



Ministry  
of Defence

## **Defence Standard 59-411 Part 2**

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Electromagnetic Compatibility

Part 2: The Electric, Magnetic and  
Electromagnetic Environment

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**Foreword****AMENDMENT RECORD**

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**REVISION NOTE**

This Part of the Standard is raised to Issue 2 to update its content. The sponsor of this Standard should be consulted for a full description of the changes.

**HISTORICAL RECORD**

This Standard supersedes the following:

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Defence Standard 59-411 Part 2, Issue 1, dated 23 January 2007

Defence Standard 08-46 Issue 2 Published 9th August 2002

Defence Standard 08-46 Issue 1 Published December 1999

- a) This Part of the Standard provides requirements for Ministry of Defence (MOD) Project Officers and defence contractors to assist them to identify and quantify the Electromagnetic Environment present for a variety of Defence Scenarios. Detailed descriptions of the environment for some particular scenarios are also given.
- b) This Standard has been produced on behalf of the Ministry of Defence (MOD) by UK Defence Equipment & Support (DE&S) Defence Electromagnetic Environmental Effects Authority (DE3A).
- c) This Standard has been reached following broad consensus amongst the authorities concerned with its use and is intended to be used whenever relevant in all future designs, contracts, orders etc and whenever practicable by amendment to those already in existence. If any difficulty arises which prevents application of the Defence Standard, DStan shall be informed so that a remedy may be sought.
- d) Please address any enquiries regarding the use of this Standard in relation to an invitation to tender or to a contract in which it is incorporated, to the responsible technical or supervising authority named in the invitation to tender or contract.
- e) Compliance with this Defence Standard shall not in itself relieve any person from any legal obligations imposed upon them.
- f) This Standard has been devised solely for the use of the MOD and its contractors in the execution of contracts for the MOD. To the extent permitted by law, the MOD hereby excludes all liability whatsoever and howsoever arising (including, but without limitation, liability resulting from negligence) for any loss or damage however caused when the Standard is used for any other purpose.

## 0 Introduction

**0.1** Military systems must be designed to ensure Electromagnetic Compatibility (EMC) with the natural and man-made Electric, Magnetic and Electromagnetic (EM) environments in which they are to be deployed. This Part of the Standard describes how to identify and quantify the environments so that their EM impact on a system can be assessed. It may then be used to determine the parameters of any incident field upon any boundary drawn around a victim platform or its systems. Equipment designers can then assess the effects of this field on internal systems by considering the EM coupling mechanisms across the chosen boundary.

**0.2** The aim of this Part of the Standard is to provide a comprehensive description of the principal intentional and unintentional EM threats, within the scope described in **Clause 1**, to which military systems will be subjected. This will assist the process of defining a specific EM environment for a system based on the operational scenario.

**0.3** Typical Air, Sea and Land design environments for a number of different military scenarios are included, which may be appropriate to certain generic equipment. Also, some guidance on possible routes to demonstrate compliance with Military EMC requirements is provided.

**0.4** The means of defining the climatic and mechanical environments that are experienced by military materiel is described in Defence Standard 00-35.

**0.5** This Part of the Defence Standard is to be read in conjunction with the following parts in the Def Stan 59-411 series.

Def Stan 59-411	Part 1:	Management and Planning
Def Stan 59-411	Part 3:	Test Methods and Limits for Equipment and Sub-Systems
Def Stan 59-411	Part 4:	Platform and System Test and Trials
Def Stan 59-411	Part 5:	Code of Practice for Tri-Service Design and Installation

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# Electromagnetic Compatibility - Part 2 - The Electric, Magnetic and Electromagnetic Environment

## 1 Scope

**1.1** This Part of the Standard provides guidance on the typical electromagnetic environment in which military equipment is deployed.

**1.2** It covers stationary and mobile military equipment including ordnance, deployed and operated by Land, Sea and Air Services on land, under and on the sea, and in the air. The environments considered include those with sources arising from natural phenomena as well as those generated by man-made activities, both civil and military. This Part of the Standard does not discuss the environment of materiel deployed outside the Earth's atmosphere.

**1.3** The electromagnetic environments due to Radio Frequency Weapons (RFW) such as High Power Microwave (HPM) and Ultra-Wideband (UWB) Weapons are not currently included in this Part of the Defence Standard. Where immunity to such threats is a requirement, specialist advice on such environments should be sought from the relevant authorities.

**1.4** This Part of the Standard only considers field magnitudes that are likely to cause malfunctions to materiel by unintentional coupling mechanisms (sometimes called "back-door" mechanisms). For this reason, many sources of EM radiation are ignored because they are evidently so low that it is inconceivable that they could cause an indirect threat to materiel. The environments described may also be used to assess the protection requirements for the "front-end" of a receiver to prevent damage. In addition, fields that may impinge on a weapon system as it approaches a hostile target and those caused by deliberate enemy jamming are not considered in this Part of the Standard. User and system requirement documents should specify if these threats need to be taken into account and the relevant scenarios should be defined by the Equipment Capability customer.

**1.5** This Part of the Standard contains descriptions of the EM environment in both the time domain and the frequency domain. When the description is in the frequency domain, the maximum frequency considered will be 40 GHz. (NOTE: above this frequency there are few deployed systems and currently no recorded problems. A system using a transmitter above 40 GHz should however include it in the environment definition for that system). Both the radiated and conducted environment (due to sources external to an equipment) are considered. For the conducted EM environment, levels will be platform specific and only the generic test limits as used in **Part 3** of this Standard are discussed. Phenomena described in the frequency domain include static and quasi-static electric and magnetic fields, communications, radar and conducted emissions. Phenomena described in the time domain include Electrostatic Discharge (ESD), switching transients, Electro-Magnetic Pulse (EMP) and lightning.

**1.6** The depth of treatment for any given environment or related matter has been determined by the availability of information on the subject, in conjunction with its importance in the light of contemporary EMC problems. For this reason the following sources of EM radiation are not treated in this Part of this Standard:

- a) Low power (<10 W) radio communications from a distant transmitter (>100m).
- b) Cosmic / solar radiation.
- c) Terrestrial magnetic field.

**1.7** Environments are given in some detail, but the methods of minimising degradation of performance and maximising reliability are not covered here. Such descriptions can be found in **Part 5** of this Standard and many textbooks.

**1.8** This Part of the Standard recognises that applying a worst case description of an environment to be used in all cases can lead to wasteful and unrealistic levels of hardening. There are two ways of overcoming this. The first is to give a statistical description of the field. This would be very difficult and time consuming to

calculate and would be dependent on the operational scenario. The second is to give a maximum likely field for a variety of operational scenarios and where classification allows the rationale for each scenario. For systems with a different scenario it will then be necessary for revised figures to be produced. This will generally require the project to consult specialist authorities. This second approach has been adopted and is expected to offer a realistic solution to the problem of unnecessarily high field descriptions. However since the number of scenarios is limited it will be necessary for projects to determine whether the scenario is relevant to some or all of their system and define additional /alternative scenarios in terms of likely distances from various types of transmitter. These can then be transformed into EM environments using the information provided in this Part of the Standard and/or seeking guidance from relevant specialists.

**1.9 Part 3** of this Standard includes a large number of EM susceptibility tests with a variety of limits which may be used for different classes of equipment. These limits have been established recognising the information contained in this Part of the Standard which may be relevant to common scenarios/conditions that exist in each service environment. **Part 1** of this Standard calls for the limits to be tailored for each project to avoid under- or over-testing. The information provided in this Part of the Standard should be used to assist this tailoring process but for classification reasons it may be necessary to seek specialist assistance.

## 2 Warning

The Ministry of Defence (MOD), like its contractors, is subject to both United Kingdom and European laws regarding Health and Safety at Work. Many Defence Standards set out processes and procedures that could be injurious to health if adequate precautions are not taken. Adherence to those processes and procedures in no way absolves users from complying with legal requirements relating to Health and Safety at Work.

## 3 Normative References

**3.1** Related publications referred to in the text of this Standard are detailed in **Part 1 Annex A** of this Standard.

**3.2** Note: Def Stan's can be downloaded free of charge from the DStan web site by visiting <http://www.dstan.dii.r.mil.uk> for those with rli access or <https://www.dstan.mod.uk> for all other users. All referenced standards were correct at the time of publication of this Standard (see 3.2, 3.3 & 3.4 below for further guidance), if you are having difficulty obtaining any referenced standard please contact the DStan Helpdesk in the first instance.

**3.3** Reference in this Standard to any normative references means in any Invitation to Tender or contract the edition and all amendments current at the date of such tender or contract unless a specific edition is indicated. Care should be taken when referring out to specific portions of other standards to ensure that they remain easily identifiable where subsequent amendments and supersession's might be made. For some standards the most recent editions shall always apply due to safety and regulatory requirements.

**3.4** In consideration of **Clause 3.2** above, users shall be fully aware of the issue, amendment status and application of all normative references, particularly when forming part of an Invitation to Tender or contract. Correct application of standards is as defined in the ITT or contract.

**3.5** DStan can advise regarding where to obtain normative referenced documents. Requests for such information can be made to the DStan Helpdesk. Details of how to contact the helpdesk are shown on the outside rear cover of Defence Standards.

## 4 Abbreviations and Definitions

### 4.1 Abbreviations

AM	Amplitude Modulation
COTS	Commercial Off The Shelf
CW	Continuous Wave
DT	Delivery Team
ECAC	Electromagnetic Compatibility Analysis Centre
ECM	Electronic Counter Measures
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EME	Electromagnetic Environment
EMP	Electromagnetic Pulse
ESD	Electrostatic Discharge
FM	Frequency Modulation
HF	High Frequency
HIRTA	High Intensity Radio Transmission Area
HPM	High Power Microwave
ITT	Invitation to Tender
NATO	North Atlantic Treaty Organization
NEMP	Nuclear Electromagnetic Pulse
P-Static	Precipitation Static
RADHAZ	Radiation Hazards (this term is usually applied to the biological effects of non-ionising, ie RF, radiation on humans but is also applied to ordnance and fuel)
RAS	Replenishment At Sea
RF	Radio Frequency
RFA	Royal Fleet Auxiliary
RFW	Radio Frequency Weapons
RN	Royal Navy
SATCOM	Satellite Communications
SRAD	Susceptibility RAHDAZ Designator
SOLAS	Safety of Life at Sea
STANAG	NATO Standardization Agreement
VHF	Very High Frequency
UHF	Ultra High Frequency
UWB	Ultra Wideband
VERTREP	Vertical Replenishment

## 4.2 Definitions

For the purpose of this Standard the definitions in ISO/IEC Guide 2 'Standardization and Related Activities – General Vocabulary' and in **Part 1 Annex B** of this Standard will apply.

## 4.3 Definition of the Environment of a System

For the purposes of this Part of the Standard, a system is defined as one or more devices that both perform a worthwhile integrated function, and that are subjected to the same external EM environment. This allows a wide range of materiel to be defined as systems. Having defined a system in this way, one can apply the same method for deriving the EM environment for any system. It is also possible and frequently necessary to define a large item of materiel as a system (for example an aircraft), and to use the EM field at the boundary of this system (ie the aircraft skin) as a source for calculating the EM environment of a subsystem. It may be necessary to define different system boundaries when considering the different EM threats, in order to allow a suitable test environment / method to be devised. It is also recognised that for some sub-systems, which are distributed throughout a higher level system, that the environment may be different for each element of the sub-system. In such cases, the manner in which each external EM threat will be modified by the platform at each sub-system may then need to be considered separately. Techniques for deriving these sub-system threat levels, which may be expressed in terms of cable currents, are discussed in **Part 5** of this Standard.

Having defined an arbitrary boundary of a system, it is then necessary to identify the EM sources external to that system. The following sections and clauses provide the necessary information for the calculation of the EM field characteristics at the system boundary due to each source.

In general the victim system may be subjected to interference from simultaneous multiple transmissions. The interference can be from a single source which is dominant at any one time or multiple simultaneous sources with intermodulation products; either may also generate significant spuri and harmonics.

Having derived a description of all the EM fields at the boundary of the system, this gives a guide as to how the system may be designed and tested for EMC. The design should be approached in an integrated manner such that protection is optimised against all threats. However, in the simplest case, if the boundary field strength is applied to the system in a test environment, then the relevant performance criteria should be achieved to demonstrate compatibility with the environment.

It is intended that the boundary EM field data will set limits of susceptibility for the system under test. It is important that the assumptions made when deriving the EM field data form, where possible, an integral part of the description of the EM environment. It is also important at the lower part of the frequency band in particular to recognise the nature of the field that exists in service and to ensure the test method reflects this as far as practicable.

While assessing the fields that penetrate a system boundary due to external sources, an assessment should be made of any sources of electromagnetic fields which are created within the system to ensure that these do not compromise the EMC of the system. In this way, both inter-system and intra-system EMC should be addressed together.

## 5 Categorisation

Materiel will in general be intended for use in a number of operational scenarios. The EM environment across the scenarios may vary but there are likely to be only a limited number of scenarios that are significantly different. Thus it is convenient to categorise materiel so that its EM environment can be determined. It is also necessary to further subdivide the EM environmental descriptions to provide a description of each threat in each scenario.

**Table 1** shows the scenarios for which the EM environments will be significantly different. Although there are different environments for different situations, it may be necessary to look at only the worst case threats when testing a system (for example, one would not manufacture an aircraft that was compatible with the EM environment in flight but not compatible with the airport EM environment).

Operational Restrictions, Failure Modes and Frequency of Occurrence: When determining the applicable EM environment, recognition needs to be given to any possible operational restrictions that may be acceptable and to potential failure modes. Thus it may be decided that a minimum separation between a system and a potential interference source can be accepted since the separation does not significantly restrict deployment; or certain failure modes are not mission or safety critical and a lesser degree of hardening is acceptable. However, the use of a minimum separation to prevent a safety hazard would only be acceptable where a well-controlled and documented clearance and control regime is in place (eg High Intensity Radio Transmission Areas (HIRTA) for aircraft). Any operational restrictions / minimum separations should be formally agreed between the Equipment Capability Manager and the Delivery Team (DT) in the process of agreeing the details of the scenarios to be used. For aircraft a Target Clearance Environment (see **Part 4** of this Standard for further discussion on this) is frequently defined based on a Target HIRTA and a target Susceptibility RADHAZ Designator (SRAD) code. This is then modified by the inclusion of safety margins to derive the aircraft test environment. The aircraft contractually specified environment may include a safety margin but it should be at a level that allows the same test evidence to be used to support both contractual clearance and the Target Clearance Environment.

Similarly, the frequency of occurrence of a particular environment may be sufficiently rare to allow it to be ignored or be considered only relevant to safety critical failure modes (eg for a direct lightning strike, some systems may only be required to remain safe but not necessarily suitable for service). Again the detail of the requirement needs to be agreed between the Capability Manager and the DT.

**Table 1**      **Categorisation**

Threat	Air	Sea	Land	Ordnance
Lightning	a) Indirect strike b) Direct strike	a) Ground nearby strike b) Ground Direct/ Indirect strike	a) Ground nearby strike b) Ground Direct / Indirect strike	a) Ground nearby strike b) Direct/Indirect strike
Electrostatic discharge (ESD)	a) Rotorcraft ESD b) P-Static c) Human ESD d) Discharge from other materials	a) Human ESD b) Discharge from other materials	a) Human ESD b) Discharge from other materials	a) Human ESD b) Discharge from other materials c) Rotorcraft ESD d) P Static
Conducted EM energy	a) In flight, power generated internally b) On ground, as for land service c) On ship flight-deck as for sea service	a) At sea, power generated internally b) In port, as for land service	a) Power generated by field / vehicle generators b) Power from civilian mains distribution c) Telephone, LAN and other data input / output lines	a) Own internal generated power b) External power as relevant land / sea / air platform
Static and Low Frequency Fields	a) Power System b) Magnetic Field c) Terrestrial d) Electric Field	a) Power System, Degaussing and Deperming b) Magnetic Fields c) Terrestrial d) Electric Field	a) Power System b) Magnetic Field c) Terrestrial d) Electric Field	a) As for relevant platform environment
Radiated Comms/ Radar	a) Rotary at airfield b) Rotary in flight c) Rotary near / on ship d) Fixed Wing at airfield e) Fixed wing in-flight f) Fixed wing near/ on ship	a) Above decks b) Submarine c) Rotary Wing near / on ship d) Fixed Wing near / on ship	a) Different classes based on proximity of transmitting antennas	a) Full life cycle (derived from one or many platform systems) b) Operational as for land / sea / air as appropriate
NEMP	a) Endo-atmospheric NEMP b) Exo-atmospheric NEMP	a) Endo-atmospheric NEMP b) Exo-atmospheric NEMP	a) Endo-atmospheric NEMP b) Exo-atmospheric NEMP	a) Endo-atmospheric NEMP b) Exo-atmospheric NEMP

NOTE This Standard does not address other effects produced by a nuclear explosion such as Transient Radiation Effects on Electronics (TREE) or Initial Nuclear Radiation (INR). The Equipment Capability Customer should be consulted as to whether hardening to these effects is required. In the relatively few cases where it is called up Def Stan 08-4 should be consulted.

## 6 Atmospheric Electricity and Lightning

This clause describes the phenomenon of atmospheric electrostatic charging and the resulting discharge as lightning. It gives the values of lightning parameters for naturally occurring cloud to ground and Inter/Intra cloud discharges and the more normal levels of electrostatic charge that exist without lightning events. The derivation of standardised definitions of lightning parameters for induced effects and for testing is also explained.

Atmospheric electricity is considered as an environment as it gives rise to induced electromagnetic effects and the possibility of direct damage due to lightning strikes. Factors involved in the electrical properties of the atmosphere include electric fields, currents and conductivity, and positive and negative ions of a wide range of size. Precipitation charging constitutes an induced environment and is dealt with in AECTP 253.

The terrestrial electrostatic field is described in Def Stan 00-35 Part 4 chapter 12-01 and also in AECTP 254.

### 6.1 Lightning

**6.1.1** Def Stan 00-35 Part 4 chapter 7-01 and AECTP 254 each contain information about the occurrence of lightning in different parts of the world. British Standard BS EN 62305-2 Part 2 Annex NK provides a map of the UK giving contours related to lightning strike frequency averaged over a number of years.

**6.1.2** A thorough description of the fields and currents due to lightning can be found in Def Stan 59-113. A lightning strike also produces a radiated EM field that can induce currents in circuits and structures. The fields from a nearby strike can reach values of up to  $> 1 \text{ MVm}^{-1}$  at 10 m.

**6.1.3** It is acknowledged that the important lightning parameters with respect to design and testing are:

- a) Peak current
- b) Rate of change of current
- c) Action Integral
- d) Charge content
- e) Duration
- f) Rate of change of E field

**6.1.4** The numerical values of the parameters of lightning strikes have been determined in measurement surveys over many years. Each lightning strike will have unique characteristics so a statistical description of the parameters is necessary. Moreover the statistics vary according to geographic location and whether the strikes are positive or negative. Data on these parameters is sparse but evidence from recent strikes has shown that levels higher than some certification standards are possible. Full international agreement on some parameter values has not therefore been reached. The data for positive and negative flashes measured at ground level are shown in AECTP 254 Tables 254-1 and 254-2. The percentages at the top of each table describe the statistical nature of the flashes. For example, in the case of peak current in negative flashes, 50% of flashes have a current greater than 20 kA, 2% have a current greater than 140 kA, and so on. The 2% values should be used for safety critical applications (ie aircraft or ordnance).

**6.1.5** The tables do not give data for  $dE/dt$ , which can be an important parameter. Although data concerning  $dE/dt$  is somewhat limited, the value usually used, as far as it affects aircraft in flight and ground installations, is  $10^{13} \text{ Vm}^{-1}\text{s}^{-1}$ .

### 6.1.6 Combined Lightning Environment

It is generally accepted that worldwide approximately 90% of all cloud-ground lightning strikes are negative and 10% positive. However, depending on the geographic region, season, type of cloud and phase of the thunderstorm, very different percentages can occur. For example in the UK the percentage of positives is about 40% in summer and 60% in winter. There is also debate on how a combined set of parameter levels should be derived even once a ratio of positive to negative strikes has been set. AECTP 254 Table 254-3 lists standard levels and alternative levels. The UK makes use of the alternative levels by default.

See AECTP 254 Table 254-3 for combined positive and negative discharge parameters for cloud to ground strikes.

The radiated environment from a nearby lightning strike is given in AECTP 254 Table 254-6.

Where necessary and since no other data is available the same levels may be used for land vehicles. It is rarely necessary for induced currents of this high amplitude to be taken into account on ship systems due to the spread of current to the sea over a wide area but the current injection test and levels quoted in **Part 3** of this Standard should be used to provide evidence of sufficient immunity. Specialist modelling will be required if this effect is thought to be an issue and the possible puncture effects on a composite mast or radome will need to be fully examined and precautions taken.

## 7 Electrostatic Charging, Discharge and Precipitation Static

**7.1** The phenomenon of electrostatic charging and subsequent discharges can result in interference to the operation of electronic equipment or damage to electronic circuitry. The energy released during discharges is potentially hazardous to personnel, fuel vapours and ordnance.

**7.2** The main problem with electrostatic charging is that the discharge of the object is usually via a series of pulses of electric current that can directly or indirectly upset sensitive circuits particularly radio receivers or initiate electro-explosive devices. It is also possible for the discharge from an insulating or poorly bonded surface of a missile or shell to couple into a firing circuit or proximity detector.

**7.3** On both fixed wing and rotary wing aircraft, two types of ESD are common. Firstly, a large charge can build up on a dielectric surface such as a window. When a discharge finally occurs, there is a large current that induces voltages on nearby cables. Secondly, when the overall charge on an aircraft gets very high, the charge starts to leak off the sharp parts of the aircraft. This transfer of charge is known as corona discharge. The remaining charge is redistributed through the metallic structure and the resulting currents, which are spiky in nature, cause broadband noise to be radiated. This noise is known as precipitation static or p-static. P-static generally affects only reception of radio signals and a fuller description is given in AEP 29.

**7.4** AECTP 253 Clause 2.1 describes the phenomenon of ESD and gives guidance as to the maximum charge that can exist on a human body (in extreme circumstances voltages up to 25 kV are possible). Such a high voltage level is rare and requires dry (favourable for static) conditions to exist. These levels are therefore generally only used where safety critical applications are being considered. Lower levels of 8 kV are commonly used in the civil community for ESD testing and these are generally sufficient for non safety critical equipment. The characteristics are as shown in IEC 61000-4-2.

**7.5** AECTP 253 Clause 2.2 describes helicopter borne electrostatic parameters to include helicopter charging characteristics, particularly vertical lift and in-flight refuelling. This is a cause for concern as the charge built up on a helicopter in flight could be discharged if the helicopter is grounded via, for example an under-slung load. Such a discharge would be extremely hazardous to both humans and equipment and generally only ordnance items that may be VERTREP need to be assessed or tested against this threat.

**7.6** ESD environments and test levels currently used are found in AECTP 253, Tables 253-1 and 253-2.

## 8 DC and Low Frequency Magnetic Fields

AECTP 255 defines the direct current (DC) magnetic and low frequency (LF) fields encountered in the shipboard operational electromagnetic environment. These environments can be used to define design and test requirements for shipboard systems and equipment. LF fields to be used as design and test requirements for aircraft and land based systems and equipment are also defined.

### 8.1 Power Supply

The conducted environment of a power supply network can be degraded by several phenomena. The problems that occur can be either due to changes in the quality of the supply from the generator, or alternatively can be due to the loads that are connected to the supply in close proximity to the point of interest. Problems due to the supply are described in terms of dips or interruption of the supply when compared with the nominal supply voltage and frequency. Problems due to nearby loads include harmonics, bursts and flicker.

The civil environment is described thoroughly in IEC/TR 61000-2-1 and IEC/TR 61000-2-2.

The low frequency "noise" that exists in a military supply is due to generators and loads. These levels may best be described by reference to the limits in the conducted emission and susceptibility tests listed in **Part 3** of this Standard. The parameters that military power supply systems must satisfy are documented in Defence Standard 61-5. Aircraft currently satisfy the requirements of British Standard BS 3G100.

### 8.2 Low Frequency Fields

The low frequency fields generated by power distribution cables should be easily calculable from formulae contained in standard text books on magnetic fields. The electric field does not generally cause any EMC problems to materiel but the magnetic field is known to cause problems to cathode ray tube monitors (distorting picture and colour), sensitive audio frequency circuits, magnetic data storage media and search tools. As integrated circuit gates become smaller it is also possible that they may be affected by these fields. Except for the special cases described below, the magnetic field radiated susceptibility test levels of **Part 3** of this Standard should be used to define this environment.

### 8.3 Degaussing / Deperming of Navy Vessels

There are known problems with degaussing systems on navy vessels. Firstly, the DC currents cause high static magnetic fields to be generated which may affect devices previously mentioned. Secondly, the electric potential generated in a circuit will be proportional to the rate of change of magnetic field. The rate of change that occurs when degaussing systems have their currents changed can be as high as  $1,600 \text{ Am}^{-1}\text{s}^{-1}$ . This relatively large rate of change of magnetic field could therefore cause pick-up in a nearby circuit and/or upset a magnetically sensitive component. In addition it has been calculated that when degaussing currents are suddenly interrupted due to emergency shut down or a fault then the subsequent collapse of the current will give rise to a high rate of change of field which may be a short damped oscillation or just a fast decay. The frequency content and duration of this will depend on the degaussing coil arrangement but work to try to characterise this more accurately has proved very complex. Estimates of a rate of change of field up to  $7200 \text{ Oes}^{-1}$  ( $5.7 \times 10^5 \text{ Am}^{-1}\text{s}^{-1}$ ) have been made using worst case assumptions but these remain to be validated. These fields would only be relevant to equipments sited within 0.5 m of a degaussing coil and only safety critical equipments possibly need to consider their effect. For equipments sited further away from degaussing cables the low frequency magnetic field radiated susceptibility test levels quoted in **Part 3** of this Standard are adequate. If this threat is considered significant for say a weapon system then the test level should be increased to match the predictions for the actual installation.

Deperming operations are carried out on submarines in order to reduce the permanent magnetic field remaining in the steel hull. These operations require the generation of high magnetic fields. Sensitive equipments will generally be removed for this operation where practicable but other equipment will be required to remain on board and some may need to be operational.

The DC magnetic field environment that is present on Navy vessels is summarised in Def Stan 08-123 data sheet 38 Table 38.1, which gives the design requirements for equipment fitted to navy surface ships and submarines. The levels quoted for degaussing systems will only exist relatively close to the degaussing cables. If a system is known to be sited some distance from the cables (say > 3 m), advice should be sought on the levels to be used. Equally, however, if a system is known to be sited very close to a degaussing cable (say within 0.3 m) considerably greater field strengths may exist and further advice should be sought.

## 9 Nuclear EMP (NEMP)

Nuclear electromagnetic pulse (NEMP) is a term commonly used to identify electromagnetic signals resulting from a nuclear detonation. AECTP 256 describes in simple terms the origin of a NEMP, its basic characteristics and methods by which it couples onto platforms and systems.

Further information on the NEMP environment and its causes can also be found in BS EN 61000-2-9.

The NEMP environment for military materiel is described in AEP 4. Due to its classification, it is not repeated here. Def Stan 08-4 discusses the NEMP environment and test methods, while Def Stan 59-188 provides information on NEMP hardening to strategic facilities.

## 10 Intentional Emitters

**Clauses 11, 12, 13 and 14** address the RF Electromagnetic Environment (EME) produced by various emitter sources such as communication and radar transmitters likely to be encountered by materiel of any service during operations.

The objective of these clauses is to provide an overview discussion, typical requirements, and definitions of the operational EME against which military hardware must be protected in order to operate and survive. The EME levels can then be used as design criteria for all new platforms, equipments, and systems intended for use by British Forces.

For equipments and materiel likely to be used in NATO operations, refer to AECTP 258.

## 11 Intentional Emitters – Air Environment

The US Federal Aviation Administration and the European Joint Aviation Authority first expressed concern, in 1986, over the integrity and safety of new technology civil transport aircraft with full electronic flight critical systems.

The Electromagnetic Compatibility Analysis Centre (ECAC) was commissioned to produce a study document to predict the maximum electromagnetic radiated fields in the United States for specific scenarios. The resultant study document, Guidelines for Developing Maximum Peak and Average Field Strengths Envelope Graphs for Aircraft, was issued in September 1987 and forms the basis for most of the EM environmental assessments that are currently performed by regulatory authorities.

The threat field in the frequency range 10 kHz–40 GHz is due to a variety of communication and radar sources.

The fields that result from various sources are derived using antenna theory (including near field correction for aperture antennas). Direct measurements are rarely needed since the theory is considered to be acceptably accurate.

The techniques and assumptions for deriving the aircraft environment are mostly taken from the Guidelines for Developing Maximum Peak and Average Field Strengths Envelope Graphs for Aircraft. To derive an EM environment for an aircraft, the characteristics of all transmitters that will be encountered in use must be evaluated.

In the UK, the High Intensity Radio Transmission Area (HIRTA) scheme is used to protect military aircraft from hazardous EM environments. The keystone of the HIRTA is a database of high power transmitters, the EM fields from which can be calculated.

Currently, the HIRTA database is used to calculate the areas in which an aircraft can safely fly based on information about the aircraft's hardness to EM fields. The HIRTA information can be used conversely to provide a description of the EM environment in the region of space in which an aircraft will fly. The region of space will mainly be governed by the capability of an aircraft to approach a transmitter (ie minimum height above ground / minimum distance of approach to airport radars etc). The assumptions of how an aircraft will operate are therefore an important part of the calculations of the EM environment of the aircraft.

The air environments described in this Part of the Standard are derived using the HIRTA database as described above and international transmitter data from similar sources.

A known EMC problem is that often a system is susceptible to an AM modulated signal when it is not susceptible to the same amplitude of CW signal. Hence the modulation type of the threat fields should be determined. For communications signals, a wide variety of different modulation techniques are employed. For radar signals, the modulation type is typically pulsed CW with between 100 and 10,000 pulses per second and a typical duty cycle of between 0.0005% and 5%<sup>1</sup>) However, due to the complex nature of radars, further information should be sought for any specific scenario.

### 11.1 Air-service Environmental Assumptions

The assumptions that were used when calculating the air-service environment for this Part of the Standard are described as follows.

- a) The electromagnetic environment exists due to the transmission of electromagnetic energy into free space. This energy is radiated from radar, radio, television, and other sources.
- b) These transmitters are ground-based, shipborne, or airborne.
- c) The electromagnetic environment has been modelled using the databases that contain parameters pertaining to all known transmitters in the United States and Western Europe. The resulting HIRF envelope is a representation of electromagnetic field strength over a frequency range of 10 kHz to 40 GHz. This HIRF envelope has been verified by examining the databases for accuracy, and, in the past, by taking measurements of field strength through flight tests at selected sites.
- d) In calculating the environment, both specific and general assumptions were made. The specific assumptions deal with aircraft to transmitter distance criteria and are discussed later for each scenario.

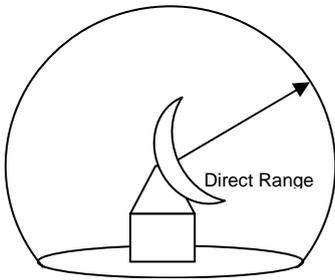
#### 11.1.1 General Assumptions

- a) The envelope was divided into frequency bands with the maximum level in each band being determined.
- b) Main beam illumination by a transmitting antenna was used.
- c) Maximum main beam gain of a transmitter antenna was used.
- d) Modulation of a transmitted signal was not considered. However, the duty cycle was used to calculate the average power for pulsed transmitters.
- e) Constructive ground reflections of High Frequency (HF) signals, ie direct and reflected waves were assumed to be in phase.
- f) Non-cumulative field strength was calculated. Simultaneous illumination by more than one antenna was not considered.

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<sup>1</sup> Duty cycle is the ratio between pulse width and pulse repetition frequency

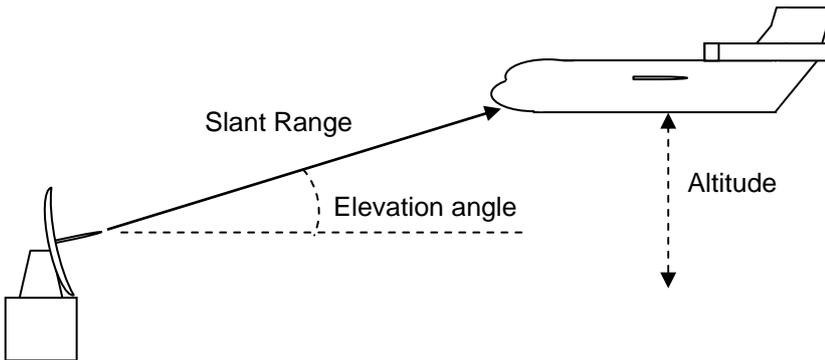
- g) Near field corrections for aperture and phased-array antennas were used.
- h) Field strengths were calculated at minimum distances that were dependent upon the location of the transmitter and aircraft.
- i) Peak field strength was based on the maximum authorised peak power of the transmitter, maximum antenna gain, and system losses (where known).
- j) Average field strength was based on the maximum authorised peak power of the transmitter, maximum operational duty cycle, maximum antenna gain, and system losses. This applies to pulse systems only.
- k) The field strength values are in volts per metre and were calculated from the power density. It is very important to note that although only values of E field are stated, an H field of magnitude  $E/377 \text{ Am}^{-1}$  is implied.
- l) The direct range represents the distance at which the main beam of a transmitter with no positional restrictions will illuminate an aircraft with a given field strength. This is illustrated in Figure 1.



With the transmitter located at the centre of the bubble, the direct range is the distance from the transmitter to the surface of the bubble. The main beam field strength is considered to be the same at all points on the surface of the bubble as the transmitter has no positional constraints and the main beam can be directed to any part of the bubbles surface.

**Figure 1 Direct Range**

- m) If a transmitter has positional restrictions, such as elevation angle, the slant range represents the distance at which the main beam of the transmitter, operating at its maximum elevation angle, will illuminate an aircraft at a given altitude. If the maximum elevation angle is not available, 90 degrees is assumed unless otherwise stated in the text. This is illustrated in Figure 2.



Slant range is the distance at which an aircraft at a given altitude will encounter the main beam of a transmitter with positional constraints, such as a maximum elevation angle less than 90 degrees.

**Figure 2 Slant Range**

- n) Transmitters with experimental licences were excluded.
- o) Transmitters located in Prohibited, Restricted or Danger areas were not included in the environment.
- p) Non-airport mobile tactical military transmitters were excluded.
- q) The assumptions about particular peacetime aircraft environments are summarised in **Table 2**.

### 11.1.2 Aircraft Scenarios

In considering what aircraft scenarios to use the following issues were taken into account:

- a) For a new aircraft project/design specific assumptions on scenarios and operational use must be made and a comprehensive study made of the EM environment that should be specified.
- b) For existing aircraft with a known clearance level new equipment will generally be specified to match that level or exceed it by a suitable margin.
- c) The EM environment for aircraft which have to undergo a mid-life update should be assessed in a similar manner as for new aircraft or be based on existing clearance levels.
- d) A target HIRTA may be agreed with the user to reduce hardening and testing costs but with possible operational restrictions (see **Clause 5**).

For these reasons the number of environments given in this Part of the Standard has been limited and the tables represent figures likely to be generated for the relevant aircraft type. They are essentially guides to a worst case level. The tables should not be used without proper consideration of their relevance following discussion with specialist authorities.

The environments cover possible wartime scenarios and where possible the assumptions made are described for each scenario. Full details of distances used cannot be included for classification reasons. As noted in **Clause 1.3** the threat which could arise from future RF weapons has been excluded. The scenarios covered which may be used for information on the generic levels to be expected for military aircraft are:

- a) Transport Aircraft
- b) Fixed Wing Aircraft capable of operating from a ship
- c) Rotary Wing Aircraft
- d) Strike Aircraft not capable of landing on a ship

**Table 2** gives the assumptions used for all aircraft types for peacetime operations. Some of the distance figures have been modified to allow for wartime scenarios but are not included here for classification reasons.

**Table 2 Summary of Assumptions for Air Environment in Peacetime**

Location	Type of transmitter	Strike aircraft assumptions	Transport aircraft assumptions	Rotorcraft assumptions
Airport Transmitters (within 5 nautical miles of an Airport runway)	Airport surveillance and Air route surveillance	500ft, slant range	500ft, slant range	300ft, slant range
	All other fixed transmitter	250ft, slant range	250ft, slant range	100ft, direct range
	Aircraft weather radar	150ft, direct range	150ft, direct range	100ft, direct range
	All other mobile transmitters, including other aircraft	50ft, direct range	50ft, direct range	50ft, direct range
Non-airport transmitters		500ft, slant range <sup>a</sup>	1000ft, slant range <sup>b</sup>	100ft, direct range
Offshore platforms		N/A	N/A	100ft, direct range
Shipborne Transmitters <sup>c</sup>		500ft, slant range	1000ft, slant range	500ft, direct range
Air - air transmitters	Non-interceptor with all transmitters operational	500ft, direct range	500ft, direct range	N/A
	Interceptor aircraft with all non-hostile transmitters operational	100ft, direct range	100ft, direct range	N/A
<sup>a</sup> Assumes a minimum flight altitude of 500ft, and avoiding all obstructions (including transmitter antennas) by 500 ft <sup>b</sup> Assumes a minimum flight altitude of 1000ft, and avoiding all obstructions (including transmitter antennas) by 1000ft. Where maximum elevation angle of antenna was not known, 45 degrees was assumed <sup>c</sup> Except for aircraft/rotorcraft capable of landing on a ship				

## 11.2 Military Fixed Wing Transport Aircraft

The environment is given in **Table 3**. The worst case value of the civilian fixed wing aircraft severe and certification environments have been used as being typical for the environment expected to be seen by this type of aircraft. See **Clause 11.1.2** before applying this table.

**Table 3 Field Strength for Military Fixed Wing Transport Aircraft**

Frequency	Peak Field Strength ( $Vm^{-1}$ )	Average Field Strength ( $Vm^{-1}$ )
10 kHz—100 kHz	50	50
100 kHz—500 kHz	60	60
500 kHz—2 MHz	70	70
2 MHz—30 MHz	200	200
30 MHz—70 MHz	50	50
70 MHz—100 MHz	50	50
100 MHz—200 MHz	100	100
200 MHz—400 MHz	100	100
400 MHz—700 MHz	730	80
700 MHz—1 GHz	1400	240
1 GHz—2 GHz	3300	200
2 GHz—4 GHz	4500	490
4 GHz—6 GHz	7200	300
6 GHz—8 GHz	1100	200
8 GHz—12 GHz	3000	330
12 GHz—18 GHz	2000	330
18 GHz—40 GHz	1000	420

### 11.3 Military Strike Aircraft – Capable of Ship Operations

For the purpose of this Part of the Standard it has been assumed that the strike aircraft is capable of vertical take-off and landing. Separation distances between any aircraft and all ship transmitters have been based on probable approach paths. The environment is given in **Table 4**. See also **Clause 11.1.2** before applying this table.

**Table 4 Field Strength for Military Strike Aircraft – Capable of Ship Operation**

Frequency	Peak Field Strength ( $Vm^{-1}$ )	Average Field Strength ( $Vm^{-1}$ )
10 kHz—100 kHz	50	50
100 kHz—200 kHz	60	60
200 kHz—2 MHz	70	70
2 MHz—30 MHz	200	200
30 MHz—150 MHz	100	100
150 MHz—200 MHz	100	100
200 MHz—225 MHz	100	100
225 MHz—400 MHz	100	100
400 MHz—700 MHz	730	80
700 MHz—790 MHz	1400	240
790 MHz—1 GHz	1400	240
1 GHz—2 GHz	3300	600
2 GHz—4 GHz	10000	950
4 GHz—6 GHz	7200	300
6 GHz—8 GHz	1100	700
8 GHz—12 GHz	10000	750
12 GHz—18 GHz	5700	700
18 GHz—40 GHz	3640	420

NOTE The levels in the above table do not allow for possible fields from high power transmitters on non-UK ships. Landing on those ships may require RADHAZ controls to be put in place (see BRd 2924).

## 11.4 Military Rotorcraft

The environment is given in **Table 5**. Since helicopters are increasingly being used for amphibious operations whatever their initially defined role, a single table only for rotorcraft is provided. If a helicopter is definitely not to be operated from a ship during its life advice should be sought on possible revised levels. See also **Clause 11.1.2** before applying this table.

**Table 5 Field Strengths for Military Rotorcraft**

Frequency	Peak Field Strength (Vm <sup>-1</sup> )	Average Field Strength (Vm <sup>-1</sup> )
10 kHz—100 kHz	150	150
100 kHz—600 kHz	200	200
0.6 MHz—30 MHz	200	200
30 MHz—150 MHz	200	200
150 MHz—400 MHz	200	200
400 MHz—700 MHz	730	200
700 MHz—790 MHz	1400	240
790 MHz—1 GHz	1400	240
1 GHz—2 GHz	5000	600
2 GHz—4 GHz	10000	950
4 GHz—6 GHz	7200	400
6 GHz—8 GHz	1100	700
8 GHz—12 GHz	10000	750
12 GHz—18 GHz	5700	680
18 GHz—40 GHz	3640	420

## 11.5 Military Strike Aircraft not Capable of Ship Operations

The environment is given in **Table 6**. See also **Clause 11.1.2** before applying this table.

**Table 6 Field Strength for Military Strike Aircraft not Capable of Ship Operation**

Frequency	Peak Field Strength (Vm <sup>-1</sup> )	Average Field Strength (Vm <sup>-1</sup> )
10 kHz – 100 kHz	50	50
100 kHz – 500 kHz	60	60
0.5 MHz – 2 MHz	70	70
2 MHz – 30 MHz	200	200
30 MHz – 70 MHz	50	50
70 MHz – 100 MHz	50	50
100 MHz – 200 MHz	100	100
200 MHz – 400 MHz	100	100
400 MHz – 700 MHz	730	80
700 MHz – 1 GHz	1400	240
1 GHz – 2 GHz	3300	380
2 GHz – 4 GHz	4500	850
4 GHz – 6 GHz	7200	300
6 GHz – 8 GHz	1100	350
8 GHz – 12 GHz	8800	540
12 GHz – 18 GHz	2300	680
18 GHz – 40 GHz	3600	420

## 12 Intentional Emitters – Sea Environment

For any new ship project, the external EM environment at relevant upper deck positions from own ship transmitters can be defined and determined using theoretical calculations, numerical modelling techniques and historical data. When equipment is to be fitted externally to an existing ship, the EM environment at the intended location should be determined with advice sought from the ship DT and the sponsor of this Standard. If a number of different platforms or locations are involved the generic information provided below should be used. For the below decks environment, account should be taken of the potential shielding provided by the hull / superstructure in the area of interest.

In addition, the generic EM environment caused by other ships in company can be determined using the information provided below. Where the EM environment for a specific scenario is required, additional advice should be sought.

The remaining content of this clause is generic information about the EM environments of current RN ships and ships in build.

## **12.1 Sea Environment – Above Decks**

The Above Decks environment on a naval platform can be stated as the area containing the exposed upper decks of the platform and a number of internal areas. These areas include the hangar, the bridge, any compartment with direct opening onto the exposed upper-deck, any compartment constructed of unshielded material (ie glass fibre) on a metallic ship and any compartment on a non-metallic ship that is not enclosed by an electromagnetic screen.

The radiated EM environment above decks on a ship is largely self-generated but systems with directional antennas on ships in company may dominate in some frequency bands. The main sources are the ship's own communications, radar and SATCOM systems. The strength and coverage of the emissions from some radar and SATCOM sources can be controlled to some extent by: sector control of transmissions / waveforms, use of blind arcs, physical blockage by RF screens or platform superstructure and synchronisation of transmitter pulses or antenna rotation. Additionally, for certain systems, it is possible to control the output power, prevent transmissions or control directivity by operational procedures or where phased arrays are being used by system design. However, owing to the unsynchronised use of most equipment a complete description of the environment becomes complex and unpredictable.

Due to the radio-frequency hazards (RADHAZ) to personnel posed by very high HF fields, the RN has conducted a measurement programme over many years. The magnitude of the electric and magnetic HF fields has been measured at points on a 1 m grid over large areas of the deck of many Royal Navy and Royal Fleet Auxiliary (RFA) ships, at a height of 1.5 m above the deck. The data has been used to derive a restricted frequency and power operating regime which minimises the affected area. More extensive hazard areas are implemented when the restrictions cannot be applied for operational reasons. The hazard areas are clearly marked and access to them is controlled. However, since these controls are for personnel safety and the areas are extensive many types of equipment will be sited within such areas.

In addition to the high fields present near HF transmitting antennas, metal structures (eg stanchions, ladders or davits) on the ship which are some distance away from the transmitting antennas can receive and re-radiate the transmitted power. This can produce a localised high field in the vicinity of the re-radiating structure. This effect is monitored during the surveys discussed above.

In order to classify the above decks ship environment it is convenient to consider different parts of the frequency range separately.

### **12.1.1 Below HF (10 kHz – 2 MHz)**

Following changes in the requirements for safety of life at sea (SOLAS), the RN no longer has any requirements for any major communications transmitters operating below 2 MHz on its ships or submarines. The EM environment for this Part of the spectrum can therefore be considered equal to the normal background/civil environment.

### **12.1.2 HF (2 MHz – 30 MHz)**

The HF transmissions can be high power typically 1 kW per transmitter and are a major source of EM energy. Wherever possible, the transmit antennas are located away from regular personnel routes and sited on top of superstructure blocks/decks or strung high between the masts. Despite this their impact upon the EM environment is one of the largest and most likely to be felt by other equipment particularly on non-metallic ships.

For HF fields the above deck areas can be considered as three zones: very close to a high power HF antenna (say < 4 m); outside this area but inside the RADHAZ area (defined as restricted area when there is no operational limit on power or frequency) and outside these areas.

- a) Very close to the antenna field strengths will be extremely high (exceeding  $1 \text{ kVm}^{-1}$ ) but will not be uniform or have the impedance of free space so a description in terms of an E-field is not meaningful. Normally equipment should be excluded from positions very close to HF antennas but where it is essential to mount equipment in these areas special precautions will be required and EMC proving will have to take place in-situ.
- b) Inside a RADHAZ zone (but at a distance > 4 m from an HF antenna) care must be taken if equipment is to be installed as electric field strengths in the HF band will be high. These fields will have high wave impedance and therefore care should be taken in designing relevant test methods. The boundary for the RADHAZ area is defined by the personnel hazard limits. The maximum field strength at these boundaries is defined in **Table 7** which defines a curve that changes between  $305 \text{ Vm}^{-1}$  and  $61 \text{ Vm}^{-1}$  over the frequency range 2 MHz to 10 MHz and is then constant at  $61 \text{ Vm}^{-1}$ . (Note that RADHAZ zones are considered to extend vertically above the deck with no height limit). The RADHAZ zones are also defined to protect personnel from high HF magnetic fields. The levels of magnetic field for defining the RADHAZ areas are shown in **Table 8**. The RADHAZ zones are determined such that neither the electric nor magnetic field strength levels are exceeded at their boundary. Clearly the closer an equipment is to the antenna the higher the field that is likely to be experienced.
- c) Outside the RADHAZ zone the fields will fall rapidly with distance. Except very close to re-radiating structures/wires, an equipment well away from the HF antenna (say > 15 m) will experience field strengths considerably less than the personnel limits and a general E field value of  $60 \text{ Vm}^{-1}$  across the band may be used.

Each ship will have drawings showing the HF RADHAZ boundaries and where equipment siting is known these drawings should be consulted to determine the zone applicable.

**Table 7 HF Electric Field Strength Levels for RN Above Decks Personnel Boundary**

Frequency	Maximum (rms) Field Strength ( $\text{Vm}^{-1}$ )
2 MHz – 10 MHz	$610 / \text{Frequency in MHz}$
10 MHz – 30 MHz	61

**Table 8 HF Magnetic Field Strength Levels for RN Above-Decks Personnel Boundaries**

Frequency	Maximum (rms) Field Strength ( $\text{Vm}^{-1}$ )
2 MHz – 10 MHz	$1.6 / \text{Frequency in MHz}$
10 MHz – 30 MHz	0.61

It should be noted that the commercial maritime standard IEC 60945 uses an above decks immunity testing level of  $30 \text{ Vm}^{-1}$  for the frequency range 1.5 MHz – 30 MHz although commercial transmitters generally have much lower power outputs than RN systems.

Portable or vehicle mounted radios used by embarked forces may dominate the levels in the HF, VHF and UHF ranges at a number of positions around a ship. Field strengths from such systems are discussed in **Clause 13**.

### 12.1.3 VHF/UHF (30 MHz – 450 MHz)

The RN operates a large number of transmitters in the VHF/UHF region. Most of these are relatively low power transmitters and have the fixed antennas sited on yardarms or the bridge roof. The personnel RADHAZ boundary limits are set very close to these antennas. However, the fields from these antennas can have a detrimental effect on other equipment, as typical intermediate frequencies are in this range. Should equipment have to be sited in close proximity to these antennas, then the fields can be predicted using numerical modelling. At distances away from these antennas (approximately > 10 m), a generic field strength of  $10 \text{ Vm}^{-1}$  may be assumed.

Other sources of radiated EM energy in this frequency range include mobile transportable and portable radios used by land / sea service personnel. These may include types of the Bowman Radio described in **Clause 13.1**. At 1 m distance the electric field strengths from a man-pack radio in this frequency range generally do not exceed  $50 \text{ Vm}^{-1}$  and those from a typical handheld radio do not exceed  $10 \text{ Vm}^{-1}$ .

On amphibious ships that carry land service vehicles, the vehicle mounted transmitters will contribute significantly to the EM environment in the HF, VHF and UHF frequency ranges.

### 12.1.4 UHF (450 MHz – 2200 MHz)

There are currently no significant fixed RN ship transmitters in this Part of the RF spectrum. However, small personal transmitters (mobile phones, mobile radios etc) may be present and hence may dominate the EM environment in this frequency range. The electric field strength at 1 m distance from a hand-set typically does not exceed  $20 \text{ Vm}^{-1}$ . The discussion on fields from mobile cellular telephones in **Clause 13.2.3** is also applicable to the sea service environment in this frequency range.

### 12.1.5 Microwave Transmitters

The principal microwave transmitters on a naval platform are radars, missile trackers and SATCOM terminals. These systems generally produce very high power directional microwave beams, which present a significant RADHAZ to approaching helicopters, personnel, fuels and ordnance. Due to the RADHAZ problems, some microwave antennas are prevented from illuminating parts of the platform superstructure or deck through the use of sector transmission arcs, ship's operating procedures and antenna blind arcs / safety cams. The average main beam field strengths generated by in-service naval microwave transmitters for a range of distances can be found by consulting the technical data in BR2924 Vol 2. For new to service equipment, theoretical predictions and/or measurements need to be made. In case of technical queries and specific problems, advice should be sought from the relevant MOD Equipment or Platform Project.

Since many areas of the upper deck will not be directly illuminated by a ship's own microwave transmitters it is possible that the high power microwave transmitters on a platform in consort will present a greater threat. In general, when RN platforms are in a task force, some microwave transmitters are restricted from illuminating other platforms, principally to reduce RADHAZ risks to fuels and ordnance. Information on RADHAZ restrictions on transmitters in a task force is contained in BR2924.

### 12.1.6 Typical Sea Service Electromagnetic Environments

The EM environments given in this clause are derived from technical data on in-service RN transmitters. Three different sets of assumptions have been used to generate the environments shown in **Table 9**, **Table 10** and **Table 11**.

The EM environment has been expressed as, an electric field strength.

**NOTE** The H-field cannot necessarily be calculated from  $E/377\Omega$  since for some RN radars the far field distance will be greater than 100 m from the transmitter. Also above 1 GHz where the calculated environment was below  $10 \text{ Vm}^{-1}$ , average and  $200 \text{ Vm}^{-1}$  peak a baseline at these levels has been assumed as a realistic minimum cut-off.

In **Table 9** the environment is based on all current naval ship and aircraft transmitters. The fields have been estimated at a distance which may be taken as typical for relativity close approach by UK consorts when no RADHAZ controls are observed and also when direct illumination by tracker and SATCOM systems is

avoided (limited RADHAZ controls column). The peak field strength values above  $200 \text{ Vm}^{-1}$  in column 4 have not been fully reflected into the generic upper deck radiated susceptibility test levels of DRS02.B shown in **Part 3** of this Standard as it is considered that the frequency of occurrence of these levels will be low and additional RADHAZ precautions will normally be taken. However, systems with receivers connected to antennas should be protected against the levels shown to ensure they are not damaged.

**Table 9 Environment from Consort Ship Transmitters**

Frequency	No RADHAZ Controls		With LIMITED RADHAZ Controls	
	Peak Field Strength ( $\text{Vm}^{-1}$ )	Average Field Strength ( $\text{Vm}^{-1}$ )	Peak Field Strength ( $\text{Vm}^{-1}$ )	Average Field Strength ( $\text{Vm}^{-1}$ )
400 MHz – 700 MHz	30	30	30	30
700 MHz – 1 GHz	30	30	30	30
1 GHz – 2 GHz	500	125	500	125
2 GHz – 4 GHz	1200	300	1200	300
4 GHz – 6 GHz	200	30	200	30
6 GHz – 8 GHz	200	120	200	30
8 GHz – 12 GHz	4000	250	200	30
12 GHz – 18 GHz	800	400	200	30
18 GHz – 40 GHz	1300	30	200	30

**NOTE** Over the frequency bands above 1 GHz some NATO partner ship transmitters are capable of producing higher field strengths than shown in **Table 9**. Additional controls such as those detailed in BR2924 may need to be implemented to prevent some systems being upset unless additional hardening is undertaken.

In **Table 10** the environment is based on all current UK naval ship radar transmitters. The fields have been estimated for a distance from the antenna that represents the potential effect of equipment being illuminated close in by the antenna main beam. It should be noted that most radars, etc are mounted on the top of masts and/or mast sponsons and yardarms, which means that most of the superstructure/deck areas are not illuminated by these fields. It should also be noted that this includes all ship mounted systems but they are not in practice all on a single ship and the levels shown will not all exist at any one place (even for all radars on a single ship). The default levels for DRS02.B shown in **Part 3** of this Standard are therefore not based on these levels but rather on the consort distance levels as discussed above. The table therefore provides a guide to the levels which could be experienced in some frequency bands by equipments sited on masts where no sector blanking takes place.

On the majority of the upper decks of ships, where areas will not be illuminated by the main beam, the field from the ship's own microwave transmitters will be caused by reflections, refractions and sidelobes. Very localised maximum levels across the microwave band may reach  $50 \text{ V/m}$  (average) but higher levels may exist on some decks where radars are not sited high on masts. The generic level of  $200 \text{ V/m}$  (peak) in DRS02.B is considered adequate for own ship threats unless equipment is sited in the antenna main beam.

**Table 10 EM Environment from all Ship Radar Transmitters in Main Beam**

Frequency	Peak Field Strength ( $Vm^{-1}$ )	Average Field Strength ( $Vm^{-1}$ )
400 MHz—700 MHz	30	30
700 MHz—1 GHz	30	30
1 GHz—2 GHz	2500	600
2 GHz—4 GHz	10000	950
4 GHz—6 GHz	200	30
6 GHz—8 GHz	750	750
8 GHz—12 GHz	10000	750
12 GHz—18 GHz	5700	680
18 GHz—40 GHz	3640	120

In **Table 11** the environment is based on all UK naval ship search and surveillance radars. The fields were calculated for a scenario which might occur during a Replenishment At Sea (RAS) operation where deliberate illumination by other systems is avoided but surveillance radars are left running at full power.

**Table 11 EM Environment for Replenishment At Sea**

Frequency	Peak Field Strength ( $Vm^{-1}$ )	Average Field Strength ( $Vm^{-1}$ )
400 MHz – 700 MHz	30	30
700 MHz – 1 GHz	30	30
1 GHz – 2 GHz	1400	370
2 GHz – 4 GHz	3600	850
4 GHz – 6 GHz	200	30
6 GHz – 8 GHz	200	30
8 GHz – 12 GHz	550	100
12 GHz – 18 GHz	500	50
18 GHz – 40 GHz	200	30

As discussed above for the consort ship environment some of these levels are considerably above the general clearance level set for DRS02.B in **Part 3** of this Standard – since additional RADHAZ precautions will normally be taken in accordance with BR2924 and only the highest part of the ship is likely to be illuminated by the relevant systems. However, consideration should be given to the protection from damage of receiver front ends to the levels shown here.

## 12.2 Sea Environment – Below Deck

The naval below decks environment is difficult to characterise and no significant work has been performed to date in truly defining the EM environment. For equipment areas inside a metal hull, it has largely been assumed that the metal will provide good attenuation to the external Above Decks EM Environment, and figures of up to 60 dB have been quoted. In most cases, the internal below decks environment is self-generated by emissions from the enclosed equipment. This had led to a radiated susceptibility test level of  $1 \text{ Vm}^{-1}$  in previous versions of **Part 3** of this Standard. However, there are a number of equipments that can raise this level, including arc welders, mobile phones, hand held radios and electrical generators. These items can generate local field strengths of up to  $10 \text{ Vm}^{-1}$  at 1 metre distance and much greater levels closer to the antenna of a mobile transmitter.

A short study was conducted in trying to define the internal field strength for a metal-hulled naval platform, using all available naval references. This study concluded that the average field strength based on these measurements was less than  $1 \text{ Vm}^{-1}$  and the level that covered 90% of all the measurements was  $1 \text{ Vm}^{-1}$ . However, the study did not include mobile transmitters. In summary, the maximum below decks fields can be assumed to be  $10 \text{ Vm}^{-1}$  except where mobile radios are to be used in close proximity (< 1 m).

For naval platforms using composite materials (eg Fibre Reinforced Plastic) for their hull structure or areas of the superstructure or alternatively areas containing large amounts of glass (eg Bridge), the Above Decks EM environment will have a direct impact on the below decks environment. This is due to the lack of screening provided by composite material, which would give at best only 1 or 2 dB attenuation. It is possible to provide some screening to the composite material through the inclusion of metallic or carbon materials into the composite. Alternatively, the inside can be screened by using metallic / conducting sprays or cloths. However, in all cases, the typical amount of screening protection offered is less than that of metallic materials required to provide the same structure. For such ships therefore the below decks environment is considered to be the same as the above decks.

## 13 Intentional Emitters – Land Environment

### 13.1 Transmitting Radios

The most common military radiated EM threats to materiel in the land environment are radio transmitters including Electronic Counter Measures (ECM), BOWMAN, etc.

BOWMAN operates in the HF band (1.6 MHz – 30 MHz), VHF band (30 MHz – 88 MHz) and UHF (225 MHz – 450 MHz). The transmitter powers vary between different types of radio which can be either manpacks (that can also be installed on board vehicles), or vehicle only units that can also be fitted to aircraft and ships. Temporary tented and permanent fixed installations are also used. The Personal Role Radio (PRR) operates at only very low power at a frequency of 2.4 GHz.

The field strengths generated by earlier radio systems were historically calculated using far field assumptions since there was little detailed experience of how to predict the near field of such antennas. However during the fit of BOWMAN systems considerable measurements have been made of the field strength produced at various distances. The likely maximum field strengths from these radios taken from a range of vehicles have therefore been characterised.

There are also numerous other military and civil transmitters which will contribute to the EM environment seen by land systems. Where data is available military transmitters have been allowed for in the levels given in the following tables. However, the fields produced by civilian systems should not exceed the personnel RADHAZ limits unless the transmit antenna has to be closely approached. In establishing the levels in the following tables therefore an assumption has been made that the current ICNIRP Occupational limit will not be exceeded for such systems. Where, however, equipment is known to be sited within the RADHAZ boundary of a transmit antenna it will be necessary for the level to be increased within that band.

Above approximately 30 MHz, for distances of a few metres from the transmitting antenna, the wave structure has  $377 \Omega$  radiated wave impedance. Hence an electric field environment implies a magnetic field environment as well. Below 30 MHz, for distances of a few metres from the transmitting antenna, the wave

structure close to the antenna does not have  $377 \Omega$  wave impedance. The transmitting antennas used in the land service are generally electric field antenna and hence the near field wave impedance will be higher than  $377 \Omega$ . The effect of these fields on electronic apparatus is not well known and there are no established laboratory test methods. Hence these field strengths should not be directly used with standard EMC test methods without appropriate validation and it is probable that at HF frequencies an installed test as well as a laboratory test will be necessary.

## 13.2 Typical Land Service Electromagnetic Environments

For new equipment projects an EMC scenario, which takes account of all transmitters expected to be in the area, should be generated. Equally, the new equipment may fall into one of the generic scenarios in this Standard.

The scenario will be especially important for systems that will be deployed close to non-standard systems.

Equipment suppliers should demonstrate compliance with the parameters identified in the agreed scenario. Advice on this matter may be sought from DE&S DE3A.

Some typical land service EMC environments, including the assumptions used, are given in the following clauses.

### 13.2.1 General Assumptions

The environments were calculated from a list of Army transmitters and RAF radios.

Above 100 MHz, the environment has been calculated using far field assumptions. Measured data has been used for lower frequencies.

### 13.2.2 Front Line and Operational Support Equipment

This environment is intended to cover equipment that would be taken into the battlefield and used with minimum restrictions as far as co-location of equipments is concerned. Examples of equipments that would fall into this scenario are those mounted externally on a fighting / engineering vehicles, or those carried outside or in unshielded trucks / utility / logistic vehicles. The levels in **Table 12** assume the equipment may be sited close to a vehicle mounted antenna (own or adjacent vehicle) with no shielding from bodywork etc. Not many equipment(s) will be within this volume and the fields will not be uniform. For these reasons the Class A limits used in the DRS02.B test in **Part 3** of this Standard do not fully reflect these very high levels. Where equipment is known to be sited in direct line of sight and closer than approximately 2 m from a vehicle mounted antenna further advice should be sought and in situ testing in addition to laboratory testing will be essential. It should also be borne in mind that re-radiation from resonant structures close to an antenna may produce local fields of a value as high as those from the antenna itself. These have not been allowed for in the table since they are very installation dependent. Again in situ tests will be required to ensure such re-radiation does not cause a problem.

Above 1 GHz the number of transmitters deployed on the battlefield with significant power output is limited and they generally have highly directional antennas for which RADHAZ controls are implemented. A generic level of 200 V/m peak and 60 V/m average is therefore considered sufficient to cover these frequencies. Any equipment sited or needing to work close to a known microwave emitter should have that situation separately assessed. Equipment designed for use in mobile and fixed command centres or alongside long range radio transmitters (eg HF or troposcatter stations) may see higher levels in the frequency bands in which those transmitters operate. Special account should be taken for these cases.

Mobile telephones are excluded from these calculations, but the fields that they create are discussed in **Clause 13.2.3**.

The calculated EM environment for these assumptions is shown in **Table 12**.

**Table 12 Front Line and Operational Support Equipment Field Strength**

Frequency	Peak Field Strength ( $\text{Vm}^{-1}$ )	Average Field Strength ( $\text{Vm}^{-1}$ )
10 kHz – 100 kHz	10	10
100 kHz – 500 kHz	10	10
500 kHz – 1.6 MHz	10	10
1.6 MHz – 5 MHz	560 <sup>a</sup>	560 <sup>a</sup>
5 MHz – 10 MHz	380 <sup>a</sup>	380 <sup>a</sup>
10 MHz – 30 MHz	200 <sup>a</sup>	200 <sup>a</sup>
30 MHz – 100 MHz	200	200
100 MHz – 200 MHz	60	60
200 MHz – 700 MHz	70	70
700 MHz – 1 GHz	60	60
1 GHz – 40 GHz	200	60

<sup>a</sup> For fields between 1.6 MHz and 30 MHz, refer to **Clauses 13.1 & 13.2.2.**

### 13.2.3 Man Portable / Man Carried Equipment

This environment is typical of small items with no restrictions on use. Examples of equipment that would fall into this scenario are man carried radios, ECM, search tools, navigation equipment and training equipment. It is considered that the environment for such equipments will be the same as for vehicles with the exception that manpack radios will produce fields which will affect both, equipment on the man carrying the radio and on adjacent personnel.

The levels in **Table 13** have been derived taking account of relevant vehicle mounted radios and the fields produced by manpack radios. In other frequency bands the same levels as in **Table 12** should be used.

Mobile cellular telephones are often used very close to man portable equipment without any precautions. At this proximity the EM energy from mobile telephones can become quite significant. However they have not been included when calculating the EM environments in this section. The fields close to a mobile phone are likely to be highly dependent on the phone type and its interaction with the user so detailed investigation of this threat is needed to ensure that it is fully characterised. It is possible to estimate typical field strengths near to a mobile phone using the following assumptions and standard RF theory. The frequencies of operation of mobile phones in the majority of the world<sup>2)</sup> is 800 MHz to 1 GHz and 1.7 GHz to 2.2 GHz. Assuming that the maximum transmitted power of the handset is 2 W and the antenna gain is 1.5 (dipole) then the electric field strength at 1 m would be  $9.5 \text{ Vm}^{-1}$  and the field strength at 0.5 m would be  $19 \text{ Vm}^{-1}$ .

<sup>2</sup> Japan also has systems that operate in the range 1.429 – 1.453 GHz

**Table 13 Man Portable / Man Carried Equipment Field Strength**

Frequency	Peak Field Strength ( $Vm^{-1}$ )	Average Field Strength ( $Vm^{-1}$ )
1.6 MHz – 5 MHz	380	380
5 MHz – 10 MHz	300	300
10 MHz – 30 MHz	200	200
30 MHz – 100 MHz	80	80

#### 13.2.4 Training, Test and Office Equipment

There are a number of equipments purchased for military use and installed in office type environments. These may or may not be on a site that contains military transmitters. In general a survey of such sites should be carried out to determine what the environment will be this will require measurements in some cases. If the survey shows that no military or high power transmitters are in the vicinity then it will normally be sufficient to use an appropriate EN Standard for the equipment. However if there are military transmitters on the site or if the equipment is mobile and will be used alongside military systems, then the RF environment will need to be quantified (possibly using one of the earlier scenarios). A scenario which may be typical for some training equipments (excluding any used on front line platforms) is given in **Table 14**. (Note that both the frequency range and level of this environment are more severe than is required for COTS office equipment).

Mobile telephones are excluded from these calculations, but the fields that they create are discussed in **Clause 13.2.3**. A baseline level of 10 V/m average and 50 V/m peak (above 1 GHz) has been applied to this environment.

**Table 14 Training, Test and Office Equipment Field Strength**

Frequency	Peak Field Strength (Vm <sup>-1</sup> )	Average Field Strength (Vm <sup>-1</sup> )
10 kHz – 100 kHz	10	10
100 kHz – 500 kHz	10	10
500 kHz – 1.6 MHz	10	10
1.6 MHz – 5 MHz	40	40
5 MHz – 30 MHz	25	25
30 MHz – 100 MHz	20	20
100 MHz – 200 MHz	10	10
200 MHz – 700 MHz	10	10
700 MHz – 1 GHz	10	10
1 GHz – 2 GHz	50	10
2 GHz – 4 GHz	50	10
4 GHz – 6 GHz	50	20
6 GHz – 8 GHz	50	35
8 GHz – 12 GHz	50	35
12 GHz – 18 GHz	50	10
18 GHz – 40 GHz	50	10
NOTE For fields between 1.6 MHz and 30 MHz, refer to <b>Clause 13.1</b> .		

## 14 Intentional Emitters – Ordnance Environment

EM fields pose a hazard to ordnance systems. The main design problem is to ensure that EM radiation does not cause Electro Explosive Devices (EEDs) to malfunction.

The design EM environment for ordnance has been assessed and developed based on the systems used throughout the UK military services, the resulting figures are published in Def Stan 59-114 Part 1, Table H.1 and is termed the Minimum Service RF Environment. This gives a single table for all 3 services since it is considered likely that any ordnance system will be carried by ship or air at some time in its life. It is applicable to ordnance, munitions and explosives which contain EEDs in their storage and transport configuration. It is to be used as a design environment against which items containing EEDs must be shown to be immune when unpowered.

Ordnance systems are also required to operate satisfactorily and safely in the EM environment in which they will be powered. These environments will generally be the same as for the service platform on which they operate and so will be less severe than the Minimum Service RF Environment. However, where, for example, a vertical launch missile is used its flight profile may mean it has to survive a considerably higher

EM environment immediately after launch. These aspects will need to be considered on a case by case basis and more discussion is provided in Def Stan 59-114.

For the related design requirements for weapons see Defence Standard 07-85 Part 1.

## **15 Test Environment Description**

### **15.1 Test Environments**

In order to test the EMC of a system, the ideal situation would be to replicate the most severe transmitters and subject the system to the resulting EM environment. This is, in practice, very costly, and the test environment used differs in some respects from the threat environment. The principle that should be used if possible is to make the test EM environment resemble the threat EM environment as closely as possible. **Part 3** of this Standard gives default limits for each service which generally reflect the levels discussed here. Each project, however, should assess the scenario in which equipment is to be used and should tailor limits (up or down) as necessary.

### **15.2 Combined or Integrated Test Environments**

The aim of "Integrated Hardening" for EMC is to devise a testing strategy where systems can be tested for EMC susceptibility by the application of as few tests as possible.

It is widely acknowledged that at least two types of test are needed for susceptibility – one frequency domain test and one time domain test.

The work done to research Integrated Hardening looked at the feasibility of combining all the time domain tests into a single pulse test. A drawback of this approach is that the derived waveform must over-test a system for all of the individual waveform characteristics to be combined. Depending on the level of over-testing, a system may be made uneconomically hard. Also the production of a generator for this purpose is very costly and a cost effective design has not been reached. The problems mean that currently individual tests for each time domain threat remain the normal way of qualifying equipments and systems. If a project wishes to undertake combined testing then further advice should be sought.

For frequency domain threats it is clearly much simpler to derive a maximum threat level for each relevant frequency band and use this to determine the test level to be applied. Considerable care is still needed though when deciding the parameters relevant to a peak pulsed field.

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