Ministry of Defence
Defence R&D Organisation

STEC PAMPHLET - 16

HAZARDS FROM ELECTROMAGNETIC RADIATION TO AMMUNITION CONTAINING ELECTRO-EXPLOSIVE DEVICES

2025

Issued by

Storage & Transport of Explosives Committee
Centre for Fire, Explosive & Environment Safety (CFEES)
Brig. S. K. Mazumdar Marg, Delhi – 110054

CONTENTS

PREFACE

The principles contained in these guidelines are the minimum recommended to prevent hazards to electro-explosive devices (EED) resulting from exposure to the electromagnetic (EM) environment at frequencies upto 40 GHz. These principles apply to EED in logistic movement, during assembly, disassembly, testing, inspection and repair when in workshops and in storage.

It is hoped that users will find this revised STEC Pamphlet 2025 simpler, easier to understand and implement, thereby promoting the safe storage and transportation of military explosive. This publication supersedes STEC Pamphlet, 2017 on the subject.

HAZARDS FROM ELECTROMAGNETIC RADIATION TO AMMUNITON CONTAINING ELECTRO-EXPLOSIVE DEVICES

Introduction

1. Electro-explosive devices (EED) are used to produce an explosive response by conversion of chemical energy into heat following their electrical initiation.

2. When the rate of advance of the exothermic reaction exceeds the velocity of sound in the explosive products, the output is said to be detonative and EED giving this type of output are referred to as detonators. When the rate of burning is less than the velocity of sound in the products, the explosive filling deflagrates and EED giving this type of output are referred to as igniters. A variety of other names such as caps, fuze heads and squibs, are also commonly used.

3. EEDs are designed to be initiated by the application of suitable electrical stimuli but unintentional initiation may occur if the EED or its associated circuitry is exposed to electromagnetic radiation. Unintentional initiation can also occur if any electrically charged body is allowed to discharge through the EED.

4. Electro-explosive devices (EED) are rugged, reliable, can be designed to have low power requirements and rapid response, and are able to initiate pyrotechnic devices and explosives; they have therefore found widespread use in military systems. Examples of their use are to:
   - (a) Detonate warheads and demolition charges.
   - (b) Ignite rocket motors.
   - (c) Ignite propellants for tube-launched projectiles.
   - (d) Ignite gas generators for :
     - (i) Removal of protective panels.
     - (ii) Inflation of flotation bags.
     - (iii) Functioning protractors.
     - (iv) Discharge of battery electrolyte.
   - (v) Removing detents.
   - (e) Initiate thermal batteries.
   - (f) Initiate cutting action
   - (g) Initiate flares and pyrotechnics
   - (h) Initiate explosive bolts.

5. A basic disadvantage of EED is that they function as a direct result of heating some part of the initiating material by an input of electrical energy which can, within wide limits, be of any frequency. Hence, in addition to the need to prevent inadvertent initiation by the intended

source of firing power or associated test equipment, it is necessary to provide protection against conducted and radiated Electromagnetic Interference (EMI) which may be induced by the electromagnetic (EM) environment. EMI could initiate an EED directly or indirectly by causing the firing circuit switches to operate prematurely.

6. The principles contained in these guidelines are the minimum recommended to prevent hazards to electro-explosive devices (EED) resulting from exposure to the electromagnetic (EM) environment at frequencies upto 40 GHz. These principles apply to EED in logistic movement, during assembly, disassembly, testing, inspection and repair when in workshops and in storage.

Type of Electro-Explosive Devices

7. The EED in current and envisaged service use can be divided into 2 groups, high voltage and low voltage types. The main features influencing their electrical performance are energy, power sensitivity and speed of response. High Voltage (HV) and certain Low Voltage (LV) Bridge-wire (BW) devices are characterized by their energy insensitivity whereas some Film Bridge (FB) and all Conducting Composition (CC) devices have been shown to be particularly energy sensitive.

Low Voltage EED

8. (a) Bridge-Wire and Film Bridge EED

(i) A device where the power dissipated by the passage of current through a resistive wire is used to raise the temperature of the primary explosive which has intimate contact with the bridge wire.

(ii) The bridge wire device is basically a short length of wire surrounded by ignitable material which fires when a suitable current is passed along the wire. The resistance of the bridge wire device is usually within the range of 0.1 to 20 ohms.

(iii) A typical device would have the firing threshold of about 300 milli-amps, or require an applied power of 80 milli-watts. The thermal time constant is of the order of 20 milliseconds; consequently, bridge wire devices are generally insensitive to the peak power of the radar pulses but do respond to the average power.

(iv) Bridge-wire devices tend to become less sensitive to EM energy as the frequency increases.

(v) A foil or FB in contact with a substrate having high thermal conductivity can be used to increase the required firing power. When rapid functioning is required from a low energy source, vacuum deposited FB of very small dimensions and low thermal mass can provide increased sensitivity to input energy.

(b) Conducting Composition (CC) EED

(i) A device where the primary explosive is intimately mixed with a small quantity of conducting materials (examples are graphite and powdered metals). On placing the mixture in a suitable container, electrically conducting chains are formed. The chains provide parallel paths between two electrically isolated electrodes.

(ii) The conducting composition EED is made up of two electrodes which are connected electrically by parallel chains of conducting particles. The conducting composition is formed by mixing a small quantity of conducting material with a sensitive initiating explosive. The chains are formed when the mix is pressed into the body of the device. The number of chains formed, and in consequence the overall resistance of the device, is determined by the load applied for a given electrode geometry and preparation of the conductive mix.

(iii) Each chain consists of a number of contacting conductor particles having a mean diameter of about 9 microns. The application of a voltage across the electrode produces spot heating that brings the conductive composition to its initiation temperature. If the applied voltage is sufficiently high the conductive mix at one or several contacts will be sputtered into the explosive.

(iv) The low thermal mass of the conductor contacts and the rapid energy transfer mechanism give rise to an extremely efficient and sensitive EED.

(v) Typically CC EED are 2 – 3 orders of magnitude more sensitive than the bridge-wire EED Functioning is also much more rapid, i.e. in microseconds as compared to milliseconds for bridge-wire EED. The energy requirements are small and can be as low as 1 microjoule. Because the reaction is fast the CC EED can be initiated by the peak power of a radar pulse as well as by the average power.

(vi) The resistance of the CC EED varies with the type and homogeneity of the mixture of explosive and conducting material. The resistance is usually in the order of hundreds of ohms or greater and the firing voltage may be as high as 50 volts.

(vii) As for the bridge-wire device, the sensitivity of the CC EED to EM energy decreases with increasing frequency.

(c) Carbon Bridge EED

(i) A carbon dot is deposited between the electrical posts of the EED to form a bridge. The resistance of this bridge varies from 1,000 ohms to 10,000 ohms. The explosive mixture in the EED is in close proximity to the carbon bridge.

(ii) The firing characteristics of the carbon bridge EED are similar to those described for the CC EED.

High Voltage EED

9. (a) Exploding Bridge wire (EBW) EED

(i) A device containing a bridge-wire through which sufficient electrical energy is dissipated in a very short time to cause the metal wire to explode. The associated very high, nearly instantaneous temperature rise and the shockwave in the vicinity of the wire are sufficient to initiate a secondary explosive.

(ii) The physical appearance of an exploding bridge-wire EED is similar to that of the conventional bridge-wire EED. The major difference is the absence of the sensitive primary explosive on the bridge-wire.

(iii) The explosive bridge-wire EED requires a large quantity of electrical energy to be dissipated in a very short period of time before initiation can occur. The energy level typically required is 1 joule in a period of less than 30 microseconds.

(iv) The high instantaneous power results in the explosion of the bridge-wire which is able to initiate a relatively insensitive secondary explosive.

(v) It is unlikely that sufficient power to initiate the EBW could be induced in the device by exposure to EM radiation. However, as a very fine bridge-wire is used, sufficient EM energy may be induced to raise the temperature of the explosive in contact with the wire to a point where it’s physical conditions are modified. It is also possible to burn out the bridge-wire with power insufficient to initiate the device. This phenomenon is known as duding and is undesirable from a reliability standpoint.

(b) Slapper Detonator

(i) Slapper detonators operate by applying a high energy impulse to a foil or film bridge causing it to explode. This punches a flyer from a plastic disc and propels it along a barrel section to impact a secondary explosive charge thereby causing detonation.

(ii) Slapper detonators are similar to EBW in term of their sensitivity and functioning times but are less prone to duding by low level currents than EBW since the bridge is separated from the explosive charge. Hence duding would require sufficient energy to melt the bridge without exploding it. These devices provide an alternative to EBW particularly in high temperature and high shock applications.

Principles of Design

10. The principles of design related to the protection of EED from inadvertent initiation are as follows:-

(a) Firing circuits of EED in on-nuclear munitions should be so designed that when the operation of an EED is unacceptable, no single fault or failure of any nature can result in initiation of an EED.

(b) EED used should be the least sensitive that will meet the system requirements and should have authorized no-fire threshold (NFT) characteristics for both normal and abnormal firing modes as appropriate.

(c) Firing circuit switches and safety breaks should not be susceptible to common-cause failures and irrespective of the operating stimulus required, should not be capable of functioning, at any stage in the service life, except when subjected to the design stimulus. They should be capable of being returned to the safe position, if required following intentional operation.

(d) The inadvertent generation of stimuli required to operate safety breaks and firing switches should not be possible in the specified service environment. Currents intended for firing EED should be DC or AC below a frequency of 10 KHz.

(e) When an EED, in isolation or incorporated in a firing circuit, is exposed to the specified EM environment, it should not be possible to induce into it a level of EMI which would encroach upon a defined safe margin below the established NFT level of the EED.

(f) When an EED firing circuit, incorporating electronic switches, is exposed in the specified EM environment, it should not be possible to induce a level of EMI into the circuit which would encroach upon a defined safe margin below the established switching threshold of the electronic switches.

(g) Any software should comply-with the relevant principles set out above. In particular such software should be rigorously specified, designed and documented with full regard for the need for independent certification of its properties in all respects which are, or may be, safety critical.

(h) Test equipment should be so designed that:

(i) No single fault or failure of any nature can result in the initiation of an EED and connection to the system under test will not degrade the EMC of the system within the specified EM environment.

No-Fire Threshold Sensitivities

11. It is impractical to attempt to define uniquely the stimulus level at which none of a particular batch of EED will fire. The threshold sensitivity of the EED is usually derived from statistical measurements, an assumption being made that the probability distribution of sensitivity obeys a normal low, when the logarithm of the applied stimulus is taken as the independent variable. The NFT is defined in terms of the level at which 0.1% of the devices will fire. Due allowance is made for sampling errors by using the single-side lower 95% confidence limit for the 0.1% probability of fire.

No-Fire Threshold Power

12. The threshold power of an EED is defined as the power required to produce a 0.1% probability of fire at the 95% single-sided lower confidence limit when applied to the EED for a time which is long compared with the time constant of the device, i.e.> 10 Tc.

Non-Fire Threshold Energy

13. The threshold energy is defined as the energy which would produce at 0.1% probability of fire at the 95% single-sided lower confidence limit if applied to the EED for a time which is short compared with the time constant of the device, i.e. < 10 Tc.

Inadvertent Application of Power

14. EEDs are intended to function when electrical power is applied to them and therefore they must be protected. Inadvertent application of power may arise as a consequence of:

(a) Failure of safety breaks and firing switch, including semi-conductor power switches and electromechanical switches controlled by electronics, or of the associated wiring, or inadvertent operation of switches by an operator, or malfunction of a sensor which allows premature application of the intended source of firing power.

(b) Failure in the electrical wiring, particularly in connectors, which allow an EED to be connected to some other source of power used in a weapon system.

(c) The use of test equipment which is not safe under single-fault conditions, or which can degrade the integrity of safety breaks and firing switches.

(d) The application of unintended power sources having connectors compatible with those used in a firing circuit and which might initiate an EED or degrade the integrity of safety breaks and firing switches.

(e) Errors in the implementation of electronic logic systems, particularly those that are software controlled. The increasing complexity of microelectronic technology has made it extremely difficult, if not impossible, to construct fault models and hence determine the consequences of single faults or failures.

Application of In-Line EED

15. An in-line EED is so called because it is permanently aligned with the explosive train which is intended to initiate. Consequently, if the EED should be inadvertently initiated, the device in which it is employed will function. The majority of EED applications come within this category.

16. The safety of a manually controlled firing system used for example to fire a gun, or the motor of shoulder-mounted anti-tank weapon, is dependent on the degree of isolation of the EED from the source of firing power, on the reliability of conventional, manual switches, of the toggle, push button or rotary type and on the prevention of inadvertent manual operation.

17. In other applications, such as the operation of gas generators or explosive bolts, the EED may be initiated automatically on receipt of signals from timers or sensors which respond to stimuli experienced during deployment of the munitions. Safety is again dependent upon isolating the EED from the source of firing power until initiation is wanted. The reliability of associated timers and sensors etc, and any potentially hazardous failure modes they may have, need carefully consideration.

18. In order to ensure the safe use of a warhead, the initiating EED is controlled by a fuzingsystem which incorporates safety and arming functions intended to ensure that the ammunition achieves a safe separation distance before its warhead can be armed. The only type of EED in current use which is sufficiently insensitive to be used in-line in a warhead application is Exploding Bridge-wire (EBW) EED. The safety of an EBW initiated warhead can be ensured by using the safety and arming functions of a fuzing system to prevent charging of the firing capacitor until required.

Applications of EDD in Out-of Line System

19. An out-of-line EED is called when, until armed, a mechanical shutter interrupts the explosive train and may also interrupt the EED firing circuit. Mechanically shuttered systems are normally employed in conjunction with low voltage EED. Because almost all applications of out-of-line EED are concerned with the initiation of warhead, only that application will be discussed here.

20. When the shutter is out-of-line i.e. in the safe position, the design is such that, should the EED be inadvertently initiated, the effect will be contained and will not result in detonation of the explosive filling. The EED is thus isolated explosively, and its inadvertent initiation is normally a reliability problem, not a safety problem. A carefully designed and installed shutter mechanism can ensure a satisfactory standard of safety during transport, storage and handling operations.

21. To ensure safety in operational use, the shutter is designed to respond only to specific environmental forces experienced by the munitions during deployment. Movement of the shutter to the in-line position is normally referred to as primary arming. A warhead however, is not fully armed until firing power is made available to the fuzing system.

22. The availability of firing power is controlled by safety switches and arming switches which are closed in a pre-determined sequence which prevents arming until required. Some safety switches are designed to function upon the application of a physical stimulus such as pressure or acceleration. Electro-mechanical and electronic switches will require an electrical stimulus that is a trigger signal. Trigger-signal generating circuits might be activated directly by sensors which monitor environmentally derived stimuli, or indirectly by such sensors providing an input to a microprocessor system under the control of software.

23. In a bomb or shell fuze application, the environmental forces which operate the shutter might also be used to activate the source of firing power. In such applications an electronic timer might be used to delay arming for a proximity or impact mode or to initiate the explosive filling. The timer effectively determines the safe separation distance and consequently it will require careful assessment of its reliability and degree of immunity to EMI. The timer must not be subjected to a failure mode which results in instant arming. Such a failure mode might hazard an aircraft releasing a bomb, or put to risk friendly troops over whom a shell may be fired.

Separation Distance from Radio Frequency (rf) Transmitters.

24. Hazards from the explosives:

(a) Ideally transmitters should be sited beyond the inhabited building distance of any explosives area in order to avoid damage in the event of an explosion. Where a smaller distance is operationally necessary, the magnitude of the hazard from air shock, ground shock and debris should be assessed.

(b) Where a transmitter is considered to be vital 1.5 times the inhabited building distance should be observed as a minimum safe distance. This greater distance provides a better degree of protection to the transmitter, particularly with respect to the air shock from explosives in hazard Division 1.1 and the debris from explosives in Hazard Divisions 1.1 and 1.2.

25. Hazards to the Explosives During Storage and Transport

(a) Storage

(i) Any firing circuit associated with an electro-explosive device (EED) has an intrinsic capability of picking up signals from an electromagnetic field in its vicinity. In view of the increased numbers and power levels of military and commercial transmitters (radio, TV, radar) and other microwave transmitters, collectively referred to as rf transmitters, it is important that due consideration be given to the possibility of inadvertent actuation of an EED and the consequential risk of a serious explosion.

(ii) All EED or Ammunition containing EED should be adequately shielded against stray electro-magnetic fields at all times by proper design and/or packaging. EED or ammunition containing EED are considered to be fully shielded if they are totally enclosed in metal containers or fitted with either soldered-on lids or a lid which is a tight fit on the container or fitted with a rf gasket. Metal skins ammunition into which EED is fitted are considered to be fully shielded provided proper metal protective covers are fitted over EED. In the same manner EED or ammunition containing EED, are considered to be fully screened when they are completely enclosed in metal foil arranged so as to make good electrical contact all round. The foil must be protected against damage during storage and handling.

(iii) During explosives workshop operations the precautions should be more stringent than during storage or transportation. In workshop operations ammunition is dis-assembled thereby exposing EED and their wiring. Additionally, test equipment with test leads which may be connected to the ammunition, or touching the ammunition with the finger, may provide paths for induced rf currents into the ammunition. The operating procedures should specify the necessary precautions and the maximum rf energy permitted for each item of ammunition. In any event the site should be assessed for potential hazard from transmitters as described in Para 38.

(b) Transportation

(i) It is not practical to achieve safety for EED during transportation by observing safe distances from EM sources. All ammunition offered for transport must therefore be safe in the EM environment likely to be encountered, see Table I, or protected as mentioned in sub paragraph 25(a)(ii).

(ii) It should be noted that power densities in excess of those in Table I can be produced by a limited number of high powered transmitters and that additional precautions, such as special surface routes, additional shielding, transmitter shut down procedure etc. may need to be observed when EED are required to be transported in close proximity to the aerial systems of such transmitters.

Handling, Testing and Assembly Facilities

26. The following recommendations are intended to minimize the risk of an electro-static discharge to EED and firing circuits within systems and sub-assemblies, during handling, testing and assembly in explosive buildings.

(a) Floors of Testing and Assembly Areas

Conductive grade materials should be used in the construction of floors where systems containing EED with less than 1 mJ NFT energy level are assembled and tested. Where EED with NFT energy levels greater than 1 mJ are assembled and tested, anti-static grade flooring may be used. Conductive and antistatic flooring should be suitably laid electrically bonded and connected to earth.

(b) Personnel Precautions

(i) All personnel working with systems containing EED should equalize their body potential with that of the system before commencing each operation, by placing their hands firmly upon the exposed metal-work of ammunition.

(ii) Inside explosives buildings, conducting footwear should be worn at all times in testing and assembly areas.

(iii) It is recommended that a personnel test meter should be used to check the resistance to earth of all personnel upon entering explosives buildings.

(c) Personnel and Equipment Earthing Facilities in Explosive Buildings:
A metal plate or mesh, electrically bonded to earth with a resistance not exceeding 10 ohm should be provided at the entrance to each assembly and test area. The plate or mesh should be sited so that personnel and trolleys conveying assemblies and sub-assemblies containing EED must, (when entering the area), make contact with the plate or mesh. Similar earthed metal plates or mesh should be provided at each working position in the area where work is carried out on EED or systems containing EED. A metal earthing bar or handrail, electrically bonded to earth should be provided along one unobstructed wall which leads to the door of each area.

(d) Fixed Equipment:-
Metal storage racks should be bonded to earth in such a manner that the resistance does not exceed 10 ohm. Provision should be made for bonding systems to storage racks. Cradles and benches upon which munitions are places should be constructed of metal with non-ferrous faces to minimize the generation of incendive sparks. The total resistance from the system, through the cradle or bench, to earth, should not exceed 10 ohm.

Protection Against Lightning Strike

27. The probability of the EED being initiated prematurely by a lightning strike is low provided that the system electrical installation is enclosed within a continuous metallic shield. The shield should have a maximum D.C. continuity resistance of 0.05 ohm between any two points. Complete protections can only be guaranteed by the erection of lightning conductors.

Conditions for Maximum Pick-up in an EED

General

28. (a) Relatively little power is required to fire most EEDs which are normally operated by a direct or alternating current firing pulse. Whether fitted to ammunition, connected to firing leads or held as separate components, EED will respond and may fire when subjected to EM energy propagated from antenna of radio and radar transmitters.

(b) Energy from the EM environment can enter an ammunition item through any discontinuity in its skin, e.g. joints, inspection windows, etc. The energy may be conducted into the EED via its firing leads or other electrical conductors such as wires, tools and fingers.

(c) The protective switch in a circuit which prevents the initiation of an EED by direct current until the desired time is not an effective barrier to EM energy.

(d) In general, ammunition containing EED are more susceptible to EM energy pick-up during assembly, disassembling, testing, handling, loading and unloading into weapons. The attachment of external cables and test sets to such ammunition usually increases its susceptibility to EM energy pick-up.

(e) The ability of a firing circuit to pick up sufficient energy to cause an EED to operate depends on many factors. These include the electrical characteristics of the EED installed, the nature of the firing line, its length and geometry, ambient EM field strength and frequency. The EM field strength is dependent on the power output of the transmitter, the characteristics of the system and the distance between the antenna and the firing circuit. It is not the position of the whole firing circuit in relation to the EM field.

Maximum Energy Pick-Up

29. The maximum energy pick-up in an EED is dependent on :

(a) the physical and electrical parameters of the firing circuit;

(b) the frequency of the transmitter;

(c) The power density of the EM field in the vicinity of the receiving antenna, i.e. the firing circuit.

Type of Antennas

30. (a) To evaluate the maximum gain, the EED firing circuit can be considered to be One of several types of antenna, namely

(i) Dipole

(ii) Loop

(iii) Long Wire

(iv) Rhombic

(b) Depending on the actual firing circuit design one or more of the above configurations can be considered a reasonable approximation as the receiving antenna. For example, placing a short circuit across the firing lines would make it equivalent in performance to either a loop or rhombic antenna.

(c) In practice, for weapon systems less than 5 m in length, the dipole antenna is a good approximation. Long wire and rhombic antenna configurations can be applicable, but not generally while the weapon is in the transport and storage mode. For missiles in excess of 5m in length and when missiles are attached to test facilities with long leads, long wire or rhombic configurations may have to be considered.

Conditions for Maximum Pick-Up

31. (a) Assuming that the receiving antenna (EED circuitry) approximates a dipole, Maximum pick-up will be attained under the following conditions:-

(i) The lead wires to the EED opened out straight, their combined length equal to half the transmitted EM wave length or an odd multiple there-off and the EED at the centre of the leads

or

(ii) One lead wire (or case) of the EED grounded and the other lead wire straight and its length equal to one-quarter of the transmitted EM wave length or an odd multiple thereof.

(iii) The lead wires parallel to the electrical field vector.

(iv) The antenna configuration and the EED in the zone of maximum radiation.

(b) It should be noted that any electrically conductive component forming the structure of a system may present a half wave antenna or a loop or a rhombic antenna and the resultant circulating currents can induce EM energy into EED circuits in the vicinity of such structures. In practice it can be considered worst case when a long wire or rhombic antenna is formed. In those cases, the amount of EM pick-up could increase approximately 10 dB relative to the pick-up in a dipole antenna.

Effect of a Metal Container

32. (a) An EED assembly incorporating a firing connector which is mounted through a metal container, such as a cartridge case, is less sensitive to EM energy when it is not connected to the firing lines due to the inefficient antenna the assembly presents. During handling, however, if contact is made between the connector and an external body such as the system structure, a length of wire, screwdriver or the finger of an operator then a more efficient antenna may be formed.

(b) A receiving antenna is most effective when situated in free space and unobscured from the source of radiation. In general, the presence of obstructions in the vicinity of the receiving antenna (EED circuitry) will reduce the power picked up by the antenna. However, under certain conditions the EM field reflected from such obstructions could increase the incident field at the receiving antenna. In ammunition where the EED and firing lines are mounted within the metal skin or situated within a metal container, then the EM pick-up may be reduced by a factor up to 20 dB relative to that from a matched antenna in free space.

Impedance of the Antenna

33. (a) Although it is unlikely that the impedance of the antenna configuration formed will match that of the EED, the possibility remains that this may occur at some frequency throughout the spectrum.

(b) Firing lines disconnected from the firing supply and short circuited will form a loop antenna and as such are more likely to pick up EM energy at lower frequencies. In addition, the impedance of a loop antenna is more likely to match the impedance of a bridge-wire EED than that of a half wave dipole; consequently more RF power will be fed to the EED.

Rhombic or Long Wire Configurations

34. The EM energy pick-up with rhombic or long wire configurations can in practice be up to 10 dB greater than that picked up by a dipole configuration. If the firing lines to an EED are open-circuited as close to the EED as possible, the susceptibility of the EED to EM fields will be reduced, where the wavelengths are large compared to the EED lead dimensions. For example, if the EED lead(s) are less than 100 mm in length, EED susceptibility will be reduced significantly at frequencies less than 750 MHz. Placing broadband RF filter(s) in the firing line(s) as close to the EED as possible will also reduce the susceptibility of the system.

35. The above configurations should be used for EED on launchers and attached to test facilities and for very long missiles for weapon system the length of which are less than 5 m, a matched half wave dipole is a good approximation of the worst case configuration.

NATURE OF THE RADIATED FIELD AND TRANSMITTER ANTENNA
Nature of the radiated field

36. (a)In the far-field the electromagnetic field radiating from a transmitting antenna consist of an electric (E) and a magnetic (H) component, which are in phase and mutually perpendicular to each other and to the direction of propagation. The strength of the field is measured in volts per m for the electric components and in amps per m for the magnetic component. The power density (S) is the power present in a unit area perpendicular to the direction of propagation and is an expression of the strength of the radiated far-field. It is measured in watts per m^2 and is related to the electric and magnetic components by :

$$S = E^2/377 = 377\ H^2 \qquad (1)$$

Where 377 ohms is the impendence of free space.

(b) Within the near-field or Fresnel Region, the magnitudes of the H and E components vary and one or the other can exceed the values they assume at the perimeter. Starting at the perimeter of the Fresnel Region the power density falls off inversely with the square of the distance.

Transmitter Antenna

37. (a) Unipole and dipole antennas are commonly used for communications in the frequency Range below 300 MHz. The radiation from this type of antenna falls into two basic regions:-

(i) The near-field region which extends out to a distance of 2-3 wavelengths from the antenna; in this region the E and H components of the radiated field have not established their correct phase relationship.

(ii) The far-field region extends beyond the near-field and as for directional antenna, the power density is given by

$$S=\frac{GP}{4\Pi d^2} \qquad (2)$$

Where G = Power ratio gain of the transmitter antenna.

P = the mean power in watts fed to the transmitting antenna (peak power x pulses per second x pulse width).

d = the distance in m from the antenna to where the field is under consideration.

(b) The radiation pattern from a highly directional radar antenna falls into two main regions as follows:

(i) A Fresnel Region which extends from the aperture of the antenna to a distance in front of the antenna dependent on the physical area of the dish.

(ii) The Fraunhofer Region or far-field. This extends beyond the Fresnel Region.

(iii) The end of the Fresnel Region and the start of the Fraunhofer Region is not well defined but is arbitrarily taken to be at a distance of 2L , where L is the largest dimension of the antenna. With the Fresnel Region the maximum power density is given by

$$S=\frac{16\Pi P}{G^2} \qquad (3)$$

this is the worst case; if an unacceptable hazard is indicated then a more detailed calculation should be carried out by the competent national authority. Beyond the Fresnel Region in the far-field or Fraunhofer Region, the maximum mean power density is given by

$$S = \frac{GP}{4\Pi d^2} \qquad (4)$$

Determination of Safe Distances

38. (a) The conditions for maximum, pick-up in an EED circuit are described in Para 28 to 35above. these conditions, in conjunction with the no-fire threshold power energy levels of the most sensitive EED in use as listed in Table II are to be used to determine the maximum RF power density in which exposed EED may be safely handled and tested in workshops in the frequency band 200 kHz to 40 GHz.

(b) The maximum power densities in which exposed EED in use may be safely handled and tested in the vicinity of continuous wave or pulsed transmission sources pulsed at more than 666 pulses per second (pps) are shown in Figure 1. The safe power densities shown are based on the US MK 114 Primer in the frequency band 200 kHz to 26 MHz and on the UK Foreheads Type F120 in the frequency band 26 MHZ to 40 GHz.

(c) Maximum safe power densities (S) for any EED in the vicinity of pulsed transmitter sources pulsed at less than 666 pps and transmitting in the frequency band 26 MHz to 40 GHz are not shown in Figure-I. Safe power densities for such transmitters are to be based on the FRG EL 37 cap and should be calculated as shown below :

$$S = \frac{3\times10^{-6}\, pps(Max-666)}{0.13\lambda^2} \qquad (5)$$

Subject to a minimum of 0.0001 Wm^{-2}

(d) The safe distances to be observed between all RF sources and workshops in which exposed EED are required to be handled or tested are to be calculated using the poser density as shown in Figure I as derived from subparagraph 38.c and the standard for field or Fraunhofer region formula as given in equation (4), namely:

$$\text{Safe distance 'd'} = (GP/4\pi S)^{1/2} \qquad (6)$$

(e) The electrical characteristics of the US MK 114 Primer, UK Fuzehead Type F 120 and the FRG EL 37 cap together with the safety factors used to calculate maximum safe power densities are shown in Table II.

Conclusions

39. (a) If ammunition is certified as being safe in the EM environment at Table I or is Protected as mentioned in subparagraph 25 (ii) then no further protection from EM radiation is necessary.

(b) Ammunition which has not been certified as being safe in the EM environment detailed at Table I or which has not been protected as mentioned in subparagraph 25 (ii) should only be stored in buildings separated from transmitting antenna in accordance with paragraph 38.

ANNEXURE

TERMINOLOGY

1. The following definitions are used for ammunition containing electro-explosive devices in electromagnetic environment.

(a) Arm and disarm (A/D): Arm and disarm (A/D) is defined as a mechanical or electromechanical device that provides a positive interruption of the firing circuit to prevent initiation of an explosive or pyrotechnic train prior to its commanded closure.

(b) Bridge wire: Bridge wire is defined as a resistance element within the electro-explosive initiator which is the final electrical element at the electrical/explosive (or pyrotechnic) interface.

(c) Dudding: Dudding means the process of permanently degrading an electro-explosive initiator to a state where it cannot perform its designed function.

(d) Electro-explosive device: Electro-explosive device is defined as any electrically initiated explosive device within an electro-explosive subsystem having an explosive or pyrotechnic output, and actuated by an electro-explosive initiator.

(e) Electro-explosive initiator: The electro-explosive initiator is the first device in a pyrotechnic or explosive train which is designed to transform an electrical, mechanical, or heat input into an explosive or pyrotechnic reaction. Detonators, electrical match, and squibs are examples of initiators.

(f) Electro-explosive subsystem: The term electro-explosive subsystem is intended to include all components required to perform control, monitor, and initiate electrically initiated ordnance/pyrotechnic function.

(g) Electromagnetic environment: Electromagnetic environment is defined as the totality of all electromagnetic energy (radiated and conducted) to which the electro-explosive subsystem will be subjected during its life cycle.

(h) Electromagnetic interference (EMI): Any electric, magnetic or electromagnetic disturbance, phenomenon or emission which causes or is likely to cause undesired response, malfunction, or unacceptable degradation of performance of anyequipment, subsystem or system or unacceptable degradations of the electromagnetic environment

(i) Electromagnetic susceptibility threshold: Electromagnetic susceptibility threshold is defined as the magnitude of the smallest electric field expressed in volts/meter or amperes/meter capable of producing a current 20 dB below the maximum DC or RF no-fire current.

(j) Exploding bridge-wire initiator: An exploding bridge-wire initiator is defined as a type of electro-explosive initiator in which the bridge-wire is designed to be exploded (disintegrated) by a high-energy electrical discharge, thus requiring no primary explosives.

(k) Maximum no-fire current: Maximum no-fire current is defined as the maximum DC or RF current level at which an electro-explosive initiator will not fire or degrade with a reliability of 0.995 at a confidence level of 95 percent.

(l) Minimum all-fire current: Minimum all-fire current is defined as the least DC or RF current level which causes initiation with a reliability of0.995 at a confidence level of 95 percent.

(m) Safe and arm (S&A) device: A safe and arm (S&A) device means a device which provided electrical interruption of the firing circuits and mechanical interruption between the initiator and the subsequent explosive or pyrotechnic train.

(n) Filter: A device or component intended to protect a sensitive load from conducted EMI.

(o) Intrinsic safety: The contact to which a circuit design is proof against unsafe failure as a result of a single internal fault.

(p) Radio-frequency gasket: Compressible and electrically conducting material used to seal a joint against the ingress of radio-frequency electro-magnetic energy.

(q) Shielding: The means of reducing the amount of radiation reaching one region from another.

(r) Shutter: A safety device in an explosive train for isolating the initiation explosive

TABLE-1

TRANSPORTATION EM ENVIRONMENT

Frequency	Mean Field Intensities VM-1	Wm-2
Communication Transmission		
200 kHz – 525 kHz	300	-
525 kHz – 32 MHz	200	-
32 MHz – 790 MHz	-	10
Radar and CW Transmission		
150 MHz – 225 MHz	-	100
225 MHz – 790 MHz	-	50
790 MHz – 18 GHz	-	1000
18 GHz – 40 GHz	-	100

Note: A pulse recurrence frequency of 200 pps should be used to define the energy density.

TABLE II
Electrical Characteristics of US MK 114 Primer,
UK Fuzehead Type F 120 and the FRG EL 37 Cap
Together with safety factors

EED Type	Resistance Range Ohm	No fire threshold value Energy mJ	Current A	Power mW	Safety factor to be applied dB
US MK 114 Primer	3-7	.19	.05	7.5	-4
UK F120	10-16	0.20	0.045	20	-10
FRG EL 37	0.8-1.7	0.030	0.15	20	-10

Note : In explanation of the different safety factors applied, the safe power density in the frequency band 200 kHz to 26 MHz is based on trials carried out by the US Navy, whereas in the frequency band 26 MHz to 40 GHz the safe power density is based on dipole calculations

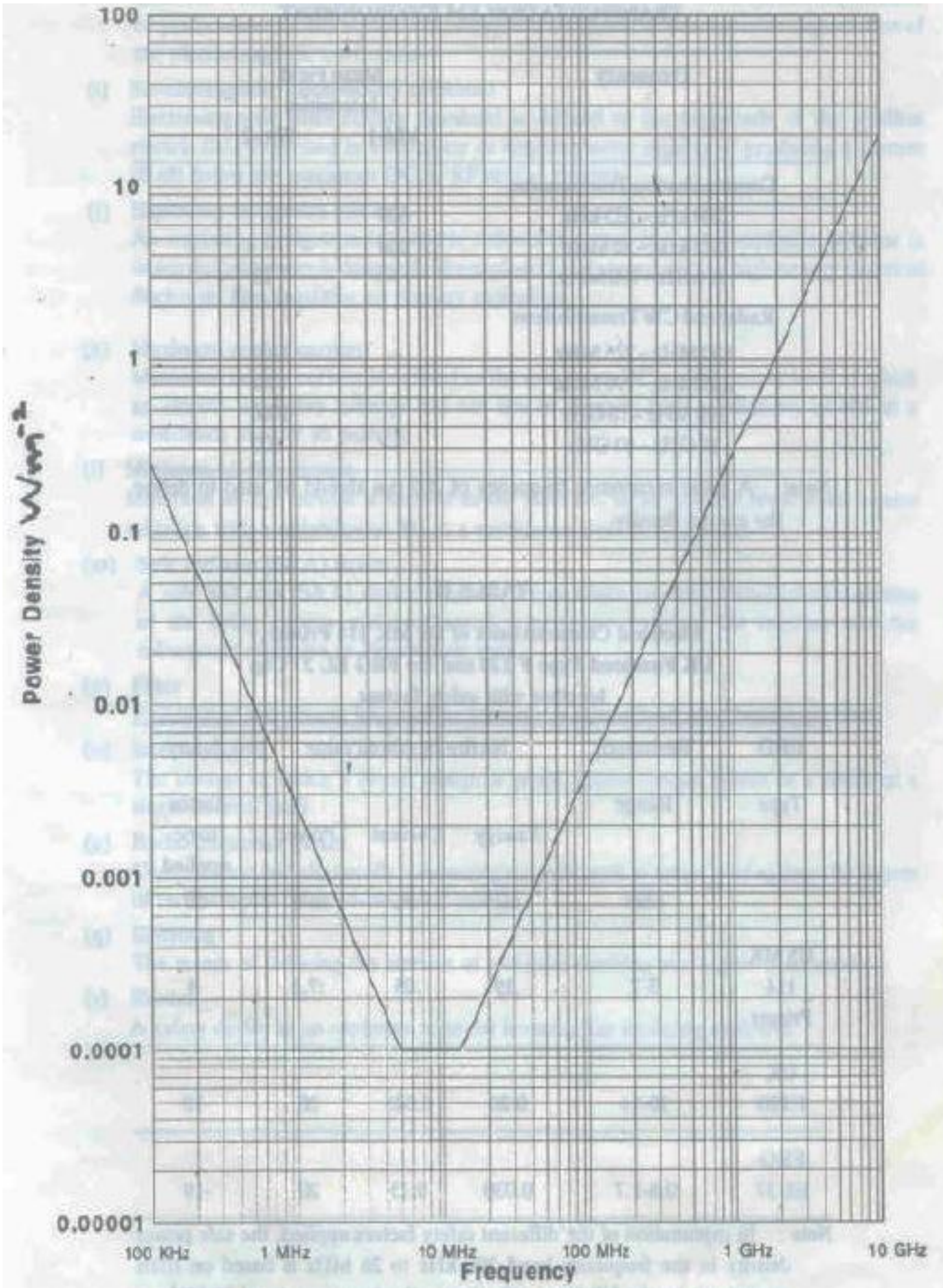

Figure-I Safe Power Densities Exposed EED CW and Pulsed Transmissions above 666 pps