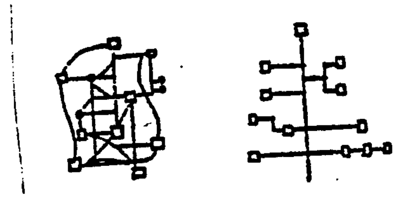

Figure 4

(a) loop layout (b) tree layout

2. 1. 4 The effect of the shielding unit's discontinuity.

The joint-free shielding unit without cracks or continuous slots is a kind of ideal structure. But the I/O port of the power supply cable and control cable, and sensor opening, etc. are required. These cause discontinuous areas, affect the shielding performance of the guidance head shell, so, the design and manufacture of the discontinuous area are very important.

2.2 Employing amplitude limiting technique and filtering technique [6]

In addition to the above mentioned methods, the amplitude limiting technique and filtering technique could be employed in the guidance head to stop or absorb useless and error signals, only allowing the useful signals to pass.

1) voltage amplitude limiter

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(undulation restraint), in the key circuit this device can be used to limit the voltage, the devices that can limit the amplitude include: medium breakdown devices (such as spark gap), semiconductor breakdown devices (such as Zener voltage stabilizing diode) and nonlinear breakdown resistance (voltage dependent resistance). The amplitude limiting level should be higher than the working level.

Because the leading edge of NEMP rises rapidly and its energy is large, considering the working characteristic of the amplitude limiting devices, the amplitude limiting devices should be used associated with the filtering devices to accomplish the task. 2) Filter: the filters used for NEMP reinforcement usually include two kinds, they are T shape and Π shape, but the Π shape low pass filter should be avoided, because high voltage can possibly affect the input capacity of this filter and cause the capacity's performance to be damaged or out of order. Because it is difficult to manufacture the heavy current filter whose cut off frequency is below 10 KHz, it is better to use the filters in pairs adjacent to the amplitude limiting devices. Besides, the following should be paid attention to: the input and output of the filter should have radio frequency insulation or shielding, install one filter or one of the multiple filter in each power supply wire, and must confirm the good ground connection to the shell and the filter box.

2.3 Improve circuit design, select reinforced parts to use

Improve circuit design and use protection circuits to avoid NEMP interference, for example, using digital logic circuits with high voltage and switch matrix instead of those switching circuits which depend on the signal fluctuation rate. Using shielding cable or optical cable instead of ordinary cable, the integrated circuit produced using sapphire (SOS) technology, the computer memory system uses magnetic drums or disks that are not easily reversed.

2.4 Ground connection

Good ground connection is useful to reduce the system's vulnerability to the NEMP, the "ground" always is viewed as a part of the circuit, it has relatively low resistance for local ground where it connected. From the viewpoint of anti NEMP, the better method is to provide a series of circuits with a single ground connection point that has the lowest resistance.

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2.5 Protection against the Internal Electromagnetic Pulse (IEMP)

The electromagnetic shielding is only effective for the EMP transmitting in the atmosphere and has no effect for IEMP, because IEMP is generated inside the guidance head.

The protection devices against IEMP include: 1) employing the low atomic number materials (such as plastic foam and other hydrocarbons) as isolating layer or filling. 2) the arrangment of devices and units should be reasonable, the wire should as short as possible; if long wire is required, then twisted wire should be employed, 3) select ground connection point, for one unit, there should not be multiple ground connection points. 4) employ multiple layer shielding; use anti-radiation cable, 5) reduce the free space volume inside the guidance head.

Conclusion

Anti NEMP reinforcement is systematic engineering, each link should be considered according to the design requirement. The carelessness of one link may cause critical results, even cause the malfunction of the whole protection system.

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