HAZARD FROM ELECTROMAGNETIC RADIATION TO AMMUNITION CONTAINING ELECTRO-EXPLOSIVE DEVICES

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Abstract
Over recent years there has been a significant increase in the use of communications equipment throughout the military and civil environment including all forms of transportation in support of management functions, control of resources and area security. These equipments produce electromagnetic radiation of varying intensity according to their output and antenna gain and are potentially hazardous when used in close proximity to explosive devices which have an installed electrical means of initiation known as electro-explosive devices (EED).
The advice contained in this chapter represents the minimum precautions to be observed in order to prevent hazard to EED resulting from exposure to the radio frequency (RF) environment at frequencies up to 40 GHz. It is intended that this chapter should provide guidance of officials concerned with the storage, movement and processing of EED or stores containing EED and the control of RF equipment which may be used within, or enter, those establishments/vehicles used for these purposes.

Keywords: electro-explosive devices, CF Environment, Assessed cut of Hazard, System Susceptibility, Safe Distance, Management Radios.

1 Introduction

Any firing circuit associated with an EED, or other electrical conductors such as wires, tools and fingers in contact with the EED, when placed in a RF field will act as an antenna with the inherent capability of picking up some electrical energy from the field.
When the leading wires of an EED are separated they could form a dipole antenna and provide an optimum match between the dipole and the EED leading to maximum transfer of power to the EED from the radiated source. Unseparated (short circuited) leading wires could form circular antennas which may also constitute good receiving systems.

Unless appropriate precautions are taken, the power/energy levels induced into the firing circuits from the standing RF fields may be sufficient to inadvertently initiate the EED.
Design criteria for the modern EED when installed in weapon systems require electromagnetic (EM) screening and specified orientation of firing leads to reduce the RADHAZ. For this reason, EED separated from their parent system are regarded as less safe than when installed into the system with all leads connected as intended by the designer.

The attachment of external cables and test sets to systems containing EED will usually increase their susceptibility to EM energy pick-up.
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 electromagnetic (EM) energy.

2 Electro-Explosive Devices

An EED is a one shot explosive or pyrotechnic device used as the initiating element in an explosive or mechanical train and which is designed to activate by application of electrical energy. In present use four techniques of electrical initiation are employed:

- Bridge-wire (BW) and Film bridge (FB) EED.
- Conducting Composition (CC) EED.
- Exploding Bridge-wire (EBW) EED.
- Slapper Detonator.

In general EED in Service use fall into two broad categories:
Those with long thermal time constants (typically 10 ms - 50 ms) such as BW which are known commonly as "slow responding power sensitive" EED.

Those with a short thermal time constant (typically 1 μs - 100 μs) such as FB and CC which are known commonly as "fast responding energy sensitive" EED. These techniques are described in greater detail at Part II, Chapter 7 of AASTP 1.

In determining hazard thresholds (known as No-Fire Thresholds (NFT)) both types of reactions are considered in relation to statistical sampling based on 0.1% probability of firing at a single sided lower 95% confidence level.

3 RF Environment

Radio and radar transmitters operate over a wide spectrum as shown in Figure 6-1. The minimum level CW of RF intensity in which all systems incorporating EED should be designed and proved to remain safe is given in Table 6-1. Where these levels are not met restrictions will be imposed or the equipmen must be protected by other means.

The system should be designed and proved to remain safe and serviceable when subjected to self generated RF fields and those which might be generated by a weapon platform (eg, ship, aircraft or vehicle) and platforms likely to be in close proximity and which may exceed the field intensity given in Table 6-1.

4 Storage and Transport

EED are encountered in a variety of configurations between their manufacturing stage and their ultimate disposal. These configurations range from trade packaging in bulk, military packaging and subpackages, and installed in munitions, to various stages of separate and exposed states which occur in processing and training.

It is important for users to understand how these configurations can influence the basic precautions to be adopted in storage and transportation. Precautions in transport should include measures to be covered in emergencies from straight forward vehicle breakdown to accidents involving fire and/or casualty evacuation.

Process and Storage Building

Building materials are generally ineffective in affording EM protection to EED. Structures provide no protection at all in transmission loss from frequencies below 1 MHz but may provide some protection in the form of reflection loss if the polarization and angle of incidence of the EM energy happens to be favourable, although this is rarely the case. Also, bars in reinforced concrete do not provide any significant degree of protection.

For all practical purposes, it should be assumed that the field strength which exists inside a building is as high as it would be if the building did not exist. However, if the protection level across the frequency spectrum for a specific building has been determined (screened room) then this level may be used to determine a safe distance from sources of electromagnetic radiation although it should be borne in mind that, if doors or windows are opened, the screening integrity may be adversely affected.

EED and systems containing EED should be stored/processed in authorized depot and unit process and storage areas. These areas should be sited taking into account the following:

- The susceptibility of the EED, store or weapon system during processing or storage as appropriate.
- The radiated power of transmitters in the area related to the susceptibility radius of the most sensitive EED present.

Transport

It is not practical to ensure the safety of an EED during transport through the observance of safe distances. For this reason all EED and systems containing EED offered for transportation must be safe in the power density likely to be encountered, see Table 6-1.

Systems containing EED and which have not been cleared to the EM environment in Table 6- must be protected during transport by carriage in a closed metal box or by screening materials which afford adequate attenuation to the external RF environment. Primers fitted to rounds or cartridges are, for example, to be protected by felt pads or cartridge clips.

When it is considered necessary to transport systems containing EED whose susceptibility is unknown, advice is to be obtained from the National Authority.

All personnel engaged in the carriage of such articles should be made aware of the hazard that may be caused by RF and observe fully the consignor´s instructions. Note should be made of any special instructions required during loading/unloading and during handling when EED are most vulnerable to EM radiation.

Emergency Transport Procedures

In the event of an incident/accident during the transport of munitions, items which do not normally present a high RADHAZ risk may become susceptible if there is damage to their inherent protection, ie structural or packaging. Pending a detailed inspection, the undermentioned restrictions on RF transmissions in the immediate vicinity should be imposed:

No radio to be allowed within 2 metres.

No radio to be allowed within 10 metres unless authorised as being intrinsically safe.

No radio with an ERP greater than 5 watts to be allowed within 50 m.

***Table 1** The Minimum Service Radio Frequency Environment*

Serial	Frequency	Field Strength/ Power Density	
		(V/M rms)	(Wm -²)
(a)	(b)	(c)	(d)
1	200 kHz – 525 kHz	300	
2	525 kHz – 32 MHz	200	
3	32 MHz – 150 MHz		10
4	150 MHz – 225 MHz		100
5	225 MHz – 790 MHz		50
6	790 MHz – 18 GHz		1000
7	18 GHz – 40 GHz		100

5 Assessment of Hazard

It will be evident from the previous paragraphs that degrees of risk of unintended operation arise in any situation in which EED are introduced into close proximity with RF fields. The degree of risk ranges from negligible to acute in terms of both the susceptibility of the EED and the power output of the transmitters creating the RF field.

There are no simple rules or procedures for assessing risk. Each situation requires individual examination which must consider the:

Susceptibility of EED whether:

- Installed.
- Exposed.
- Packaged.
- Specifically protected.

Characteristics of transmitters.
Distance between the EED and radiating systems such as radios etc.

System Susceptibility

Using the NFT parameters described in paragraph 1.6.0.3. d), the assessment of the EED firing circuit susceptibility to induced pick up from RF radiation and the method of calculating the resulting degree of risk are described in Part II Chapter 7.

For systems with an unknown susceptibility, the maximum safe power density in the vicinity of CW or pulsed transmission sources pulsed at more than 666 pulses per second (pps) can be determined from the graph at Figure 6-II. The electrical characteristics of the US MK 114 Primer, UK Fuzehead Type F 120 and the FRG EL 37 cap together with a safety factor (Table 6-2) for a system with a 5 metre firing line was used to calculate the maximum safe power density.

This will enable a worst case CW assessment to be made and used until appropriate advice can be obtained from National Authorities.

Where RF pulse environments are encountered, special care should be taken of energy sensitive EED whose susceptibility changes significantly according to the emitter's pulse and time constant. In the absence of specific advice, a 20 times multiple of the distance calculated for CW should be applied.

***Table 2** EED Electrical Characteristics*

EED Type	Resistance Range Ω	No-Fire Treshold Values			Typical Safety Factor dB
		Energy mJ	Current A	Power mW	
(a)	(b)	(c)	(d)	(e)	(f)
US Mk 114 Primer	3 - 7	0,19	0,05	7,5	-4
UK F120	10 – 16	0,2	0,045	26	-77
FRG EL 37	0,8 – 1,7	0,3	0,015	20	-10

Safe Distance

Unless otherwise directed by the appropriate National Authority, it is accepted that the following basic far field formula should be used for safety evaluations:

$$S = \frac{GP}{4\pi d^2} \quad (1)$$

which rearranges to:

$$d = \sqrt{\frac{GP}{4\pi S}} \quad (2)$$

where:
S = Safe Power Density (Wm^{-2}) as shown in Figure 6-II
G = Antenna gain relative to an isotropic (numerical ratio not dB)
P = Mean power fed to antenna (W)
d = Safe distance (m)

6 Management Radios

For VHF/UHF transmitters, ie management radios, where the antenna gain in dB and the power in watts is known, safe distances can be established for known EED by reference to look-up graph at Figure 6-III.

The example below illustrates how this graph can be used:

Equipment Data	Graph Line (Figure 6 - 2)	System Susceptibility
Antenna Gain 3dB Transmitter Power 20W	6	5.0 Vm^{-1}

Procedure: Read across from the right to left at 5.0 Vm-1 coordinate to graph line No. 6. Read downwards vertically to the X axis (distance in metres). This shows that the Safe Distance = 7 metres

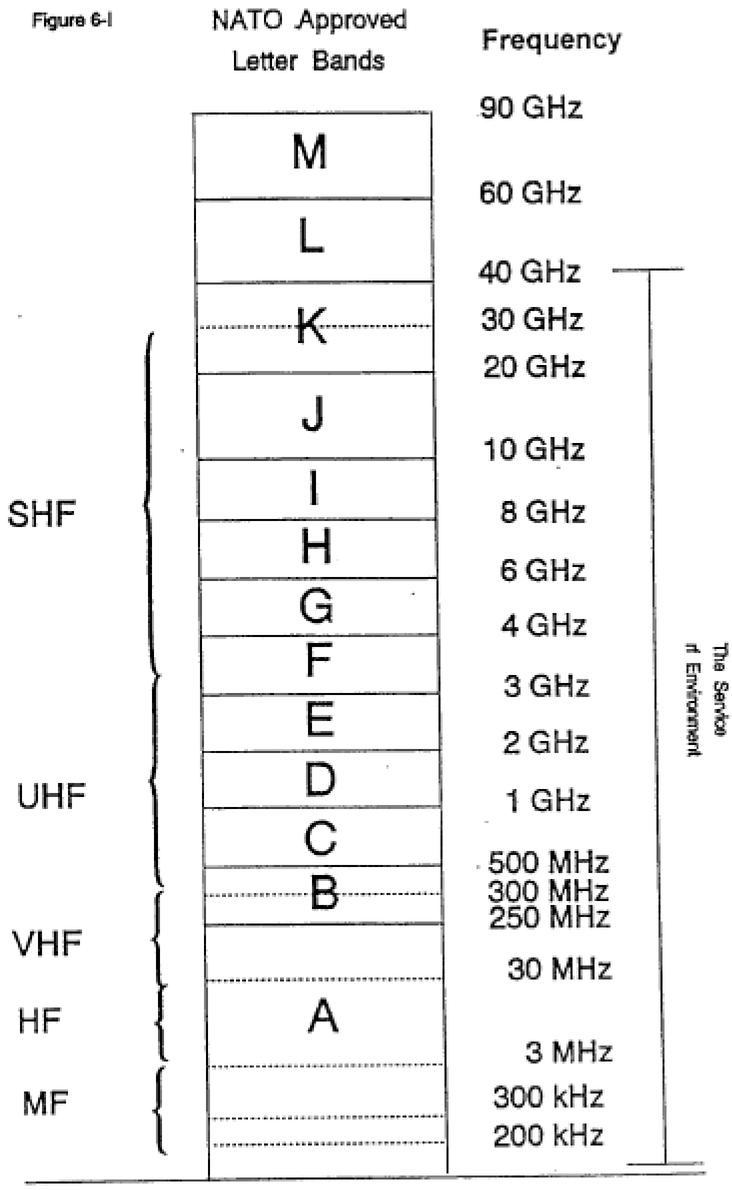
Summary

Where a worst case theoretical approach is considered restrictive, advice should be sought from National Authorities.

References

[1] Stanag 4235: Electrostatic Discharge Environmnet, 2004.
[2] Stanag 4236: Lichting Environment, 2007.
[3] AASTP – 1: Manual on Safety principles for the Storage of Ammunition and explosives, 2010.
[4] AECT – 100: Environmental Guidelines for Defence Material, 2009.

Figure 6-I



Letter Designators for RF Bands

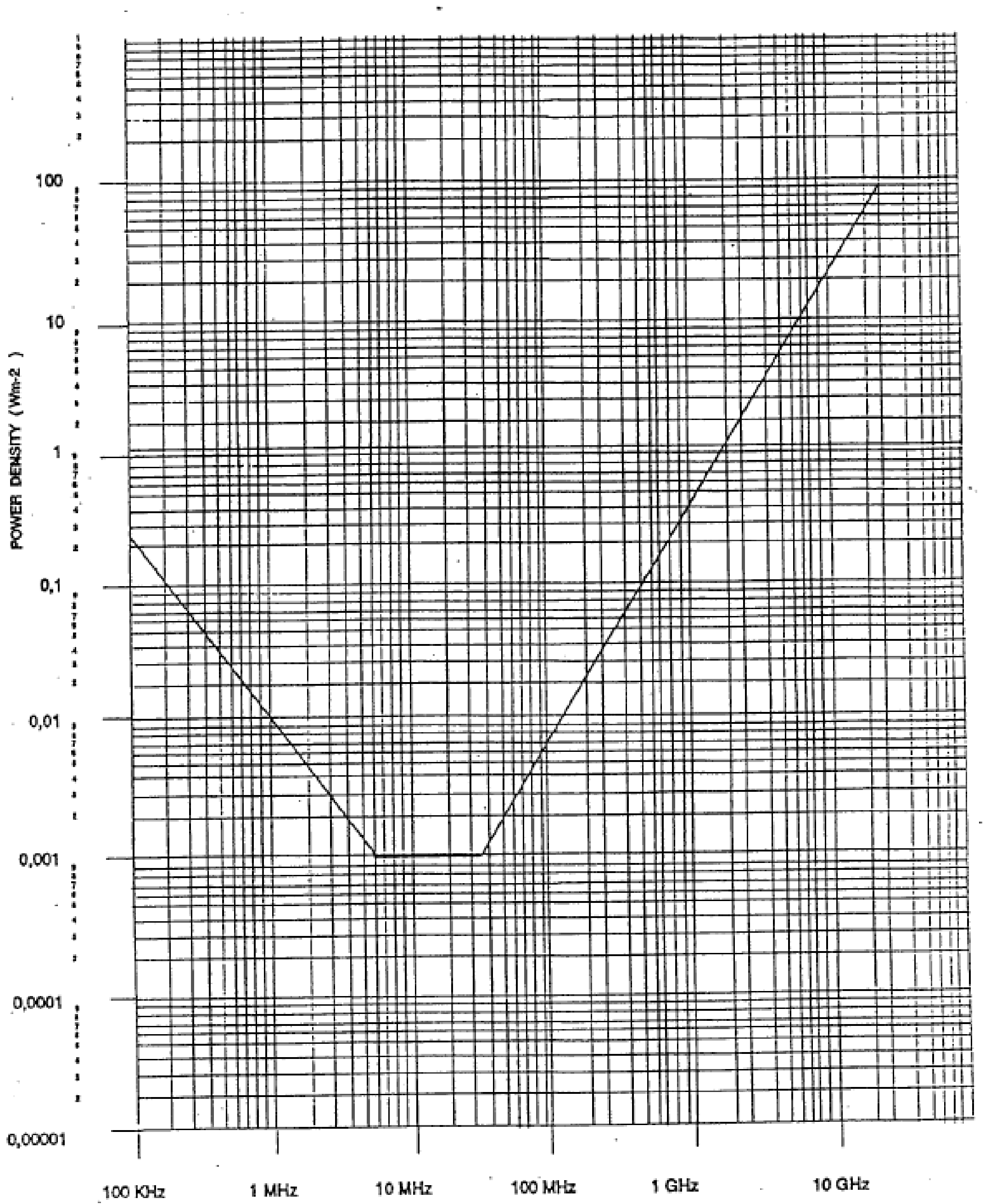


Fig. 6-II: Safe Power Densities Exposed EED, CW and Pulsed Transmissions above 666 pps