ENGINEERING PRACTICE STUDY

March 2, 2001

Results Of Detailed Comparisons Of Individual EMC Requirements And Test Procedures Delineated In Major National And International Commercial Standards With Military Standard MIL-STD-461E

Study Conducted By:

DoD/Industry Electromagnetic
Environmental Effects Standards Committee
(Chaired by DISA/Joint Spectrum Center and
American Standards Committee C63 on EMC)

FOREWORD

1. This Engineering Practice Study (EPS) provides results of detailed comparisons of individual EMC requirements and test procedures delineated in major national and international commercial standards with military standard MIL-STD-461E. Differences in limits, frequency ranges, and test procedures are identified and their potential significance is discussed. Guidance is provided on judging the acceptability of a particular commercial standard for a specific military application.

2. This EPS is for informational purposes only and is not contractually binding.

3. This EPS was prepared by the DOD/Industry Electromagnetic Environmental Effects (E3) Standards Committee (DIESC). Industry representation included SAE, ANSI, EIA, IEEE, NEMA, and others as requested by ANSI. DoD representation included Joint Spectrum Center, Army, Air Force, Navy, and DTRA. Liaison Government agencies included NATO. The DIESC effort was co-chaired by the ASC C63 Committee on EMC and the DISA/Joint Spectrum Center.

4. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Joint Spectrum Center, Attn: JSC/J52, 2004 Turbot Landing, Annapolis, MD 21402-5604, by using the self-addressed standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1. INTRODUCTION

1.1 Purpose. On June 29, 1994, the Secretary of Defense issued a directive requiring the military to use performance-based requirements in procurements and to apply commercial specifications and standards whenever possible. This guide is intended to aid personnel who procure hardware for the military to assess the suitability of using equipment qualified to commercial electromagnetic interference (EMI)/electromagnetic compatibility (EMC) standards in specific military applications. This document supports Department of Defense efforts to use commercial items as addressed in DoD 5000.2-R and SD-2.

1.2 Scope. This document provides the results of detailed comparisons of individual requirements and test methods in MIL-STD-461E with available commercial standards that are the most similar. Differences in limits and test methodology are identified and their potential significance is discussed. Guidance is provided on judging the acceptability of a particular commercial standard for a specific application. Detailed lists of various standards associated with the EMI/EMC areas are included as reference material in appendix B.

1.3 Use. Information is provided at several levels of detail. There is some high-level information, which can be considered as general guidance material for personnel with a cursory understanding of EMI requirements. Ideally, it would be desirable to be able to make simple, direct statements on the equivalence of particular commercial standards with military counterparts. However, comparisons are often not straightforward (see Table 5.1 which shows a high-level comparison matrix of commercial and military requirements), and it is usually not possible to make statements that a particular commercial standard is a universal replacement. Subjective judgment is necessary for particular applications. Therefore, summary descriptions explaining the basis for the information in Table 5.1 are given in Section 6 of this document. More detailed discussions oriented towards personnel who have specialized knowledge in EMI requirements and testing and who have the skills necessary to apply the guide to the circumstances of specific procurements are presented in Annex A. Finally, Annex B1 gives lists of relevant military and commercial standards and B2 provides an annotated classification of these standards.

2. REFERENCED DOCUMENTS

2.1 Commercial

ANSI

C63.4 American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

C63.12 American National Standard for Recommended Practice for Electromagnetic Compatibility Limits.

C63.14 American National Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP),

	and Electrostatic Discharge (ESD) (Dictionary of EMC/EMP/ESD Terms and Definitions)
IEC	(See list of IEC and CISPR Publications in Annex B.1)

European Union

73/23/EEC	Low Voltage Directive
93/68/EEC	Low Voltage Directive
89/336/EEC	Electromagnetic Compatibility Directive

RTCA

DO-160D	Environmental Conditions and Test Procedures for Airborne Equipment

2.2 Military

DoD 5000.2-R	Mandatory Procedures for Major Defense Acquisition Programs (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs
JAN-I-225	Interference Measurement, Radio, Methods of, 150 Kilocycles to 20 Megacycles (For Components and Complete Assemblies)
MIL-I-6181	Interference Limits and Tests; Aircraft Electrical and Electronic Equipment
MIL-STD-461E	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
SD-2	Buying Commercial & Nondevelopmental Items: A Handbook

3. DEFINITIONS AND ACRONYMS

3.1 Definitions. Definitions used in this document are in accordance with ANS C63.14 (available from IEEE Standards Association, 645 Hoes Lane Piscataway, NJ 08855-1331, USA) and JCS Pub 1-02.

3.2 Acronyms A complete list of acronyms is included in Annex C.

4. CONCEPTS

4.1 Rationale for Requirements. The motivation behind the development of military and commercial requirements is similar. Both are concerned with controlling emissions from equipment that may couple to electronics with very sensitive interfaces (particularly antenna ports) and with providing adequate immunity of other electronic equipment to similar electromagnetic disturbances present in the environment such as EM emissions (both intended and unintended), electrical transients, and power line voltage distortions. The main distinction between the military and commercial requirements occurs on platforms, in particular ships, aircraft and tanks. Typically, these platforms have a heavy concentration of equipment including high power transmitters and sensitive receivers. Submarines have special requirements because of their extensive use of sonar and ELF/VLF communications.

4.2 Evolution of Requirements

4.2.1 Military. The military first established EMI emission requirements for equipment in 1945 with the issuance of JAN-I-225. Conducted and radiated measurements were imposed over the frequency range of 0.15 to 20 MHz. The first susceptibility requirement (expressed in terms of immunity in most commercial standards) was introduced in 1950 in MIL-I-6181 as a radio frequency (RF) pin injection drive on electrical interfaces. As electronics became more sophisticated and applications more widespread, the requirements evolved and expanded significantly over time. A variety of documents were issued with frequency ranges for emission requirements becoming broader and an ever increasing emphasis on various types of susceptibility requirements. In 1967 many of these documents were consolidated with the issuance of MIL-STD-461 and MIL-STD-462. In the latest version, the two documents have been merged into one, MIL-STD-461E.

4.2.2 Commercial. The Federal Communications Commission (FCC) has imposed requirements in the United States (US) for many years on radiated characteristics from equipment antennas. Requirements on more general types of electronics were first introduced by the FCC in 1979 for "computing devices" in the Code of Federal Regulations (CFR) 47, Docket 20780. The requirements used today are essentially the same and are limited to conducted emissions on AC power interfaces and radiated emissions. The FCC does not yet mandate immunity requirements for general electronics. Significant changes are occurring in the commercial world because of the EMC Directive, 89/336/EEC, issued by the European Union which became effective on January 1, 1996. This directive requires equipment sold in Europe to meet both emission and immunity requirements. US manufacturers who wish to sell their products in Europe must meet these requirements. This situation has prompted greater interest in the US in establishing voluntary immunity requirements on equipment, in general. In the comprehensive list of EMC standards given in Annex B, Annex B1 lists standards according to the sponsoring organization. Annex B2 is an annotated list of standards (both commercial and military) organized by type – definition, environment, basic, generic, and product.

4.3 Summary of Relevant EMC/EMI Standards. Differences between the ways requirements are specified and test methodology as implemented in the military and commercial standards presents challenges in making comparisons. These differences are treated in detail in the body of the guide. A summary of some of the aspects of various standards is presented below.

4.3.1 Military. MIL-STD-461E specifies requirements and limits based on issues such as platform types (surfaces ships, aircraft, etc.), location (internal or external to structure), and unique platform features (anti-submarine warfare capability). Although tailoring of the requirements is encouraged for individual procurements, MIL-STD-461E is structured to provide a reasonable set of default requirements if tailoring is not specified. It also provides standardized test methodology, which is consistent among the various requirements. There are setup conditions which are common to all the tests such as ground plane usage, electrical cable construction and routing, and powerline treatment.

4.3.2 Commercial. There are a variety of commercial standards which are considered in this guide. The most predominant are those set by the European Community. Others are Federal Communication Commission (FCC) regulations and Radio Technical Commission for Aeronautics (RTCA) DO-160D, and the American National Standards Institute (ANSI).

4.3.2.1 International Standards. The most significant standards have been written in the International Electrotechnical Commission (IEC), the International Special committee on Radio Interference (CISPR), an organization affiliated with the IEC, and the International Organization for Standardization (ISO). CISPR standards primarily limit emissions, both conducted and radiated from all devices, classified in various ways, capable of causing interference to radio and television and other radio services, whereas IEC TC 77 is concerned with emissions below 9 kHz and prepares basic immunity measurement techniques over the entire frequency range. In addition, various IEC technical committees concerned with specific products prepare EMC standards for these products. Similarly, ISO technical committees prepare EMC standards. Examples are TC 20, on aircraft, and TC 22, on motor vehicles.

4.3.2.1.1 European Union. The European Union EMC efforts are extensive and complicated. The EMC Directive specifies general requirements that apparatus be constructed such that: a) "the electromagnetic disturbance it generates does not exceed a level allowing radio and telecommunications equipment and other apparatus to operate as intended" and b) "the apparatus has an adequate level of intrinsic immunity of electromagnetic disturbances to enable it to operate as intended." The European Committee for Electrotechnical Standardization (CENELEC) is largely responsible for approving detailed standards which are acceptable for demonstrating compliance with the EMC Directive. Most, but not all, CENELEC approved standards are identical to or contain only minor deviations from those developed by the IEC and CISPR. All of the European documents discussed in this guide are either IEC or CISPR standards. All are not yet adopted by CENELEC. Immunity test procedures covered in so-called basic IEC standards tend to be written in a fashion to allow flexibility in applying them depending on the particular application. Also, a range of suggested limits is generally given. The manufacturer or some other authority must specify a particular level for certification. Another characteristic of these documents is that each tends to stand alone regarding test methodology. They do not have the consistency among setups specified in the military standards.

4.3.2.1.2 CE Mark. Products sold in Europe must comply with a number of European Union directives and contain the CE mark as an indication of compliance. For electronic products, this mark indicates compliance with both the Low Voltage Directive (73/23/EEC, 93/68/EEC), which addresses electrical safety, and the EMC Directive. The following discussion concentrates on aspects of the EMC Directive. There are a several routes that can be followed for compliance. One approach is a self declaration where the manufacturer issues a "Declaration of Conformity" that the product complies without third party participation. This declaration should be available upon request and must list the specifications used to demonstrate compliance. The alternative is to produce a "technical construction file (TCF)" containing the details of the methods on complying with the EMC Directive and submit it to a "Competent Body" for approval. The self declaration is apparently the most common route for items that clearly fall under a particular generic or product standard (as described below) while the TCF is more commonly used where more complicated conditions exist. The self declaration is more risky for the manufacturer in the event that compliance is challenged. The CE mark indicates that a decision has been made by someone that the equipment meets the broad intent of the wording EMC Directive. It does not necessarily indicate what specific tests have been performed or what specific limits have been met.

4.3.2.1.3 Generic Standards. IEC has issued four generic standards IEC 61000-6-1, 2, 3, and 4, which specify emission and immunity requirements for two classes of equipment: “industrial” or “residential, commercial, and light industrial.” The generic standards are available to be used when a “product” standard which addresses the particular item does not exist. The generic standards list the individual test standards (generally, IEC and CISPR documents) that are applicable and the limits that apply.

4.3.2.1.4 Product Standards. Product standards are produced by product committees who determine what requirements must be applied for a particular product or product family to meet the intent of the EMC Directive. These committees review the application of the product and the expected environments where the product is expected to be used to determine the appropriate requirements. The selected requirements will be generally be derived from the IEC and CISPR standards.

4.3.2.2 National Standards. Emissions in the radio frequency range are controlled in the United States by the Federal Communications Commission. Emissions below 9 kHz and immunity of various equipment are controlled by a variety of “voluntary” standards.

4.3.2.2.1 FCC. For certain types of non-transmitting electronics, most notably computers, the FCC has issued requirements presently contained in CFR 47, Part 15 (similar to CISPR 22). The requirements are limited to conducted emissions on commercial AC power lines and radiated emissions. There are two sets of limits, one for residential areas and a second for industrial areas. Separate FCC requirements in CFR 47, Part 18 (similar to CISPR 11), are applicable to industrial, scientific, and medical (ISM) equipment which intentionally uses RF energy in its basic operation. Requirements for Part 18 are limited to radiated emission controls which are dependent on the characteristics of the RF source.

4.3.2.2.2 ANSI. Test methodology for certifying equipment as meeting requirements in CFR 47 part 15 is provided in American National Standard (ANS) C63.4, prepared by American National Standards Committee C63. In addition, ANS C63.12 Standard of Electromagnetic Compatibility Practice – Recommended Limits, contains guidance in selecting immunity for three classes of equipment – residential, industrial, and those in severe environments, other C63 standards cover instrumentation, antenna and site calibration and other related topics.

4.3.2.2.3 RTCA DO-160D. DO-160D is used by the commercial airline industry to qualify equipment as part of Federal Aviation Administration certification of aircraft. Among commercial standards, DO-160D is the most similar to MIL-STD-461E. The test methodology addresses many issues important in MIL-STD-461E including ground planes, electrical cabling, and consistency among setups. DO-160D provides a number of different categories to which equipment can be certified depending on the type of equipment, its installation location, and the desires of the equipment and aircraft manufacturers.

4.3.2.2.4 Other Commercial Standards. There are many standards covering specialized topics produced under the auspices of various professional and trade organizations, such as IEEE, NEMA, EIA, CEMA, and SAE. Because of their specialized nature, there are not specifically referred in this document. However, the user of the document should be alert to the possibility that they may have been applied in the development of a particular item to be used in military applications. The reader may note that the content of this document may be of assistance in evaluating such items because of similarities in test procedures and limits in standards discussed in detail herein. As an example, we note that fourteen SAE J1113 series standards covering motor vehicles were screened for homogeneity to requirements and test methods specified in MIL-STD-461E counterpart test methods. None of these can be accepted as replacements for the MIL-STD-461E without modification of some performance parameter.

4.3.3 Differences Between Commercial and Military Standards. For orientation purposes we itemize below the most significant differences between commercial and military standards.

a) Requirements in the VLF range for submarines are unique because of critical dependence on the reception of sonar and VLF electromagnetic signals.

b) There is a high concentration of electronic equipment aboard ships and other military platforms including emitters and sensitive receivers. For this reason, military radiated emission limits are more severe than corresponding commercial limits. The military also places high immunity requirements on devices exposed to nearby intentional emitters.

c) The general availability of grounded conducting surfaces (ground planes) for mounting equipment on military platforms. Most commercial equipment (when it is light in weight or portable) is mounted on an ungrounded table top. However, this difference is not pervasive, e.g. floor mounted commercial equipment is frequently bonded to a ground plane.

d) Some frequency ranges are more extensive in military requirements than they are in commercial requirements, hence if an equipment is tested to meet commercial requirements, additional testing may be needed for military use.

These differences make it impossible to find commercial qualified equipment that is completely equivalent to one meeting military requirements. This means that a detailed analysis is required to determine the adequacy of equipment tested to commercial requirements to meet the requirements of a particular military environment.

5. SELECTION OF COMMERCIAL ITEMS FOR MILITARY USE.

In selecting commercial items (CI) for military purposes one must relate the characteristics of the anticipated electromagnetic environment (EME) to the characteristics of the equipment under consideration. In order to determine whether a CI is adequate for a particular military application, it is necessary to determine which commercial standards are applicable to the equipment, evaluate whether the commercial standards are adequate for the intended applications, and if not, to determine which additional requirements can be imposed, and what they are.

5.1 Decision Process. Ideally, the overall decision process that should be followed to evaluate the adequacy of any item for an intended military application is illustrated in Figure 5.1. The process is largely similar for both military and commercial equipment. Included in this category are defining mission support requirements, identifying the function (e.g. control, communications, surveillance, navigation) to be performed by the equipment, and defining the operational performance requirements.

The performance requirements should take into account whether the performance of the equipment is safety or mission critical. This determination must consider both the potential impact of externally imposed EMI on safety or mission critical equipment (i.e. the immunity of a safety or mission critical equipment) as well as, the impact that emissions from the equipment itself may have on other critical equipment.

5.2 Anticipation of Environment. In order to evaluate the applicability of commercial standards for military purposes, it is necessary to define the EME in which the equipment will operate. Examples of areas which may be considered to have particular environmental characteristics include ship topside, ship below deck, submarines, aircraft carriers, aircraft external (e.g. HIRF), aircraft internal, ground combat, etc. In traditional military procurement, the contracting agency assesses the anticipated use of the equipment and levies appropriate requirements from MIL-STD-461E or as an alternative, with the requirements and limits tailored as necessary to match the anticipated environment. The equipment is then designed to meet these requirements and is tested accordingly. However, if existing commercial equipment is to be utilized, the contracting agency generally does not have the design option and must instead determine what data are available which describes the electromagnetic characteristics of that equipment and how well those characteristics meet its anticipated needs. Thus, it is most expedient to use MIL-STD-461E as the basic reference for establishing EMI requirements. This is shown in the upper half of the flow chart. The procedure deviates in the center of the chart depending on whether the equipment is a military type or a commercial type. If the latter, commercial complex evaluation process is initiated, guidance on which is the subject of the remainder of this guide.

5.3 Overall Evaluation of Compatibility. The matrix of Table 5.1 provides a gross assessment of the acceptability of equipment that conforms with the most prevalent commercial standards for use on typical military platforms. The commercial standards are divided into these categories: DO-160D, International, and National. The matrix is formatted in both color and alphabetic criteria to provide the user with a rapid snapshot of the EMI posture of the particular equipment/system they are considering purchasing:

- Acceptable with a low risk (L, green)
- Acceptable or moderate risk (M, black)
- Unacceptable, high risk (H, red)
- Unacceptable, high risk, there is no similar commercial requirement (H/N, red)
- No military requirement for this platform (N/A, blue)

Each intersection of a row with a column consists of fourteen sub-blocks. As per the legend at the base of Table 5.1, these sub-blocks represent, on a column-by-column basis, the Conducted Susceptibility, Conducted Emission, Radiated Emission, and Radiated Susceptibility information, respectively. For example, the intersection of the row for Navy Ground and National standards shows that for the 14 tests called out in MIL-STD-461E, five do not apply to this platform, and nine do. For those that apply, four tests are moderate risk and five tests are is high risk. For requirements according to DO-160D, the numbers are similar; but the tests at risk change somewhat (the CS114 and RS103 requirements are now at moderate rather than high risk and the CE106 and RE103 requirements are at high risk).

5.4 Risk Evaluation. Because military and commercial standards have been written by different individuals, there are significant differences in all corresponding requirements, which leads to the necessity to note that using one type of standard in place of another always incurs a certain risk. To reduce or eliminate the initially stated "risk" level given in Table 5.1, one must actually make a technical analysis of the differences in instrumentation, measuring technique and limits and evaluate their consequences.

5.5 Lightning Protection. IEC 61000-4-5 covers surges such as might be introduced in circuit by lightning and also from certain switching operations. The basic test waveform has voltage rise and fall times of 1.5?s and 50 ?s respectively (1.5/50 ?s) and an associated short circuit current waveform with rise and fall times of 8 ?s and 20 ?s respectively (8/20 ?s).

MIL-STD-461E does not require a test with these waveforms. Rather the effects of lightning are simulated with the two requirements of CS115 and CS116. CS115 provides a test waveform with a few nanosecond rise time and CS116 provides for an oscillatory transient.

DO-160D contains two lightning susceptibility tests; one for induced effects and the other for direct stroke effects. A variety of pulses is used including the 1.2/50 ?s waveform.

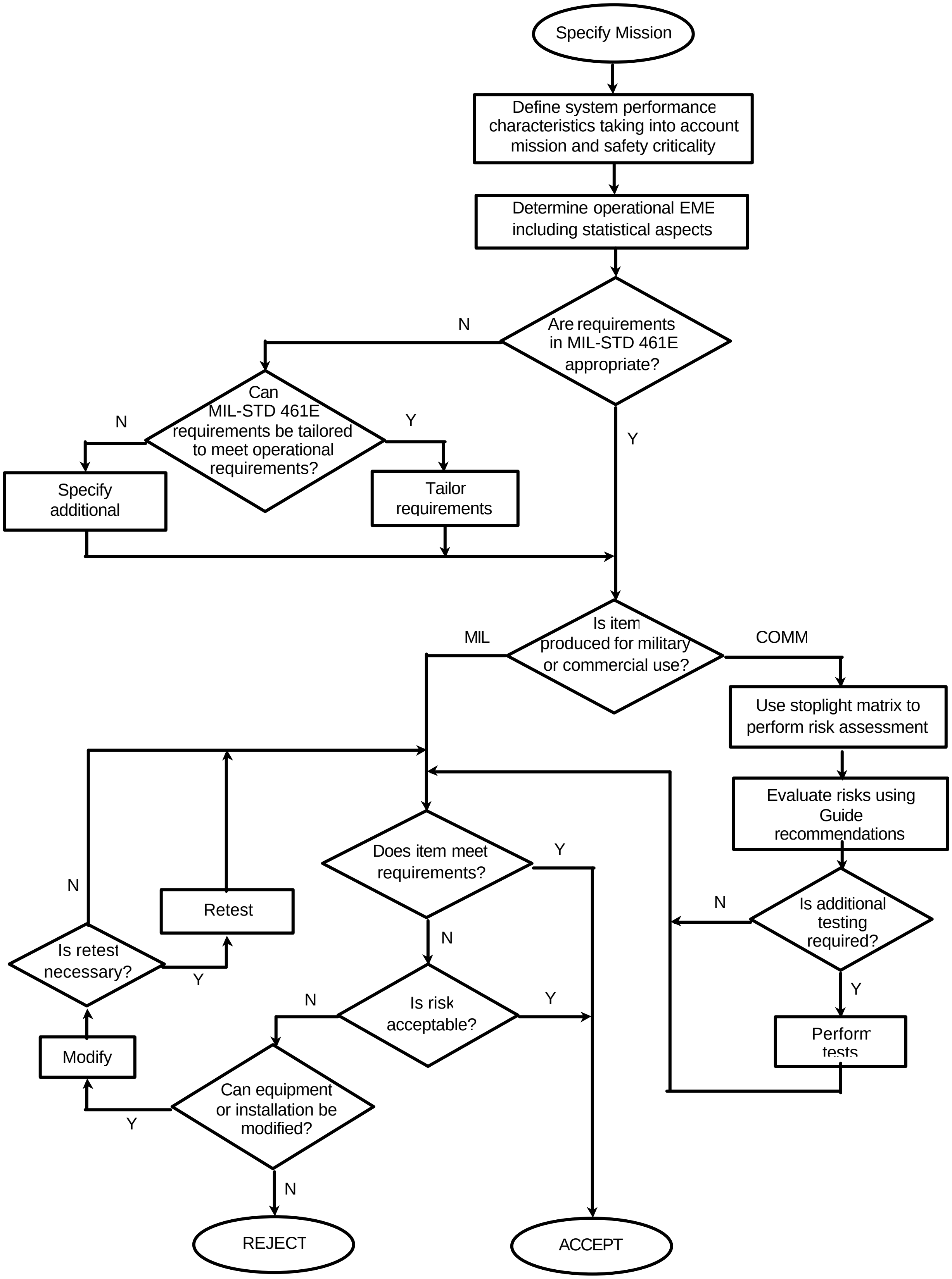


Figure 5-1: Flow Chart for the Procurement of Electromagnetically Compatible Systems or Equipment

Table 5-1: Assessment of Commercial Standards vs. MIL-STD-461E

Standards Qualification Status / Application Platform	DO-160D				INTERNATIONAL (IEC/CISPR)				NATIONAL (FCC PART 15/ ANS C63)			
SURFACE SHIPS	H	N/A	H	H	H	N/A	H	H	H	N/A	H	H
	H	M	M	H	H	M	H	H	H	M	M	H
	M	H	H	H	H	M	H		H	M	M	H
	N/A				N/A				N/A			
	H				M				H			
SUBMARINES	H	H/N	H/N	H/N	H	H	H	H	H/N	H/N	H/N	H/N
	H/N	M	M	M	H	H	H	H	H/N	L	H	H/N
	M	H/N	H/N	H/N	H	H	H	M	H/N	H/N	H/N	H/N
	H/N				M				H/N	See Note 1.		
	H/N				M				H/N			
AIRCRAFT, ARMY (Including Flight Line)	M	H	H	H	H	H	H	H	H	H	H	H
	N/A	L	M	M	N/A	M	H	M	N/A	M	H	H
		H	H	H	M	H	H	M	H	H	H	H
	H				M				H			
	H				M				H			
AIRCRAFT, NAVY	M	H/N	H/N	H/N	H	M	H/N	H/N	H/N	H/N	H/N	H/N
	N/A	M	M	M	N/A	M	H/N	M	N/A	M	M	H/N
	L	N/A	N/A	N/A	M	N/A	N/A	M	H/N	N/A	N/A	H/N
	H/N				H/N				H			
	M				M				H/N			
AIRCRAFT, AIRFORCE	M	N/A	N/A	N/A	H	N/A	N/A	N/A	H/N	N/A	N/A	N/A
	N/A	L	L	L	N/A	M	H	M	N/A	M	H	N/A
	L	H/N	H/N	N/A	M	H	H	N/A	H/N	H/N	H/N	N/A
	H/N				M				H/N			
	H/N				M				H/N			
SPACE SYSTEMS (Including Launch Vehicles)	M	N/A	N/A	N/A	H	N/A	N/A	N/A	H/N	N/A	N/A	N/A
	N/A	L	L	L	N/A	M	M	M	N/A	M	M	H/N
	L	H/N	H/N	N/A	L	H	H	N/A	H/N	H/N	H/N	N/A
	H/N				M				H/N			
	H/N				M				H/N			
GROUND, ARMY	M	N/A	N/A	H	H	N/A	N/A	H	H	N/A	N/A	H
	N/A	L	M	M	N/A	M	H	H	N/A	M	H	H
	L	H/N	H/N	N/A	M	H	H	N/A	H/N	H	H/N	N/A
	H/N				M				H/N			
	H/N				M				H/N			
GROUND, NAVY	H	N/A	N/A	N/A	H	N/A	N/A	N/A	H	N/A	N/A	N/A
	N/A	M	M	M	N/A	M	H	M	N/A	M	M	H
	M	H	H	H	H	M	H	L	H	M	M	H
	N/A				N/A				N/A			
	H				M				H			
GROUND, AIR FORCE	M	N/A	N/A	N/A	H	N/A	N/A	N/A	H/N	N/A	N/A	N/A
	N/A	L	L	L	N/A	M	H	M	N/A	M	H	N/A
	L	H/N	H/N	N/A	M	H	H	N/A	H/N	H/N	H/N	N/A
	H/N				M				H/N			
	H/N				M				H/N			

LEGEND

CS101	CE101	RE101	RS101
CS109	CE102	RE102	RS103
CS114	CE106	RE103	RS105
CS115			
CS116			

RISK

L	= Low Risk
M	= Moderate Risk
H/N	= High Risk, No Similar Commercial Requirement
H	= High Risk
N/A	= Military Requirement that's not applicable to this platform

*Note 1: Submarine CE 102 is “low risk” for ANS C63.4, “moderate risk” for FCC, Part 15**.**

6. COMPARISONS OF MILITARY & COMMERCIAL STANDARDS

This section of the guide gives a summary of comparative characteristics of corresponding standards which will enable one to make an initial judgement on the probable suitability of a product designed to a specific commercial standard to meet the particular requirements imposed by a given military environment. Annex A gives additional details some of the comparisons. One should note the existence of product specific standards which are discussed briefly in Annex B. These standards take into account specific product technical characteristics and typical installation environments. In cases where such product specifications exist an initial reference to them will aid in the performance of any required analysis.

6.1 CE101 – Conducted Emissions, Power Leads, 30 Hz to 10 kHz This requirement is applicable for power leads, including returns, that obtain power from other sources not part of the EUT for submarines, Army aircraft (including flight line) and Navy aircraft.

For equipment intended to be installed on Navy aircraft, this requirement is applicable only for aircraft with Anti-Submarine Warfare (ASW) capability.

For AC power applications, this requirement is applicable starting at the second harmonic of the EUT power frequency.

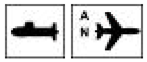
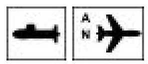
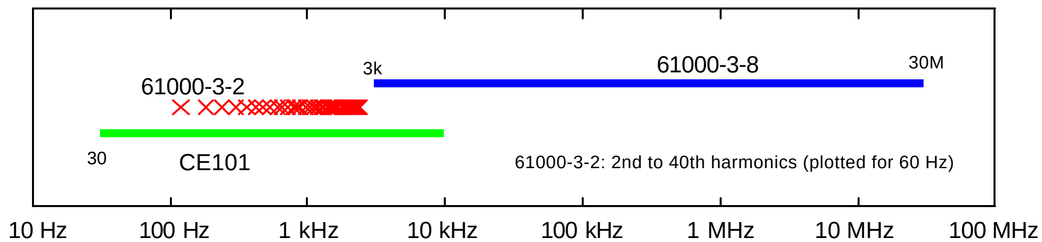
Two commercial counterparts to CE101 are IEC 61000-3-2 and IEC 61000-3-8. A summary comparison of these standards is provided in Table 6.1.1. Details on the differences are discussed in Annex A.

6.1.1 CE101 vs. IEC 61000-3-2

IEC 61000-3-2 is a product-family standard covering all equipment connected to AC mains operating at 220, 230, or 240 V at 50 or 60 Hz with rated input current ? 16 A per phase. DC, 115 V, and 400 Hz systems are not covered. In the case of Class D equipment (see Limits section below for definition) IEC 61000-3-2 is applicable only for equipment with power ratings between 75 W and 600 W.

6.1.1.1 Frequency Coverage. IEC 61000-3-2 covers only emissions at specific harmonic frequencies up to the 40^{th} harmonic whereas CE101 covers the whole range continuously throughout 30 Hz to 10 kHz. Due to the frequency coverage, IEC 61000-3-2 certified equipment can only be considered for CE101 qualification if interharmonic emissions are not appreciable and if the equipment does not have internal sources in the range 2 kHz - 10 kHz such as might appear in switching power supplies. Some other well-known sources of interharmonic emissions are: static frequency converters, cyclo-converters, induction motors, welding machines and furnaces.

Table 6.1-1: CE101 Summary Comparison with Commercial Standards

Parameter	**CE 101**	**IEC 61000-3-2**	**IEC 61000-3-8**	**Comments**
Applicable Equipment Type	DC:  AC: 115 V, 60 & 400 Hz 	AC: 220/230/240 V, ≤ 16 A per phase, 50 or 60 Hz (Applicable to 115 V systems if limits are doubled)	AC: Mains-signaling equipment only (using range 3 kHz - 525 kHz for transmission)	Commercial scope being expanded to cover 115 V AC systems explicitly
Frequency Range				Except for IEC 61000-3-8 there is a commercial void from 2.4 kHz to 10 kHz
Methods / Procedures				techniques differ but the same quantity is measured.
Sensor	current probe	harmonic current meter	LISN measurement ports	
Power Source	mains (LISN optional)	dedicated generator	mains (3 different LISNs used)	
Limits	highest and lowest limits apply to submarines	generally comparable to military in some limits but there are significant deviations	comparable	both mil. & commercial have limits fixed (independent of input current) and variable (dependent on input current)

6.1.1.2 Methodology. Both CE101 and IEC 61000-3-2 attempt to measure the same quantity, but by significantly different methods. In CE101 laboratory power is supplied to the EUT through an LISN (unless there is a specific agreement to replace or remove it) and the currents are measured with a low-input impedance instrument inserted in series between the generator and the EUT.

6.1.1.3 Limits. The limits can be separated into two sets: fixed limits and variable limits, which are proportional to the current drawn at the fundamental power frequency. These are plotted in Annex A in Figure A.1-2 and Figure A.1-3, respectively. The military limits for 400 Hz systems are not applicable for comparison but are provided for reference. Even though IEC 61000-3-2 is intended for 230 V systems, the corresponding fixed limits for 115 V systems are projected by doubling the appropriate limits of IEC 61000-3-2; this is especially appropriate for dual 230/115 V systems operating at 115 V.

The limits can be seen to differ in both level and form. However, it can be seen that there are two classes of IEC 61000-3-2 tested equipment which may satisfactorily meet the CE101 requirement for submarines, namely, Class C and D equipment rated at 1 k VA and below.

6.1.1.4 Conclusions. Due to the frequency coverage, IEC 61000-3-2 qualified equipment can only be considered for CE101 qualification with considerable risk. If it can be determined that EUT is not capable of generating inter-harmonic emissions, especially in the range 2 kHz – 10 kHz, this risk can be reduced considerably. Some other well-known sources of inter-harmonic emissions include: static frequency converters, cyclo-converters, induction motors, welding machines and furnaces.

Table 6.1-2 provides some guidance on the probable acceptability of IEC 61000-3-2 certified equipment in each class A, B, C, D for meeting CE101 requirements. Again it is necessary to emphasize the assumption that important emissions do not appear at frequencies other than at specific harmonics of the power frequency up to the 40^{th} order. In setting its limits, the IEC has taken into account the historically higher emission levels at odd harmonics (usually due to rectification) and balanced the need for emission control with its cost. The military, on the other hand, is predisposed to simple curves so that the CE101 limits are perhaps rather severe at the 3^{rd}, 5^{th}, and 7^{th} harmonics. For Table 6.1.2, at least a 10 dB difference is maintained between the CS101 curves and the voltage produced by a IEC 61000-3-2 third harmonic current from a single device across the impedance of the Line Impedance Stabilization network.

Table 6.1-2: Acceptability of IEC 61000-3-2 Qualified Equipment for Military Use

Eq. Class	Submarines 60 Hz, < 1 kVA	Submarines 60 Hz, ≥ 1 kVA	Navy ASW & Army aircraft (incl. flight line) > 28 V	Navy ASW & Army aircraft (incl. flight line) ≤ 28 V	Sub-marines 400 Hz	DC
A	acceptable if input current ≥ 4 A	not acceptable Margin ~ 25 dB	not acceptable Margin ~ 5 dB	not acceptable Margin ~ 15 dB	N/A	N/A
B	acceptable if input current ≥ 6 A	not acceptable Margin ~ 28.5 dB	not acceptable Margin ~ 8.5 dB	not acceptable Margin ~ 8.5 dB	N/A	N/A
C	acceptable	acceptable	acceptable if input current ≤ 4 A	acceptable if input current ≤ 2 A	N/A	N/A
D	see A	see A	see A	see A	N/A	N/A
Margins are calculated with assumption that military limits at the 3rd, 5th, and 7th harmonics are too severe. If protection at these harmonics is desired at the present levels in CE101, the margins must be increased by ~ 10 dB.						

6.1.2 CE101 vs. IEC 61000-3-8

IEC 61000-3-8 addresses only one type of equipment, namely that which uses a building's power distribution system for signaling purposes. This type of equipment deliberately induces a voltage on the load side of the power distribution system. The standard contains requirements for intentional "in band" signals as well as unintentional "out of band" conducted and radiated emissions on both the load and the supply sides of the equipment. For the purposes of military procurements the requirements of this standard might be applied to non-signaling systems in which case the load side requirements may be ignored.

6.1.2.1 Frequency Coverage. IEC 61000-3-8 covers the range from 3 kHz to 30 MHz whereas CE101 covers 30 Hz - 10 kHz.

6.1.2.2 Methodology. The measuring technique used in IEC 61000-3-8 closely resembles that used in CE 101, except for differences in the line impedance stabilization network and the fact that voltage in measured across a 50-ohm resistor rather than current. The differences in the LISNs are discussed in Annex D.,Section D1

6.1.2.3 Limits. The voltages measured in IEC 61000-3-8 can be converted to currents with knowledge of the line-ground impedance of the LISNs.

6.1.2.4 Conclusions. IEC 61000-3-8 certified mains-signaling equipment can be considered to meet CE101 requirements. Because of its rather restricted scope, IEC 61000-3-8 is not expected to be of much significance for military applications.

6.2 CE 102 - Conducted Emissions, 10 kHz to 10 MHz

This requirement is applicable from 10 kHz to 10 MHz for all power leads, including returns that obtain power from other sources not part of the EUT.

Commercial specifications corresponding to CE102 are DO 160D, ANS C63.4, ANS C63.12, FCC Parts 15 & 18 and CISPR Publications 11, 14, 15, 16 and 22. It is noted that this comparison applies to both AC and DC lines. A summary comparison of these standards is given by Table 6.2-1. DC lines are also covered in CISPR 25 (vehicles) and SAE J1113-41, but these documents are not discussed further in this section.

6.2.1 CE102 vs. DO160D

6.2.1.1 Frequency Coverage. See Table 6.2-1.

6.2.1.2 Methodology. DO-160D utilizes an LISN with an impedance characteristic similar to that used in MIL-STD-461E. However, it exhibits a resonance in the vicinity of 20 kHz.

6.2.1.3 Limits. DO-160D limits are shown in Figure 6.2-1. There are two limit sets depending on the location of the equipment. There are no limits below 150 kHz. The more severe limits are in the same range as several of the commercial limits. The more relaxed limits are above both the commercial and the military limits.

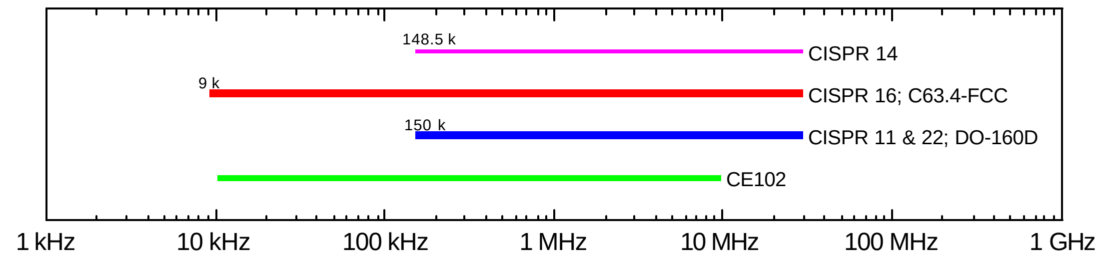
6.2.1.4 Conclusion. DO-160D provides a viable alternative for meeting the requirements of CE102.

6.2.2 CE102 vs CISPR Standards. CISPR Publications 11, 14, 15, and 22 cover respectively industrial scientific and medical (ISM) equipment, appliances, lighting equipment, and information technology equipment.

6.2.2.1 Frequency Range The frequency range covered extends from 150 kHz to 30 MHz

6.2.2.2 Methodology There are basic differences in the measurement set-ups. MIL-STD 461E calls for using the standard military set-up with the EUT placed on a ground plane. Commercial test procedures (see Figures A.2-1 and A.2-2) call for mounting a table top device on a table 80 cm above the ground plane. This is not considered to affect measurement levels in a significant way. MIL-STD 461E calls for measurement of any voltage with a peak detector. The prevailing commercial practice is to measure the voltage with a quasi-peak(QP) and a linear average detector. However, to expedite measurement , the commercial emission measurements are generally made initially with a peak detector, followed by quasi-peak or average measurements for those levels exceeding the limit. For a CW signal, the peak, QP and average detectors produce the same indicated value . For an impulsive type signal, the QP will be somewhat lower depending on the repetition rate of the signal. When the repetition rate is at 100 Hz, the QP value will be 7 dB lower than the peak value. It will be lower still if the repetition rate is lower. However, in most cases the repetition rate will be above 120 Hz.

Table 6.2-1: CE102 Comparison with Commercial Standards

Test Parameter	**CE102**	**CISPR 11, 14, 15, 16, 22**	**DO-160D: 21**	**C63.4-FCC**	**Comments**
Equipment Type / Platform	All mains-connected equipment All Platforms	11: ISM 14: motor-operated & thermal appliances for household use, electric tools 15: Lighting equipment 16: unrestricted (no limits) 22: ITE	Airborne equipment	non-I.S.M. equipment, except TV & FM receivers, (≤ 600 V)	general coverage
Frequency Range					Only limited commercial coverage below 150 kHz
Methodology					much similarity
Set-up	EUT on benchtop (usually on ground plane) Power leads only	similar to CE102, but usually not on ground plane	similar to CE102, but only grounded benchtops Power & intercon. leads	similar to CISPR	
Sensors	MIL-LISN meas. port thru 20 dB attenuator	CISPR-LISN meas. port	LISN meas. port, or current probe	CISPR-LISN meas. port or voltage probe	
Limits		Acceptable 150 kHz & above. Requires tailoring below 150 kHz	Acceptable 150 kHz & above.	Acceptable 150 kHz & above, class B only	Comparable

6.2.3 CE102 vs. National Standards. ANS C63.4 is broadly applicable measurement standard for all low-voltage equipment (rated ? 600 V DC or rms AC), except for avionics ISM, and TV & FM broadcast receivers. CE measurements are made from 9 kHz to 30 MHz, which encompasses the CE102 range of 10 kHz - 10 MHz.
Corresponding FCC limits are given in CFR 18.307(a) [10 kHz to 450 kHz] and 107(a) [0.45 to 30 MHz] (Limit B) and are of general applicability.

6.2.3.1 Frequency Coverage. The frequency range covered extends from 9 kHz to 30 MHz which overlaps that of CE102.

6.2.3.2 Methodology. The measurement and instrumentation used in C63.4 are similar to those used in CISPR. Comments in clause 6.2.2.2 apply.

6.2.3.3 Limits. The comparison of limits is shown in Figures 6.2-1 and 6.2-2. Since commercial equipment is compared, the MIL-STD-461E CE 102-1 limit for 115 VAC power leads is used (Basic +6 dB). Since in Europe the voltage is 230 VAC, the (Basic +9 dB) limit could also be used. This will make the comparison even more favorable from the point of using the commercial limits in lieu of the CE102 limits.

From the figures it can be seen that both the FCC Part 15 Class B and Part 18 Ultrasonic limits are acceptable for CE102 requirements, but neither of these wholly cover the frequency range of CE102. Therefore, a judgement will have to be made as to the importance of the unaccounted for frequencies. The figures also show that over the limited frequency range of 450 kHz to 10 MHz the FCC limits are at least 5 dB more stringent than the CE 102 limit. However, qualification to Part 15 Class A is less likely to be acceptable for CE102 requirements.

More detailed discussion of these limits is given in Annex A.

6.2.3.4 Conclusions. Commercial standards provide viable alternatives for meeting the requirements of CE102.

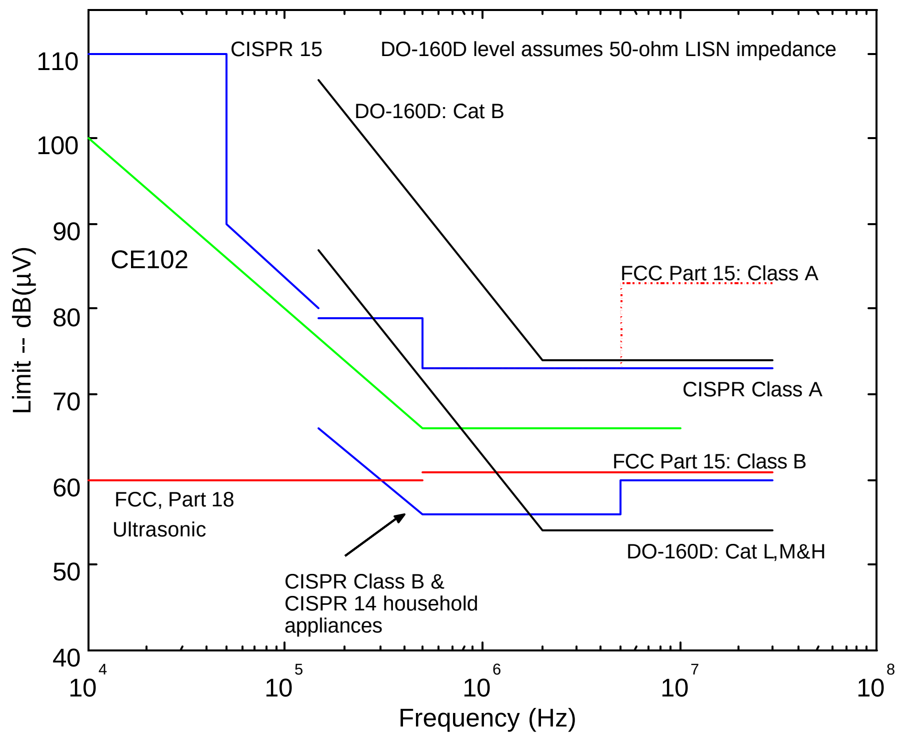


Figure 6.2-1: CE102 and Commercial (Peak/Quasi-peak)

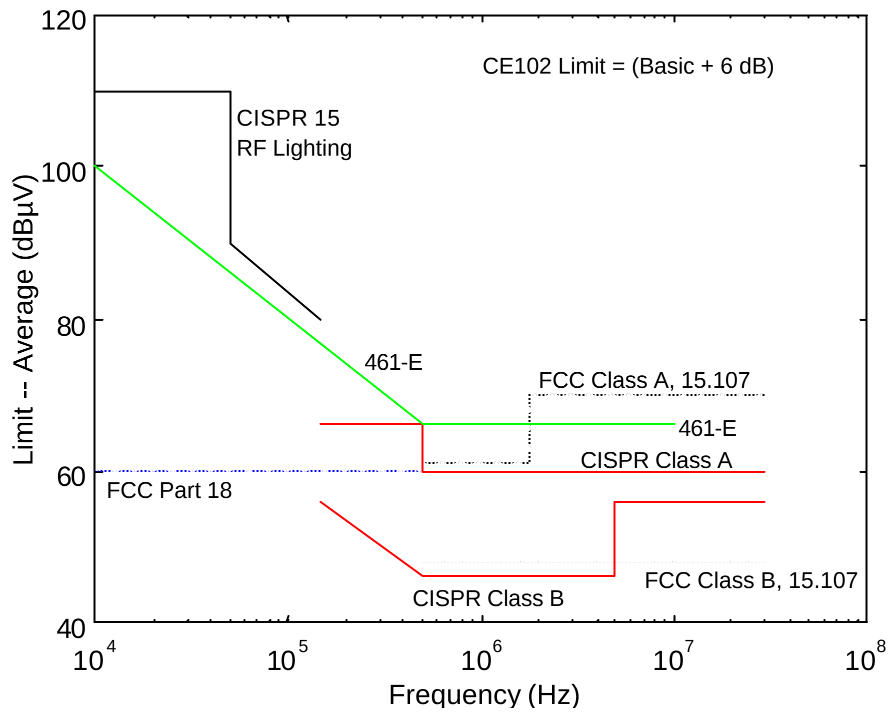


Figure 6.2-2: CE102 and Commercial (average) Limits

6.3 CE106, Conducted Emissions, Antenna Terminal, 10 kHz to 40 GHz

The requirement is applicable for transmitters, receivers and amplifier. The requirement is not applicable to equipment designed with antennas permanently mounted to the EUT. The "transmit" mode portion of this requirement is not applicable within the EUT necessary bandwidth and within ± 5 percent of the fundamental frequency.

Commercial standards corresponding to CE106 include CISPR 13 and IEC 61244-IA. An overall comparison of these standards appears in Table 6.3-1. Measurements similar to CE106 are required for equipment licensed by the Federal Communication Commission.

6.3.1 CE106 vs. CISPR-13. CISPR 13 covers interference from sound and television broadcast receivers and associated equipment. The intent of the CISPR-13 test procedure is in agreement with the receiver and "standby mode" portions of the CE106 test. Stand-by mode refers to transmitters "not transmitting". Therefore, CISPR-13 does not address requirements on harmonics and spurious output from transmitters in the transmit mode of operation.

6.3.1.1 Frequency Coverage. CE106 covers the frequency range from 10 kHz to 40 GHz, applied as shown in Table 6.3-2. CISPR-13 covers 30 MHz to 1750 MHz.

Table 6.3-2: CE106 Frequency Requirements

EUT Operating Frequency Range	Start Frequency of Test
10 kHz - 3 MHz	10 kHz
3 MHz - 300 MHz	100 kHz
300 MHz - 3 GHz	1 MHz
3 GHz - 40 GHz	10 MHz
* End frequency is 40 GHz or twenty times the highest generated or received frequency within the EUT.	

6.3.1.2 Methodology. The measurement techniques that are discussed in Annex A, clause A.3, are different but basically equivalent. The measured quantities should be the same as long as any corrections required by impedance mismatches are accounted for.

6.3.1.3 Limits. CE 106 has two sets of limits, one set for receivers and amplifiers and transmitters operating in the standby mode and another set for amplifiers and transmitters operating in the transmit mode. The limits of CISPR-13 are based upon a 75 ohm system and therefore need to be adjusted for military purposes by $L_{50} = L_{75} + 10 \log (50/75)$. With this correction factor added to CISPR's strictest limits (i.e. television receivers) an additional 12 dB needs to be taken from the requirement to lower it to the CE106 requirement of 34 dB?V (see Table 6.3-3).

Table 6.3-1: CE106 Comparison with Commercial Standards

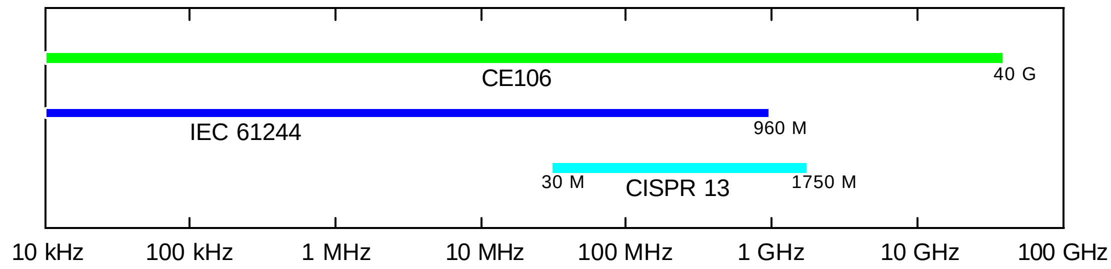
Parameter	CE106	CISPR 13	IEC 61244-1A	COMMENTS
Equipment Type / Platform	Transmitters, Receivers, Amplifiers, disconnectable antennas All Platforms	Sound & Television Receivers Transmitters in Standby mode	Transmitters in Transmit mode	The two commercial methods measure the same quantities as the military
Frequency Range				Military frequency range much broader
Methodology	Precalibrated Receiver Peak Detector	Substitution Measurement Combiners &matching networks	a) Precalibrated b) Substitution c) Directional couplers in antenna feed	All methods will provide almost equivalent results
Limits	Receivers & Transmitters (standby) 34 dB(μV) Transmitters (transmit) 80 dB down from fund. 2^{nd} & 3^{rd} harmonics: $\min(80, 50+10\log \mathbf{P}_{fund})$ down	Typically 12 dB above military's	Vary with frequency separation from carrier	Military limits most severe

Table 6.3-3: Comparison of CE106 and CISPR-13 Limits

	CE106 (all)	CISPR-13 (tele. rec. 30 MHz – 1 GHz)
10 kHz - 30 MHz	34 dBμV	N.A.
Harmonics 30 - 950 MHz	34 dBμV	46 dBμV
Harmonics 950 - 1750 MHz	34 dBμV	54 dBμV*
Spurious 30 - 1750 MHz	34 dBμV	46 dBμV
1750 MHz - 40 GHz	34 dBμV	N.A.
* The value of 54 is intended to be reduced to 46		

6.3.1.4 Conclusions. CE106 methods and limits are based upon operating in a 50 ohm system. CISPR-13 is based upon a 75 ohm system. Therefore when testing a military 50 ohm system a correction factor of $L50 = L75 + 10 \log (50/75)$ must be added to all limits in the CISPR-13 document. Additionally, CISPR-13 uses different limits depending on what type of receiver is being tested. For this comparison the most stringent limits, with correction factor already applied, were used (see Table 6.3-3).

The CISPR-13 method could be utilized for testing military and commercial equipments, being procured for the military, if appropriately expanded frequency ranges and associated limit corrections are specified by the procuring activity (12 dB assuming the limits for television receivers are utilized). This would provide a known level of control for harmonic and spurious output from receivers, and transmitters in stand-by mode.

6.3.2 CE106 vs. IEC 61244-2 and 61244-2A. The IEC 61244-2A test procedure corresponds to the "transmit mode" requirement of CE106. IEC 61244-2A contains appendices for IEC 61244-2.

6.3.2.1 Frequency Coverage. CE106 covers the frequency range from 10 kHz to 40 GHz. IEC 61244-2 is limited to a maximum frequency of 960 MHz.

6.3.2.2 Methodology. Measured quantities should be comparable between CE106 data and any of the methods contained in the IEC 61244-2 procedure.

6.3.2.3 Limits. IEC 61244-2 has several limits based upon application, transmitter peak output power and the operational frequency band of the transmitter (see Table 6.3-4). Additionally, variances to these requirements are allowed per notes to the "limits" chart. CE106 requirements are for the 2nd and 3rd harmonics to be down by a factor of $50 + 10 \log P$ (dB) from the fundamental frequency, or 80 dB, whichever requires less suppression (P = peak power of output). All other harmonics and spurious outputs are required to be at least 80 dB down from the fundamental (see Curves #1 & 2 Figure 6.3-1). A direct comparison demonstrates that the CE106 limits are a considerably more stringent requirement.

Table 6.3-4: IEC Limit Line Application

Applicable Limit Lines	Frequency
A, A1, A2	10 kHz - 30 MHz
C, C1	30 MHz - 235 MHz
E	235 MHz - 960 MHz
E1	235 MHz – 470 MHz

6.3.2.4 Conclusions. Equipment produced in accordance with IEC 61244-2 requirements, as for that produced in accordance with CISPR 13 requirements, can be utilized for military purposes only where the application permits relaxation of the frequency range and limits. IEC 61244-2 is complementary to CISPR 13 in that it covers transmitters operating in the transmit mode.

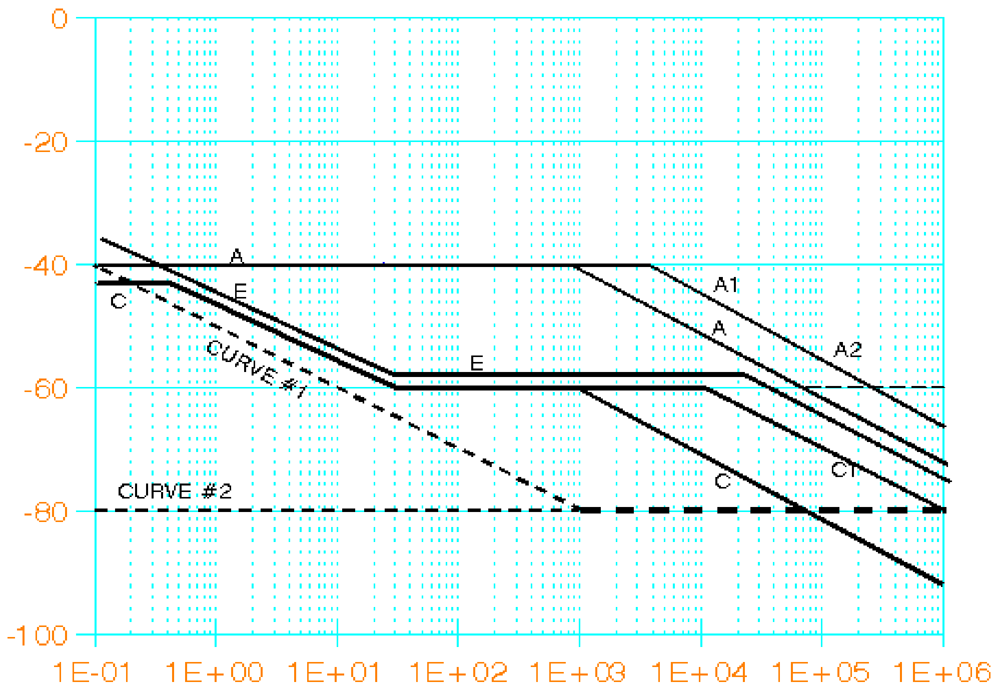


Figure 6.3-3: Comparison of CE106 and IEC 61244-2 Limits

NOTES:
1. y-axis is dB below power of fundamental frequency
2. x-axis is peak output power of transmitter (watts)
3. Curves #1 & #2 are CE106 Limits
4. For A, A1, A2, C, CI, E see Table 6.3-4
   A1 applies to mobile transmitters
   A2 applies to transmitters above 50 kw
   C1 applies to special areas where relaxation is possible
   E1 applies to transmitters up to 470 MHz

6.4 CS101, Conducted susceptibility, Power Leads, 30 Hz to 150 kHz

This requirement is applicable to equipment and subsystem AC and DC input power leads, not including returns. If the EUT is DC operated, this requirement is applicable over the frequency range of 30 Hz to 150 kHz. If the EUT is AC operated, this requirement is applicable starting from the second harmonic of the EUT power frequency and extending to 150 kHz.

Corresponding commercial standards include IEC 61000-4-13, and DO 160D. A summary chart comparing these standards is shown in Table 6.4-1. In addition, there are related requirements in IEC Publication 60533.

6.4.1 CS101 vs. IEC 61000-4-13. IEC 61000-4-13 is a basic standard which tests for immunity to harmonics and interharmonics for electrical and electronic equipment with rated current up to 16A on low voltage 50 or 60 Hz power mains. It does not apply to equipment operating on DC or 400 Hz power systems.

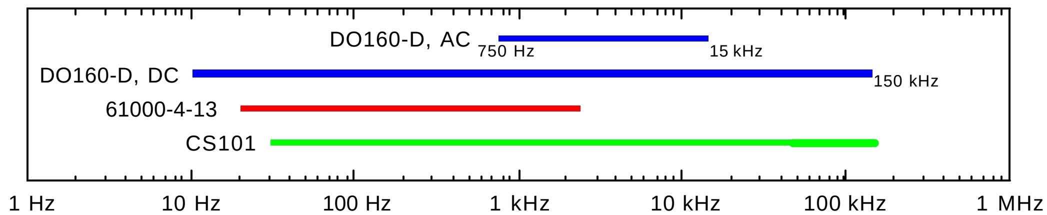
6.4.1.1 Frequency Coverage. IEC 61000-4-13 covers only harmonics up to the 40th harmonic of the mains frequency (2.4 kHz) and interharmonics from 16 Hz to 2.4 kHz, whereas, CS101 covers the range from 30 Hz to 150 kHz. Due to the limited frequency coverage, IEC 61000-4-13 certified equipment can only be considered for CS101 qualification if the major interference sources on the power mains are harmonics of the supply frequency. If other system loads contain switching power supplies, static frequency converters, induction motors, welding machines, or ISM equipment, IEC 61000-4-13 certification would probably not be sufficient.

6.4.1.2 Methodology. CS101 utilizes a transformer to inject the interference voltage into each power line in sequence with an LISN inserted between the power source and the point of injection. IEC 61000-4-13 requires a special generator to be inserted between the power source and the EUT which can superimpose individual sine waves at frequencies in the test range or distorted wave forms at the power frequency on one or more phases simultaneously. The distortion waveform may be flat tapped or more peaked than an undistorted sine wave. Except for the distorted waveform test (which is believed is used infrequently) and the simultaneous testing feature (which probably is a more severe test), the results obtained are generally comparable with the military test. Detailed discussion of these methods is given in Annex A, Clause A.4.

6.4.1.3 Limits. There are significant differences between test levels (limits) of method CS101 and the commercial standards. The comparison is further complicated by the fact that all of these standards designate different classes or categories of equipment qualified to one of these standards, it is of paramount importance to know into which class the equipment is qualified.

Test method CS101 specifies two limit curves, one applicable to power mains where the voltage is 28V or less, the other applicable to mains where the voltage is greater than 28V. These limit curves are shown in Figure 6.4-1.

Table 6.4-1: CS101 Comparison with Commercial Standards

Parameter	CS101	IEC 61000-4-13	DO-160D	COMMENTS
Equipment Type / Platform	AC & DC equipments All Platforms	AC, 50/60 Hz only, ≤ 16 A per phase	AC & DC airborne equipments	D.C. will be covered in IEC 61000-4-17
Frequency Range				Limited coverage in IEC 61000-4-13
Methodology				
Injection Method	transformer--secondary in series	unspecified	similar to CS101	
EUT Power	mains power via LISN	dedicated test generator	mains power (LISN not specified)	
Tests Performed	Frequency sweep with sinusoidal ripples, one phase at a time	Perform IN ORDER 1. "Harmonic Combination" tests: chopped peak, voltage overswing. *Test on 3 phases simultaneously* 2. Frequency sweep with sinusoidal ripples, one phase at a time 3. Single frequency tests (if failed step 2), at 0º & 180º	similar to CS101	Chopped peak test Unique but not used extensively. 3-phase tests more indicative of real-life situations
Measurements	**Y**-power: L-N voltages Unearthed **Y**: L-L voltages ? -power: L-L voltages **1**-phase: L-N voltage	**Y**-power: L-GND voltages & line currents Unearthed **Y**: unspecified ? -power: unspecified **1**-phase: L-GND & N-GND voltage & current on neutral	**Y**-power: unspecified Unearthed **Y**: unspecified ? -power: unspecified **1**-phase: L-N voltage	Comparable
Limits		Different limits for each test. Class 3 sweep limits acceptable to 2.4 kHz	extensive tailoring required	Requires detailed analysis

6.4.1.4 Conclusion. For commercial equipment being procured by the military, both IEC 61000-4-13 and DO-160D (with appropriate categories specified) will provide a known level of immunity for equipment certified to these standards. This is particularly true if the primary threat environment is harmonics of the power frequency. Neither of these specifications will provide adequate protection for the very low frequency threat of some navy platforms.

The standard also has a provision that the limit is met if the disturbance signal source is adjusted to dissipate 80 watts into a 0.5 ohm load and cannot develop the required voltage at the EUT power mains terminals but the EUT remains immune to the injected signal. For DC mains, the requirement is applicable from 30 Hz to 150 kHz. For AC mains, the requirements are applicable starting at the second harmonic of the main frequency to 150 kHz.

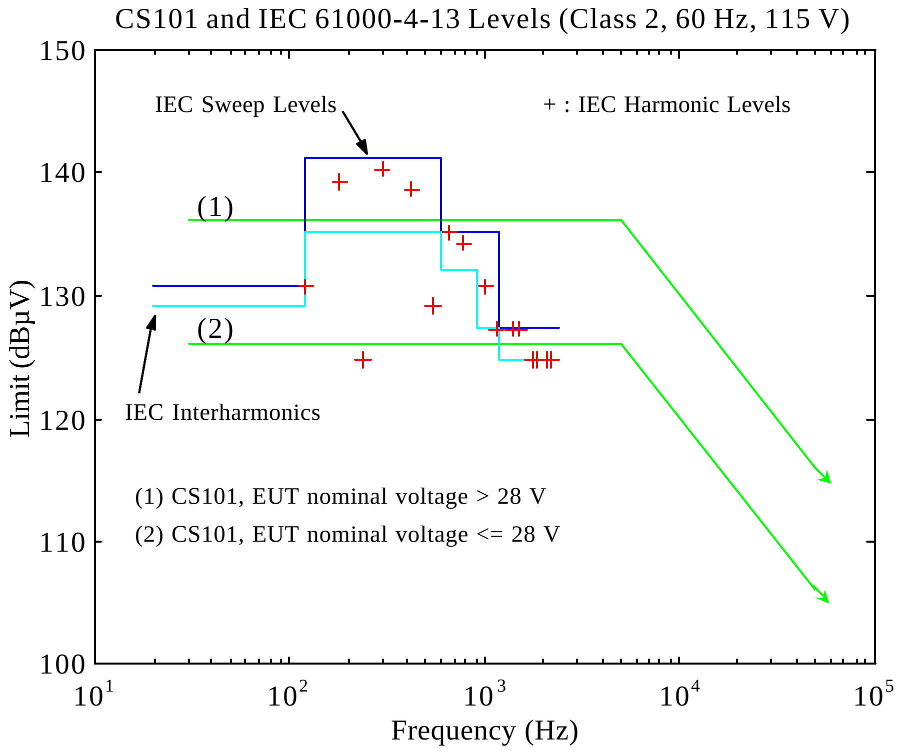


Figure 6.4-1: Comparison of CS101 & IEC 61000-4-13 Class 2 Levels (60 Hz, 115 V)

IEC 61000-4-13 classifies EUTs into three classes, 1, 2, and 3, according to the environment in which it is expected to operate. Class 1 EUTs consist of devices that are expected to operate with protected supplies such as uninterruptible power supplies, filters or surge capacitors. This class requires lower testing levels. Class 2 applies to devices that are connected to public networks or that operate in a light industrial environment. Class 3 refers to a heavy industrial environment, for example, an environment where a major part of the load is fed through converters, where welding machines are present, where large motors may be turned on and off frequently, or where loads vary rapidly. In IEC 61000-4-13, limits are given only for classes 2 and 3. For a rough comparison, the IEC 61000-4-13 test levels for an EUT operating in a class 2 environment with 120 V rms, 60 Hz AC power is plotted superposed on the CS101 limit curves in Figure 6.4-1. For a class 3 environment, the limits are shown in Figure 6.4-2. As can be seen, the levels of IEC 61000-4-13 class 2 compare favorably with CS101 from the second through the 13th harmonic, but there is no test required above the 37th harmonic or 2 kHz, which ever is greater. For a class 3 equipment, the IEC 61000-4-13 limits exceed CS101 levels for odd harmonics through the 13th and are almost equal to CS101 up through the 29th harmonic. The class 3 interharmonic levels approximate CS101 from 16 Hz to 750 Hz.

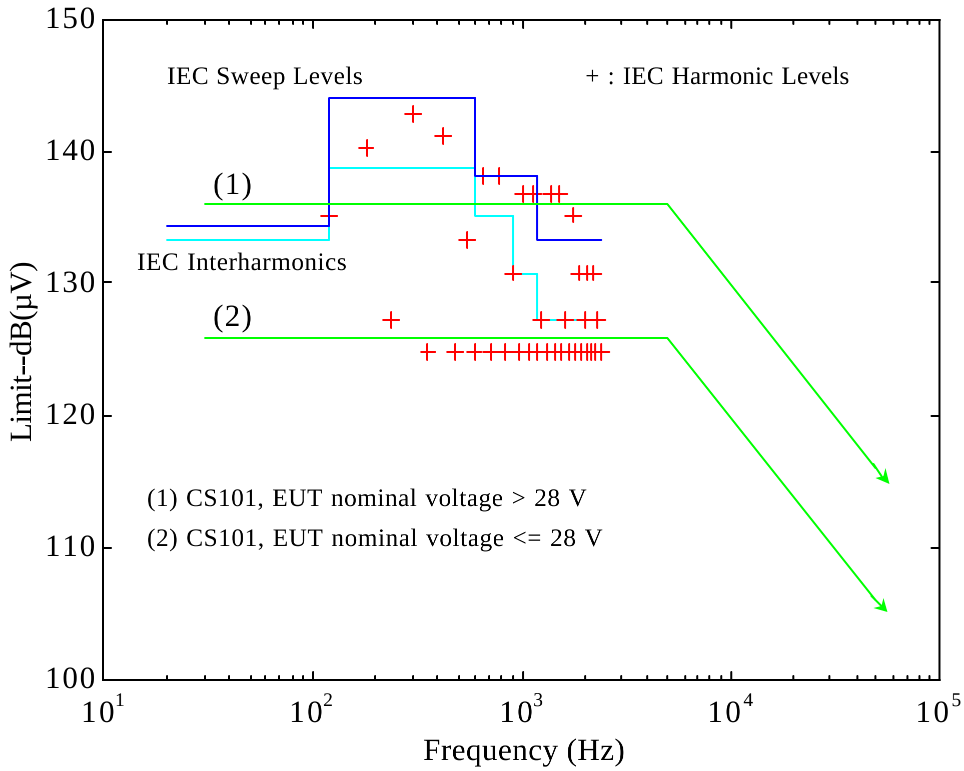


Figure 6.4.2: Comparison of CS101 & IEC 61000-4-13, Class 3 Levels (60 Hz, 115 V)

6.4.2 CS101 vs. DO-160D. RTCA DO-160D is intended for airborne equipment only, but may satisfy other installations. Section 18 of DO-160D provides an audio frequency susceptibility test very similar to CS101.

6.4.2.1 Frequency Coverage. DO160D covers only the frequency range of 750 Hz to 15 kHz for AC power systems and 10 Hz to 150 kHz for DC power systems. However, the test levels below 1 kHz and above 15 kHz effectively limit its coverage to that range. CS101 covers the range from 30 Hz to 50 kHz. As many switching power supplies operate in the 15 to 50 kHz range, analysis of the intended usage may be required. This concern can be alleviated somewhat if a test requirement such as CS114 (with the neutral/return removed) is applied. Otherwise, except for platforms with ELF sensors, the frequency coverage of DO-160D is probably acceptable.

6.4.2.2 Methodology. DO-160D does not have complete test setup details; however, the measurement techniques seem generally equivalent to those in CS101.

6.4.2.3 Limits. The limits of these two standards are compared in Figure 6.4-3. DO-160D provides limits for four categories of equipment, which are:

Category A: Equipment supplied from constant frequency AC systems with DC power supplied via transformer rectifier units.

Category B: Equipment used on DC systems supplied by engine driven alternator/rectifiers or that are battery stabilized.

Category E: Equipment supplied from AC power systems only.

Category Z: Equipment that may be used on all types of electrical system (which is the most commonly used category.)

For AC equipment the limit is 5% of the fundamental voltage. (Figure 6.4-2 shows the limit for a 115 V rms system) For DC equipment the limit is a fixed voltage as shown.

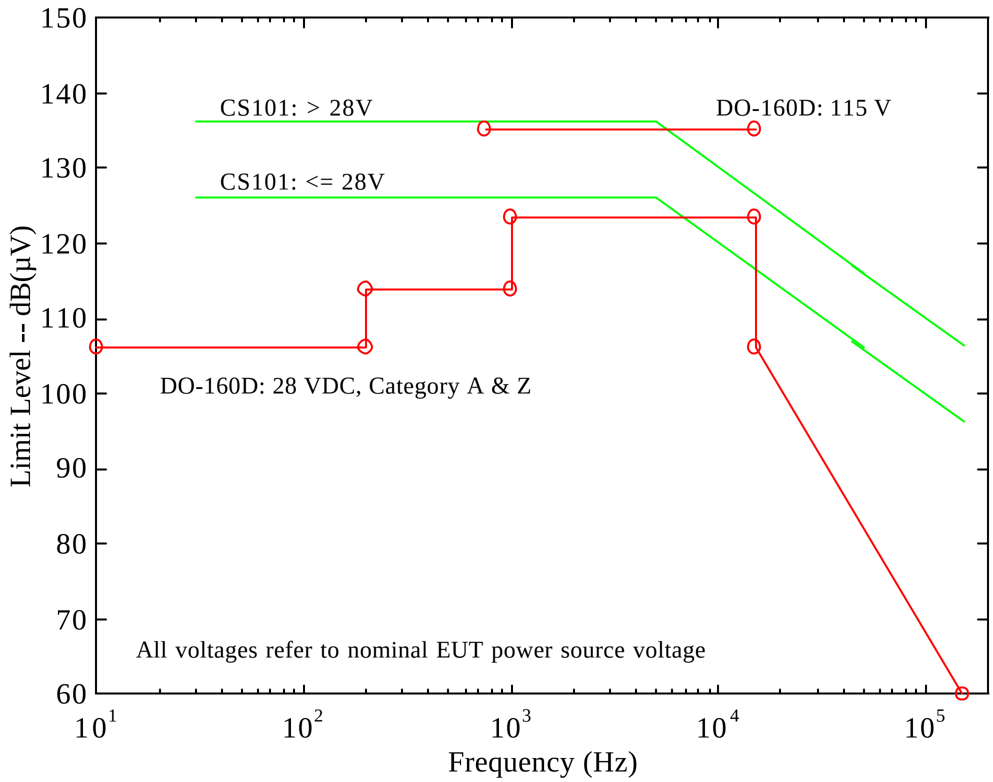


Figure 6.4-3: CS101 & DO-160D Category A&Z Levels

6.4.2.4. Conclusions. Equipment qualified to DO-160D is probably acceptable for most military applications. The relatively benign requirements below 1 kHz might pose problems for some navy platforms or systems using MIL-STD-704 as their power quality basis but generally the concern would be for emissions rather than susceptibility in this frequency range.

As can be seen, the levels of DO-160D compare favorably with CS101 in the 750 Hz to 15 kHz frequency range, (the 2nd through 37 harmonics of 400 Hz). Except for systems, which employ extremely low frequency sensors, such as submarines or some Navy aircraft, the DO-160D limits are probably acceptable.

6.4.3 CS101 VS. IEC 61533. Another IEC standard that has some similarity to method CS101 is IEC 61533. IEC 61533 is an installation guide for electric/electronic equipment on commercial ships.

6.4.3.1 Frequency Coverage. IEC 61533 contains a requirement for an immunity test of the input power leads to conducted radio frequency voltages from 10 kHz to 30 MHz.

6.4.3.2 Methodology. Both the frequency range and the test methodology of this test are more similar to the original CS02 than to CS101. For this reason and because of the severe lack of detail of the test methodology, it is not possible to make a useful comparison between method CS101 and IEC 61533. Although the equipment may well be acceptable for many military applications, qualification to IEC 61533 does not establish that.

6.4.3.3 Limits. The limits of IEC 61533 are significantly different from those of method CS 101. These differences may be summarized as follows:

a) IEC 61533 imposes requirements over the frequency range of 10 kHz to 30 MHz as compared to the 30 Hz to 150 kHz requirement of CS101. Thus, whereas the primary objective of CS101 is to evaluate the impact of harmonic distortion on equipment performance and VLF signal coupling, IEC 61533 is basically oriented to evaluating VLF and HF signal coupling. It would, therefore, be more appropriate to compare IEC 61533 to method CS 114.

b) The injected test signal level of IEC 61533 is 1.0V at 10 kHz decreasing linearly on a log-log plot of 0.1V at 30 MHz, (0.63V at 50 kHz). This compares somewhat with the CS 101 requirement for 28V power lines, with a limit of 2.0V at 10 kHz decreasing linearly above 5 kHz on a log-log plot to 0.067 V at 150 kHz. It does not compare well with the CS 101 requirement for 115V power lines, which has a limit identical in shape to the 28V DC with a level of 6.3 V at 10 kHz decreasing to 0.21V at 150 kHz.

c) IEC 61533 also specifies that the test signal shall be 30% modulated, but the modulation frequency is not specified. CS 101 uses unmodulated test signals.

6.4.3.4 Conclusions. Commercial equipment tested per IEC 61533 may also be acceptable but this particular certification provides very limited information relative to comparison with method CS101 requirements. In all cases, the specific test set up should be explored to ensure that the results are consistent with the planned application.

6.5 CS109, Conducted Susceptibility, Structure Current, 60 Hz to 100 kHz

This requirement is applicable to equipment and subsystems that have an operating frequency range of 100 kHz or less and an operating sensitivity of 1 µV or less (such as 0.5 µV). Handheld equipment is exempt from this requirement corresponding commercial standards include IEC 61000-4-16 and IEC 61533.

6.5.1 CS109 vs. IEC 61000-4-16. CS 109 is designed to test the immunity of so-called "structure currents" appearing in the electrical safety ground and metallic structures primarily due to harmonics of the power frequency coupled into it by means of filter capacities in various equipment power supplies. IEC 61000-4-16 is a basic EMC standard covering immunity to conducted common-mode disturbances at low frequencies. Equipment using a power frequency of 400 Hz is not explicitly covered, but the technique is applicable to 400 Hz systems without any technical changes. A comparison summary is given in Table 6.5-1.

6.5.1.1 Frequency Coverage. Coverage IEC 61000-4-16 covers the range DC to 150 kHz, encompassing the range of CS109 (60 Hz - 100 kHz).

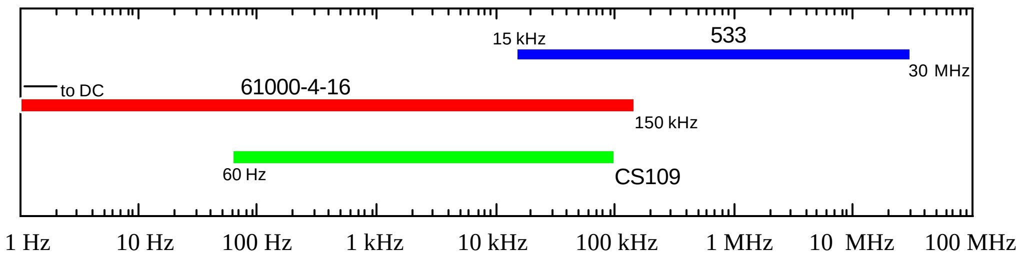
6.5.1.2 Methodology. IEC 61000-4-16 is primarily a cable test, however, structure currents such as in CS109 will occur when current is injected onto the shield of a cable. Current injection is achieved via coupling networks, except for shielded cables where injection is directly onto the shields. Decoupling networks are used to direct energy towards the EUT and protect any auxiliary equipment that may be connected to it.

6.5.1.3 Limits. Although the coupling mechanisms may be different, the interference source considered coincides with that for which CS109 is designed: return currents in the grounding system. Therefore, a limit comparison is pertinent. The limits are depicted in Figure 6.5-1. The voltage limits in IEC 61000-4-16 have been converted to current values with the assumption of a 150 ? common-mode impedance, except for cable-shield injection where the impedance is 50 ? (internal impedance of test generator). The four test levels in IEC 61000-4-16 correspond to the EM severity of the environment:

Level 1 (L1): well-protected;
Level 2 (L2) protected;
Level 3 (L3) typical industrial environment;
Level 4 (L4) severe industrial environment.

The circles are the test levels at the power frequency, in this case 60 Hz. Shield injection levels are ~ 9.5 dB higher than corresponding non-shield levels.

Table 6.5-1: CS109 Comparison with Commercial Standards

Parameter	**CS109**	**61000-4-16**	**61533**	**COMMENTS**
Equipment Type / Platform	unrestricted	unrestricted	shipboard equipment	
Frequency Range				
Methodology				
Test Set-up	Input cable grounds disconnected; EUT on non-conducting surfaces with single-point ground	EUT grounded as in typical use	not specified	Modification of 61000-4-16 required obtain cabinet corner to corner injection
Injection Sites	diagonally across cabinet corners	cables & shields	shields & cabinet corners	
Injection Technique	Direct injection	unshielded cables: CDNs shielded cables: Direct injection Communication lines:T-network	bifilar wound transformer	
Measurements	Voltage across 0.5 ?	None, (voltage across known impedance measured during calibration)	unclear	
Limits		dramatically different, unacceptable	dramatically different, unacceptable	requires comparison and clarification on phenomena for which tests are designed

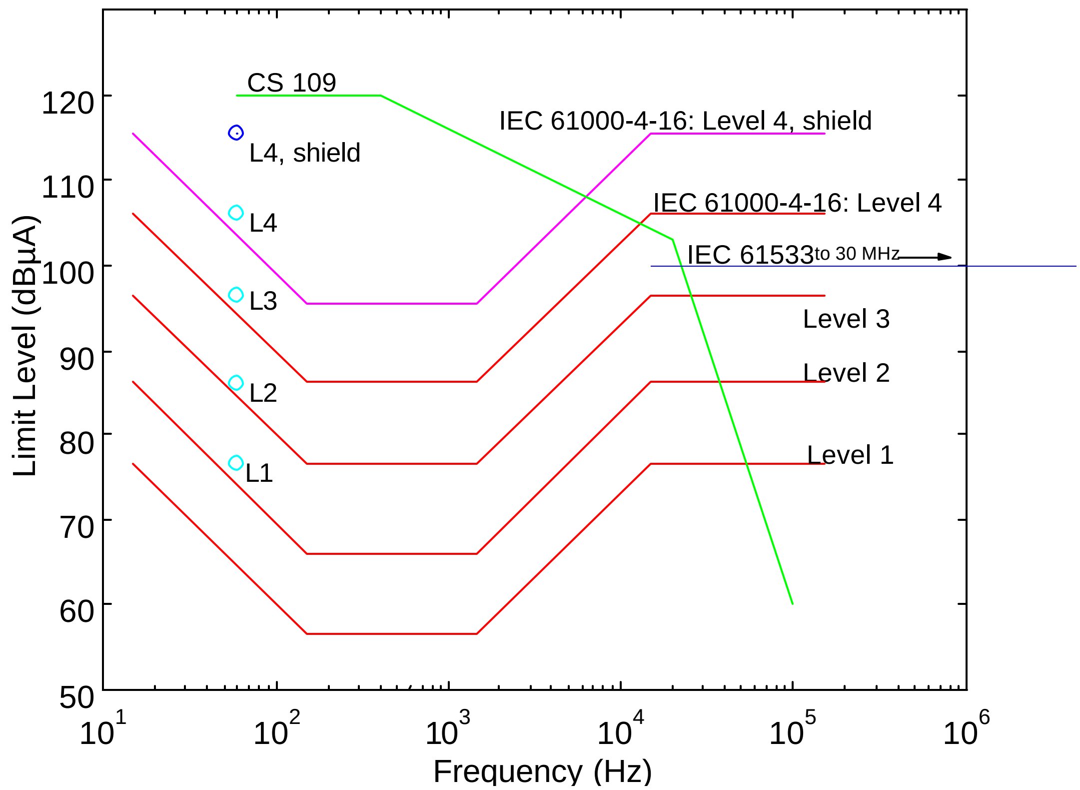


Figure 6.5-1: CS109 & IEC 61000-4-16 Limit Levels (60 Hz)

6.5.1.4 Conclusions. IEC 61000-4-16 limits were placed with consideration of the typical emission profile in a public network. The power distribution network on a ship may have a significantly different profile. In contrast, CS109 limits were placed with consideration of the coupling energy of the induced voltage from structure currents. Consequently, pending review of CS109, equipment qualified to IEC 61000-4-16 is not acceptable for meeting CS109 requirements unless the limits are properly tailored. Also, note that the 61000-4-16 test provides more severe limits at higher frequencies (above about 80 kHz) which may be of interest to military systems in which switching power supplies are used.

6.5.2 CS109 vs. IEC 61533 IEC 61533 is a system standard covering electrical and electronic installations in ships which is currently under revision. Paragraph 25.6 of IEC 61533 contains a test of circulating currents through cabinet metalwork and cable screens.

6.5.2.1 Frequency Coverage. Paragraph 25.6 covers the range 15 kHz - 30 MHz, which overlaps the frequencies of CS109 only from 15 - 100 kHz.

6.5.2.2 Methodology. The test in paragraph 25.6 injects current via a 1 mH (each winding) bifilar wound transformer onto shielded cables and across all corners of the cabinet. The bifilar transformer suppresses any common-mode currents that may be injected to ensure greater measurement accuracy. CS109 injects across diagonal corners via a 0.5 ? resistance in the loop.

6.5.2.3 Limits. The limits are plotted in Figure 6.5-2. As for IEC 61000-4-6 the limits are much more stringent than CS109 at high frequencies but less stringent at low frequencies.

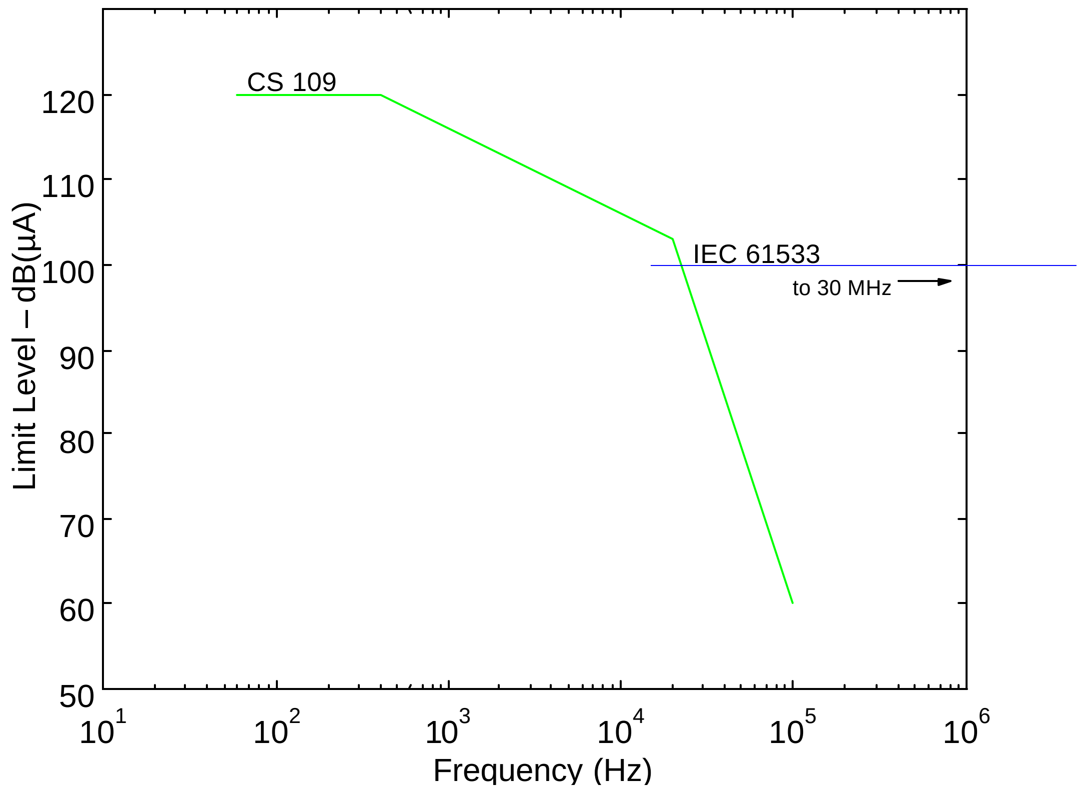


Figure 6.5-2: CS109 and IEC 61533 Structure Current Limits

6.5.2.4 Conclusions. Due to the lack of frequency coverage, equipment qualified to IEC 61533 will not be acceptable for meeting CS109 requirements.

6.6 CS114, conducted susceptibility, bulk cable injection, 10 kHz to 200 MHz.

This requirement is applicable to all interconnecting cables, including power cables. The requirement is applicable to equipment and subsystems, based on the intended installation as follows:

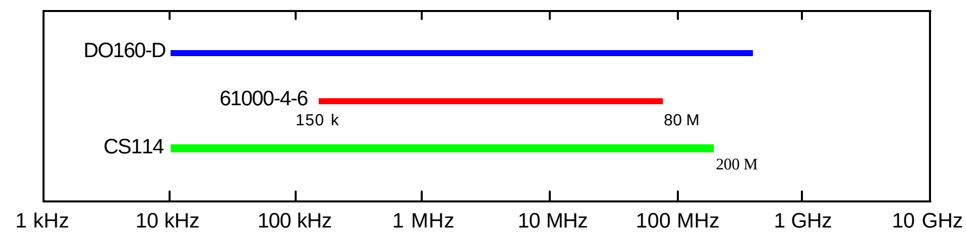
A summary comparison for between CS114 and commercial standards is given in Table 6.6-1.

6.6.1 CS114 vs. IEC 61000-4-6. CS114 and IEC 61000-4-6 both are concerned with conducted disturbances induced by radio frequency fields.

6.6.1.1 Frequency Range. IEC 61000-4-6 covers the frequency range from 150 kHz to 80 MHz. CS114 covers from 10 kHz to 200 MHz. The radiated immunity testing of IEC 61000-4-3 is used above 80 MHz to assess performance. MIL-STD-461E recognizes an overlap region between the CS114 conducted susceptibility requirements and the RS103 radiated susceptibility requirements.

6.6.1.2 Test Comparison. Aside from the frequency coverage, the most important differences between CS114 and IEC 61000-4-6 are injection techniques and test setup arrangements. CS114 drives signals onto cables with an inductive injection probe. IEC 61000-4-6 has three different techniques: injection using coupling and decoupling networks (CDNs), direct injection onto shields, and electromagnetic (EM) clamp or current clamp (same as inductive injection probe). The primary technique uses CDNs with the others being considered alternatives. The concept with the CDNs is that each electrically isolates the EUT interfaces from other connected equipment while establishing a 150 ohm common mode impedance to a ground plane (300 ohm total impedance). In contrast to CS114, there is no current monitoring and the only measured parameter is the open-circuit voltage output of the test generator. IEC 61000-4-6 uses sinusoidal amplitude modulation, while CS114 uses square wave modulation. Square wave modulation is generally more severe. Test setup differences introduce some uncertainty in making comparisons. In simulating commercial applications, IEC 61000-4-6 test setups use the ground plane only for instrumentation reasons and do not electrically bond EUT enclosures to the ground plane, as is the case for MIL-STD-461E setups. Also, IEC 61000-4-6 uses physically short cables, while MIL-STD-461E requires cables representative of the installation. CS114 also tests the power cables with the neutral/return removed; IEC 61000-4-6 does not.

Table 6.6-1: CS114 Comparison with Commercial Standards

Test Parameter	CS114	61000-4-6	DO-160D	Comments
Equipment Type / Platform	unrestricted	unrestricted	airborne equipment	
Frequency Range				Except for DO-160D Commercial range restricted
Methodology				
Injection Technique(s)	current probe	a) CDNs (preferred) b) Direct shield injection c) EM Clamp d) Current Clamp	current probe	EUT unfounded when using IEC CDNs
Calibration Technique (to set generator output level)	current on 50 ? test jig	a,b,c) volt. across 300? d) voltage across 300 ? or current on 50 ? test jig	current on 50 ? test jig	equivalent
Measurement Technique (during testing)	current probe	a,b) none c,d) current probe	current probe	comparable except for unperformed feature
Limits	5 levels	3 levels	5 levels	Limit levels generally overlap

6.6.1.3 Limits. In Figure 6.6-1, "suggested" voltage limit curves in IEC 61000-4-6 have been converted to current using the 300 ohm common mode impedance established by the CDNs for comparison with CS114 limits. The curves must be compared conservatively because of differences in modulation techniques and test setup differences.

6.6.1.4 Conclusions. IEC 61000-4-6 requirements cover the most important part of the CS114 frequency range. Differences in test methodology introduce some uncertainty in comparisons. Level 2 of IEC 61000-4-6 is acceptable for Curve 1 of CS114. Level 3 of IEC 61000-4-6 is acceptable for Curve 2 of CS114 and marginally acceptable for Curve 3. Unless a special IEC level is stipulated, no IEC 61000-4-6 certified equipment meets the requirements of Curves 4 and 5 of CS114.

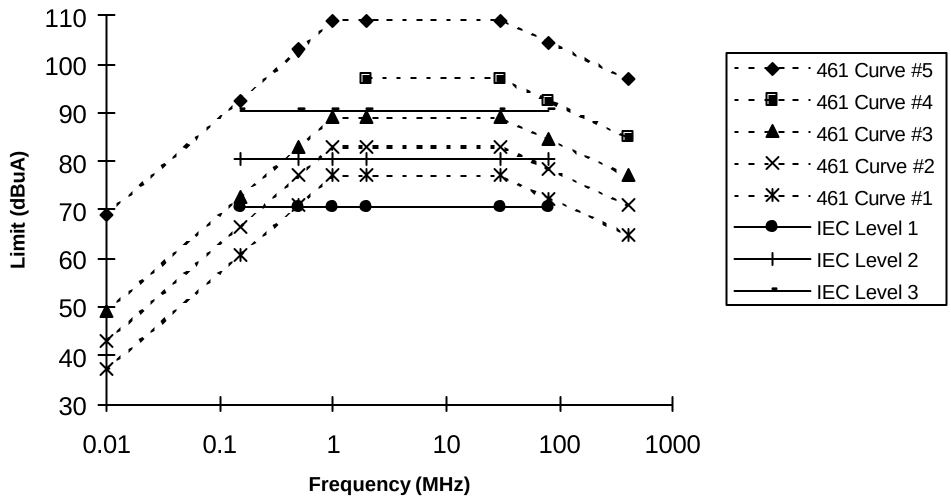


Figure 6.6-1: Comparison of CS114 and IEC 61000-4-6 Limits

6.6.2 CS114 vs. RTCA DO-160D. Test methodology in CS114 and the conducted susceptibility portion of DO-160D, Section 20, are very similar. DO-160D is intended for airborne use, although it could be applied elsewhere. There are some differences in limits.

6.6.2.1 Frequency Coverage . CS114 covers 10 kHz to 200 MHz, while Section 20 covers 10 kHz to 400 MHz.

6.6.2.2 Methodology. Other than using different line impedance stabilization networks, the test methodology has no significant differences.

6.6.2.3 Limits. In Figure 6.6-2, CS114 limits are compared to Section 20 limits. Section 20 categories are selected by the equipment manufacturer or purchasing organization. There are no defaults.

6.6.2.4 Conclusions. Section 20 can be substituted for CS114 provided equipment is certified to appropriate limits. Table 6.6-2 shows acceptability of the Section 20 categories as compared to CS114 limit curves.

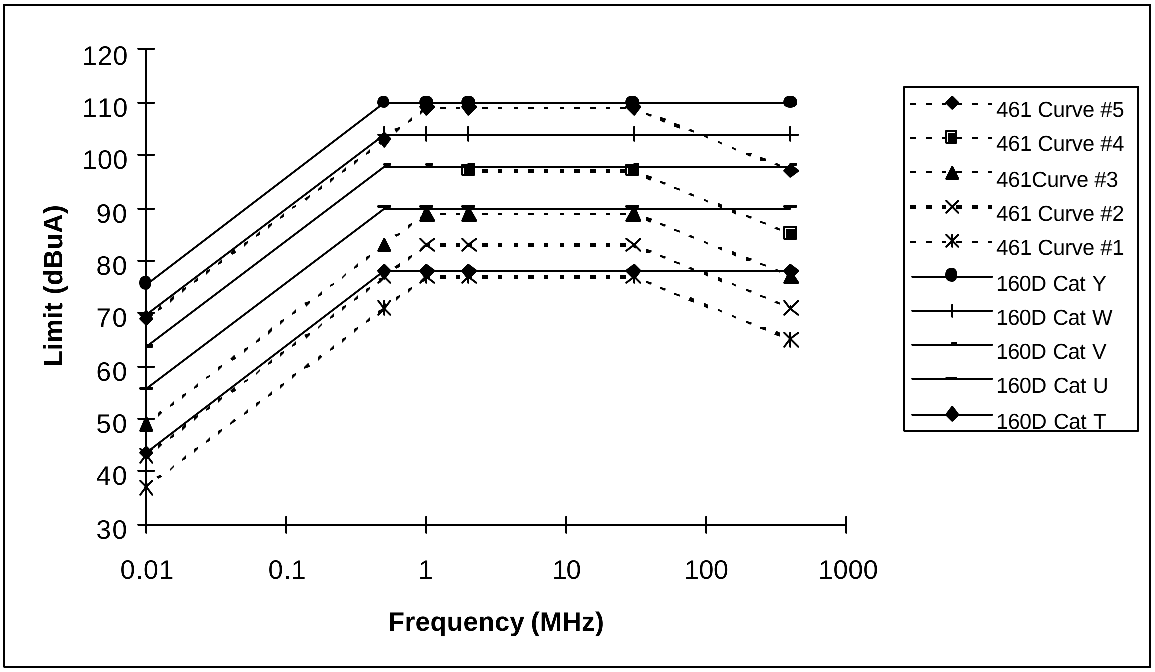


Figure 6.6-2: Comparison of CS114 and DO-160D, Section 20 Limits

Table 6.6-2: Comparison of CS114 and DO –160D, Section 20 Limits

DO-160D, Section 20	**CS114: #1**	**CS114: #2**	**CS114: #3**	**CS114: #4**	**CS114: #5**
Category Y	Y	Y	Y	Y	Y
Category W	Y	Y	Y	Y	Y
Category V	Y	Y	Y	Y	Y
Category U	Y	Y	Y	N	N
Category T	Y	N	N	N	N

6.7 CS115, Conducted susceptibility, bulk cable injection, impulse excitation.

This requirement is applicable to all aircraft, space, and ground system interconnecting cables, including power cables. The requirement is also applicable for surface ship and submarine subsystems and equipment when specified by the procuring activity. A summary comparison of CS 115 with IEC 61000-4-4 is given in Table 6.7-1

6.7.1 CS115 vs. IEC 61000-4-4. CS115 and IEC 61000-4-4 are both concerned with potential effects from fast rise time transients.

6.7.1.1 Frequency Coverage/Test parameters. See Table 6.7-1.

6.7.1.2 Methodology. CS115 drives transients onto both power cables and interconnecting signal and control cables in a common mode configuration using a inductive injection (current) probe. CS115 also tests power cables with the neutral/return removed whereas IEC 61000-4-4 does not. IEC 61000-4-4 injects onto individual power leads through a capacitor and onto interconnecting signal and control cables in a common mode configuration using a capacitive injection clamp.

Test setup differences introduce some uncertainty in making comparisons. In simulating commercial applications, IEC 61000-4-4 test setups use the ground plane primarily for instrumentation reasons with the only EUT connection to the ground plane being the earth (safety) ground wire. In MIL-STD-461E, EUT enclosures are usually bonded to the ground plane to simulate platform installations.

6.7.1.3 Limits. The limit for CS115 is a 5 ampere current (used for all applications) in a test fixture which corresponds to 500 volts being developed across a 100 ohm loop impedance. IEC 61000-4-4 contains a range of suggested open circuit voltage levels for the transient source as shown in Table 6.7.-2. The individual manufacturer, user, or product committee must specify the appropriate level for a particular product. The estimated current available for Level 3 is 5.6 amperes.

6.7.1.4 Conclusions. While the requirement definitions and test methodologies for the two requirements are substantially different, similar levels of equipment immunity can be obtained with some confidence by ensuring that equipment is certified to IEC 61000-4-4 at an appropriate level. A comparison that takes into account some limited laboratory experimentation suggests that military equipment normally expected to meet CS115 should be qualified to at least Level 3 of IEC 61000-4-4 to provide reasonable confidence that similar immunity is ensured. The voltage level corresponds to an estimated current of 5.6 amperes compared to the 5.0 amperes of CS115.

Table 6.7-1: CS115 Comparison with Commercial Standards

Test Parameter	CS115	61000-4-4
Pulse rise time	$\leq$ 2 ns	5 ns
Pulse width	$\geq$ 30 ns	50 ns
Repetition Rate	30 Hz	2.5 to 5 kHz in bursts of 15 ms, burst repetition rate 3.3 Hz
Test Set-up	Table-top or floor-mounted, grounded & bonded as in typical use	Table-top: 0.8 m from ground plane Floor-mounted: 0.1 m from ground plane EUT wire-grounded as in use, $\geq$ 0.5 m from other ground planes
Tests on	Signal cables (bulk) Power cables (bulk, complete) Power cables (bulk, returns excluded)	Signal cables (bulk) Power cables (each lead)
Coupling Method	Current injection probe	CDNs (ground lead, power leads w/ input current $\leq$ 100 A) Coupling capacitor (power cables, input current > 100 A) Capacitive clamp (signal cables)

Table 6.7-2: IEC 61000-4-4 Suggested Test Levels

Level	Power Supply Ports		Signal, Data, & Control Ports	
	Voltage (kV)	Rep Rate (kHz)	Voltage (kV)	Rep Rate (kHz)
1	0.5	5	0.25	5
2	1	5	0.5	5
3	2	5	1	5
4	3	2.5	2	5
X	Special	Special	Special	Special

6.8 CS116, conducted susceptibility, damped sinusoidal transients, cables and power leads, 10 kHz to 100 MHz.

This requirement is applicable to all interconnecting cables, including power cables, and individual high side power leads. Power returns and neutrals need not be tested individually. The corresponding commercial standard is IEC 61000-4-25.

6.8.1 CS116 vs. IEC 61000-4-12 and IEC 61000-4-25. CS116 is intended to test against transients from lightning, EMP, and platform switching. IEC 61000-4-25, which specifies requirements designed to protect against HEMP, is in the final stages of adoption. IEC 61000-4-12, which is referenced in IEC 61000-4-25, is intended to test against damped oscillatory transients (both single-shot and repetitive pulses) occurring in power networks which arise from switching transients and remote lightning. Provision is made for testing with two waveforms; 1) a non-repetitive highly damped 100 kHz “ring wave,” and 2) a repetitive damped oscillatory wave (100 kHz and 1MHz). The latter wave is described as occurring primarily in high and medium voltage stations. 61000-4-25 references only the damped oscillatory wave of 61000-4-12. A summarized comparison of CS116, and the IEC 61000-4-12 and IEC 61000-4-25 combination is presented in Table 6.8-1.

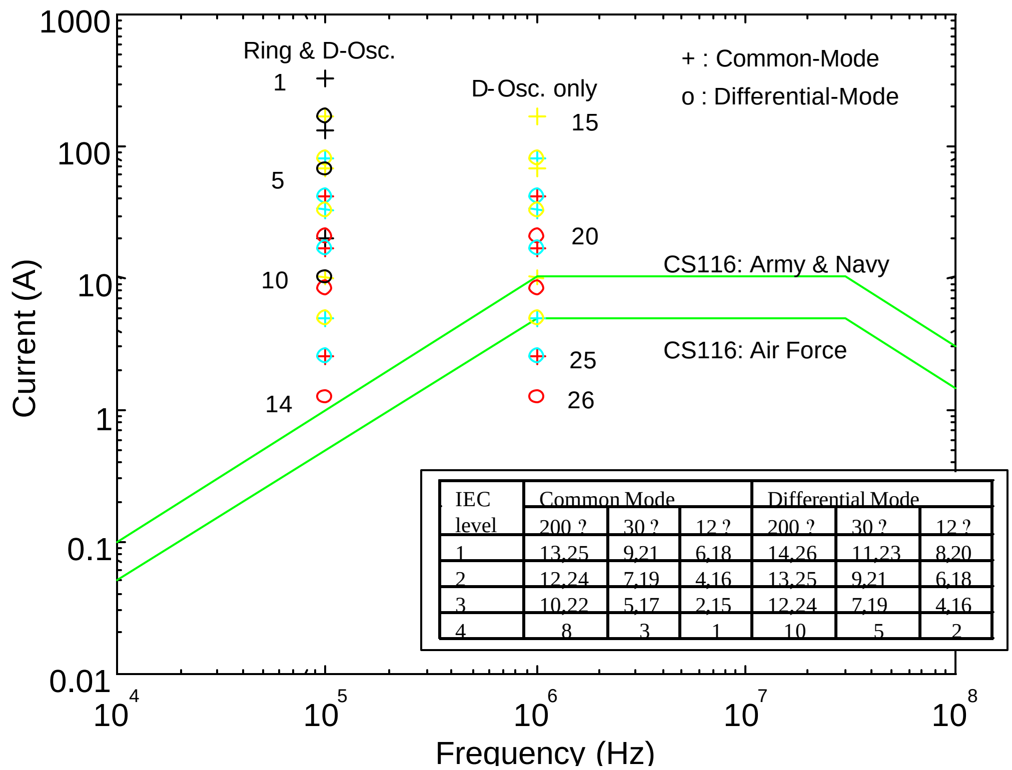
Table 6.8-1: Comparison of CS116 & IEC 61000-4-25

Test Parameter	**CS116**	**IEC 6100-4-12, IEC 61000-4-25**
Frequency	10 kHz - 100 MHz (0.01, 0.1, 1.0, 10.0 and 30.0 MHz)	1 MHz 10 MHz, 50 MHz proposed
Waveform	Damped sinusoid (repetitive)	Damped sinusoid (single shot & repetitive)
Applied to	Signal cables (CM) Power cables (DM, CM)	Signal cables (DM, CM) Power cables (DM, CM)
Calibration Technique	Scan while injecting 1 mW, measured at generator output, to obtain Ampere (induced)/Watt curve. Note resonance frequencies.	verification of characteristics of generator & CDN.
Injection Technique	BCI at stepped and resonance frequencies. Inject gradually from 0 to current limit. Repeat with power off. For power cables, also inject on each lead. Monitor injected current level	CDN injection on single cables (DM & CM). Gradual amplitude increase unclear, no power-off tests, but refer to product standard for final qualification. Monitor voltage at EUT terminals
Test Set-up	Table-top or floor-mounted, grounded & bonded as in typical use. Standardized treatment of cables. LISN used, no isolation for Auxiliary Equipment(AE)	Table-top or floor-mounted, grounded as in typical use. EUT bonding unclear. Use of ground plane preferred. 1 m cables (10 m in certain cases), excess bundled. Power source and AEs isolated.

6.8.1.3 Limits. Figure 6.8-1 shows limits for peak current injection required in CS116. The peak current varies with the frequency and is maximum in the range from 1 to 30 MHz and is higher by a factor of two for the Army and Navy than for the Air Force. Tests must be conducted at the specific frequencies of 0.01, 0.1, 1.0, 10.0, 30, and 100 MHz.

61000-4-12 provides for the ring wave generator to have three internal impedances, namely 12, 30 and 200? . Thus the test current, which is to be compared with the current in CS116, depends on the impedance used, and is to be specified for each product in the product specification. For the damped oscillatory wave the generator impedance is fixed at 200? . Figure 6.8-1 shows the corresponding current levels at the two test frequencies.

In IEC 61000-4-25 seven sets of levels are given among which one is selected depending on the degree of protection needed at the location of the installation. In addition separate requirements are stated for protection against early-time, intermediate-time, and late-time HEMP waveforms. As the military requirements correspond most nearly to the early-time phenomenon, only those requirements in IEC 61000-4-25 are considered here for comparison purposes.



IEC level	Common Mode			Differential Mode		
	200 ?	30 ?	12 ?	200 ?	30 ?	12 ?
1	13,25	9,21	6,18	14,26	11,23	8,20
2	12,24	7,19	4,16	13,25	9,21	6,18
3	10,22	5,17	2,15	12,24	7,19	4,16
4	8	3	1	10	5	2

Figure 6.8-1: CS116 and IEC 61000-4-12 Limit Levels

Table 6.8-2 shows the levels of immunity from EC1 through EC10 and ECX from which the user makes a selection. Those most nearly corresponding to the military requirements are EC4 and EC5. The levels specified (respectively 10 and 5 Amperes) are the short-circuit currents from a 200-ohm generator and will vary in test depending on the actual impedance of the test arrangement. Tests are made at oscillation frequencies of 1, 10 and 50 MHz, a range in which the military requirement is almost flat with frequency. For CS116 the damping factor of the oscillation is set at 15 $\pm$ 5 whereas in IEC 61000-4-25 it varies from 13 to 27 over the specified frequency range.

Table 6.8-2: Early time conducted immunity test levels

Level	V_{oc} V	I_{sc} A	Waveform	Basic Standard	Severity level in the basic standard
EC1	125	0,625	Damped sinusoids*	IEC 61000-4-12	x
EC2	250	1,25	Damped	IEC 61000-4-12	1*
EC3	500	2,5	sinusoids**	IEC 61000-4-12	1
EC4	1 000	5	Damped	IEC 61000-4-12	2
EC5	2 000	10	sinusoids**	IEC 61000-4-12	3
EC6	4 000	20	Damped	IEC 61000-4-12	x
EC7	4 000	80	sinusoids**	IEC 61000-4-4	4
EC8	8 000	160	Damped	IEC 61000-4-4	x
EC9	16 000	320	sinusoids**	IEC 61000-4-4	x
EC10	25 000	500	Damped	IEC 61000-4-25	EC10
EC11	160 Kv	3 200	sinusoids**	IEC 61000-4-25	EC11
ECX	Special	Special	5/50 ns	IEC 61000-4-25	ECX
			5/50 ns		
			5/50 ns		
			25/500 ns		
			10/100 ns		
			Fast transient*		

*Differential mode of level 1 is used for EC2.

** Each test level consists of three frequencies: 1 MHz, 10 MHz, and 50 MHz. IEC 61000-4-12 will be modified to include these frequencies in the damped to 160 kV: 40 kV, 80 kV and 120 kV. This level category is intended for testing equipment directly connected to long oscillatory wave test. The Q of the damped oscillatory wave test, as defined by equation D1 in IEC 61000-2-10, ranges from 13 to 27.

Notes:
1. Voltage and current levels shown in the table are for common mode values.
2. EC10 consists of two sublevels in addition to 16 kV: 4 kV and 8 kV.
3. EC11 consists of three sublevels in addition MV distribution power lines protected against lightning. If lightning protection is not used, increase Voc to 1.6 megavolts and Isc to 4000A. (see Annex A).

6.8.1.4 Conclusions. Although the test methods are different, current injection (military) vs voltage injection (commercial), and commercial tests are made at fewer frequencies than the military, the commercial test levels can be more severe than the military. Actual commercial test levels are set by a specification in the individual product, or by a generic, specification. IEC 61000-4-25 provides for very high test levels to evaluate protection against HEMP.

6.9 RE101, Radiated emissions, magnetic field, 30 Hz to 100 kHz

This requirement is applicable for radiated emissions from equipment and subsystem enclosures, including electrical equipment and associated cables. The requirement does not apply at telecommunication transmitter fundamental frequencies, but does apply to the operating frequencies of sonar and industrial, scientific, and medical (ISM) subsystems and equipment. The requirement does not apply to radiation from antennas. For Navy aircraft, this requirement is applicable only for aircraft with an ASW capability. The nearest corresponding commercial standards are CISPR15 and IEEE 1140. A summary comparison of these methods is shown on Table 6.9-1.

6.9.1 RE101 vs. CISPR 15. CISPR 15 is a product-family standard covering electrical lighting and similar equipment.

6.9.1.1 Frequency Coverage. CISPR 15 covers magnetic field emissions over the frequency range of 9 kHz to 30 MHz whereas RE101 covers the frequency range of 30 Hz to 100 kHz. CISPR 15 does not cover the 30 Hz to 9 kHz frequency range. The 30 Hz to 9 kHz frequency range is important to the military because the emissions in this frequency range are usually made up of the power frequencies and their harmonics. These magnetic field emissions are usually produced by power supplies and power distribution systems. Controlling and characterizing magnetic field emissions is critical because of the many military areas where there are high equipment densities in relatively small spaces. In many locations this problem is compounded by the fact that the military uses equipment with very low sensitivities.

6.9.1.2 Methodology. CISPR 15 is a completely different test than RE101. The CISPR 15 magnetic field measurement is performed using a loop antenna ranging in size from 2 to 4 meters in diameter. During the test this antenna surrounds the EUT and effectively measures the equivalent dipole strength of the emitted magnetic field. The current induced into this loop by the EUT is used to determine the magnetic field emissions. RE101 uses a relatively small loop antenna (13.3 cm diameter) placed 7 cm from the EUT. This loop is then used to probe the EUT to find the location of maximum emissions. The data obtained using CISPR 15 does not provide the point of maximum emissions nor does it provide the emission levels in close proximity to the EUT but in cases where the point of leakage can be identified with cabinet apertures the field measured with RE 101 can be estimated from the CISPR 15 measurement (see Clause A.9.1 Annex A).

6.9.1.3 Limits. Figure A.9 shows the RE101 limits. CISPR 15 limits cannot be compared directly with RE101 limits since they are expressed in terms of current measured in the large loop antennas. CISPR 15 provides formulas for conversion of limits to equivalent dB(? V/m) field strength at distances varying between 3 to 30 meters from the EUT.

CISPR 15 magnetic field disturbance limits are expressed in Tables 3 and 4 of that standard. The limits cover the frequency range of 9 kHz to 30 MHz. Table 3 specifies the limits for the frequency range of the test with the exceptions of the frequencies designated for use by ISM equipment. The limit for frequencies of ISM equipment is given in Table 4 of CISPR 15.

Table 3 of CISPR 15 provides the limits in terms of dB?A with respect to size of the loop antenna. Table 4 of CISPR 15 provides the limits in terms of dB?V/m at a 10 m distance. Annex C of CISPR 15 provides conversion factors to convert all the current readings to dB?V/m for 3 m, 10 m, and 30 m distances. The limits on Table 3 of CISPR 15 at 9 kHz is 88 dB?A (93 dB?V/m using the factor for 10 m) decreasing to 22 dB?A.

Table 6.9-1: RE101 Comparison with Commercial Standards

Test Parameter	RE101	CISPR 15	IEEE 1140
Frequency Range	30 Hz - 100 kHz	9 kHz - 30 MHz	5 Hz – 400 kHz
Equipment Type	Unrestricted	Non-incandescent lighting devices and similar equipment with operating frequency $\geq$ 100 Hz and < 3.6 m long	Video Display Terminals
Test Set-up	Table-top or floor-mounted, grounded/bonded as in typical use. Standard treatment of cables	As in typical use; EUT grounded as in typical use	As in typical use. Ground plane not required
Test Method	Surface/cable scan at 7 cm	3-axis Large-Loop Antenna (1 - 4 m diameter) with current probes to measure currents in loops	Small loop at 0.5 m distance
Limits	Differences in submarine and army limits	RE101 much more severe	No limits in standard. Refer to regulatory requirements

6.9.1.4 Conclusions. Qualifying an item to CISPR 15 may provide some insight as to its RE101 characteristics, if the source of the magnetic field can be identified.

6.9.2 RE101 vs. IEEE 1140. IEEE 1140 is a product-family standard covering Video Display Terminals (VDTs). This standard is specifically applicable for VDTs containing Cathode Ray Tubes (CRTs) and not applicable VDTs using Liquid Crystal Displays.

6.9.2.1 Frequency Coverage. IEEE 1140 covers magnetic field emissions over the frequency range of 5 Hz to 400 kHz where as RE101 covers the frequency range of 30 Hz to 100 kHz. The frequency range of the IEEE 1140 covers the entire frequency range of RE101.

6.9.2.2 Methodology. The test procedure in the IEEE 1140 has a number of significant differences from that of RE101. The differences are:

1) RE101 and IEEE 1140 both measure Tesla with only a small difference in the capture area of the measurement loops. The area for the RE101 loop is 0.014 m^2. The area for IEEE 1140 loop is 0.0096 m^2.

2) IEEE 1140 measures all the emissions in just two frequency bands. The first band is 5 Hz to 2 kHz. The second band is 2 kHz to 400 kHz. RE101 requires that the emission levels be measured at each frequency using specific minimum bandwidths.

3) IEEE 1140 positions the measurement loop antenna at predetermined, standard locations with respect to the EUT. This allows the shape of the EUT to influence the distances between the EUT and the measurement loop.

6.9.2.3 Limits. IEEE 1140 does not provide limits because its purpose is only to be used to acquire data. However, there are recommended ambient (background/sensitivity) levels that should be met before conducting the test. These levels are 40 nT (92 dBpT) for Band 1 (5 Hz to 2 kHz) and 5 nT(14 dBpT) for Band 2 (2 kHz to 400 kHz).

6.9.2.4 Conclusions. Magnetic field emission data obtained using the measurement procedure of IEEE 1140 will not replace RE101 test data. If, for the EUT the source files magnetic field can be identified, one can estimate the corresponding level that would be measured using RE 101.

6.10 RE102, Radiated Emissions, Electric Field, 10 kHz to 18 GHz.

This requirement is applicable for radiated emissions from equipment and subsystem enclosures, all interconnecting cables, and antennas designed to be permanently mounted to EUTs (receivers and transmitters in standby mode). The requirement does not apply at the transmitter fundamental frequencies. The requirement is applicable as follows:

a)	Ground	2 MHz to 18 GHz*
b)	Ships, surface	10 kHz to 18 GHz*
c)	Submarines	10 kHz to 18 GHz*
d)	Aircraft (Army)	10 kHz to 18 GHz
e)	Aircraft (Air Force and Navy)	2 MHz to 18 GHz*
f)	Space	10 kHz to 18 GHz*

* Testing is required up to 1 GHz or 10 times the highest intentionally generated frequency within the EUT, whichever is greater. Measurements beyond 18 GHz are not required.

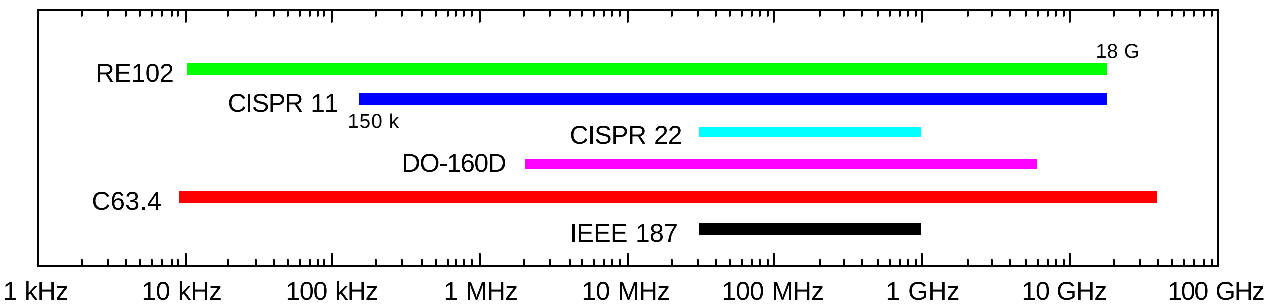
Corresponding commercial standards are CISPR 11 and 22, ANS C63.4, DO-160D, and IEEE 187 Section 21. A summary comparison of these methods is shown in Table 6.10-1.

6.10.1 RE102 vs. CISPR 11. CISPR 11 is a product-family standard covering ISM (Industrial, Scientific, and Medical) equipment. It is contains both conducted and radiated tests and is not intended for lighting equipment, which is covered in CISPR 15, or I.T.E. (Information Technology Equipment), which is covered in CISPR 22.

6.10.1.1 Frequency Coverage. At present, measurements for CISPR 11 are normally made from 150 kHz - 1 GHz & 11.7 - 12.7 GHz, unless the equipment is expected to operate in a "safety-service" area, whereupon the range is 150 kHz - 1.215 GHz & 11.7 - 12.7 GHz. In contrast RE102 covers the range 10 kHz - 18 GHz. Important devices, which will not be protected from I.S.M. emissions include maritime transmitters at the low-frequency end and certain radar & communication systems at the high frequency end. Radar and satellite systems usually have antennas with high directivity so that the relative position of the equipment to the antenna is as important as the emission level in considering interference potential.

6.10.1.2 Methodology. The main differences between CISPR 11 and RE102 are summarized in the Table 6.10-1. Details on the instrumentation and measurement method differences are given in Annex A, Part A.10.

Table 6.10-1: RE102 Comparison with Commercial Standards

Parameter	**RE 102**	**DO-160D, Sec. 21**	**CISPR 11**	**CISPR 22**	**ANSI C63.4**	**IEEE 187**	**Comments**
Equipment Type / Platform	unrestricted	airborne equipment	I.S.M. only	I.T.E. only	non-I.S.M., except TV & FM receivers	TV & FM Receivers	
Frequency Range							Limited commercial application below 1 MHz
Methodology							
Site	(Semi) Anechoic Chamber		Open Area or Anechoic Room			Open Area	
Test Setup	Table-top or floor mounted; grounded as in typical use Cable treatment standardized		Table-top or floor mounted; grounded as in typical use Cables varied to maximize emission			Table top mounted	commercial? typically table top mounted military ? typically ground plane mounted
Distance	1 m		3, 10, or 30 m			3, 10, or 30 m	1 m, military requiremnt severe
Antennas	≤ 30 MHz: monopole 30 – 200 MHz: biconical ≥ 200 MHz: horns		≤ 30 MHz: loop 30 – 80 MHz: dipole of 80 MHz, or broadband 80 – 300 MHz: resonant dipole, or broadband ≥ 300 MHz: horns			30-1 GHz dipole	Comparable
Limits	severe at low frequencies external to vehicles	compare with military aircraft requirements	except for group 2, class A, no limits below 1 MHz	no limits below 30 MHz	CISPR (FCC) limits apply	CISPR (FCC) limits apply	considerable variation

6.10.1.3 Limits. Since CISPR 11 does not allow for compensation for distances different from that defined with the limits, its limit values will have to be compared directly with RE102's. Even though measurements below 30 MHz are made with the loop, the limits are given in terms of dB?V/m so that no conversions are needed for comparison with RE102. The assumed relationship between the electric and magnetic field is **E** = 120?·**H**. The power limits (erp, referred to half-wave dipole) given in CISPR 11 for 11.7 - 12.7 GHz (curve 9) can be converted to field values using the relation:

$$\mathbf{E} \; ? \; 7\frac{\sqrt{erp}}{r}$$ (IEC 61000-2-3, *r* = distance between the EUT and the antenna)

The limits are plotted in Figure 6.10-1 with *r* set at 3 m for a normal (non-safety service area) test.

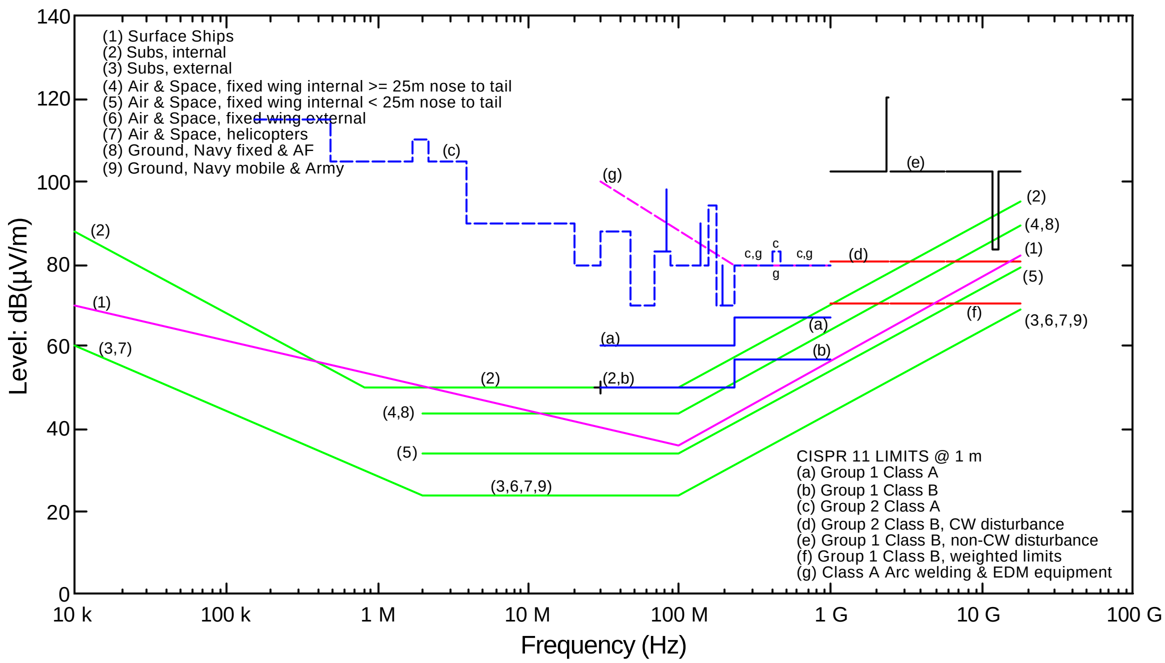


Figure 6.10-1: Limit Comparison of CISPR 11 & RE102

The Groups and Classes are defined as follows:

Group 1: ISM equipment which uses or intentionally generates RF conducted energy

Group 2: ISM equipment which uses or intentionally generates RF radiated energy for the treatment of material

Class A: Equipment not intended for home use

Class B: Equipment intended for home use

Note that some frequencies are reserved by the International Telecommunication Union for ISM equipment and ISM emission in these frequencies may be unrestricted. These are summarized below in Table 6.10-2.

Table 6.10-2: Fundamental I.S.M. Frequencies

Center Frequency (MHz)	*Frequency Range (MHz)*			*Maximum Radiation Limit*
6.78	6.765	-	6.795	Under Consideration
13.56	13.553	-	13.567	**Unrestricted**
27.12	26.957	-	27.283	**Unrestricted**
40.68	40.66	-	40.70	**Unrestricted**
433.92	433.05	-	434.79	Under Consideration
915.0	902	-	928	**Unrestricted**
2,450	2,400	-	2,500	**Unrestricted**
5,800	5,725	-	5,875	**Unrestricted**
24,125	24,000	-	24,250	**Unrestricted**
61,250	61,000	-	61,500	Under Consideration
122,500	122,000	-	123,000	Under Consideration
245,000	244,000	-	246,000	Under Consideration

6.10.1.4 Conclusions. Although CISPR 11 presents a viable alternative testing technique to RE102, due to its frequency coverage and different limit shapes and levels, ISM equipment qualified to CISPR 11 will be acceptable for military use only for environments in which the RE 102 requirements can be relaxed such as when the equipment is used in a commercial environment.

6.10.2 RE102 vs. CISPR 22. CISPR 22 is a product-family standard covering Information Technology Equipment (ITE). It contains both conducted and radiated tests. An ITE is any equipment which:

a) has a primary function of: entry, storage, display, retrieval, transmission, process, switch, or control data and telecommunication messages

b) has a supply voltage not exceeding 600 V.

6.10.2.1 Frequency Coverage. At present, CISPR 22 radiated measurements are made only in the frequency range 30 MHz - 1 GHz, which does not encompass the range of RE102: 10 kHz - 18 GHz. Possible military equipment not protected from CISPR 22 qualified ITEs are identified in the section *RE102 vs. CISPR 11*.

6.10.2.2 Methodology. Table 6.10-1 summarizes the major differences between the tests.

6.10.2.3 Limits. Due to the many differences in the test setups, a comparison of the limits is at best approximate. Unlike CISPR 11, CISPR 22 does allow for compensation of limit levels with measurement distance. The attenuation factor is assumed to be $1/r$ in CISPR 22. However, below ~ 48 MHz, RE102 measurements are made in the near field; preliminary studies have shown that the attenuation factor in the near field is approximately $1/r^{2.3}$. The limits are plotted in Figure 6.10-2 superposed on the military limits. Since the plot is only intended to be a rough estimate of the stringency, variations in the field levels which may arise due to different test setups have been neglected, and the attenuation factor is assumed to be $1/r$ in accordance with the standard. The Classes in CISPR 22 are defined as follows:

Class A: Equipment which satisfies Class A limits but not Class B limits (to be labeled with a warning)

Class B: Equipment intended for use in homes

6.10.2.4 Conclusion. Due to the frequency coverage and different limit shapes and levels, ITE equipment qualified to CISPR 22 will not be acceptable for military purposes unless it is used in a commercial-like environment.

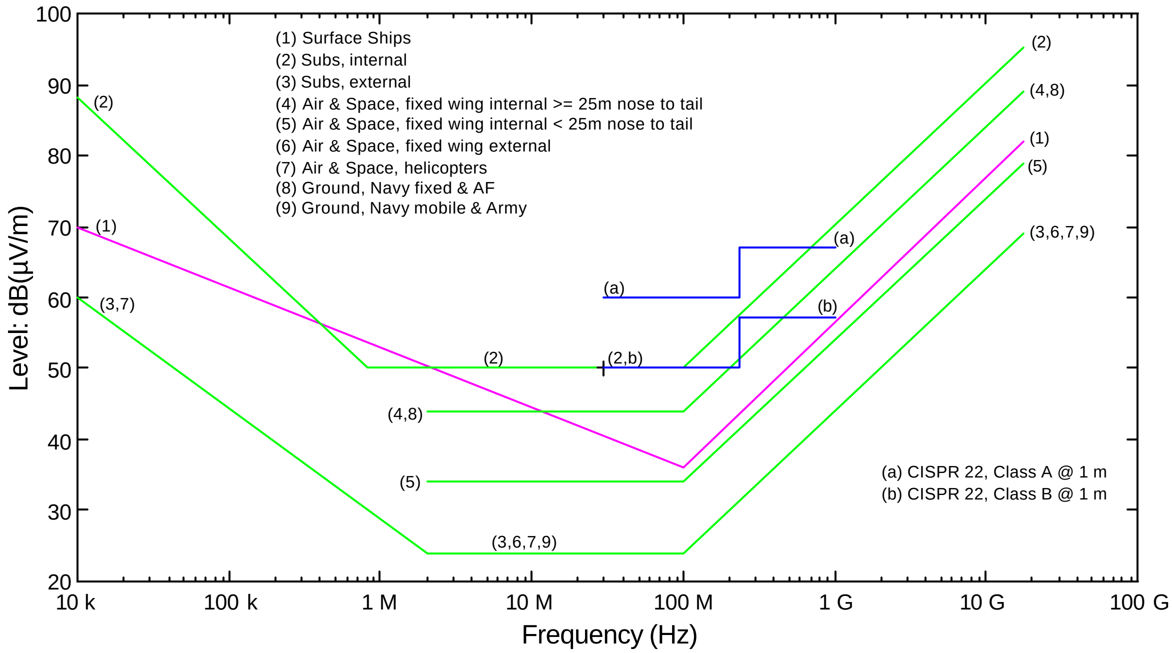


Figure 6.10-2: RE102 & CISPR 22 Limits (at 1 m)

6.10.3 RE102 vs. RTCA DO-160D. RTCA DO-160D is an industry standard covering all airborne equipment. Section 21 of DO-160D contains tests of both conducted and radiated emissions of radio-frequency energy.

6.10.3.1 Frequency Coverage. For the radiated tests, measurements are made from 150 kHz to 1.215 GHz. In contrast, the RE102 range is from 10 kHz - 18 GHz. Possible military equipment not protected from emissions from DO-160D tested devices include some maritime transceivers in the kHz end and radar and communication systems at the GHz end.

6.10.3.2 Methodology. The test methods seem similar, but there are subtle differences which will need consideration when judging suitability of equipment tested to DO-160D requirements for military use. The major differences are outlined below.

Antennas. RE102 is specific on the type of antennas to be used: 104-cm monopole rod with counterpoise and impedance matching network for frequencies 30 MHz and below, 137-cm biconical for 30 MHz to 200 MHz, and double-ridged horns for frequencies 200 MHz and above. In contrast, DO-160D poses no specific requirement on the type of antennas; the appropriate antennas for testing are left to the judgement of the tester. A log-spiral antenna may be used even though RE102 cautions against this due to the confusion that may arise with the 3 dB correction factor and the fact that at some frequencies the antenna pattern may not be centered on its physical axis.

Multiple Antenna Locations   RE102 specifies multiple antenna locations if the EUT and its associated cabling are not wholly covered within the 3dB beam width of the (horn) antenna, DO-160D does not require multiple antenna locations. However, the standard suggests testing with many EUT orientations for equipment with multiple apertures and sensors. This is comparable to military practice, but differences may arise due to the lack of guidance in DO-160D in this aspect and the possibility complicated relationships between aperture orientations and antenna beam width with distance.

LISN Device   DO-160D does not specify a specific LISN, only the impedance range that the device must meet. The frequencies of this impedance range encompasses that defined in MIL-STD 461E, but there are significant differences in characteristics below approximately 2 MHz. The effects of LISN usage for RE102 testing are still unclear, thus these differences in LISN characteristics between DO-160D and MIL-STD 461E cannot be ignored.

Bandwidths of Detectors. Differences in detector bandwidths as discussed in clause A.10.1.2 of Annex A may be accountable for differences in the measurements between the two tests, in particular, in the frequency range 2 MHz to 400 MHz. Some correction for these differences in the bandwidths may be necessary when comparing emission levels.

6.10.3.3 Limits. Since the narrow band readings are expected to remain approximately the same when the detector bandwidth is increased, the narrow band limits can be compared directly with RE102 limits. The broadband limits, however, are given in terms of dBµV/m/MHz so that a multiplication with the detector bandwidths (in MHz) is needed to obtain the field values. In Figure 6.10-3 DO-160D limits are multiplied with the bandwidths of the RE102 detector to obtain the field values that the commercial limits would represent in a RE102 test. The equipment classes in DO-160D are defined as follows:

Class Z: Equipment intended for operation in systems where interference-free operation is required

Class A: Equipment intended for operation in systems where interference-free operation is desirable

Class B: Equipment intended for operation in systems where interference should be controlled to a tolerable level

6.10.3.4 Conclusions. Except for Class A or Z equipment with narrowband emissions (curve 7), no other airborne equipment qualified to DO-160D, Section 21 is acceptable for military purposes due to the frequency coverage and the different limit shapes and levels. Curve (7) may be acceptable for curves (1), (3), or (5) with allowances at the high and low frequency ends (equipment not expected to be near susceptible receivers). The maximum difference of approximately 7 dB between curves (7) and (5) lies at 25 MHz, and between curves (7) and (1,3) at 100 MHz.

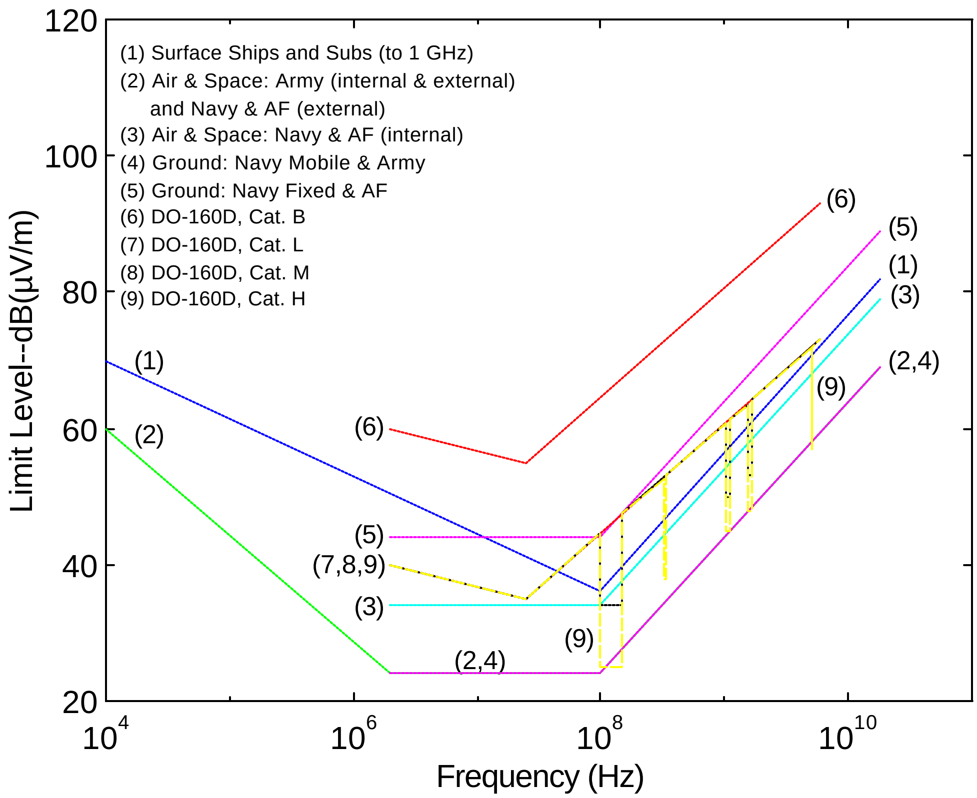


Figure 6.10-3: RE102 & DO-160D, Section 21 RE Limits

6.10.4 RE102 vs. ANS C63.4. ANS C63.4 is a national standard on methods of measurement of radio-noise emissions from low-voltage (≤ 600 V) non-ISM equipment, AC or DC. For TV and FM receivers, IEEE 187 is more apt.

6.10.4.1 Frequency Coverage. C63.4 covers the range 9 kHz to 40 GHz, which encompasses the range of RE102 (10 kHz - 18 GHz).

6.10.4.2 Test Comparison. The procedure in ANS C63.4 is in many respects similar to those in CISPR 11 and 22, except that it is more detailed in its procedures and the absorbing clamp alternative. Table 6.10-4 summarizes the major differences between the tests.

6.10.4.3 Limits. The limits are prescribed in the FCC regulations; they are very similar to the CISPR limits.

6.10.4.4 Conclusions. Due to the frequency coverage of the limits, equipment qualified to FCC regulations according to the measurement procedure in ANS C63.4 will be acceptable for military purposes only if it is used in a civilian environment. Equipment qualified via measurements with the absorbing clamp will only be acceptable for meeting requirements if a satisfactory correlation between conducted power and field readings can be established.

Table 6.10-4: RE102 and ANS C63.4 Test Comparison

Parameter	RE102	ANSI C63.4
Frequency Range	10 kHz – 18 GHz	9 kHz – 40 GHz
Equipment Type	unrestricted	non-ISM, except TV & FM receivers
Measurement Distance	1 m	3, 10, or 30 m
Test Setup	Standardized in MIL-STD 462	Typical of installation, but no bonding of equipment to ground plane
Test Site	Anechoic Room	Open Area
Test Antennas	10 kHz - 30 MHz: rod 30 MHz – 200 MHz: biconical 200 MHz – 1 GHz: horn	9 kHz - 30 MHz: loop & rod 30 MHz - 1 GHz: dipole 1 GHz - 40 GHz : horn

6.10.5 RE102 vs. IEEE 187. IEEE 187 is a national standard covering radiated emissions of TV & FM receivers.

6.10.5.1 Frequency Coverage. IEEE 187 covers the range 30 MHz – 1 GHz.

6.10.5.2 Methodology. In IEEE 187 the receiver under text is placed on a rotatable, non-conducting table 0.8 meters above a conducting ground plane and a receiver antenna of specified design is connected to the receiver and located at a height of 4 meters. The antenna of a field strength measuring instrument is located at a recommended spacing of 3m from the receiver antenna with a height adjustable from 1 to 4 meters. However, if this is impractical, measurements may be made at 10m or 30m and field levels interpolated on a ½ basis.

6.10.5.3 Limits. The limits are covered in the FCC regulations. They are similar to the CISPR limits.

6.10.5.4 Conclusions. Due to the frequency coverage and limit levels, TV & FM receivers qualified to FCC regulations according to the measurement technique in IEEE 187 will be acceptable for meeting RE102 requirements only if they are expected to be used with separation distances from susceptible antennas as below.

Ground; Navy Fixed & AF	1.9 m	6 ft
Ground; Navy Mobile & Army	19 m	60 ft
Air & Space; Navy & AF (internal)	5.6 m	18 ft
Air & Space; Army (internal & external) and Navy & AF (external)	19 m	60 ft
Ships & Subs	5.6 m	18 ft

6.11 RE103, Radiated Emissions, Antenna Spurious and Harmonic Outputs, 10 kHz to 40 GHz

This requirement may be used as an alternative for CE106 when testing transmitters with their intended antennas. CE106 is the preferred requirement unless the equipment or subsystem design characteristics preclude its use.

6.11.1 Commercial Standards

Requirements exist in the FCC regulations, the NTIA Manual and ITU recommendations. IEC 60244-2A provides only for measurements into the antenna (by means of directional couplers, etc.) and not for radiated measurements as such.

The NTIA Manual, Chapter 5 gives detailed requirements on various types of transmitters, some of these parallel the ITU requirements. Measuring methods are given in Annex M of the Manual, which frequently references EIA measurement standards.

6.11.2 Frequency ranges

The FCC calls for measurements over the frequency range from that of the lowest radio frequency used in the equipment cabinet to a) if the equipment operates below 10 GHz, the 10th harmonic of the highest fundamental frequency, or 40 GHz, whichever is lower, 2) for equipment operating between 10 GHz and 30 GHz, the 5th harmonic of the highest fundamental frequency or 100 GHz, whichever is lower, or 3) if the equipment operates above 30 GHz, the fifth harmonic of the highest fundamental frequency or 200 GHz, whichever is lower.

ITU-R M1177 covers up to 18GHz while NTIA generally covers the frequencies called out in Table 6.3-4 (10kHz-960MHz).

6.11.3 Methodology

In 47CFR sub-clause 2.993 the FCC calls for radiated tests in the “far field” using typical commercial practice. For emergency position indicating radio beacons (EPIRB) measurements are to be made on a 30m open field test site in which the receiving antenna height is to be raised from 1-4 meters. ITU-R M1177 gives detailed measurement procedures using either antenna to antenna coupling or a direct waveguide connection. Additional details on these measurement techniques are given in Annex A, Section A.13.

6.11.4 Limits

For EPIRB the FCC limit for spurious emissions is 30 dB below the fundamental. Otherwise the military NTIA limits generally correspond to those given on Figure 6.3-3.

6.11.5 Conclusions Equipment produced in accordance with commercial spurious omission requirements can be used for military purposes only where the application permits relaxation of the frequency range and/or limits.

6.12 RS101, Radiated Susceptibility, Magnetic Field, 30 Hz to 100 kHz

This requirement is applicable to equipment and subsystem enclosures, including electrical cable interfaces. The requirement is not applicable for electromagnetic coupling via antennas. For equipment intended to be installed on Navy aircraft, the requirement is applicable only to aircraft equipment with ASW capability. For Army ground equipment the requirement is applicable only to vehicles having a minesweeping or mine detection capability. The requirement is applicable for Navy ground equipment when specified by the procuring activity

6.12.1 RS101 vs. IEC 61000-4-8, 9, 10. The nearest corresponding civilian standards are IEC 61000-4-8, -9, and –10. A summary comparison of these standards is presented in Table 6.12-1

6.12.1.1 Frequency Coverage . As noted in Table 6.12-1, IEC 61000-4-8 has requirements only at the power distribution frequencies of 50 or 60 Hz.. IEC 61000-4-9 provides for a magnetic field pulse with a rise time of 6.4 µs. and a half value width of 16 µs. IEC 61000-4-10 provides two damped oscillatory magnetic fields, the frequencies of oscillation being respectively 100 kHz and 1 MHz with the amplitude decaying to 50% after 3 to 6 cycles. RS101 has requirements over the 30 Hz to 100 kHz frequency band.

6.12.1.2 Test Comparison. As noted in Table 6.12-1, the civilian and military magnetic field immunity tests are quite different. RS101 produces local fields by using a small exploring coil to determine locations on the cabinet where there may be field leakage to circuits inside. IEC 61000-4-8, 9, and 10 determine "global" immunity characteristics of equipment by immersing the entire cabinet in a magnetic field. When susceptibility is found not only is the level of the field recorded but also the location of the susceptible point on the EUT. More detail on the measurements with these methods is given in Annex A, Section A.12.

IEC 61000-4-8 test is conducted by placing the EUT in the center of a relatively large induction coil. There is not a single standard size or shape for this coil. The standard provides instructions for making coils of different sizes and shapes depending on the size of the EUT. The standard also covers the possible use of a double or Helmholtz coil to achieve the required field levels.

6.12.1.3 Limits. (See Table 6.12-2) Since IEC 61000-4-8 only has requirements at the power frequency, direct comparison of the limits between IEC 61000-4-8 and RS101 can be made only at that frequency (50/60 Hz). The maximum 61000-4-8 requirement is 100 A/m at the center of the immersion coil. The maximum RS101 requirement at the power frequency is 180 dBpT or approximately 800 A/m at a distance of 5 cm from the plane of the loop. Thus which test is the more severe will depend on the location of the susceptible circuit within the cabinet of the equipment. IEC 61000-4-8 also has requirements for short duration testing (1 to 3 sec.). The maximum amplitude of this short duration transient is 1000 A/m. There is no corresponding RS101 short duration requirement. In IEC 61000-4-9 the maximum pulse amplitude is 1000 A/m and in IEC 61000-4-10 the maximum value of the damped oscillatory field is 100 A/m.

Table 6.12-1: RS101 Comparison with Commercial Standards

Test Parameter	RS101	IEC 61000-4-8, 9, 10	Comments
Frequency	30 Hz - 100 kHz	50 or 60 Hz	
Transient	None	Pulse, damped sine wave	
Test Method	EUT surface & connector scan at 5 cm distance	Immersion method with inductive loops	
Limits	Note: Navy & army limits differ		

6.12.1.4 Conclusions. Although there are major differences in the military and commercial test procedures, comparisons may be made to show that commercial tests may provide a basis for determining that commercial equipment meets the military requirements. The following comments indicate bases that can be used in particular applications.

Table 6.12-2: Limits for IEC Magnetic Field Immunity Standards

Test Level Identifier	TEST LEVEL PEAK MAGNETIC FIELD (A/M)		
	IEC 61000-4-8	IEC 61000-4-9	IEC 61000-4-10
1	1	*n.a.*[2)]	*n.a.*[2)]
2	3	*n.a.*[2)]	*n.a.*[2)]
3	10	100	10
4	30	300	30
5	100	1000	100
x[1)]	special	special	special

NOTES:
[1)] "*x*" is an open level. This level can be given in a product specification.
[2)] "*n.a.*" = not applicable

1) If the dominant source of the magnetic field arises from large equipment operating at the power frequency, IEC 61000-4-8 may provide a test more severe than the military test because it is an "immersion" test.

2) IEC 61000-4-9 is a pulse test having a frequency spectrum flat up to about 70 kHz. Since it is an intense requirement it may be effective, depending on the equipment's response bandwidth, in determining adequate immunity at frequencies up to the maximum in the military requirement.

3) IEC 61000-4-10 provides, at 100kHz, a test that may be equally severe as the military test; at 1 MHz it provides a test beyond the military requirement.

6.13 RS103, Radiated Susceptibility, Electric Field, 2 MHz to 40 GHz

This requirement is applicable to equipment and subsystem enclosures and all interconnecting cables. The requirement is applicable as follows:

a)	2 MHz to 30 MHz	Army ships: Army Aircraft, including flight line; Navy (other than aircraft); and optional* for allothers
b)	30 MHz to 1 GHz	All
c)	1 GHz to 18 GHz	All
d)	18 GHz to 40 GHz	Optional* for all

*Required only if specified in the procurement specification

The requirement at the tuned frequency of an antenna-connected receiver is 20 dB above the RE102 limit associated with the particular platform application.

Corresponding commercial requirements are IEC 61000-4-3 and IEC 61000-4-6, DO-160D, and SAE J1113-21. A comparison of RS103 and IEC 61000-4-3 is summarized in Table 6.13-1. Because of its special application only to road vehicles, a comparison of SAEJ1113-21 and RS103 is presented in Annex A, Section A.13.

Table 6.13-1: RS103 & IEC 61000-4-3 Test Comparison

Test Parameter	**RS103**	**IEC 61000-4-3**
Frequency Range	2 MHz - 40 GHz	80 MHz - 1 GHz
Test Area	Partially anechoic room	Anechoic room recommended
Calibration	2 MHz - 1 GHz: Field probe with EUT in place 1GHz - 10 GHz: E-sensor or horn 1 m from antenna	Sensor grid w/o EUT in place. 1 or 3 m from antenna
Test Setup	Table-top or floor-mounted, grounded & bonded as in typical use. Standardized treatment of cables	EUT is insulated from ground plane by 0.1 or 0.8 m, (floor-standing or table-top, respectively). Cables are placed to back of setup. Only grounding is through “green” wire ground.
Transmitting Antenna	Testing facility’s choice (no circularly polarized fields)	Biconical or log-periodic, OR circularly-polarized with 3 dB increase in power, OR striplines for small EUTs
Illuminate	2 MHz - 200 MHz: EUT & 2 m of cable 200 MHz - 1 GHz: EUT & 35 cm 1 GHz - 40 GHz: EUT & 7 cm Most susceptible side of EUT; multiple antenna positions; above 30 MHz, both horiz. & vert. polarizations	Method emphasizes illuminating 4 sides of EUT enclosure, horiz. & vert. polarizations. ~ 1 meter of cabling to rear of setup does not receive special treatment
Test Signal Modulation	Square wave, 1 kHz, 50% duty cycle	80% sine wave AM, 1 kHz
Sweep Rate Max. (decades/s)	2 - 30 MHz: 1.4×10^{-3} 30 – 1 GHz: 0.72×10^{-3}	1.5×10^{-3}
Step Size, (f_t = tuned frequency of signal source)	2 - 30 MHz: $\leq 1\% f_t$ 30 - 1000 MHz: $\leq 0.5\% f_t$	$\leq 1\% f_t$
Dwell time	> 3 seconds	Not specified
Requirement	5 – 200 volts/meter	1 – 10 volts/meter

6.13.1 RS103 vs. IEC 61000-4-3 and IEC 61000-4-6. In IEC at low frequencies radiated susceptibility is measured by injecting currents on cables using coupling-decoupling networks and otherwise isolating the EUT from the ground plane (it is mounted 10 cm above it). This procedure is described on IEC 61000-4-6 that covers the frequency range from 150 kHz to 80 MHz. Above 26 MHz a directly radiated test is employed (IEC 61000-4-3).

6.13.1.1 Frequency Coverage. RS103 covers the frequency from 2 MHz to 40 GHz (30 MHz - 18 GHz is always required, but testing in other ranges depends on application). While IEC 61000-4-3, as noted in its Annex H, may cover from 26 MHz to a maximum of 1000 MHz, it is normally applied only above 80 MHz. The conducted immunity testing of IEC 61000-4-6 is utilized to assess equipment performance at frequencies below 80 MHz.

6.13.1.2 Methodology Where IEC 61000-4-6 has been used the requirements may be compared with the requirements and test methods of CS114. Typically the radiated test in IEC 61000-4-3 is applied only above 80 MHz. Note also that RS103 describes a reverberation chamber test method in addition to an anechoic or partially anechoic chamber method. IEC 61000-4-3 covers only the latter technique at the present time, but the reverberation chamber method is in development.

One of the major differences in the test procedures is in the method of calibration. IEC 61000-4-3 requires measurements of the field strength at up to 16 points over the surface of the plane where the front of the EUT will be located. At 12 of these points the field strength must be equal to the calibrated test field or not more than 6dB above it. In RS103, the field is measured in several locations near the EUT with field probes in place at the time of the test.

Another difference in the test is the modulation applied to the test signal. RS103 calls for 50% duty cycle pulse modulation, whereas IEC 61000-4-3 calls for 80% sine wave modulation. The RS103 modulation is more severe that the IEC modulation.

6.13.1.3 Limits . IEC 61000-4-3 provides three levels of protection ranging from 1 to 10 volts per meter (V/m). RS103 requirements range from 5 to 200 V/m depending upon what platform the equipment is to be used on (i.e. ship, airframe etc). The limits are plotted in Figures 6.13-1, 6.13-2 and 6.13-3 according to the intended platform.

6.13.1.4 Conclusions. Because of the more limited frequency range covered in IEC 61000-4-3 (usually only above 80 MHz), it is necessary to also consider results of tests on commercial equipment with conducted immunity tests made according to IEC 61000-4-6 for meeting requirements in RS103.

Due to the many differences between the RS103 and IEC 61000-4-3 requirements and test methods, it is often not suitable for a device qualified under the latter to be applicable for direct substitution for military purposes. As outlined in the body of this document, it would require many modifications or stipulations be made to the IEC 61000-4-3 test procedures for it to be utilized as a direct alternative for test methodology presently used for military equipment or subsystems.

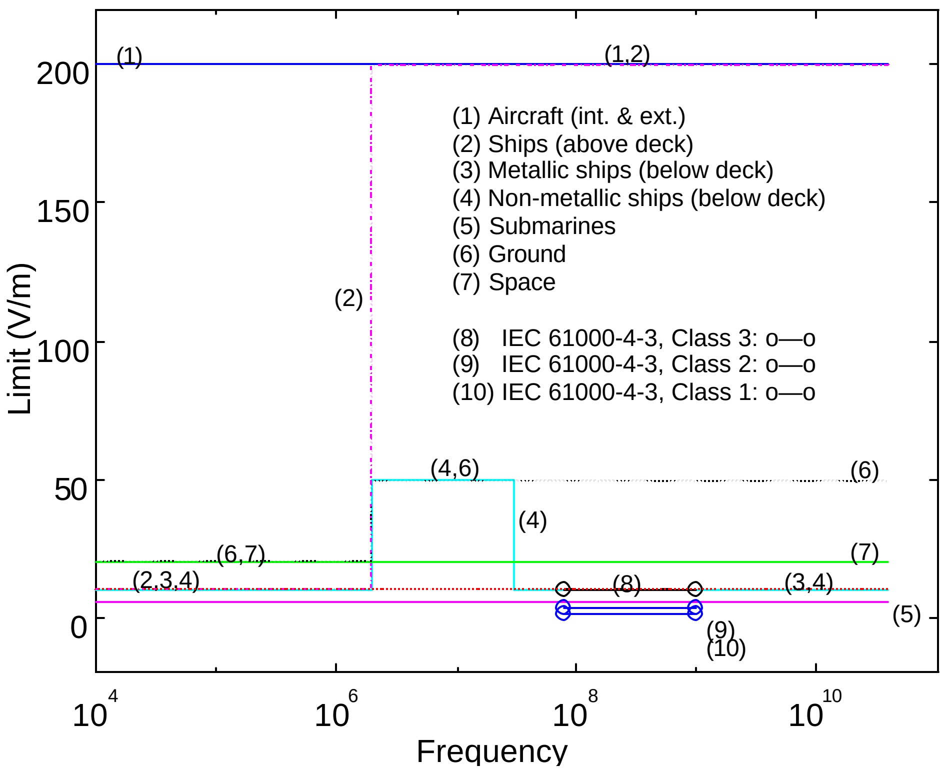


Figure 6.13-1: Army RS103 and IEC 61000-4-3 Limits

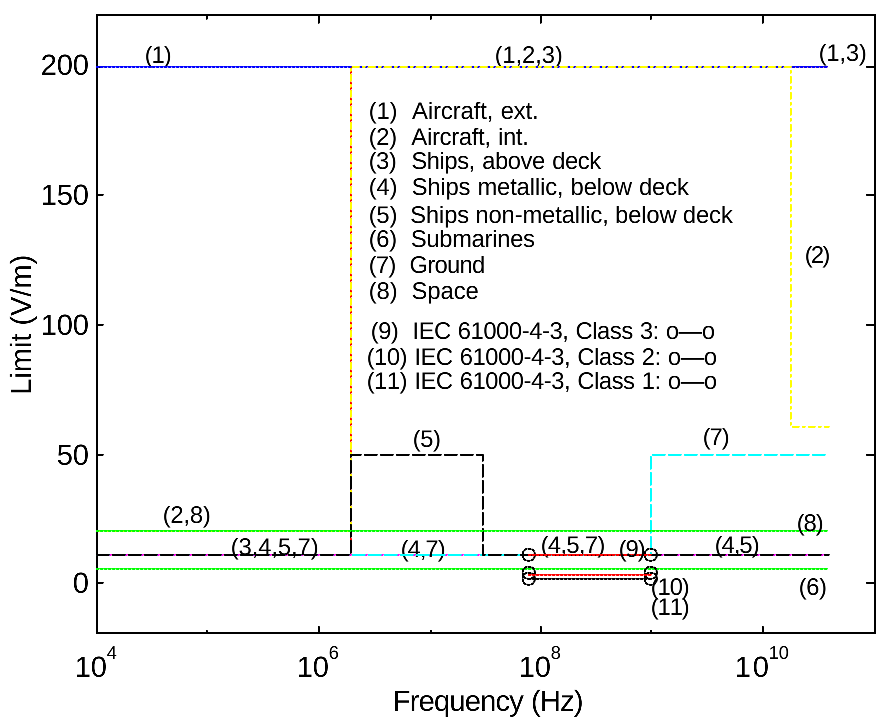


Figure 6.13-2: Navy RS103 & IEC 61000-4-3 Limits

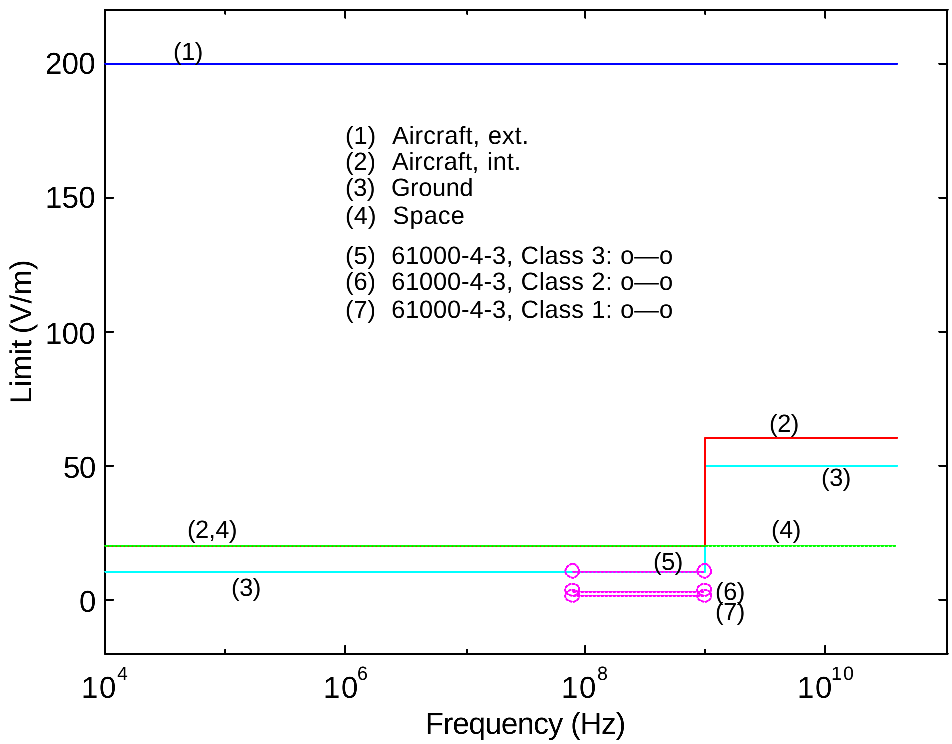


Figure 6.13-3: Air Force RS103 & IEC 61000-4-3 Limits

6.13.2 RS103 vs. DO-160D. RTCA DO-160D is intended for airborne use, although it could be applied elsewhere. The most significant differences between the two test procedures (other than the frequency range) exist in the method of measuring the radiated electric field and in scan speeds applied. The RS103 method utilizes real time feedback to monitor the RF field strength during testing. DO-160D precalibrates the field in the test zone prior to the placement of the EUT. Then the calibration levels are repeated after the addition of the EUT in the test area. The scan speeds used by DO-160D are somewhat faster than those of RS103 (see Table 6.13-2).

6.13.2.1 Frequency Range. RS103 test frequency ranges from 2 MHz to 40 GHz, depending upon the platform where the equipment is installed. However, the majority of usage is limited to 2 MHz and 18 GHz (optional above 18 GHz for all applications). Frequency coverage of DO-160D is limited to 100 MHz to 18 GHz. Below 100 MHz DO-160 utilizes cable injection techniques to evaluate the equipment under test.

6.13.2.2 Methodology. Test setups and methodologies used for RS103 and DO-160 are very similar.

6.13.2.3 Limits. In Table 6.13-3, limits are compared between RS103 and DO-160. DO-160D categories are selected by the equipment manufacturer or purchasing organization. There are no defaults.

6.13.2.4 Conclusions. RTCA DO-160D, Section 20 can be substituted for RS103 provided that equipment is certified to appropriate category limits over the correct frequency ranges (see 6.13.2.1 above). Figure 6.13-3 shows correlation between MIL-STD-461 field level requirements and DO-160D test categories.

Table 6.13-2: RS103 & DO-160D Scan Rate Comparison

Frequency Range	RS103 Analog Scans	DO-160D Analog Scans	RS103 Stepped Scans	DO-160D Stepped Scans
30 Hz - 1 MHz	0.0333 f_o/sec	decade/120 sec	0.05 f_o	decade/100sec*
1 MHz - 30MHz	0.0667 f_o/sec	"	0.01 f_o	"
30 MHz - 1GHz	0.00333 f_o/sec	"	0.005 f_o	"
1 GHz - 8 GHz	0.00667 f_o/sec	"	0.001 f_o	"
8 GHz - 40 GHz	0.00333 f_o/sec	"	0.0005 f_o	"
* At 100 frequencies per decade with a minimum 1 second dwell time.				

Table 6.13-3: Comparison of RS103 and DO-160D Limits

Field Strength (V/m)	RS103 Requirement (example)	DO-160D Category
5	Submarines	Category T*
10	Ships (below decks)	N.A.
20	Space	Category U*
50	Ground	Category V*
100	N.A.	Category W
200	Aircraft	Category Y
* Only specified to 1.215 GHz.		

6.13.3 RS 103 vs. SAE J1113-21 SAE J1113-21 is intended for testing of road vehicles; however, it could be applied elsewhere.

6.13.3.1 Frequency Range RS103 test frequency ranges from 2MHz to 40 GHz, depending upon the end platform for the equipment. However, the majority of usage is limited to between 2 MHz and 18 GHz (optional above 18 GHz for all applications). Frequency coverage of J1113-21 is limited to 10 kHz to 18 GHz.

6.13.3.2 Methodology. The main differences between the two test procedures are summarized in Tables 6.13-4 and 6.13-5:

Table 6.13-4: Main Differences Between RS103 & SAE J1113-21

Parameter	**RS103**	**SAE J1113-21**
Frequency Range	2 MHz-40 GHz	10 kHz – 18 GHz
E-field Measurement Method	Isotropic probe provides feedback during test	Either isotropic probe method or substitution method
Frequency Step Increments	Summarized in Table 6.13- 5	Summarized in Table 6.13- 5
Antenna Placement for Physically Large Systems Under Test	Method for multiple test antenna positions based upon beamwidth of antenna	Not addressed
E-Field Modulation	1 kHz square wave	CW and 1 kHz sine wave, 80% AM
LISN	50 ?H	5 ?H
Test Dwell Time	3 sec.	2 sec.
The step sizes used by J1113-21 are four to twenty times larger than those of RS103 (continuous analog rates are not provided in J1113-21).		

Table 6.13-5: Comparison of RS103 and J1113-21 Step Sizes

Frequency Range	RS103 Stepped Scans*	SAE J1113-21 Stepped Scans**
10 kHz		10 kHz
100 kHz – 1 MHz		100 kHz
1 MHz – 10 MHz	0.01 *fo*	1 MHz
10 MHz – 30 MHz	0.01 *fo*	2 MHz
30 MHz – 200 MHz	0.005 *fo*	2 MHz
200 MHz-1 GHz	0.005 *fo*	20 MHz
1 GHz – 8 GHz	0.001 *fo*	200 MHz
1 GHz – 18 GHz	0.0005 *fo*	200 MHz
* With minimum dwell time of 3 seconds ** With minimum dwell time of 2 seconds		

6.13.3.3 Limits. In Table 6.13-6 limits are compared between RS103 and J1113-21. Test severity levels in J1113-21 are provided as examples, with determiniation of real test levels left to the user.

Table 6.13-6: Comparison of RS103 and J1113-21 E-Field Limits

E-field Strength (V/m)	RS103 Requirements (example)	J1113-21 Test Severity Level
5	Submarines	N.A.
10	Ships (below decks)	N.A.
20	Space	N.A.
25	N.A.	L1
50	Ground	L3
100	N.A.	L6
200	Aircraft	N.A.

6.13.3.4 Conclusions. For most bench size components, J1113-21 can be substituted for RS103 provided that equipment is certified to appropriate limits and associated frequency ranges specified by the procuring activity. However, analysis may need to be conducted to determine possible effects of utilizing J1113-21's larger step sizes and less severe modulation parameters.

6.14 RS105, Radiated Susceptibility, Transient Electromagnetic Field

This requirement is applicable to equipment and subsystem enclosures when the equipment or subsystem is to be located external to a hardened (shielded) platform or facility., The requirement is applicable to equipment intended solely for use on non-metallic platforms when specified by the procuring activity. The requirement is applicable to Army aircraft for safety critical equipment and subsystems located in an external installation. Commercial standards corresponding to RS105 are IEC 61000-4-25 and IEC 61000-4-20. A summary comparison of RS105 and IEC 61000-4-20 is shown in Table 6.14-1.

6.14.1 RS105 vs. IEC 61000-4-20 (TEM Cells).

6.14.1.1 Frequency Coverage. Since the waveforms are identical (as discussed in 6.14.1) the frequency capability of the TEM cells to be used must therefore be similar. The maximum frequency resolution is on the order of 500 MHz. For the IEC 61000-4-20 immunity test, the frequency range is not specified but the procedure is designed for "high frequencies" to greater than 5 GHz.

6.14.1.2 Methodology. RS105 is designed to test against EMP fields for equipment located outside of the platform structure. Typically the test uses a TEM cell, although parallel plate open strip lines are permitted. IEC 61000-4-20, Immunity and Emission Testing in TEM Cells (presently in draft form), provides a standard procedure for emission and immunity testing with TEM cells and is referenced in IEC 61000-4-25; currently it is designed for CW testing but recommendations have been made to include a pulse testing technique. See Table 6.14-1.

6.14.1.3 Limits. IEC 61000-4-20 does not prescribe any limits (see 6.14.2 below).

6.14.1.4 Conclusions. Test procedure in IEC 61000-4-20 should be suitable for determining compliance with RS105

6.14.2 RS105 vs. IEC 61000-4-25. IEC 61000-4-25 states requirements for immunity to HEMP radiated phenomenon; it specifies tests and provides the characteristics for three standard pulses that may be used in testing: the Early-Intermediate- Late-time HEMP.

6.14.2.1 Frequency Coverage. See 6.14.1.1. More detailed discussion of the test procedures is given in Section A.14 of Annex A.

6.14.2.2 Methodology. The test procedures are quite similar except that IEC 61000-4-25 provides for "large simulators" in addition to "small radiated test facilities". Additional differences are:

1) IEC 61000-4-25 requires E and H field sensors whereas MIL-STD 461E requires E-dot and B-dot sensors

2) IEC 61000-4-25 requires the pulse spectrum to meet stated requirements whereas MIL-STD-461E has no such requirements.

Table 6.14-1: RS105 and IEC 61000-4-20 Comparison

Test Parameter	**RS105**	**IEC 61000-4-20**
Testing Device	TEM cells, parallel plates, or equivalent	Single-port or Dual-port TEM cells, (enclosed cells presumed)
Calibration Technique	Field probe at EUT site used with integration Terminal HV probe Verify pulse parameters	Field probe at EUT site (implied) HF voltmeter at generator output/cell input * Input level required for prescribed field level as function of frequency Field calibrated to (0 to +6 dB)
Test Setup	TEM cell bonded to GND All cables shielded in conduit beneath bottom plate (excluded from test) Power thru TPDs and LISNs (outside cell) Measuring equipment in shielded enclosure (open radiator), EUT grounding unclear (only thru LISN?) AE treatment unclear	TEM cell bonding unclear Cables as in typical use (unshielded & parallel to **E** field preferred), Excess lengths bundled Power thru line filters (bonded beneath cell bottom plate), Power lines 1 m Measuring equipment may not be in shielded enclosure EUT grounded as in typical use AE treatment unclear
Testing Technique	Monitor field with D-dot, B-dot sensors & integrators Usage of extra cables for EUT monitoring unclear Gradual amplitude increase from 50 to 100% Apply $\leq$ 1 pulse per minute Pulse polarization unclear EUT in orthogonal positions	Field monitoring technique unclear EUT monitoring only with EUT cables (no extras), and video cameras Test at prescribed level, decrease to find level of susceptibility (optional) Rotate EUT about all axes if possible, vertical axis at minimum
*CW-specific requirements AE – Auxiliary Equipment		

6.14.2.3 Limits. IEC 61000-4-25 provides for a total of 7 specific test levels, which are selectable depending on the degree of protection provided by a facility. The IEC Early-HEMP waveform for R7 level testing is derived from IEC 61000-2-9 and is identical to the RS105 waveform. (See Figure 6.14-1).

IEC 61000-4-25 allows for lower test levels (500 and 5000 V/m) in addition to the 50 kV/m level. The lower levels will be applied in cases where the equipment under test normally operates in a partially shielded location. In addition, IEC 61000-4-25 provides for a limit level "X" which can be any specified test level.

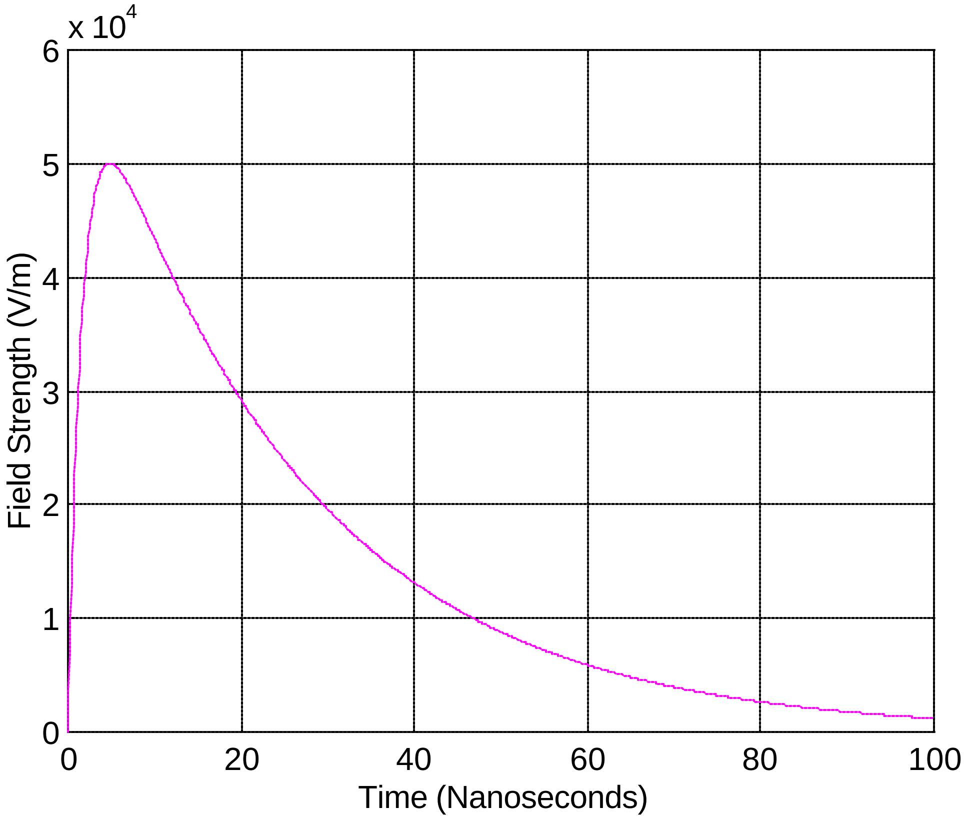


Figure 6.14-1: IEC Early HEMP & RS105 Waveforms

6.14.2.4 Conclusions. The IEC 61000-4-25 radiated requirement for the R7 level is identical to the RS105 requirement. The test procedures differ, but a device tested to IEC 61000-4-25 should be acceptable for meeting RS105 requirements.

Annex A

Detailed Analysis

Annex A

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A.0 Introduction

This annex gives details on the comparison of MIL-STD-461E and commercial standards, the results of which are summarized in Section 6 of this report. For the convenience of the reader, much of the material in Section 6 is repeated in this part. As mentioned in Section 5, the substitution of a commercial requirement for an equipment to be used in a military environment is never done without incurring a certain amount of risk that the device constructed to the commercial requirement will not perform satisfactorily. By carrying out a detailed analysis of known equipment characteristics and the anticipated electromagnetic environment in which it will be used it may be possible to considerably reduce the risk. As in section 6, the presentations in this annex are organized in accordance with the MIL-STD-461E requirements.

A.1 CE101, Conducted Emissions, Power Leads, 30 Hz to 10 kHz

This requirement is applicable for power leads, including returns, that obtain power from other sources not part of the EUT for submarines, Army aircraft (including flight line) and Navy aircraft.

For equipment intended to be installed on Navy aircraft, this requirement is applicable only for aircraft with Anti-Submarine Warfare (ASW) capability.

For AC applications, this requirement is applicable starting at the second harmonic of the EUT power frequency.

Two commercial counterparts to CE101 are IEC 61000-3-2 and IEC 61000-3-8.

A.1.1 CE101 vs. IEC 61000-3-2 IEC 61000-3-2 is a product-family standard covering all equipment connected to AC mains operating at 220, 230, or 240 V at 50 or 60 Hz with rated input current ? 16 A per phase. DC, 115 V, and 400 Hz systems are not covered. In the case of Class D equipment (see Limits section below for definition) IEC 61000-3-2 is applicable only for equipment with power ratings between 75 W and 600 W.

A.1.1.1 Frequency Coverage. IEC 61000-3-2 covers only emissions at specific harmonic frequencies up to the 40^{th} harmonic whereas CE101 covers the whole range continuously throughout 30 Hz to 10 kHz. Due to the frequency coverage, IEC 61000-3-2 certified equipment can only be considered for CE101 qualification if interharmonic emissions are not appreciable and if the equipment does not have internal sources in the range 2 kHz - 10 kHz such as might appear in switching power supplies. Some other well-known sources of interharmonic emissions are: static frequency converters, cyclo-converters, induction motors, welding machines and furnaces.

A.1.1.2 Instrumentation. Both CE101 and IEC 61000-3-2 attempt to measure the same quantity, but by significantly different methods. In CE101 laboratory power is supplied to the EUT through an LISN (unless there is a specific agreement to replace or remove it) and the currents are measured with a low-input impedance instrument inserted in series between the generator and the EUT.

To ensure that source voltage distortions do not affect measurements, IEC 61000-3-2 imposes strict distortion limits during testing. CE101 does not impose a similar requirement but notes that the emission current levels will be “somewhat independent of power source variations as long as the impedance of the emission source is significant in relation to the power source impedence.” Unlike CE101 which specifically requires that the current be measured with a current probe, IEC 61000-3-2 does not specify a method of measurement, only that the input impedance of the measuring instrument be sufficiently low so as the source distortion limits are not violated. Nevertheless, if the standard’s requirements are followed, any technique chosen for IEC 61000-3-2 measurements will also give reliable data.

The measurement techniques used to test the EUT are essentially the same for CE101 and IEC 61000-3-2. Both use a frequency selection receiver to measure the harmonic currently emitted by the EUT. However, each method has a different approach for maintaining consistency with the testing. CE101 determines the acceptability of the source voltage by substituting a resistor for the EUT. The value of the resistor is selected to so the current draw would be the same as the EUT. The residual interference current from the power supply is then measured and is expected to be 6 dB below the CE101 requirements. IEC 61000-3-2 maintains consistency by imposing requirements on the distortion of the supply voltage during the test. These requirements are imposed to insure that the source voltage distortion does not influence the test results. Figure A.1-1 is a comparison between some of the total source distortion requirements of CE101 and IEC 61000-3-2 for 115 V, 60 Hz systems. For 115 V systems, the dividing line between input power being < 1 kVA and $\geq$ 1 kVA is approximately 8.5 A of fundamental input current. Since CE101 allows relaxation of limits according to the input current, curve (1) in the figure represents the maximum distortion permitted for < 1 kVA systems; likewise, curves (2) at 8.5 A and at 32 A show the progression as the limit is relaxed according to the fundamental input current. The values for CE101 were obtained by multiplying the permissible ambient current levels by the impedance of the line in conjunction with the military LISN. The permissible distortion levels are for the large part similar between CE101 and IEC 61000-3-2. It should be noted that neither test method contains techniques to monitor source voltage distortion during the actual testing of the EUT.

There should be no difference between the measured quantities of CE101 and IEC 61000-3-2. Both tests measure emission current. CE101 uses the MIL-STD 461 LISN and it is believed that this LISN has little effect on the measurements in this frequency range. How much this is true remains a question for deliberation. IEC 61000-3-2 uses a dedicated generator with low impedance.

A.1.1.3 Limits. The limits can be separated into two sets: fixed limits and variable limits, which are proportional to the current drawn at the fundamental power frequency. These are plotted in Figure A.1-2 and Figure A.1-3 respectively. The military limits for 400 Hz systems are not applicable for comparison but are provided for reference. Even though IEC 61000-3-2 is intended for 230 V systems, the corresponding fixed limits for 115 V systems are projected by doubling the appropriate limits of IEC 61000-3-2; this is especially appropriate for dual 230/115 V systems operating at 115 V.

The limits in IEC 61000-3-2 are specified for four classes of equipment:

Class A: Balanced three-phase equipment and all other equipment, except that stated in one of the following classes.
Class B: Portable tools
Class C: Lighting equipment, including dimming devices
Class D: Equipment having an input current with a special wave shape, as defined in Figure A.1-4 and an active power, P< 600W.

The limits can be seen to differ in both level and form. However, it can be seen that there are two classes of IEC 61000-3-2 tested equipment which may satisfactorily meet the CE101 requirement for submarines, namely, Class C and D equipment rated at 1 k VA and below.

A.1.1.4 Conclusions. Due to the frequency coverage, IEC 61000-3-2 qualified equipment can only be considered for CE101 qualification with considerable risk. If it can be determined that EUT is not capable of generating inter-harmonic emissions, especially in the range 2 kHz – 10 kHz this risk can be reduced considerably. Some other well-known sources of inter-harmonic emissions include: static frequency converters, cyclo-converters, induction motors, welding machines and furnaces.

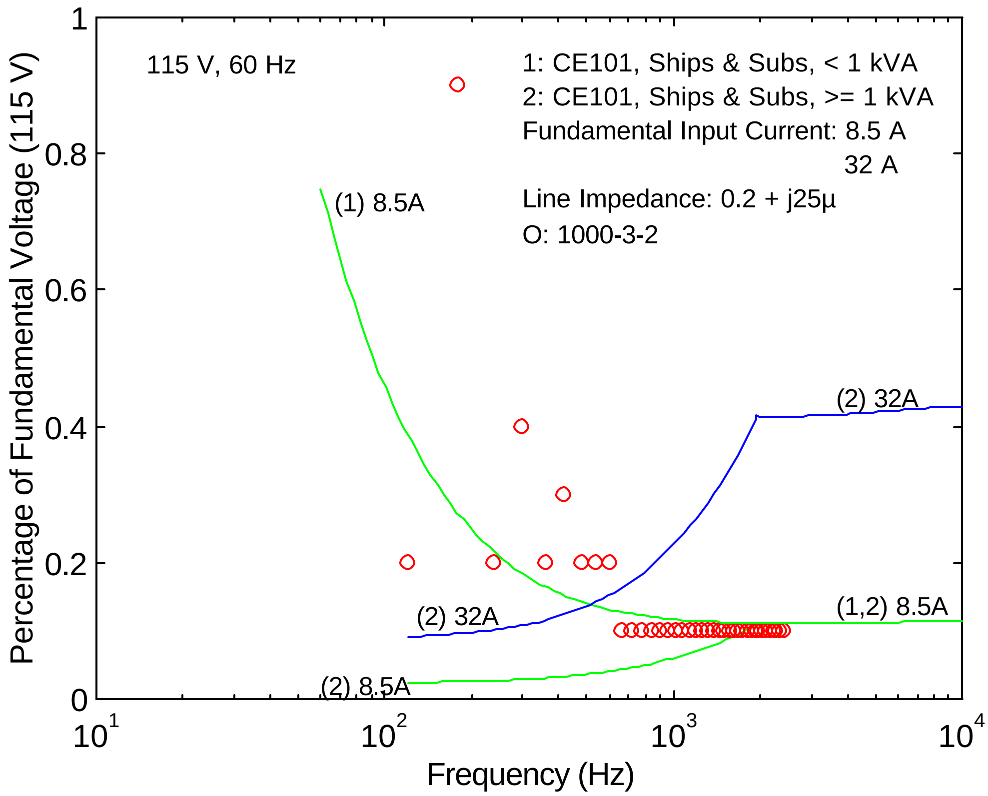
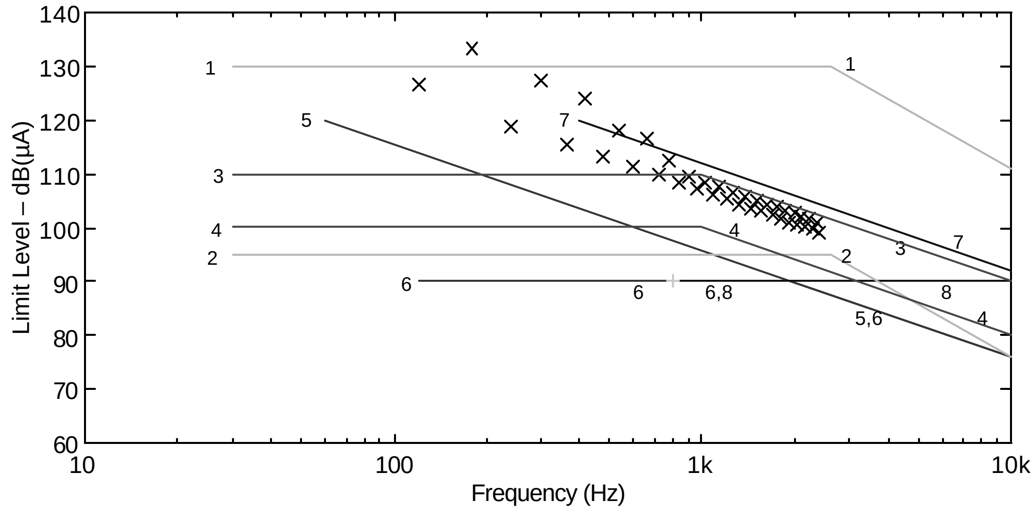
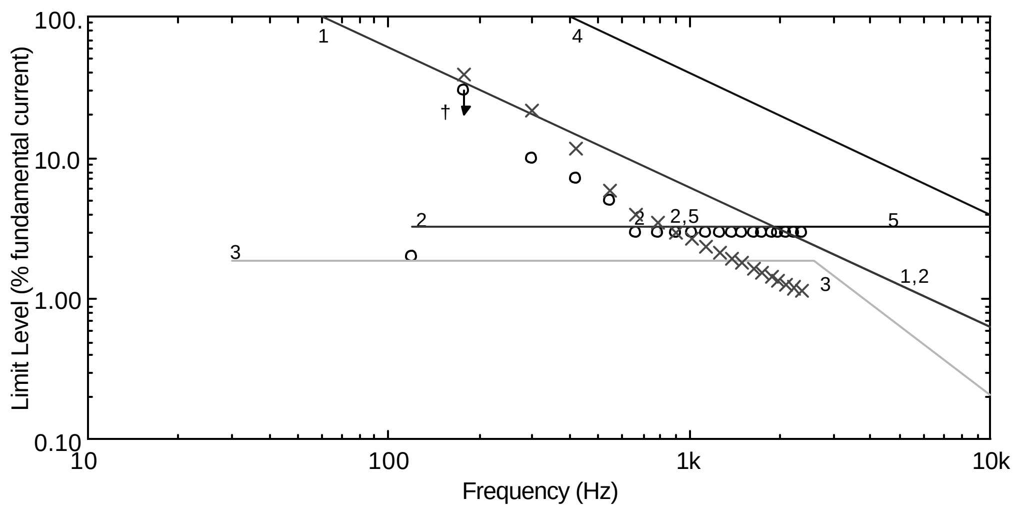


Figure A.1-1: CE 101 (Subs, 60 Hz) and IEC 61000-3-2 Source Voltage Distortion Limits



1) Submarines, DC, >= 185 A
2) Submarines, DC, <= 3 A
3) Navy ASW & Army aircraft (incl. flight line), > 28 V
4) Navy ASW & Army aircraft (incl. flight line), <= 28 V
5) Submarines, 60 Hz, < 1kVA, <= 1A
6) Submarines, 60 Hz, >= 1kVA, <= 1A
7) Submarines, 400 Hz, < 0.2 kVA multi-phase or < 2 A single-phase
8) Submarines, 400 Hz, >= 0.2 kVA multi-phase or >= 2 A single-phase
X) IEC 61000-3-2 Class A, 115 V (projected limits) and Class D maximum limits; for Class B add 3.5 dB to each point

Figure A.1-2: Comparison of CE101 and IEC 61000-3-2: Fixed Limits



1) Submarines, 60 Hz, < 1kVA, fundamental current > 1 A
2) Submarines, 60 Hz, >= 1kVA, fundamental current > 1 A
3) Submarines, DC, 3 A < fundamental current < 185 A
4) Submarines, 400 Hz multi-phase, < 0.2 kVA, fundamental current > 1 A
5) Submarines, 400 Hz multi-phase, >= 0.2 kVA, fundamental current > 1 A
O) IEC 61000-3-2 Class C, †: 3rd harmonic limit = 30% • power factor
X) IEC 61000-3-2 Class D (for 115V); max. absolute limits = Class A limits

Figure A.1-3: Comparison of CE101 and IEC 61000-3-2 Variable Limits

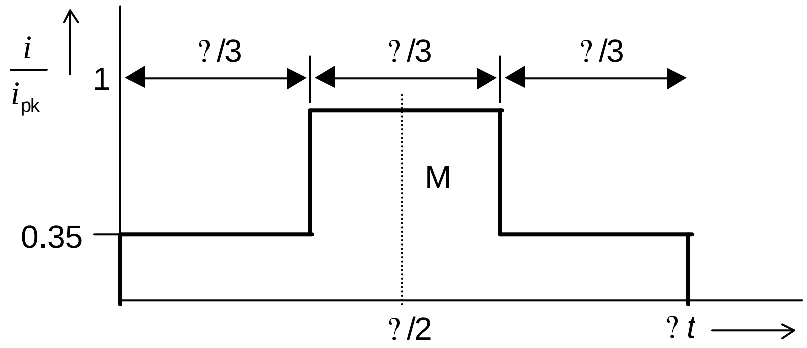


Figure A.1-4: IEC 61000-3-2 Class D Input Current Envelope

Class D input current waveshape for each half period, referred to its peak value i_{pk} is within the envelope of the figure for at least 95% of the duration of each half period. Line M coincides with the peak value of input current.

A.1.2 CE101 vs. IEC 61000-3-8 IEC 61000-3-8 addresses only one type of equipment, namely that which uses a building's power distribution system for signaling purposes. This type of equipment deliberately induces a voltage on the load side of the power distribution system. The standard contains requirements for intentional "in band" signals as well as unintentional "out of band" conducted and radiated emissions on both the load and the supply sides of the equipment. For the purposes of military procurements the requirements of this standard might be applied to non-signaling systems in which case the load side requirements may be ignored.

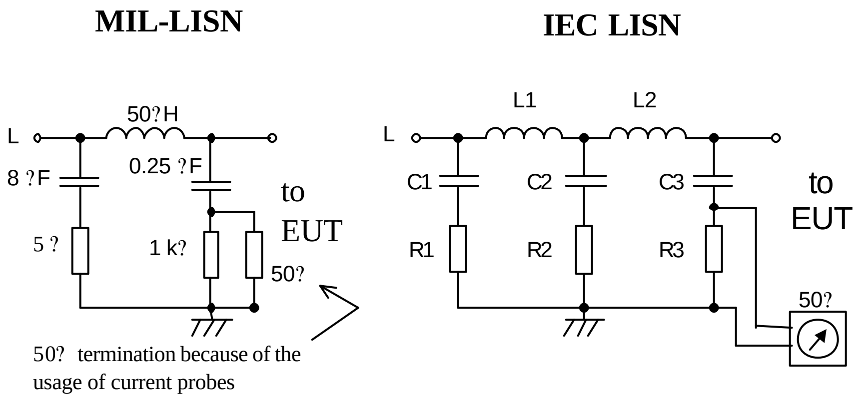
A.1.2.1 Frequency Coverage. IEC 61000-3-8 covers the range from 3 kHz to 30 MHz whereas CE101 covers 30 Hz - 10 kHz.

A.1.2.2 Test Comparison. The measuring technique used in IEC 61000-3-8 closely resembles that used in CE 101 except for differences in the line impedance stabilization network and the fact that voltage in measured across a 50-ohm resistor rather than current.

There are two major differences in the instrumentation of these standards:

i. IEC 61000-3-8 measures the voltage at the input of an LISN whereas CE101 measure the current with a current probe.

ii. The LISN designs are different (see Figure A.1-5); their corresponding impedance characteristics are depicted in Figure A.1-6 in the "worst-case" scenario where the line impedance is 0.2 + *j*50µ.



IEC 61000-3-8			
	LISN 1	LISN 2	LISN 3
	3 k – 9 kHz	9 k – 150 kHz	150 k – 30 MHz
L1	50 ?H	250 ?H	–
L2	50 ?H	50 ?H	50 ?H
C1	40 ?F	4 ?F	–
C2	60 ?F	8 ?F	1 ?F
C3	0.47 ?F	0.25 ?F	0.1 ?F
R1	3 ?	10 ?	–
R2	1.5 ?	5 ?	0

Figure A.1-5: LISN Designs for MIL-STD 461E and IEC 61000-3-8

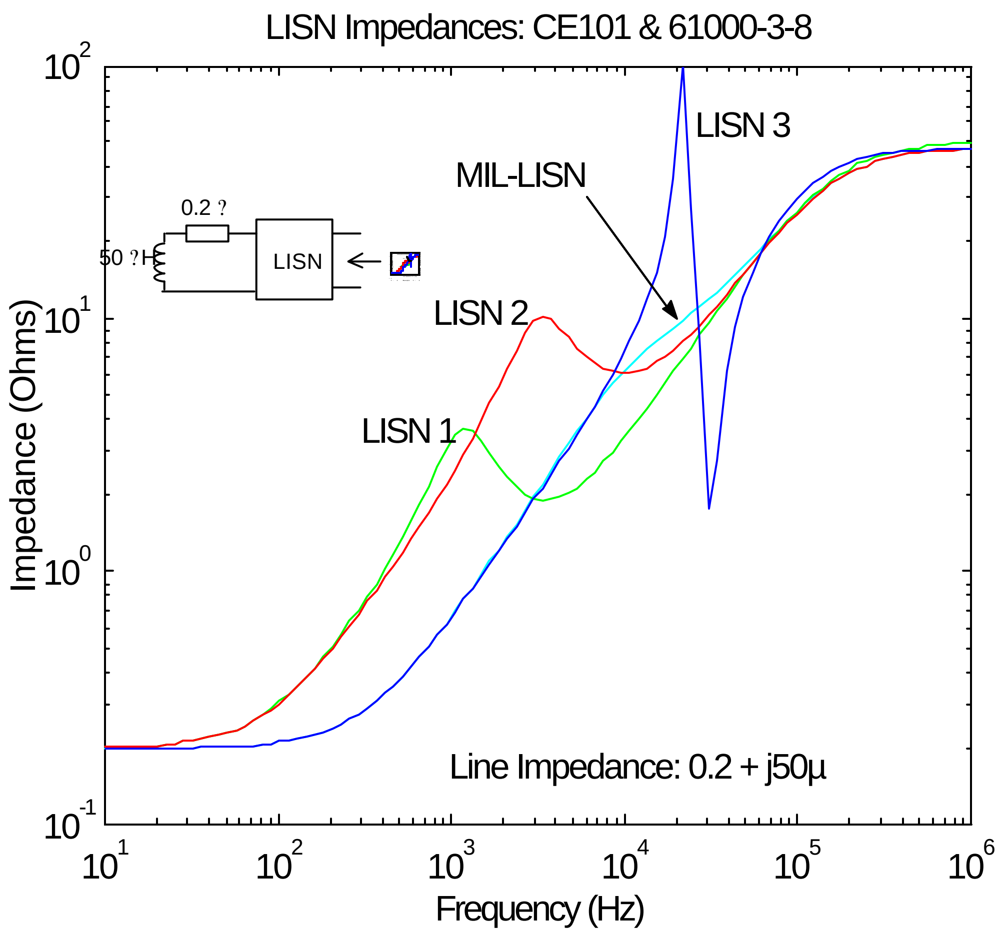


Figure A.1-6: Impedance Characteristics of MIL-STD-461E and IEC 61000-3-8 LISNs

In contrast to CE101 and IEC 61000-3-2, IEC 61000-3-8 indicates no special concern for distortion of the source of power. IEC 61000-3-8 measures voltage at the terminals of the LISNs.

A.1.2.3 Limits. The voltages measured in IEC 61000-3-8 can be converted to currents with knowledge of the line-ground impedance of the LISNs.

The relationship between the measured quantities of CE101 and IEC 61000-3-8 depends on the impedance of the LISNs used. The current measurements of CE101 can be correlated to the voltage measurements of IEC 61000-3-8 using the impedance values plotted in Figure A.1-6. For the range 30 Hz to approximately 3 kHz, the correlation is approximately linear, but from 3 kHz to 10 kHz resonance phenomena dominates the impedance characteristics.

A.1.2.4 Conclusions. IEC 61000-3-8 certified mains-signaling equipment can be considered to meet CE101 requirements. Because of its rather restricted scope, IEC 61000-3-8 is not expected to be of much significance for military applications.

A.2 CE 102, Conducted Emissions, 10 kHz TO 10 MHz

This requirement is applicable from 10 kHz to 10 MHz for all power leads, including returns that obtain power from other sources not part of the EUT.

A.2.1 CE102 vs CISPR Standards CISPR Publications 11, 14, 15, and 22 cover respectively industrial scientific and medical (ISM) equipment, appliances, lighting equipment, and information technology equipment.

A.2.1.1 Frequency Range The frequency range covered extends from 150 kHz to 30 MHz

A.2.1.2 Instrumentation and Measurement Techniques For calibration, CE102 uses a signal generator and an oscilloscope that are not required in ANS C63.4. For testing, ANS C63.4 may use two different LISN designs; Figure A.2-1 compares the different LISNs. However the impedance characteristics at the measurement port are essentially the same in the applicable frequency range, so no difference in reading is expected.

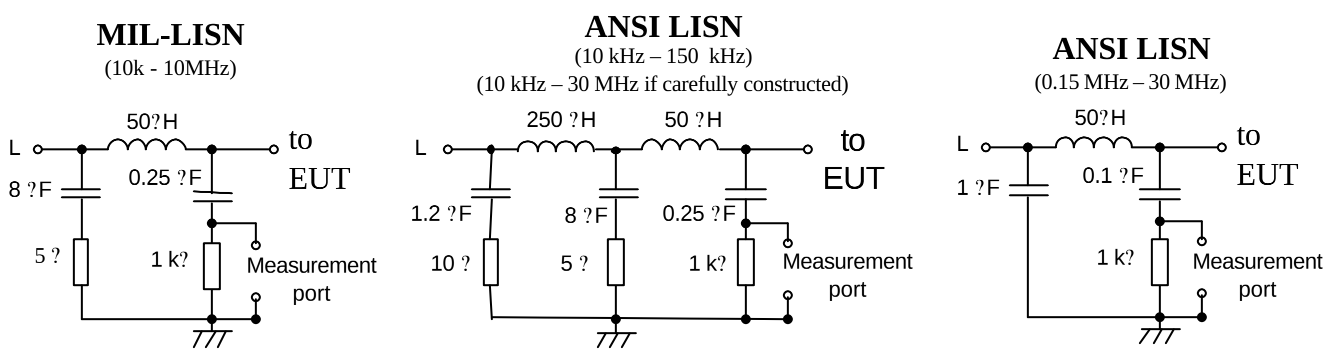


Figure A.2-1: LISN Designs for MIL-STD-461E and ANS C63.4

The measurement method of CE102 has an upper frequency of 10 MHz to avoid resonances of the 1.5m power cord between the EUT and the LISN. In the commercial specifications the power cord length is limited to 1 m and the upper frequency is limited to 30 MHz.

For DC lines, generally a 5 µH (50 ? /5 µH + 1?) LISN is used. This is referenced in CISPR Publication 16-1, subclause 11.4 and in CISPR 25, which is practically the same as SAE J 1113-41. The measurement quantity is up to 10 dB lower in the frequency range of 10 kHz to 1 MHz when using the 5 µH LISN.

In addition there are differences in the bandwidths of the instruments used as shown in Table A.2-1. These differences may be significant below 0.25 MHz.

Table A.2-1: MIL-STD 461E & Commercial Detector Bandwidths

Frequency Range, MHz	MIL Bandwidth	Commercial Bandwidth
0.01 to 0.15	1 kHz	220 Hz
0.15 to 30	10 kHz	10 kHz

A.2.1.3 Limits

A.2.1.3.1 CISPR 11(EN 55011), ISM Equipment

Two groups of ISM equipment are identified:

Group 1 Contains all ISM equipment in which there is intentionally generated and/or used conductively coupled radio frequency energy which is necessary for the internal functioning of the equipment itself.

Group 2 Contains all ISM equipment in which radio frequency energy is intentionally generated and/or used in the form of electromagnetic radiation for the treatment of material, and spark erosion equipment.

Two classes of equipment are identified:

Class A Equipment suitable for use in all establishments other than domestic and those not directly connected to a low voltage power supply network which supplies buildings used for domestic purposes. - Class A equipment shall meet Class A limits.

NOTES

a) Operation of equipment which does not meet the Class A limits but does not result in unacceptable degradation of radio services may be sanctioned on a case-by-case basis by the competent national authority.

b) Although Class A limits have been derived for industrial and commercial establishments, administrations may allow, with whatever additional measures are necessary, the installation and use of Class A ISM equipment in a domestic establishment or in an establishment connected directly to domestic electricity power supplies.

Class B Equipment suitable for use in domestic establishments and in establishments directly connected to a low voltage power supply network which supplies buildings used for domestic purposes. Class B equipment shall meet Class B limits.

The conducted power line limits are as shown in Table A.2-2: Limits are also shown in Figures A.2-2 and A.2-3, which are the same as given in Figures 6.2-1 and 6.2-2. They are repeated here for the reader's convenience.

Note the following:

? Limits below 150 kHz are not specified for power line emissions.

? Group 1, Class A limits are shown in Table A.2-2

? Group 2, Class A limits of Table A.2-2 are relaxed as shown in Table A.2-3

? Group 1 and Group 2 Class B limits are identical and are shown in Table A.2-2.

Table A.2-2: Limit Comparison of Various Emission Specifications

Part 1, Class B Limits for Primarily Residential Areas									
FREQUENCY RANGE, MHz 0.15 → 0.5 → 5 → 30 → 230 → 1000									
SPECIFICATIONS	dB? V		dB? V		dB? V		dB? V/m	dB? V/m	NOTES
	QP (1)	AVG (1)	QP	AVG	QP	AVG	QP	QP	
EN 50081-1 "B"	66 - 56	56 - 46	56	46	60	50	30	37	@ 10 m, B-Limit
EN 55011 "B"	66 - 56	56 - 46	56	46	60	50	30	37	@ 10 m, B-Limit
EN 55013 (2)	66 - 56	56 - 46	56	46	60	50	45 - 55 (3)	-	dBpW, Absorbing Clamp
EN 55014	66 - 56	56 - 46	56	46	60	50	45 - 55 (3)	-	dBpW, Absorbing Clamp
EN 55014 "B"	66 - 56	56 - 46	56	46	60	50	34	37	@ 10 m
FCC Part 15 "B"	-	(4)	61	48	61	48	40 (4)	46	@ 3 m
Part 2, Class A Limits for Industrial Areas									
EN 50081-2 "B"	79	66	73	60	73	60	30	37	@ 30 m, A-Limit
EN 55011	79	66	73	60	73	60	30	37	@ 30 m, A-Limit
EN 55022	79	66	73	60	73	60	30	37	@ 30 m
FCC Part 15 "A"	-	(4)	73	60	83	70	40 (4)	46	@ 10 m

NOTES:

1. The dash between two numbers (e.g. 66 - 56) indicates that the limit decreases with the logarithm of frequency. The limits are plotted on semi-log paper. The vertical scale being the limit and the horizontal scale being the frequency. The two points shown are plotted and a straight line is drawn between them.
2. EN55013 also has other limits for antenna emissions from receivers and televisions
3. The absorbing clamp measurement is performed from 30 - 300 MHz
4. The FCC Class A and B Limits are as follows:

Frequency, MHz	**B Limit**	**A Limit**
0.45 - 1.705	48 dB? V*	60 dB? V*
1.705 - 30	48 dB? V*	70 dB? V*
30 - 88	40 dB? V/m @ 3 m	40 dB? V/m @ 10 m
88 - 216	43 dB? V/m @ 3 m	43 dB? V/m @ 10 m
216 - 960	46 dB? V/m @ 3 m	46 dB? V/m @ 10 m
> 960	54 dB? V/m @ 3 m	50 dB? V/m @ 10 m
(*) Narrowband Limit, Broadband limit is 13 dB higher		

A.2.1.3.2 CISPR 14(EN 55014) Appliances

? This specification has only one limit for the residential environment.

? The limits shown in Table A.2-3 apply for household appliances and tools up to 700 W.

For tools with input power above 700 W the limits of Table A.2-2 are relaxed as shown in Table A.2-4.

? The specification also relaxes the limit for transients (clicks) lasting longer than 10 ms (but shorter than 400 ms) by 20 log (30/N). Where N = clicks per minute. When N = 1, relaxation is 44 dB.

A.2.1.3.3 CISPR 15(EN 55015) Lighting Equipment . The document specifies that the fluorescent light fixture must have an insertion loss of 28 to 20 dB over the frequency range of 0.15 to 1.605 MHz. For other types of RF light fixtures the limits shown for CISPR 14 apply and in addition the following limits must be met:

9 - 50 kHz:	110 dBµV
50 - 150 kHz:	90 - 80 dBµV

A.2.1.3.4 CISPR 22/EN 55022. The limits are shown in Table A.2-2.

A.2.1.4 Conclusions Commercial standards provide viable alternatives for meeting the requirements of CE102.

Table A.2-3 Relaxation of Group 2, Class A limits compared with Group 1, Class B Limit

Frequency Range	QP Relaxation	avg. relaxation
0.15 – 0.50 MHz	+21 dB	+ 24 dB
0.5 – 5 MHz	+13 dB	+ 16 dB
5 – 30 MHz	+ 27 dB*	+ 20 dB
*Decreasing with the logarithm of frequency. At 30 MHz, relaxation is 0 dB.		

Table A.2-4 Relaxation of Limits for tools with Power > 700 W

Frequency	700 W to 1,000 W	above 1,000 W
0.15 - 30 MHz	+ 4 dB QP & Avg	+ 10 dB QP & Avg

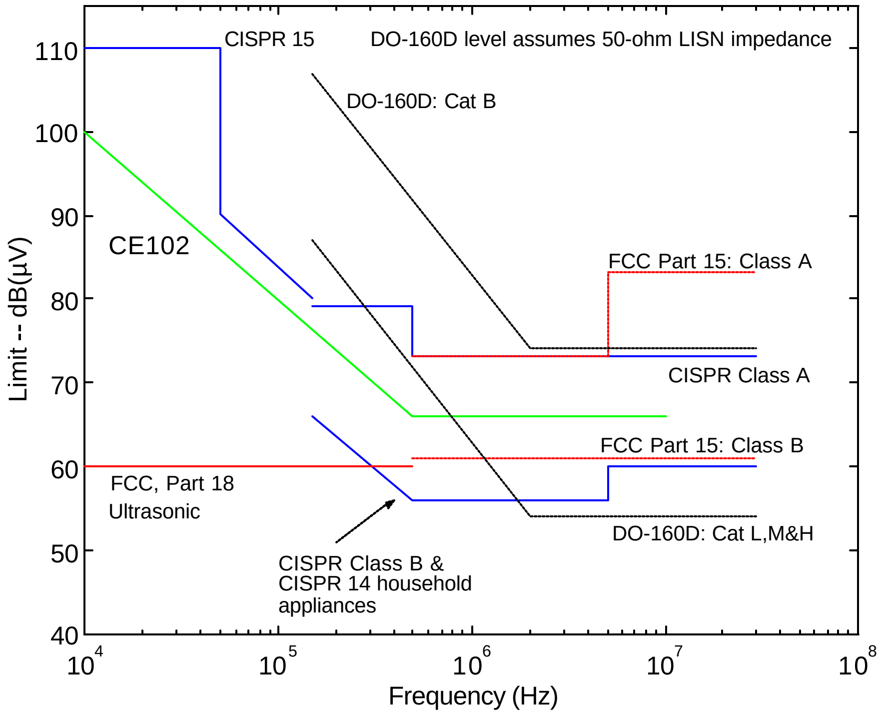


Figure A.2-2: CE102 and Commercial (Peak/Quasi-peak)

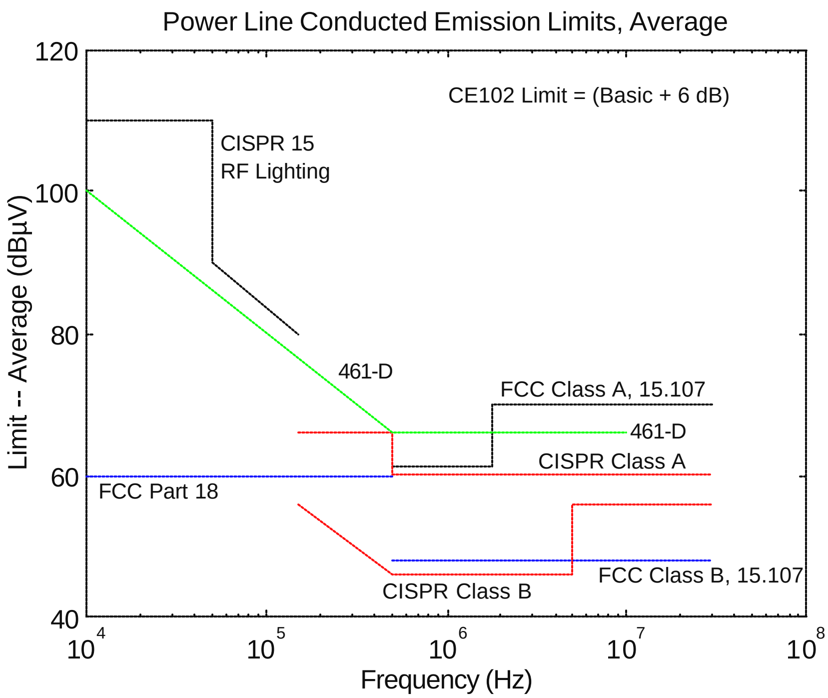


Figure A.2-3: CE102 and Commercial (average) Limits

A.2.2 CE102 vs National Standards.

ANS C63.4 is a broadly applicable measurement standard for all low-voltage equipment (rated ≤ 600 V DC or rms AC), except for avionics, ISM, and TV & FM broadcast receivers. CE measurements are made from 9 kHz to 30 MHz, which encompasses the CE102 range of 10 kHz – 10 MHz.

Corresponding FCC limits are given in CFR 18.307(a) [10 kHz to 450 kHz] and 107(a) [.45 to 30 MHz] (Limit B) and are of general applicability.

A.2.2.1 Frequency Range The frequency range covered extends from 9 kHz to 30 MHz which overlaps that of CE102.

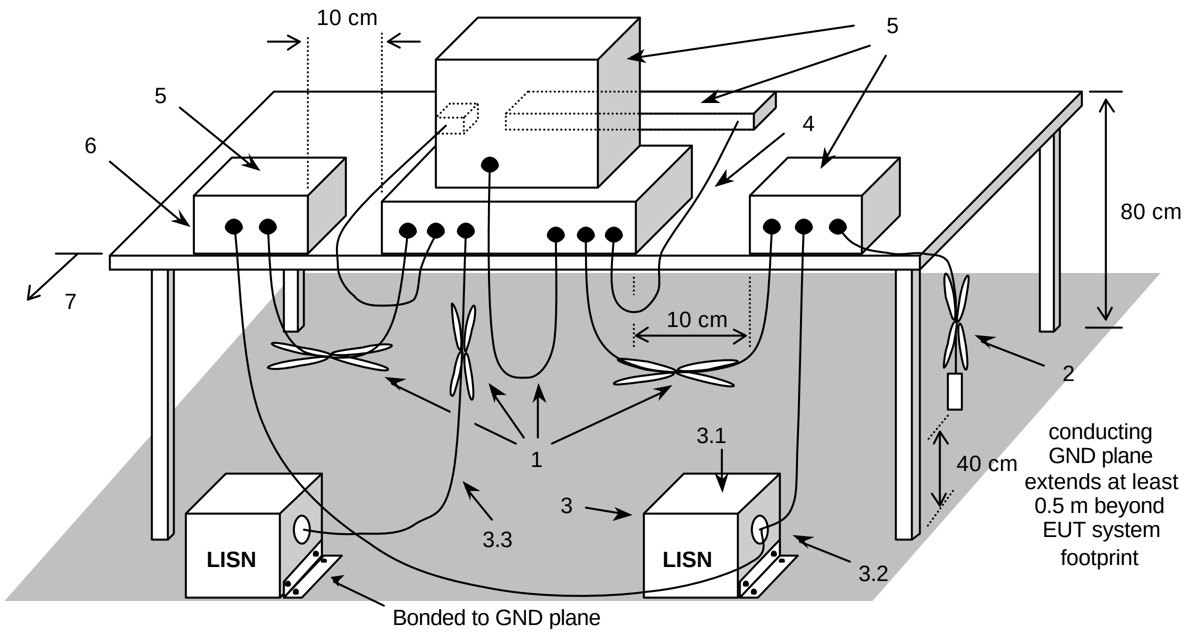
A.2.2.2 Measurement & Instrumentation The measurement and instrumentation used in C63.4 are similar to those used in the CISPR. Comments in clause A.2.2.2 apply. detailed rules for set-ups are given in the standard, some of which are shown in Figures A.2-1, A.2-4 and A.2-5.

Of particular note is the requirement of a vertical ground plane 40 cm away from the rear of the EUT; this requirement is to ensure that measurements inside and outside a screened room are comparable, as some effects of a vertical ground have been observed. In ANS C63.4, various pre-testing trials are necessary to identify the one configuration that produces the most emission, and this configuration will be used throughout testing, and unlike CE102, C63.4 has no specific calibration procedures other than a background emissions sweep. Calibration is presumably accounted for with calibration of equipment. ANS C63.4 also allows the use of a voltage probe for EUTs requiring such high currents that the use of an LISN is not possible. CE102 does not consider this situation.

A.2.2.3 Limits. The comparison of limits is shown in Figures A.2-2 and A.2-3. Since commercial equipment is compared, the MIL-STD-461E CE 102-1 limit for 115 VAC power leads is used (Basic +6 dB). Since in Europe the voltage is 230 VAC, the (Basic +9 dB) limit could also be used. This will make the comparison even more favorable from the point of using the commercial limits in lieu of the CE102 limits.

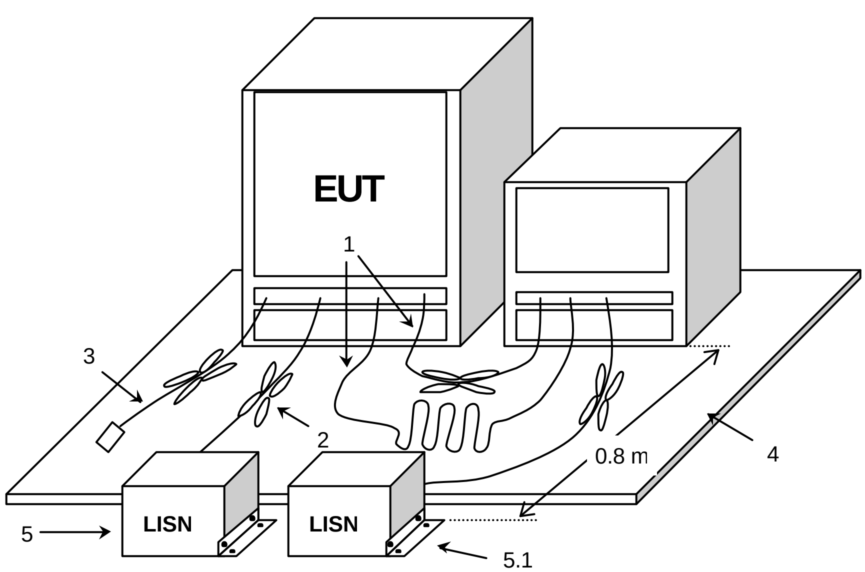
From the figures it can be seen that both the FCC Part 15 Class B and Part 18 Ultrasonic limits are acceptable for CE102 requirements, but neither of these wholly cover the frequency range of CE102 so a judgement will have to be made as to the importance of the unaccounted for frequencies. The figure also shows that over the limited frequency range of 450 kHz to 10 MHz the FCC limits are at least 5 dB more stringent than the CE 102 limit. However, qualification to Part 15 Class A is less likely to be acceptable for CE102 requirements.

A.2.2.4 Conclusions Commercial standards provide viable alternatives for meeting the requirements of CE102.



1. Interconnecting cables that hang closer than 40 cm to the ground shall be folded back and forth forming a bundle 30 to 40 cm long, hanging approximately in the middle between ground plane and table.
2. I/O cables that are connected to a peripheral shall be bundled in center. The end of the cable may be terminated if required using correct terminating impedance. The total length shall not exceed 1m.
3. EUT connected to one LISN. Unused LISN connectors shall be terminated in 50 ? . LISN can be placed on top of, or immediately beneath the ground plane (conducted tests only).
   - 3.1 All other equipment powered from second LISN.
   - 3.2 Multiple outlet strip can be used for multiple power cords of non-EUT equipment.
   - 3.3 LISN at least 80 cm from nearest part of EUT chassis.
4. Cables of hand-operated devices, such as keyboards, mouses, etc., have to be placed as close as possible to the host.
5. Non-EUT components of EUT system being tested.
6. Rear of EUT including peripherals shall be aligned and flush with rear of table top.
7. Rear of table

Figure A.2-4: C63.4 Tabletop Set-up, General Rules



1. Excess I/O cables shall be bundled in center. If bundling is not possible, the cables shall be wound in turns. Bundling shall not exceed 40 cm in length.
2. Excess power cords shall be bundled in the center or shortened to appropriate length.
3. I/O cables which are not connected to a peripheral shall be bundled in the center. The end of the cable may be terminated if required using correct terminating impedance. If bundling is not possible, the cable shall be wound in turns.
4. EUT and all cables shall be insulated from ground plane by 3 to 12 mm.
5. EUT connected to one LISN. LISN can be placed on top of, or immediately beneath

Figure A.2-5: C63.4 Floor Standing Steps

A.3 CE106, Conducted Emissions, Antenna Terminal, 10 kHz to 40 GHz.

The requirement is applicable for transmitters, receivers and amplifiers.

A.3.1 Introduction. The basic concern is to protect antenna-connected receivers both on and off the platform from being degraded due to radiated interference from the antenna associated with the EUT. The limit for transmitters in the transmit mode is placed primarily at levels which are considered to be reasonably obtainable for most types of equipment. Suppression levels that are required to eliminate all potential electromagnetic compatibility situations are often much more severe and could result in significant design penalties. The limit for receivers and transmitters in standby is placed at a level that provides reasonable assurance of compatibility with other equipment. Common requirements are specified for all applications since the concerns are the same for all platforms.

A.3.1.1 Limit Setting Examples. As an example of an antenna coupling situation, consider a 10 watt VHF-AM transmitter operating at 150 MHz and a UHF-AM receiver with a sensitivity of -100 dBm tuned to 300 MHz with isotropic antennas located 10 meters apart. The requirement is that the transmitter second harmonic at 300 MHz must be down 50 + 10 log 10 = 60 dB. The free space loss equation. $P_R/P_T = (?^2 G_T G_R)/(4? R)^2$ indicates an isolation of 42 dB between the two antennas.

P_R	= Received Power	G_R	= Receive Antenna Gain = 1
P_T	= Transmitted Power	G_T	= Transmitter Antenna Gain = 1
?	=Wavelength = 1 meter	R	= Distance between Antennas = 10 meters

A second harmonic at the limit would be 60 + 42 = 102 dB down at the receiver. 102 dB below 10 Watts (40 dBm) is -62 dBm which is still 38 dB above the receiver sensitivity. The level that is actually required not to cause any degradation in the receiver is -123 dBm. This value results because the worst-case situation occurs when the interfering signal is competing with the sidebands of the intentional signal with a signal amplitude at the receiver sensitivity. For a standard tone of 30% AM used to verify sensitivity, the sidebands are 13 dB down from the carrier and a 10 dB signal-to-noise ratio is normally specified. To avoid problems, the interfering signal must, therefore, be 13 + 10 = 23 dB below -100 dBm or -123 dBm. This criterion would require the second harmonic to be 121 dB down from the transmitter carrier that could be a difficult task. Harmonic relationships can sometimes be addressed through frequency management actions to avoid problems.

Assessing the 34 dB?V (-73 dBm) requirement for standby, the level at the receiver would be-115 dBm which could cause some minimal degradation in the presence of a marginal intentional signal.

Greater antenna separation or antenna placement not involving direct line of sight would improve the situation. Also, the VHF antenna may be poorer than isotropic in the UHF band. CE106 does not take into account any suppression associated with frequency response characteristics of antennas; however, the results of the case cited are not unusual. RE103, which is a radiated emission control on spurious and harmonic outputs, includes assessment of antenna characteristics.

Since the free space loss equation indicates that isolation is proportional to the wavelength squared, isolation values improve rapidly as frequency increases. Also, antennas are generally more directional in the GHz region and receivers tend to be less sensitive due to larger bandwidths.

The procuring activity may consider tailoring contractual documents by establishing suppression levels based on antenna-to-antenna coupling studies on the particular platform where the equipment will be used. Another area could be relaxation of requirements for high power transmitters. The standard suppression levels may result in significant design penalties. For example, filtering for a 10,000 watt HF transmitter may be excessively heavy and substantially attenuate the fundamental frequency. Engineering trade-offs may be necessary.

A.3.1.2 Modulation During Testing. The selection of modulation for transmitters and frequency, input power levels, and modulation for amplifiers can influence the results. The CE106 procedure requires that parameters that produce the worst case emission spectrum be used. The most complicated modulation will typically produce the worst case spectrum. The highest allowable drive level for amplifiers usually produces the worst harmonics and spurious outputs. However, some amplifiers with automatic gain controls may produce higher distortion with drive signals set to the lowest allowable input due to the amplifier producing the highest gain levels.

A.3.1.3 Instrumentation and Measurement Technique. Measured quantities should be the same as long as any corrections required by impedance mismatches are accounted for.
Both test procedures use a limited amount of test instrumentation including measurement receivers and attenuators. CISPR-13 makes use of a signal generator to measure the amplitude of spurious output and harmonics using direct substitution while CE106 only uses it for calibration of the receiver. Most importantly CISPR-13 utilizes combiners and matching networks not required in CE106.

CE106 conducts measurements by direct connection to the antenna port of the equipment under test (EUT), through attenuation, into an impedance matched receiver (see Figure A.3-1). CISPR-13 utilizes the antenna outputs and a signal generator, both connected to a combining network, which in turn connects to a measuring receiver (see Figure A.3-2). Matching networks are inserted as necessary along the above measurement path. In this manner a signal substitution is conducted to ascertain the levels of harmonics and spurious output.

CE106 utilizes a peak detector receiver, with specified bandwidths, to measure the harmonic and spurious output of the EUT. CISPR-13 uses a quasi-peak detector and does not have specified bandwidths.

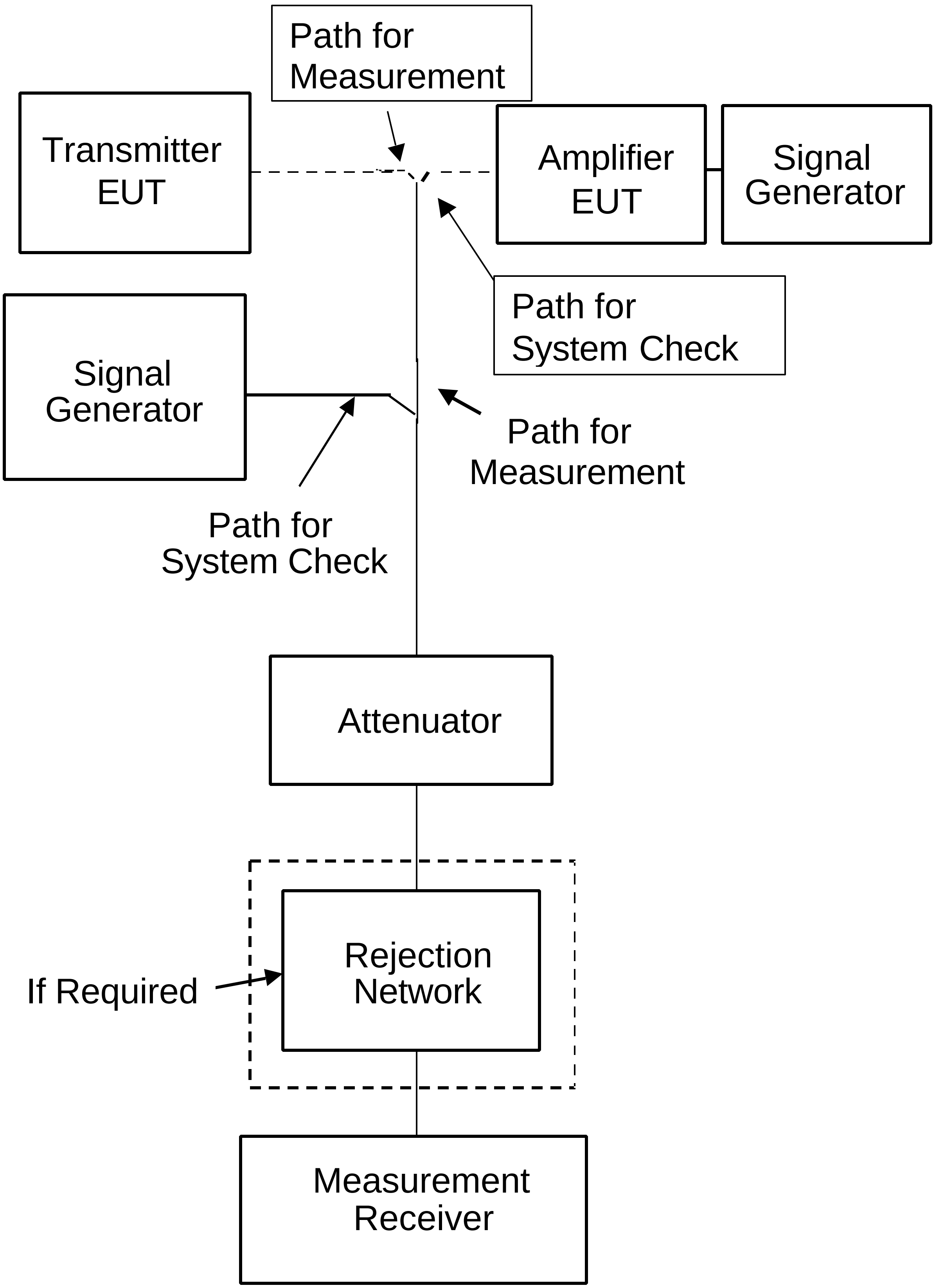


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Figure A.3-1: CE106 Setup for Low Power Transmitter

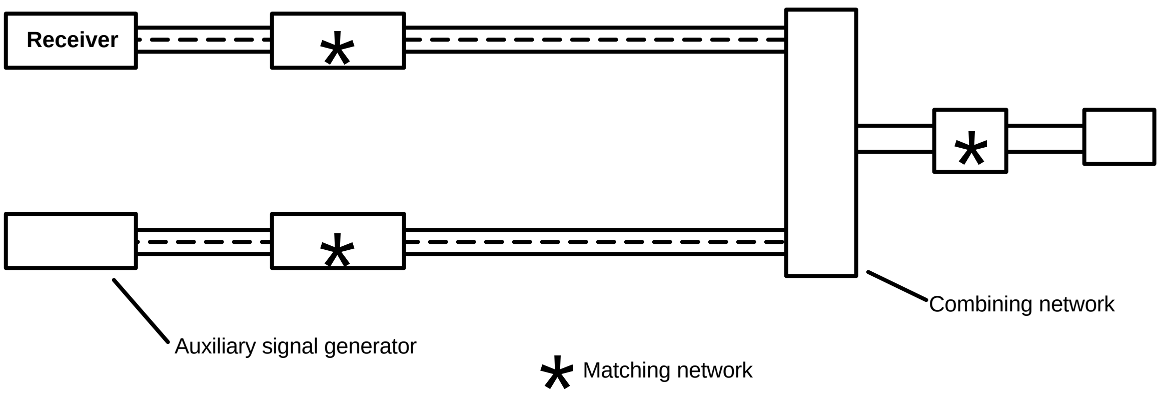


Figure A.3-2: CISPR-13 Test Setup

A.3.2 <u>CE106 vs. IEC 60244-2 and IEC 60244-2A</u>. The IEC 60244-2 requirements corresponds to the "transmit mode" requirement of CE106. IEC 60244-2A contains appendices of IEC 60422-2, which describe detailed measurement procedures.

A.3.2.1 <u>Instrumentation & Measurement Techniques</u>. CE106 conducts measurements by direct connection to the antenna port of the equipment under test (EUT), through an attenuator and/or rejection network, and into an impedance- matched receiver (Figure A.3-1). IEC 60244-2 presents several comparable methods to conduct measurements:

a) <u>Signal Substitution</u>. A signal generator with variable input is substituted for the radio transmitter and adjusted to produce the same level in intensity as the radio transmitter.

b) <u>Direct Methods.</u>

1) The voltage, current and power factor are determined at one point on the feeder using a selective radio receiver tuned to the mean frequency of the spurious radiation concerned, and coupled to the desired point of the feeder.

2) The forward and reflected powers are determined by using a pair of inverse directional couplers, inserted directly in the feeder line or the test load; a selective power measuring device is switched alternately to the couplers and tuned to the mean frequency of the spurious radiation concerned. The difference between these two measured powers gives the power supplied to the antenna on the frequencies of the spurious radiation.

3) Measured quantities should be comparable between CE106 collected data and any of the methods contained in the IEC 60244-2A procedure.

For transmit mode testing CE106 uses various test instrumentation, to include: attenuators, couplers, loads, rejection networks, signal generators and measurement receivers. IEC 60244-2A uses these items plus coupling loops.

A.4 CS101, Conducted Susceptibility, Power Leads, 30 Hz to 150 kHz.

This requirement is applicable to equipment and subsystem AC and DC input power leads, not including returns. If the EUT is DC operated, this requirement is applicable over the frequency range of 30 Hz to 150 kHz. If the EUT is AC operated, this requirement is applicable starting from the second harmonic of the EUT power frequency and extending to 150 kHz.

Corresponding commercial standards include IEC 61000-4-13, and DO 160D. In addition, there are related requirements in IEC Publication 61533, and SAE J1113.

In this Annex details on differences in test methods are described. These differences may influence the determination of the equivalence of limits in the several standards.

A.4.1 MIL-STD-461E Test Method In CS101 the disturbance voltage is injected onto power leads via a coupling transformer with its secondary connected in series as in Figure A.4-1 through Figure A.4-3.

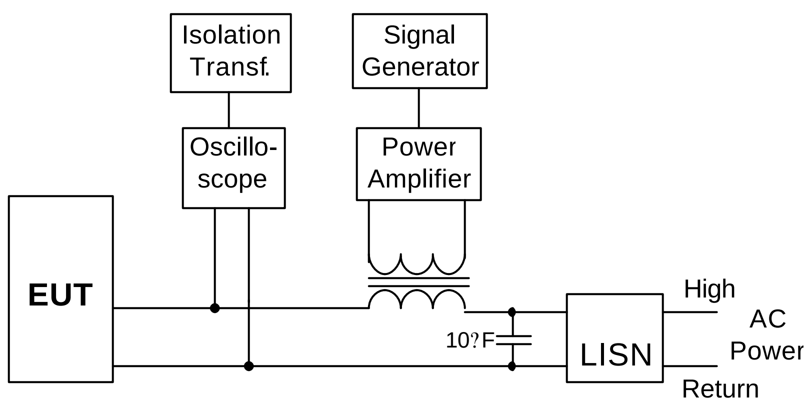


Figure A.4-1: CS101 Signal Injection, DC or Single-Phase AC

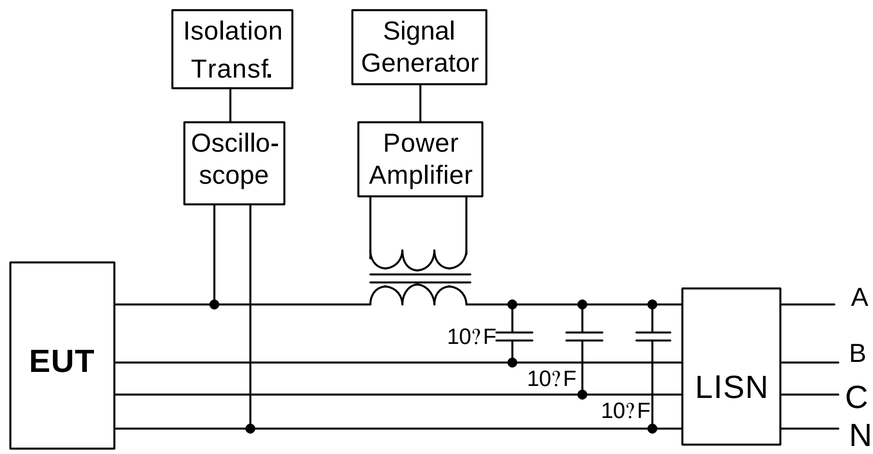


Figure A.4-2: CS101 Signal Injection, 3-Phase Wye

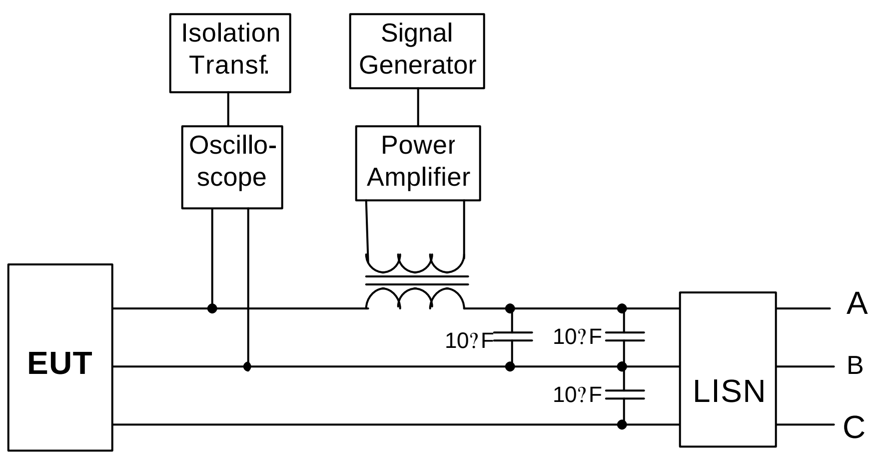


Figure A.4-3: CS101 Signal Injection, 3-Phase Delta

Referring to Figure A.4-1 most of the injected voltage will appear at the EUT's terminals if its input impedance is much higher than the impedance of the capacitor throughout the frequency range, i.e. if the EUT's effective impedance is much greater than approximately 530 ? . However, since a portion of the injected voltage will drop across the capacitor, voltage measurements must be taken at the EUT's power terminals to ensure proper immunity test levels. The 10?F capacitor must be able to withstand the full line voltage. The capacitor, when acting in conjunction with the 50?H inductor in the LISN, may also cause unwanted resonance effects, especially around 7 kHz, so that care must be taken near this frequency to avoid exceeding the EUT's operating power voltage.

A potential problem for the power amplifier exists due to an induced voltage fed back to the primary side of the coupling transformer caused by the EUT's load current. A scheme is provided to mitigate this effect whereby the EUT's current load is mirrored with a dummy load and a pair of transformers is used to induce equal (canceling) voltages onto each lead of the power amplifier as in Figure A.4-4.

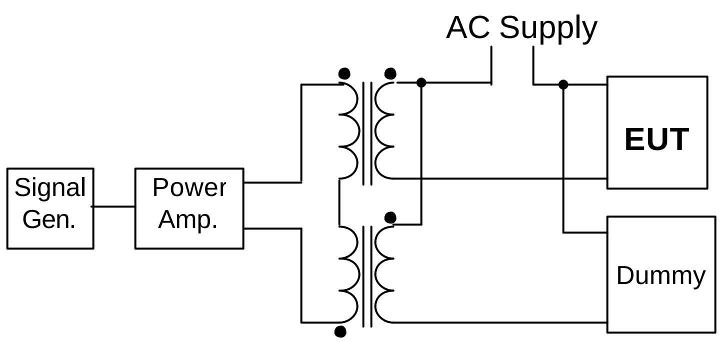


Figure A.4-4: CS101 Power Amplifier Protection Scheme

This scheme requires a measurement of the EUT's characteristics before injection in order to find an appropriate dummy load which will satisfactorily mirror the EUT's characteristics throughout all the test modes. Also, it is unclear as to how this will work for three-phase power.

A.4.2. <u>IEC 61000-4-13</u> . IEC 61000-4-13 uses a dedicated generator, which also supplies power to the EUT whereas CS101 powers its EUT through an LISN. The test generator superimposes the harmonics onto the power lines and compensates for any internal voltage drops so that the required voltages appear at the terminals of the EUT. It is unclear as to whether this generator can be used for delta systems.

In IEC 61000-4-13 the tests are performed in three stages according to the flowchart shown in Figure A.4-5 below. This scheme is intended to minimize testing time. The first stage (Harmonic Combination Tests) is a quick (dis)qualifier; the second stage sweeps the EUT over the frequency range at test levels generally higher than that required for final qualification; the last stage tests the EUTs at individual frequencies where performance anomalies were observed and at final qualification levels. The harmonic combination parameters are depicted in Figure A.4-6. The set-up for a test sweep is shown in Figure A.4-7. Further comparison will require a

more in-depth knowledge of the injection technique used in the generator.
For three-phase equipment, all tests are performed injecting on all three phases simultaneously; this is in contrast with CS101 where injection is one phase at a time. Whether or not this adequately models naturally occurring phenomena remains to be discussed. Nevertheless, the military should consider this method of testing along with the Harmonic Combination tests for inclusion in its requirements. For three-phase equipment without a neutral connection, testing at the triple-*n* harmonics is not considered to be necessary.

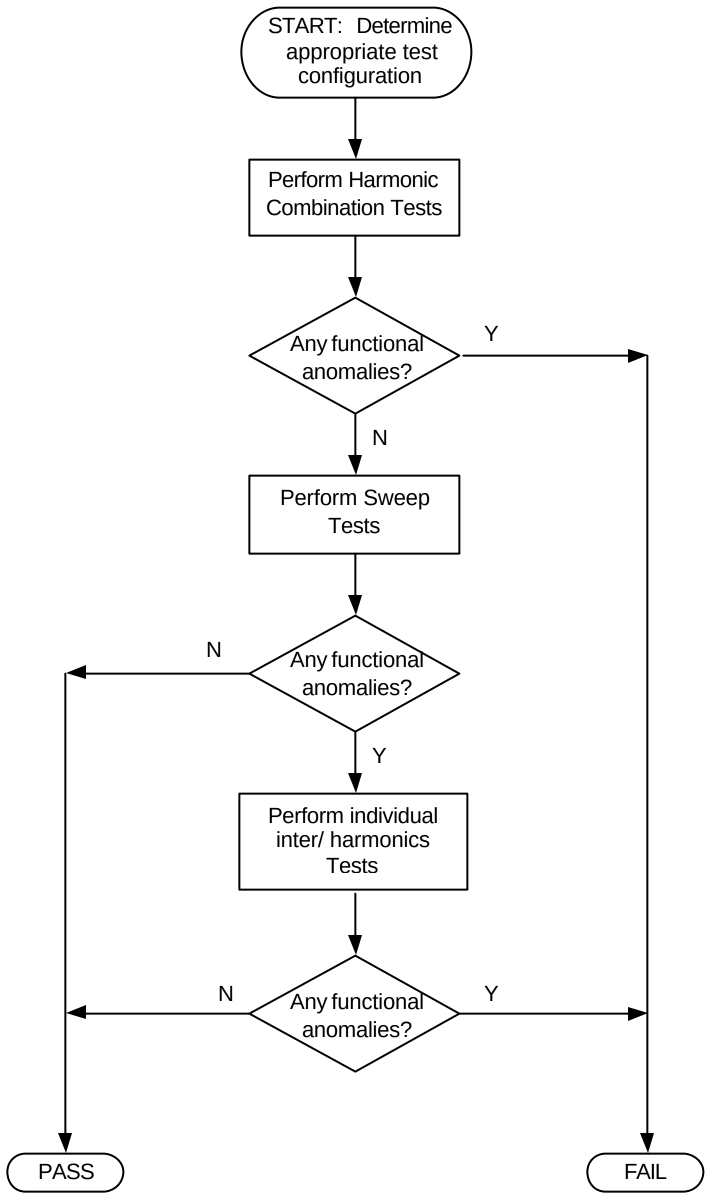


Figure A.4-5: IEC 61000-4-13 Test Process Flow

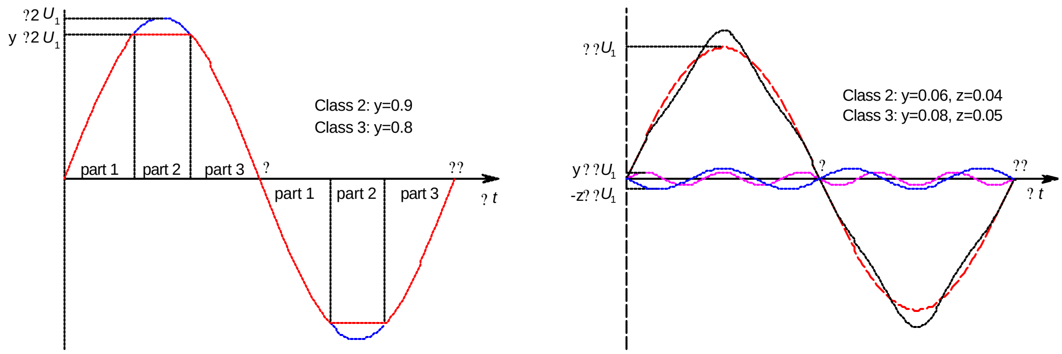


Figure A.4-6: IEC 61000-4-13 Harmonic Combination Waveforms

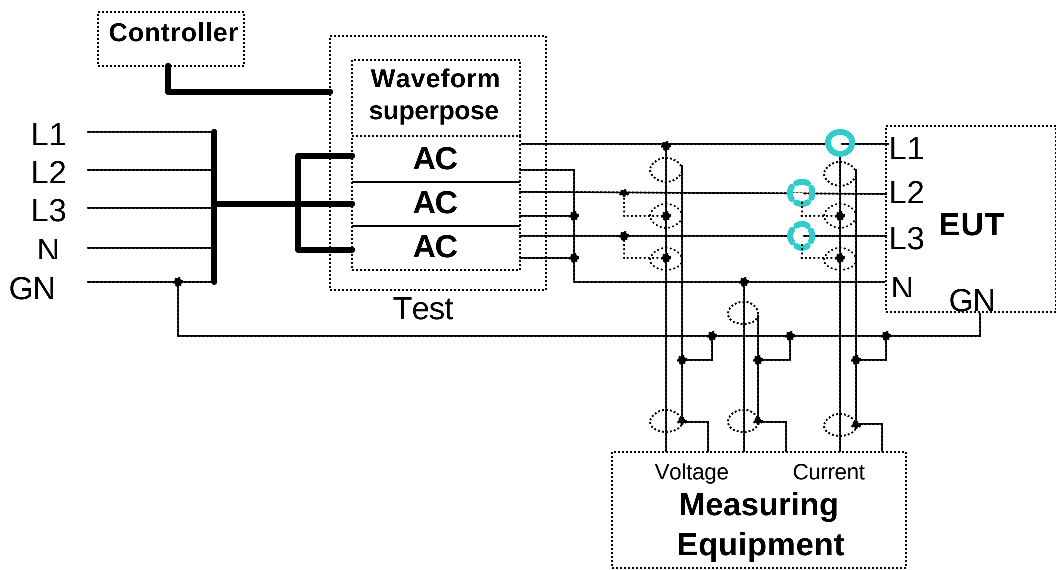


Figure A.4-7: IEC 61000-4-13 Setup for 3-Phase Equipment

A.4.2.1 Analysis of Relationship Between Measured Quantities. Both CS101 and IEC 61000-4-13 measure harmonic and interharmonic voltages so with proper account of the effects of the different set-ups, the quantities can be compared directly. IEC 61000-4-13 also measures currents, which may be of use in later analysis.

The standard also has a provision that the limit is met if the disturbance signal source is adjusted to dissipate 80 watts into a 0.5 ohm load and cannot develop the required voltage at the EUT power mains terminals but the EUT remains immune to the injected signal. For DC mains, the requirement is applicable from 30 Hz to 150 kHz. For AC mains, the requirements are applicable starting at the second Harmonic of the main frequency to 150 kHz.

A.4.3 DO-160D. RTCA DO-160D is intended for airborne equipment only but may satisfy other installations. Section 18 of DO-160D provides an audio frequency susceptibility test very similar to CS101.

A.4.3.1 Measurement and Test Instrumentation. DO-160D does not have complete test setup details; however, the measurement techniques seem generally equivalent to those in CS101.

A.4.3.2 Instrumentation. DO-160D uses dedicated AC and DC power supplies whereas CS101 supplies AC power through an LISN. For AC equipment, DO-160D does not use a 10?F capacitor across the power source. Presumably the impedance of the source is much lower than that of the EUT in the specified frequency range. For DC equipment a capacitor of at least 100 ?F is connected across the power source.

A.4.3.3 Measurement Techniques. Aside from the instrumentation differences, the measurement techniques are similar. DO-160D's set-up is shown in Figure A.4-8.

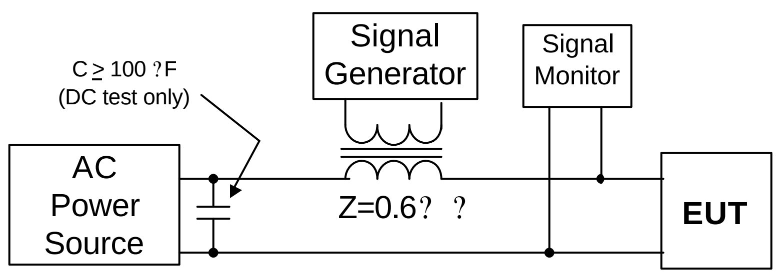


Figure A.4-8: DO-160D Test Setup

Mention is made in RTCA D0-160D of a phase-shifting network to eliminate the power frequency component at the signal monitor. This technique will give unreliable results due to the portion of the injected voltage that appears across the AC power source's terminals producing ripples on the power signal (albeit small). These ripples will not be accounted for with this phase-shifting technique. However, if the voltage across the power source can be tapped without altering the low-impedance characteristics at that end, then this voltage can satisfactorily be phase-shifted and combined with the signal monitor's readings to obtain a measurement of the ripple superposed by the signal generator across the EUT's terminals.

Other minor differences are noted below:

i. DO-160D does not specify that an oscilloscope be used to measure the injected signal, which means that any type of volt meter could be used.

ii DO-160D does not contain the calibration requirement of MIL-STD-461E.

A.4.3.4 Analysis of Relationship Between Measured Quantities. The measured quantities may be compared directly. Once the EUT's input current is accounted for, conversion of the measured current to voltage requires the knowledge of the characteristics of the probe and the input impedance of the EUT; the latter may be difficult to characterize.

A.4.4 CS101 vs. IEC 61533. Another IEC standard which has some similarity to method CS101 is IEC 61533. IEC 61533 is an installation guide for electric/electronic equipment on commercial ships. It contains a requirement for an immunity test of the input power leads to conducted radio-frequency voltages from 10 kHz to 30 MHz. Both the frequency range and the test methodology of this test are more similar to the original CS02 than to CS101. For this reason and because of the severe lack of detail of the test methodology, it is not possible to make a useful comparison between method CS101 and IEC 61533. Although the equipment may well be acceptable for many military applications, qualification to IEC 61533 does not establish that.

A.4.4.4 Instrumentation and Measurement Techniques.

A.4.4.4.1 Instrumentation. The testing procedures of IEC 61533 are severely lacking in detail so it is difficult to establish a comparison; however, the following differences may be noted.

i. IEC 61533 utilizes an unspecified "isolation network" between the power source and the EUT. This is probably an LISN but no further definition is provided. The 10?F capacitor, required by MIL-STD-461E, is not used.

ii. IEC 61533 utilizes an unspecified "adapter network" between the test signal generator and the injection capacitor. The only hint as to what this network is, is provided by a statement: "The signal generator shall be correctly terminated and shall be connected to the cable under test via a capacitor having an impedance less than 5 ? at the measurement frequency." It can be assumed to be a 50 ? to 5 ? impedance matching network. It can also be the point at which the level of the injected signal is measured, but this is not specified.

A.4.4.4.2 Measurement Techniques. Again, the testing procedures are severely lacking in IEC 61533 but these observations are provided:

i. IEC 61533 utilizes capacitive injection of the test signal.

ii. IEC 61533 does not specify how the level of the injected test signal is measured. (Or for that matter that it is measured except by inference that it is at least a certain level.)

A.4.4.4.3 Analysis of Relationship Between Measured Quantities. Both CS101 and IEC 61533 state the requirement as a differential voltage impressed across the power mains input terminal of the EUT without causing malfunction or performance degradation. It must be noted, however, that the testing procedures in IEC 61533 are not detailed enough to determine where the voltage is actually measured so the results may require some manipulation to determine the value at the power input terminal of the EUT.

A.4.5 SAE J1113 . SAE J1113 is a series of measurement procedures and limits for vehicle components. J1113-2 is concerned with conducted immunity in the frequency range 30 Hz to 250 Hz for all leads, not just power leads. The test methodology for this commercial specification is based on CS101 and is therefore extremely homologous to CS101.

A.4.5.1 Instrumentation. There are two basic differences between J1113-2 and CS101: J1113-2 does not use an LISN with AC power, and the capacitor across the leads is 100 ?F instead of 10 ?F.

A.4.5.2 Measurement Techniques. Aside from the differences mentioned above, the two methodologies are basically the same. The set-up for SAE J1113-2 is shown in Figure A.4-9. SAE J1113-2 permits the measurement of the EUT current as below as an alternative to voltage measurement. It is unclear as to how one would account for the EUT input current.

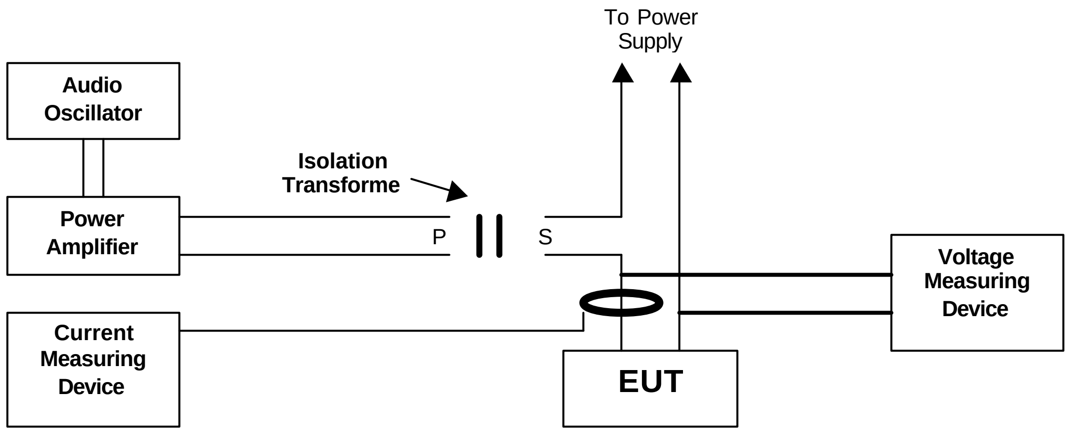


Figure A.4-9: SAE J1113-2 Setup for Power Leads

A.4.5.3 Analysis of Relationship Between Measured Quantities. The measured voltages can be compared directly. Once the EUT's input current is accounted for, conversion of the measured current to voltages requires the knowledge of the characteristics of the probe and the input impedance of the EUT; the latter may be difficult to characterize.

A.5 CS109, Conducted Susceptibility, Structure Current, 60 Hz to 100 kHz

This requirement is applicable to equipment and subsystems that have an operating frequency range of 100 kHz or less and an operating sensitivity of 1 µV or less (such as 0.5 µV). Handheld equipment is exempt from this requirement. In this section the measurement techniques of CS109 is compared with these utilized in IEC 61000-4-16 and IEC 61533.

A.5.1 IEC 61000-4-16. IEC 61000-4-16 is a standard covering immunity of equipment to conducted common-mode disturbances from DC to 150 kHz. It does not specifically cover structure currents in that the disturbances are applied to the signal and the power conductors rather than to the structure itself. In this sense it can be considered as an extension of the test procedure of IEC 61000-4-6 to lower frequencies. (See CS114 vs. IEC 61000-4-6). However an amendment to the document could be quite readily accomplished to meet the structure current test requirement, especially if the structure current test could be shown to apply to commercial applications. This requires the generator ground connection to be removed from ground and brought out separately. (See Figure A.5-1).

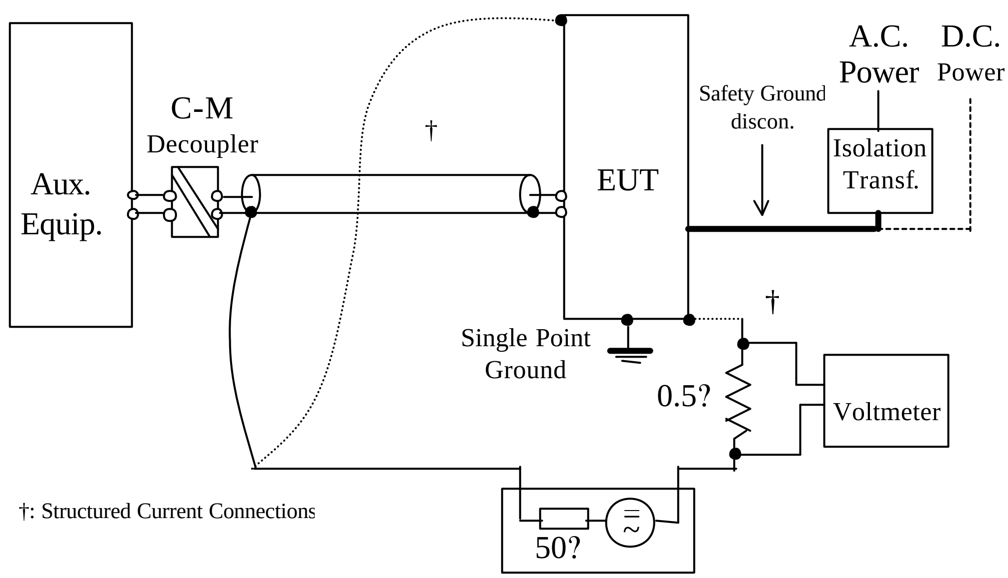


Figure A.5-1: Simulation of CS109 Using IEC 61000-4-16

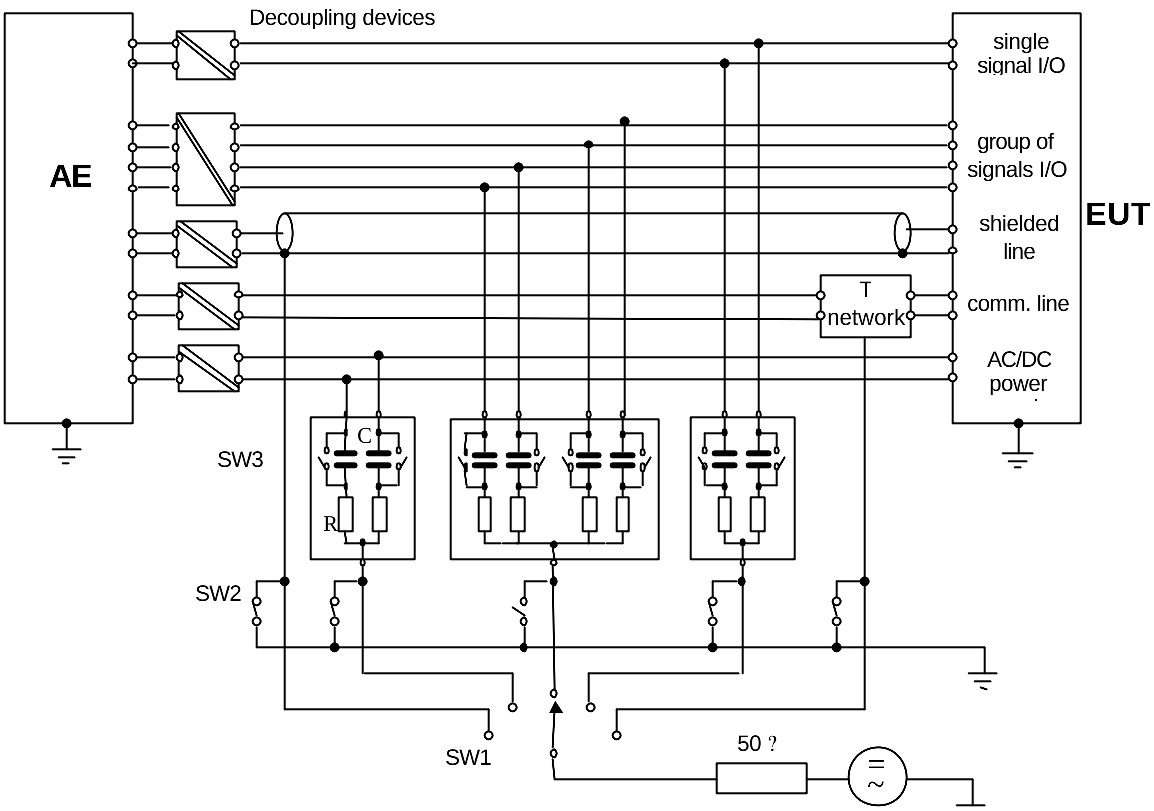
CS109 permits the application of the disturbance between cable shields and ground as this has been found to be an important interference mechanism. Thus, for this purpose IEC 61000-4-16 can be applied directly.

A.5.1.1 Instrumentation. IEC 61000-4-16 is a cable injection test which may provide some feature of a structure current test because structure currents may also appear. The test requires the use of coupling and decoupling networks. The coupling devices (see Figure A.5-2) are used to insure that the common-mode disturbance is impressed on the EUT rather than the auxiliary equipment (AE); their specifications call for a 60 dB common-mode attenuation in the frequency range 15 Hz - 150 kHz and transparency to the differential-mode operating signals of the EUT. The instrumentation requirements are essentially the same, with one exception: in CS109 the generator output is coupled to the EUT with a step down transformer of low impedance; in IEC 61000-4-16, in order to achieve the maximum current level of 1 A specified in CS109, the voltage generator (with 50 ? internal impedance) must be able to deliver 50 V whereas the maximum voltage in IEC 61000-4-16 is only 30 V (except for the "special" class of tests).

A.5.1.2 Measurement Techniques. For convenience, the complete set-up of IEC 61000-4-16 is reproduced below in Figure A.5-2. In this case, the only measurement taken is the input voltage. Conversion into current values for comparison with CS109 is possible only if the common-mode impedance seen by the generator is known. Except for a shielded wire test 100 ? resistors are added in series with the generator's impedance giving a 150 ? source impedance in IEC 61000-4-16. For the shielded wire test the impedance is 50 ? and the resulting current is as much as 10 dB higher. This represents the only significant difference between the two measurement techniques.

A.5.1.3 Analysis of Relationship Between Measured Quantities. In both the military and commercial tests, one is essentially measuring injected currents. However, the effects of these currents are not the same because the coupling mechanisms are not the same. In IEC 61000-4-16, coupling can occur between the shield and the inner conductor(s) of the injection cables as well as between the surface currents on the chassis and the inner electronics of the EUT. But the type of coupling for which IEC 61000-4-16 is primarily intended is common-impedance (C-I) coupling. This type of coupling occurs when the disturbance source and the EUT's port line have a common reference (ground). For example, this situation will arise when the neutral line is grounded at the distribution mains and the EUT is grounded at the cabinet. For IEC 61000-4-16, this coupling mechanism may be modeled as in Figure A.5-3.

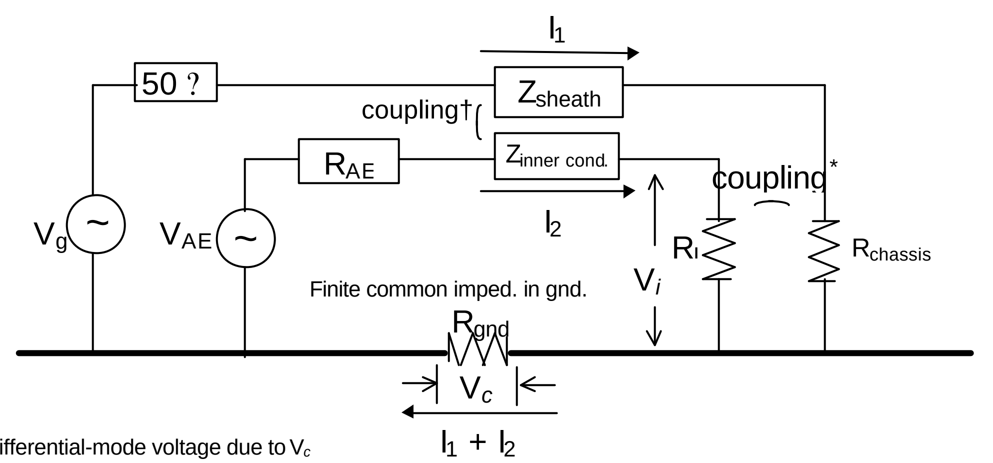
The contribution of the cable to conducted common-mode interference theoretically can be accounted for with the concept of transfer impedance. For example, a straight 1 meter section of RG58/U cable isolated from the ground plane will have a transfer impedance of approximately 16 m? for frequencies up to 100 kHz. This means that a common-mode sheath current of 1 Ampère will contribute about 16 mV to the (coupled) input voltage.



C = 1.0 ?F, to be short circuited for DC voltage test (SW3)
R = 100 ? × n conductors belonging to the port concerned

Example for n = 4: R = 4 × 100 ?

Figure A.5-2: IEC 61000-4-16 Setup



V_i: differential-mode voltage due to V_c

* coupling situation in CS109 & IEC 61533

† coupling situation occurring in 1000-4-16 (and 61533) but for which test is not primarily intended to measure

$$\text{C-I coupling}_{dB} \; ? \; 20\log_{10} \frac{R_L R_{gnd}}{(50 \, ? \, Z_{sheath} \; ? \; R_{chassis})(R_{AE} \; ? \; Z_{inner\ cond.} \; ? \; R_L)}$$

Figure A.5-3: Common-Mode Coupling in IEC 61000-4-16

A.5.2 CS109 vs. IEC 61533

A.5.2.1 Applicability. IEC 61533 is a system standard covering electrical and electronic installations in ships which is currently under revision. Paragraph 25.6 contains a test of circulating currents through cabinet metalwork and cable screens.

A.5.2.2 Frequency Coverage. Paragraph 25.6 of IEC 61533 covers the range 15 kHz - 30 MHz, which overlaps the frequencies of CS109 only from 15 - 100 kHz.

A.5.2.3 Test Comparison. The test in paragraph 25.6 of IEC 61533 injects current via a 1 mH (each winding) bifilar wound transformer onto shielded cables and across all corners of the cabinet. The bifilar transformer is to suppress any common-mode currents that may be injected to ensure greater measurement accuracy. CS109 injects across diagonal corners via a 0.5 ? resistance in the loop.

A.5.2.3.1 Instrumentation. The method of current injection used in IEC 61533 is slightly different from that in CS109. Here the current is injected via an amplifier and a bifilar wound transformer as in Figure A.5-4. The current is passed from one corner to all other corners of the chassis in turn. Where the EUTs are connected via shielded cables, the current is also passed through each shield in turn. Thus the significant instrumentation differences are the bifilar wound transformer and the non-existence of an isolating transformer for the EUT and signal source.

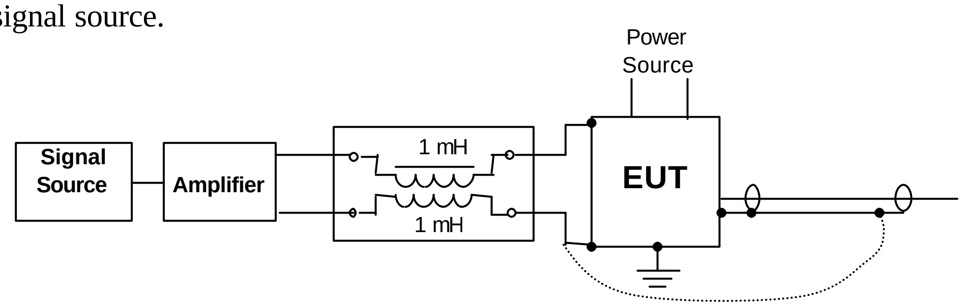


Figure A.5-4: IEC 61533 Clause 25.6 Current Injection (15 kHz – 30 MHz)

A.5.2.3.2 Measurement Techniques. For IEC 61533, the injection technique has been depicted in Figure A.5-4. No method of current measurement is specified so that a comparison cannot be made; presumably a current probe is used. There exists a possibility of interference to and from other sources connected to the supply since there is no isolation for the EUT, that is, if the power source is not a dedicated supply. The standard also does not specify how the shielded cables are terminated or how and if decoupling of the auxiliary equipment is achieved. Lastly, the characteristics of the signal source & amplifier are not specified.

A.5.2.3.3 Analysis Of Relationship Between Measured Quantities. In both IEC 61533 and MIL-STD-461E, the measured quantity is the injected current and there should be no differences in the readings. However, since IEC 61533 does not specify how cables are terminated, a comparison in this situation cannot be made.

A.6 CS114, Conducted Susceptibility, Bulk Cable Injection, 10 kHz to 200 MHz

This requirement is applicable to all interconnecting cables, including power cables. In this section, the measuring techniques used in this and corresponding commercial test procedures are examined in detail.

A.6.1 IEC 61000-4-6.

A.6.1.1 Instrumentation. IEC 61000-4-6 uses three methods of injecting signals, involving different instrumentation. The primary technique, if feasible, is to use coupling and decoupling networks (CDNs) for injection of test signals and isolation of auxiliary equipment. The signals are injected through coupling capacitors in the networks. A diagram of a typical CDN is shown in Figure A.6-2. The second technique is a variation of this approach where shielded cables are driven by direct injection on the shield with decoupling still in place. The third technique is bulk cable injection (termed “clamp injection”) or electromagnetic (EM) clamp, which is specified in the document as the appropriate method for equipment with more complicated interfaces.

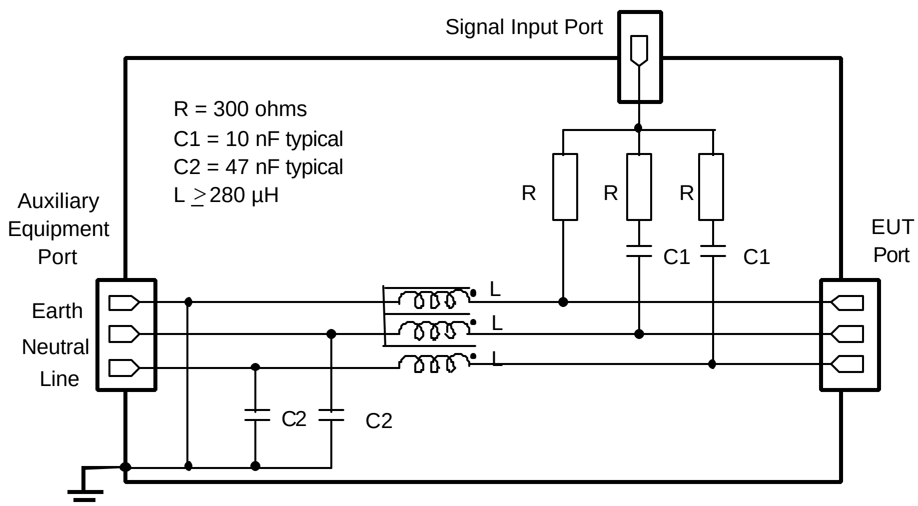


Figure A.6-1: A Typical CDN

The CDN approach is based on obtaining the best repeatability through the use of circuit elements that standardize impedances in the setup. However, if they are not carefully designed, they may actually introduce failures which are not representative of the actual equipment. There is a general principle in testing that the properties of the equipment under test should be disturbed as little as possible in setting up the equipment under test. It is usually better to inject a signal in a fashion that does not interrupt the basic design features present (such as a twisted pairs) and let the interaction of the induced signal and the design features determine the stresses that appear at electrical interfaces. The introduction of networks in a balanced circuit could be the major source of imbalance in the circuit and unrealistic differential (line-to-line) stresses may be developed due to the physical layout and electrical components in the network. Also, the networks are designed to have a significant affect on signals above 150 kHz and an underlying assumption that this characteristic won't affect the intentional signals on the interface. Some higher frequency interface circuits used in military equipment may experience problems.

Since many military equipment items have literally hundreds of interfaces, the use of CDNs would usually not be practical and bulk cable injection would normally be applicable.

A.6.1.2 Measurement Techniques. The basic injection concept used by IEC 61000-4-6 is shown in Figure A.6-3. Cable interfaces are referenced to the ground plane through the CDNs. The intent is to establish a 150 ohm impedance to the ground plane on each cable interface. The CDNs are configured so that the parallel combination of the resistors in series with the injection path equal 100 ohms (see Figure A.6-2). The inductors in the CDNs produce a series high impedance to the outside world. Even normal grounding connections through wire grounds (earth terminals) have impedance inserted in series before being attached to the ground plane. As shown in the figure, the chassis of the equipment under test is electrically isolated from the ground plane. The arrangement is appropriate for commercial applications where there are no significant ground planes present. However, this arrangement is contrary to the general concepts used in MIL-STD-461E, where electronics enclosures are electrically bonded to the ground plane. The MIL-STD-461E arrangement simulates the installation in most military systems. The ground plane can play a role in the path of current flow, effectiveness of filters, and subsequent response of equipment.

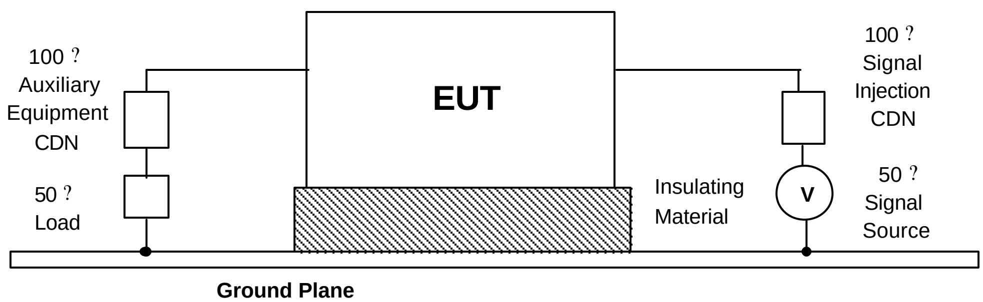


Figure A.6-2: IEC 61000-4-6 Injection Concept

The frequency range of IEC 61000-4-6 is from 150 kHz to 80 MHz, while CS-114 covers from 10 kHz to 200 MHz. While the frequency range of IEC 61000-4-6 probably encompasses the most important portion of the spectrum for this type of evaluation, some information is lost. It may be possible to extend the test to higher frequencies; however, extending the test to lower frequencies is hampered by the use of the CDNs. The radiated immunity requirements of IEC 61000-4-3 start at 80 MHz. MIL-STD-461E recognizes an overlap in frequency coverage between CS114 and the radiated susceptibility requirements of RS103. IEC 61000-4-6 uses 1 kHz, 80% amplitude modulation, while CS-114 uses a 1 kHz square wave modulation. The CS114 modulation tends to be more severe by encompassing the basic aspects of amplitude modulation with the addition of a faster rise time and greater sidebands.

A.6.1.3 Analysis of Relationship between Measured Quantities. CS114 and the IEC 61000-4-6 bulk cable approach both use current induced in a test fixture with a 100 ohm loop impedance as the required drive level for testing. CS114 also monitors the actual common mode current induced in cable harnesses. IEC 61000-4-6 only requires monitoring if certain conditions are not met.

For the direct injection approach using capacitive coupling in the CDNs, IEC 61000-4-6 requirements are based on the open circuit voltage of the 50 ohm signal source. Based on the model shown in Figure A, a current can be calculated which assumes essentially that there is 300 ohms in series with this open circuit voltage. This calculation essentially assumes that input wiring and output wiring is directly connected together.

A distinction between the bulk cable techniques of CS114 and IEC 61000-4-6 can lead to differences in the effect of an injected level. CS114 requires cable lengths to be similar to the actual installation. Common mode voltages and currents will develop at the input to individual circuits based on circuit shielding (associated transfer impedances of shields), overall impedance distributions, and resonance conditions. IEC 61000-4-6 specifies that short cables be used in order to maintain better control at higher frequencies. For cables that don't contain shielded components, this technique may work well since the coupled voltage from the injection probe will directly drive interface circuits. However, the approach may not produce correct results on cables with shielded components since the voltage developed at the circuit interface is dependent upon the interaction of the driven current with the transfer impedance of the entire length of the shield.

A.6.2 RTCA DO-160D. The test methodology in CS114 and the conducted susceptibility portion of DO-160D, Section 20, are very similar. DO-160D is intended for airborne use, although it could be applied elsewhere. Other than using different line impedance stabilization networks, the test methodology has no significant differences.

A.6.2.1 Instrumentation. CS114 and Section 20 both use current probes for injecting signals and monitoring levels. They vary in the type of line impedance stabilization network (LISN) used on powerlines. CS114 uses a 50 microhenry LISN similar to those used in CISPR 11 and ANS C63.4. DO-160D imposes an impedance curve for power inputs apparently derived from a 5 microhenry LISN model. DO-160D allows the use of the MIL-STD-461E LISN as an option.

A.6.2.2 Measurement Techniques. CS114 and Section 20 both use standard setups with ground planes and electrical bonding between electronics enclosures and the ground plane. This arrangement simulates the installation in many military systems and commercial aircraft. CS 114 covers 10 kHz to 200 MHz while Section 20 covers 10 kHz to 400 MHz. CS 114 and Section 20 both use a 1 kHz square wave modulation. Section 20 also requires continuous wave.

A.6.2.3 Analysis of Relationship between Measured Quantities. Measured quantities are the same. Both CS114 and Section 20 use current induced in a test fixture with a 100 ohm loop impedance as the criteria for measurement. Both monitor the actual common mode current induced in cable harnesses.

A.6.3 SAE J1113/4. The stated objective of J1113/4 is to simulate direct and wire harness coupling that occurs when a vehicle is driven near high powered transmitting antennas or when a mobile transmitter is used on a vehicle. The intent, test methodology, levels, and frequency coverage are very compatible with Army, Air Force and Navy MIL-STD-461E requirements.

A.6.3.1 Instrumentation. Instrumentation and set-up required by J1113/4 are almost identical to those required by MIL-STD-461E. J1113/4 has an optional power meter monitoring forward power while CS114 utilizes a measurement receiver. J1113/4 requires that the cable harness must be either the actual or a 1meter sample of the harness. Bonding is to be from the EUT's actual installation bonding point to the ground plane, Figure A.6-6.

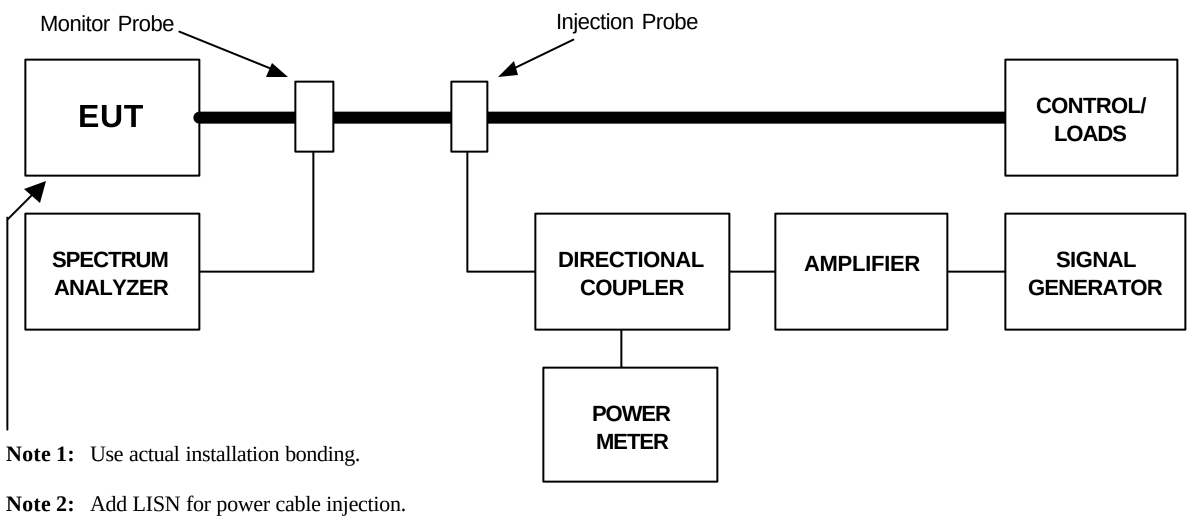


Figure A.6-3: SAE J1113/4 Setup

A.6.3.2 Measurement Techniques. CS114 and SAE J1113/4 are extremely compatible. Both use current induced in a test fixture with 100 ohm loop impedance as the required drive level for testing. Both also measure the common mode current induced in the cable harness. J1113/4 recommends the use of a cable harness representing actual installation. Although induced currents vary by service for 461E and by Class and Region for SAE, there is plenty of room for compatibility between the two specifications. Compatibility with CS114 requirements may hinge on the relevance of pulse modulation and the lack of J1113/4 testing below 1 MHz. J1113/4 has measurements made at 120mm, 450mm, and 750mm from the EUT cable harness connector while CS114 has one position 5cm from the EUT connector.

A.6.3.3 Analysis of Relationship between Measured Quantities. Measurements made in compatible frequency ranges, at similar test levels, with similar probe positions (5cm and 120m), and utilizing cable harnesses representing actual platform installation, will produce compatible results.

A.7 CS115, Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation.

This requirement is applicable to all aircraft, space, and ground system interconnecting cables, including power cables. The requirement is also applicable for surface ship and submarine subsystems and equipment when specified by the procuring activity. In this section, we compare the CS measuring technique with those of corresponding commercial standards.

A.7.1 IEC 61000-4-4. The stated objective of IEC 61000-4-4 is to "establish a common and repeatable basis for evaluating the performance of electrical and electronic equipment when subjected to repetitive fast transients (bursts), on supply, signal and control ports." This objective is similar to CS115.

A.7.1.1 Instrumentation. The basic instrumentation for each requirement is similar limited. Both require a transient signal source and a coupling device. CS115 requires a 50 ohm source producing the trapezoidal pulse shown in Figure A.7-1. IEC 61000-4-4 requires a source producing a double exponential pulse as shown in Figure A.7-2. IEC 61000-4-4 uses a capacitive coupling clamp shown conceptually in Figure A.7-3 on signal lines and coupling/decoupling networks (for injection of the signal and for isolation of the power source) on power leads as shown on Figure A.7-4. On power leads, CS115 leaves the line impedance stabilization networks (for standardization of power line impedance) in place that are part of the general setup requirements.

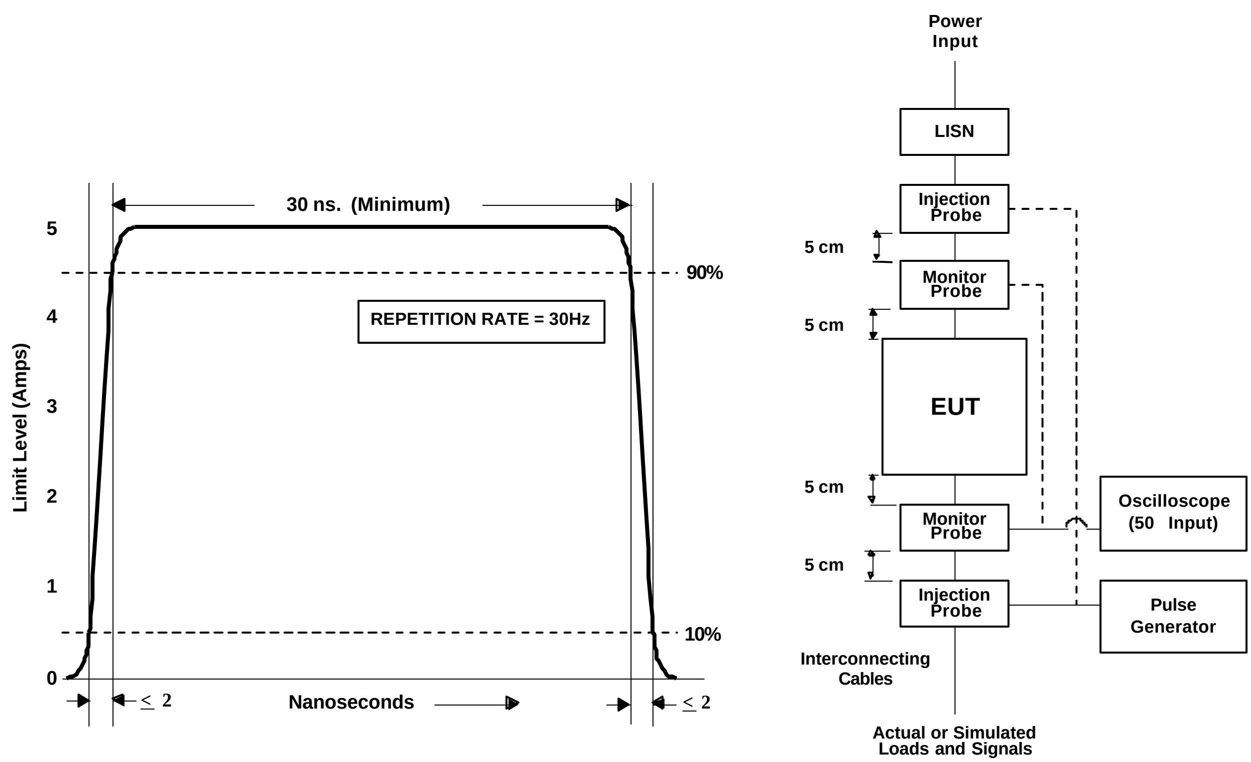


Figure A.7-1: CS115 Limit and Setup

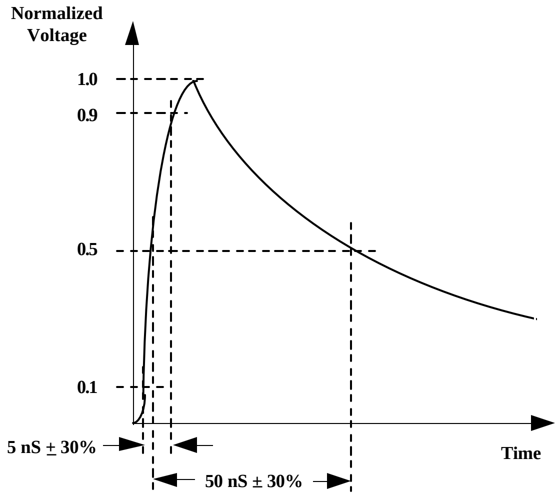


Figure A.7-2: IEC 61000-4-4 Waveform

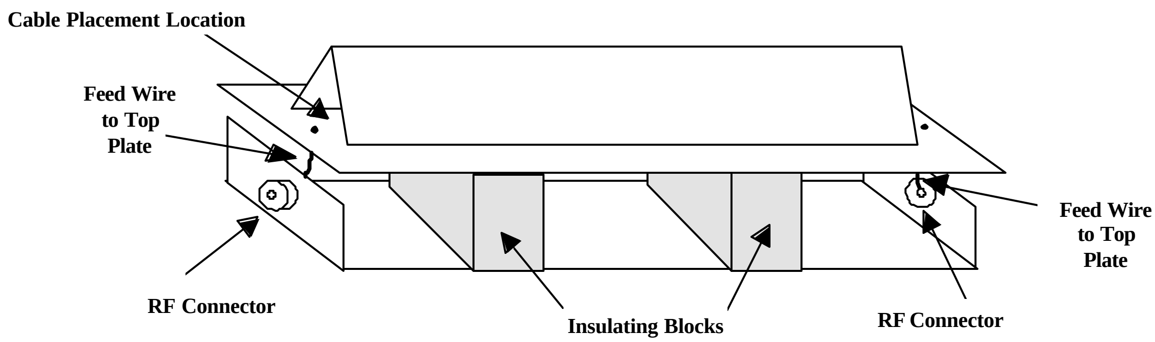


Figure A.7-3: IEC 61000-4-4 Capacitive Injection Clamp

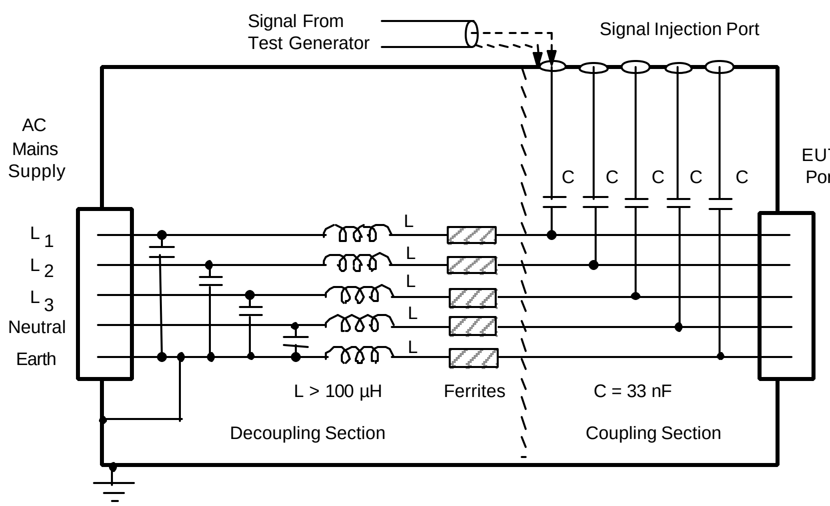


Figure A.7-4: Coupling/Decoupling Network

A.7.1.2 Measurement Techniques. CS115 requires that transients be applied at a 30 Hz rate, while IEC 61000-4-4 uses a 5 kHz rate during bursts (250 actual pulses per second on the average). Both require application for at least one minute.

For signal cables, both methods use common mode injection. For power input circuits, IEC 61000-4-4 evaluates each power lead individually by injection though a capacitor. CS115 tests power inputs in a common mode fashion by first driving the entire power cable and then driving the power cable with the returns removed. CS115 is oriented toward common mode issues because it is primarily addressing electromagnetically coupled transients where all wires in a cable will be excited simultaneously. There is a portion of the test, which removes power returns to address the case where system structure is used for current return and wire returns are not present. Test method CS116 includes differential coupling (line-to-line) to power leads where higher energy (and lower frequency) type transients might be directly conducted along a power bus and appear in differential mode.IEC 61000-4-4 electrically isolates equipment under test from the ground plane except for the normal grounding connection through a wire ground. The test instrumentation is tied to the ground plane. CS115 uses the standard setup from MIL-STD-461E that includes a ground plane for most applications to which equipment enclosures are electrically bonded. The MIL-STD-461E arrangement simulates the installation in military systems where metallic equipment enclosures are electrically bonded to system structure. The ground plane can play an important role in the path of current flow, effectiveness of filters, and subsequent response of equipment. It is understood that the wire grounds used in the basic IEC 61000-4-4 are attempting to simulate commercial installations; however, this arrangement can be expected to lead to variability due to the fast rise time pulses being used. Since the development of stresses across any particular electrical interface is dependent on the actual physical attachment points for the transient generator and the electrical circuit parameters of all elements between these points, the ground wires will probably play a significant role in the distribution of voltage stresses.

A.7.1.3 Analysis of Relationship between Measured Quantities. A direct comparison of quantities associated with the two methods is difficult, since CS115 uses inductive coupling and IEC 61000-4-4 uses capacitive coupling. Some observations can be made. The transient stress for CS115 is calibrated in a test fixture with a 100 ohm loop impedance, which essentially requires that a specified current and voltage be available in the coupled circuit. There are no constraints on the probe provided it can produce the required waveform in the fixture. IEC 61000-4-4 controls the source impedance of the generator and the range of the capacitance used for injection. The value is specified as 50 - 200 pF for signal lines through the capacitive clamp and 33 nF for powerlines. The developed voltages and currents in any particular circuit will depend on the impedance characteristics of the circuit for both methods. The short duration of the transients will tend to excite resonances in electrical cabling in the setup. Resonant frequencies of the cabling can be expected to be in the several tens of MHz. At these frequencies, the capacitance of the IEC 61000-4-4 injection clamp will represent an impedance on the order of 100 ohms, which could be a significant influence on coupled levels. The impedance of the powerline injection capacitor will be on the order of tenths of ohms and should effectively pass the transient. Laboratory experience with the capacitive injection clamp has shown a significant variation in coupled signal based on positioning of the cable within the clamp. The inductive coupling probe of CS115 should be more consistent.

The basic characteristics of the pulses are similar. The more significant difference between these pulses is probably the rise time. The IEC 61000-4-4 rise time is 5 nanoseconds, while the CS115 rise time is 2 nanoseconds. CS115 will tend to excite resonances under more circumstances because of the higher frequency content of the pulse. Experience with CS115 has shown that the currents that are induced on cables are representative of the natural response of the cable and do not resemble the applied waveform in the MIL-STD-461E calibration fixture. The same result would be expected with the IEC 61000-4-4 waveform.

A.8 CS116, Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads, 10 kHz to 100 MHz.

This requirement is applicable to all interconnecting cables, including power cables, and individual high side power leads. Power returns and neutrals need not be tested individually. Corresponding commercial standards are IEC 61000-4-12 and IEC 61000-4-25. In this section, the measurements techniques are compared in detail.

A.8.1 CS116 Measurements. The following comparison addresses instrumentation, measurement techniques, and the analysis of measured quantities. The analysis is performed using the concept of the action integral since the two specifications calibrate the waveforms using various techniques and loads. The action integral introduces a single parameter, which can be used to compare the waveforms in terms of energy delivered to the load.

A.8.1.1 Instrumentation. For performing MIL-STD-461E testing, the required equipment is listed in Table A.8-1.

Table A.8-1: List of Equipment for CS116 Test

Item	**Characteristics/Application**
Damped Sinusoidal Transient Generator	10 kHz – 100 MHz up to 10 kW – peak
Bulk Cable Injection Probes	at least two cover 10 kHz – 100 MHz
Oscilloscope	at least a 200 MHz bandwidth to capture a 100 MHz transient and digitizing rate of at least 1 GHz
Calibration Fixture	50-ohm coaxial
Current Probes	at least two to cover 10 kHz - 100 MHz; needs to have relatively flat response to avoid distortion of waveform
Receiver	for impedance measurement
RF Amplifier	for impedance measurement
Signal Generator	for impedance measurement
LISN	for power line stabilization
Ground Plane	To stabilize measurement arrangement

CS116 test setup is shown in Figure A.8-1. A transient generator is used to produce a damped sine waveform at a frequency between 10 kHz and 100 MHz and calibrated on a known load using the calibration fixture. This waveform is coupled onto each cable in turn and on the high conductor of a power lead using a bulk cable injection probe and the injected waveform is measured using a current probe and oscilloscope. The generator's output is set to minimum and increased until the test level is reached. Injection is performed at either the calibration setting or the current limit defined in MIL-STD-461E depending on the impedance of the cable under test. All signal and power cables are tested and all power is stabilized by using LISNs. Prior to actually performing the CS116 injection, a cable impedance measurement is required to determine resonance. The CS116 test is then to be performed at the 6 required frequencies (0.01, 0.1, 1, 10, 30, 100 MHz), critical frequencies, and resonance frequencies. The resonance test is performed only when the actual test cables are available which is rare. Therefore, the following comparison does not address the impedance measurement section which is similar to the CS114 Test requirement.

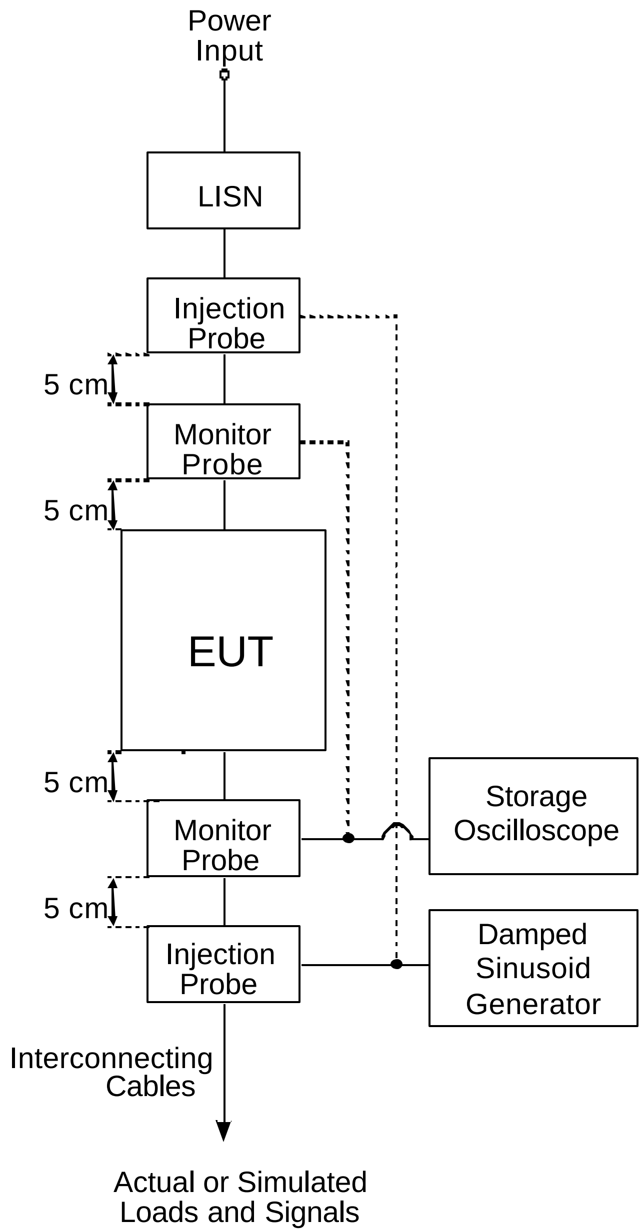


Figure A.8-1: CS116 Setup

A.8.1.2 Test Methodology**.** In the performance of calibration procedure, method CS116 calls for voltage measurement across a known resistance that is compared to a current limit. During injection, the current is measured via a current probe placed around the cable under test. Normally, no voltage measurement is made. The generator output is increased until the current limit is reached or the calibration level is achieved. The test transient is injected common mode on the entire cable bundle under test and also on only the high leads of power conductors.

A.8.2 IEC 61000-4-25. IEC 61000-4-25 refers to IEC 61000-4-12 for the test method.

A.8.2.1 Instrumentation. For performing the IEC 61000-4-12 test the equipment shown in Table A.8-2 is required:

Table A.8-2 Equipment Required for IEC 61000-4-12 Testing

Test Generator	100 kHz (ring and damped) and 1 MHz 250 V various currents
Oscilloscope	20 MHz minimum bandwidth
Voltage Probe	250 V capability
Current Probe	350 A capability and flat response between 10 kHz and 10 MHz
Coupling/Decoupling Network	required for power and I/O cables
Ground Plane	

The test methodology gives extensive testing instructions for various types of cables and includes both common-mode and differential-mode injection. Injection is in parallel by means of a capacitor to each conductor, which requires coupling/decoupling networks to be inserted between the EUT and any associated auxiliary equipment. A typical IEC 61000-4-12 test setup is shown in Figure A.8-2.

In order to verify the waveform requirement of IEC 61000-4-12, an oscilloscope, a voltage probe, and a current probe are required.

A.8.2.2 Measurement Techniques. The measured quantities are voltage and/or currents in both requirements. The source impedance requirements of IEC 61000-4-12 are verified by measuring the voltage and current simultaneously. The test procedures are different. IEC 61000-4-12 requires a calibration on a short circuit current measurement directly from the test generator, while CS-116 requires current measurement in a 100 ohm coaxial fixture. The measured values can be related and compared for harmonization.

A.8.2.3 Test Methodology. Calibration for IEC 61000-4-12 is performed both on an open circuit and a short circuit. Peak voltage and current measurements are made. The source impedance of the generator is determined from the results. While injections are performed, no measurements are made. Injections are made in both common and differential modes.

These results are summarized in Table A.8-3:

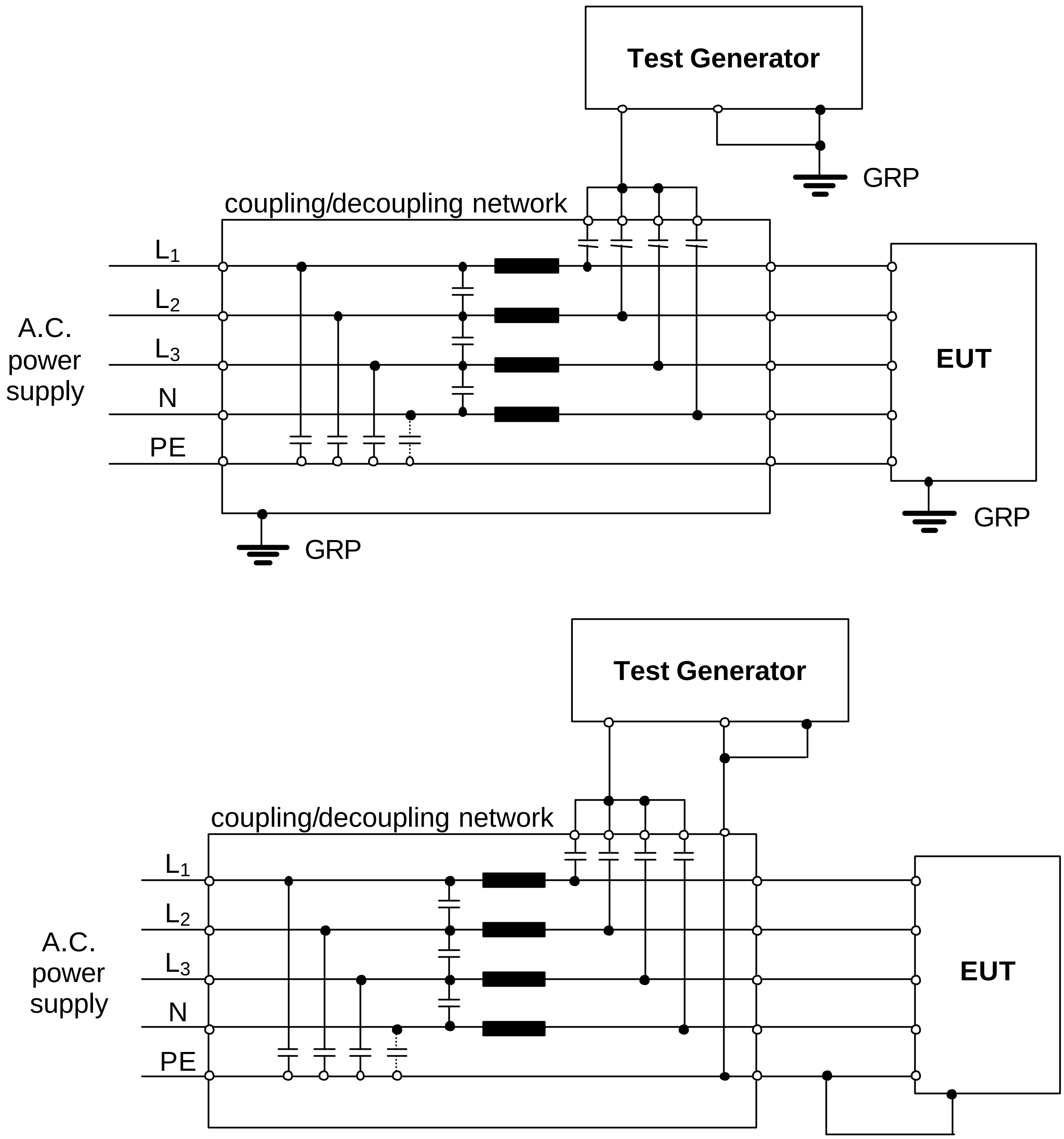


Figure A.8-2: IEC 61000-4-12 Test Setups

A.8.2.4 Analysis Of Relationship Between Measured Quantities. Since the major difference in measurements is open circuit/short circuit versus voltage and current measurements across a known load, the analysis consist of dividing voltages and currents to determine source impedance and then determine the current on the known load. For example, IEC 61000-4-12 requires open circuit voltage of 250 V - 4 kV and short circuit current of 20 - 333 A depending on required test level. This requires a source impedance of 12, 30, OR 200 ohms depending on the test level. This will translates into a current of approximately 1.25 -333 A when calibrated using the CS116 methods (assuming no distortions or non-linear effects due to addition impedances at the connections). The main difference is not in the measurements but in the limits which are discussed in the next section.

Table A.8-3: Test Methodology Comparisons

Standards	Calibration or Injection Levels	Primary Injection Method	Injection Mode
CS116	Both	Inductive	Common
IEC 61000-4-12	Calibration	Capacitive	Com. and Differential

Note: 'Calibration or Injection Levels' indicates when the required levels are monitored.

A.8.3 Action Integral. Since the test methodologies are varied, a new parameter was introduced to compare limits of both techniques. The parameter used is the action integral defined as:

$$AI = \int i^2(t)dt \qquad (1)$$

This parameter is a measure of the energy delivered by the test current. The integral is evaluated over the time interval of interest. Since the actual energy delivered cannot be calculated without knowing the resistance of the system under test, the action integral is used to compare the delivery of energy through the injections of the various waveforms to be investigated. This measure eliminates the problem of comparing limits with various source impedance requirements and difference in calibration loads.

Table A.8-4 lists the test frequencies and the corresponding current limits and action integrals for MIL-STD-461E, Method CS116. The levels shown are the Army/Navy current limit with a worst case damping factor of 20. As discussed in Section 4, the action integral is a quantitative method of comparing the various transient standards. The action integral allows for measure of the potential of susceptibility of the equipment.

The highest CS116 test levels occur at the test frequency of 1.0 MHz. At 1.0 MHz, the peak current is 10 amperes, the peak voltage possible assuming the maximum allowable source impedance of 100 ohms is 2000 volts, and the action integral has a value of 1.69×10^{-4}.

IEC 61000-4-12 contains specifications for several severity levels depending on the electromagnetic severity level of the intended environment for the EUT. Different levels are also specified for different lines under test and for common and differential injection modes. Table A.8-5 lists the waveforms with their corresponding current limits and action integrals for IEC 61000-4-12. The worst case damping of the damped oscillatory waveforms was used in each case.

Table A.8-4: CS116 Test Level Parameters

FREQUENCY (MHz)	CURRENT LIMIT (A)	ACTION INTEGRAL
0.01	0.1	1.69×10^{-6}
0.1	1.0	1.69×10^{-5}
1.0	10	1.69×10^{-4}
10	10	1.69×10^{-5}
30	10	5.62×10^{-6}
100	3.0	1.52×10^{-7}

Table A.8-5: IEC 61000-4-12 Test Parameters

WAVEFORM	CURRENT LIMIT (A)	ACTION INTEGRAL
Ring Wave	333	2.78×10^{-1}
	133	4.44×10^{-2}
	20	1.00×10^{-3}
Damped Osc.-100 kHz	12.5	2.81×10^{-3}
Damped Osc.-1 MHz	12.5	2.99×10^{-4}

The 1 MHz damped oscillatory wave of IEC 61000-4-12 has a peak current of 12.5 amperes, a voltage level of 2500 volts, and an action integral of 2.99×10^{-4}. The 100 kHz damped oscillatory wave has the same voltage and current levels as the 1 MHz wave, but its action integral is 2.81×10^{-3}. At the 4 kilovolt maximum ring wave voltage level, the current and action integral ranges from 20 amperes and 1.00×10^{-3} to 333 amperes and 2.78×10^{-1} respectively. These levels are calibration levels only and may not be present on the test lines. These levels do not take into consideration Category X, in which higher levels may be specified.

The test level comparisons are summarized in Table A.8-6 which lists the highest voltage levels and action integral range for both of the test specification under comparison.

Table A.8-6: Test Level Comparisons

Standard	PEAK VOLTAGE (kV)	ACTION INTEGRAL RANGE ($A^2 \cdot s$)
CS116	2.0	$2\times10^{-7} – 1.69\times10^{-4}$
IEC 61000-4-12	4.0	$3\times10^{-4} – 2.78\times10^{-1}$

A.9 RE101, Radiated Emissions, Magnetic Field, 30 Hz to 100 kHz

This requirement is applicable for radiated emissions from equipment and subsystem enclosures, including electrical equipment and associated cables. The requirement does not apply at telecommunication transmitter fundamental frequencies, but does apply to the operating frequencies of sonar and industrial, scientific, and medical (ISM) subsystems and equipment. The requirement does not apply to radiation from antennas. For Navy aircraft, this requirement is applicable only for aircraft with an ASW capability.

A.9.1 Comparison of Levels Measured Utilizing Various Techniques. The following discussion is intended to provide a basis for comparing measurements made with the exploring loop of MIL STD 461E and that made with the large loop antenna (LLA) of CISPR Publication 15.

A.9.1.1 Assumptions We consider the equipment under test has a metal cabinet for which the emitted magnetic field occurs at an aperture. Assume, the aperture dimensions are small compared with the loop distance (7 cm. for RE101). Thus, we assume source is an equivalent magnetic depole.

A.9.1.2 Calculations The highest magnetic field at a given distance, r, is in the direction of the dipole source and is given by:

$$H = \frac{M}{2?r^3}$$

Where M is the magnitude of the dipole in ampere meters squared. For the large loop antenna of publication CISPR 15, the relation between the field strength and the current in the loop is dependent on the loop size and cross section. For reference, we assume the 3 meter diameter loop and initially calculate the field at a distance of 3.0 m from the object under test. Further, we note that the limit in CISPR 15 is given in terms of equivalent electric field strength (?V/m) which is equal to magnetc field strength (?A/m) plus 51.5 dB. Thus, one has, from the bottom of p. 91 of CISPR 15 and accompanying corrections, for this configuration,

$$H[dB(?V/m)]_{3m} = I_m[dB(?A)] + 39$$

Where I_m[dB(?A)] is the current measured in the 3m large loop antenna. Thus, converting from a) equivalent electric field to actual magnetic field (-51.6 dB), b) from magnetic field expressed in microamperes per meter to picoTesla (+2 dB) and c) the field at 3m to that at 7 cm(+98 dB), one obtains:

$$B[db(pT)]._{07m} = I_m[dB(?A)] +39 +98 – 51.5 +2$$
$$= I_m[dB(?A)] + 87.5$$

The correction factors vary with frequency as is shown in CISPR 15.

The final comparison of military and CISPR 15 limits is shown on Figure A.9. Generally, the military limits are much more severe than the commercial limits. This results from assumptions about the spacing of a susceptible device from the source of the field. If actual spacings are larger than the 7 cm measuring distance the military limit could be reduced accordingly.

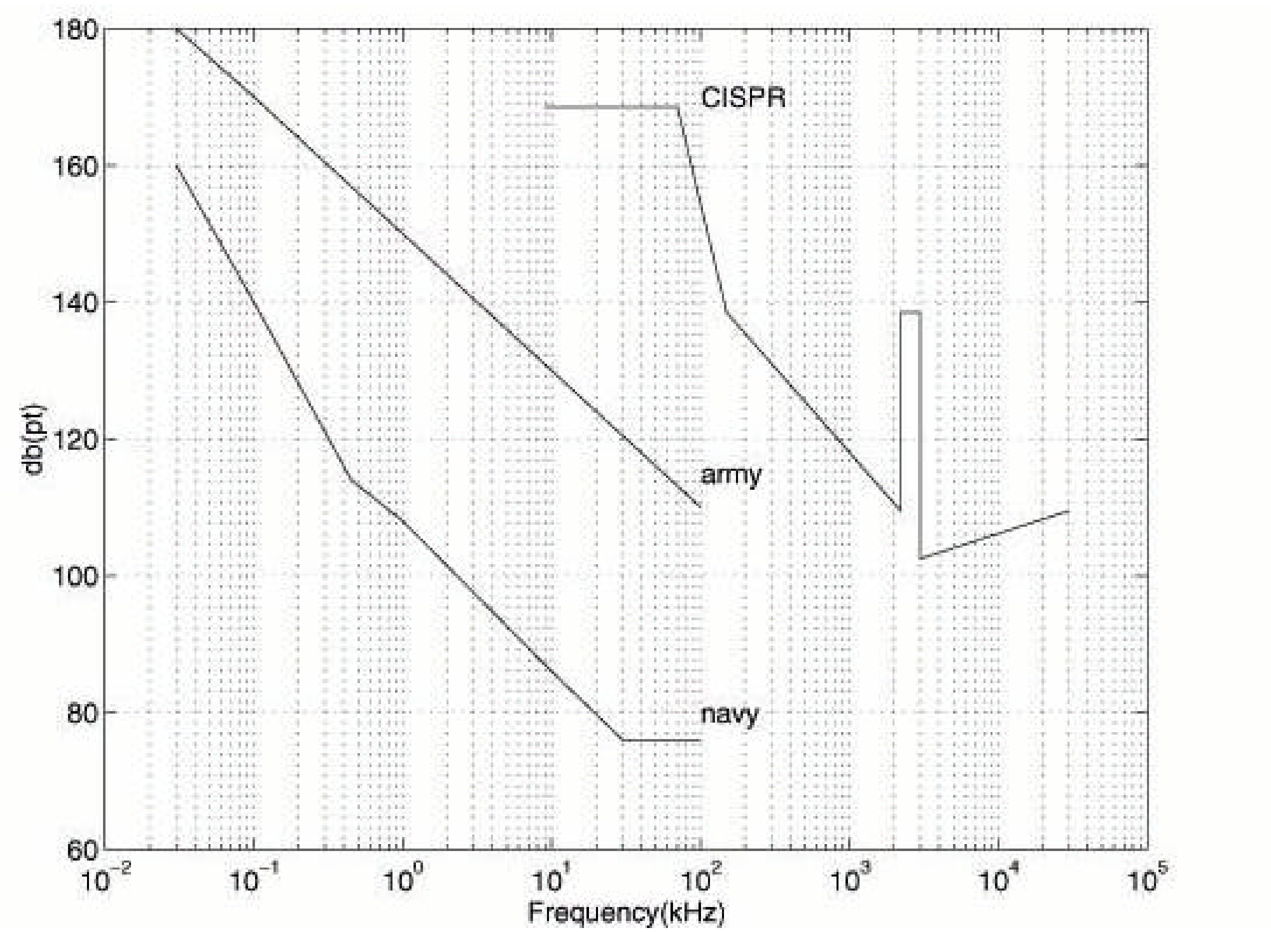


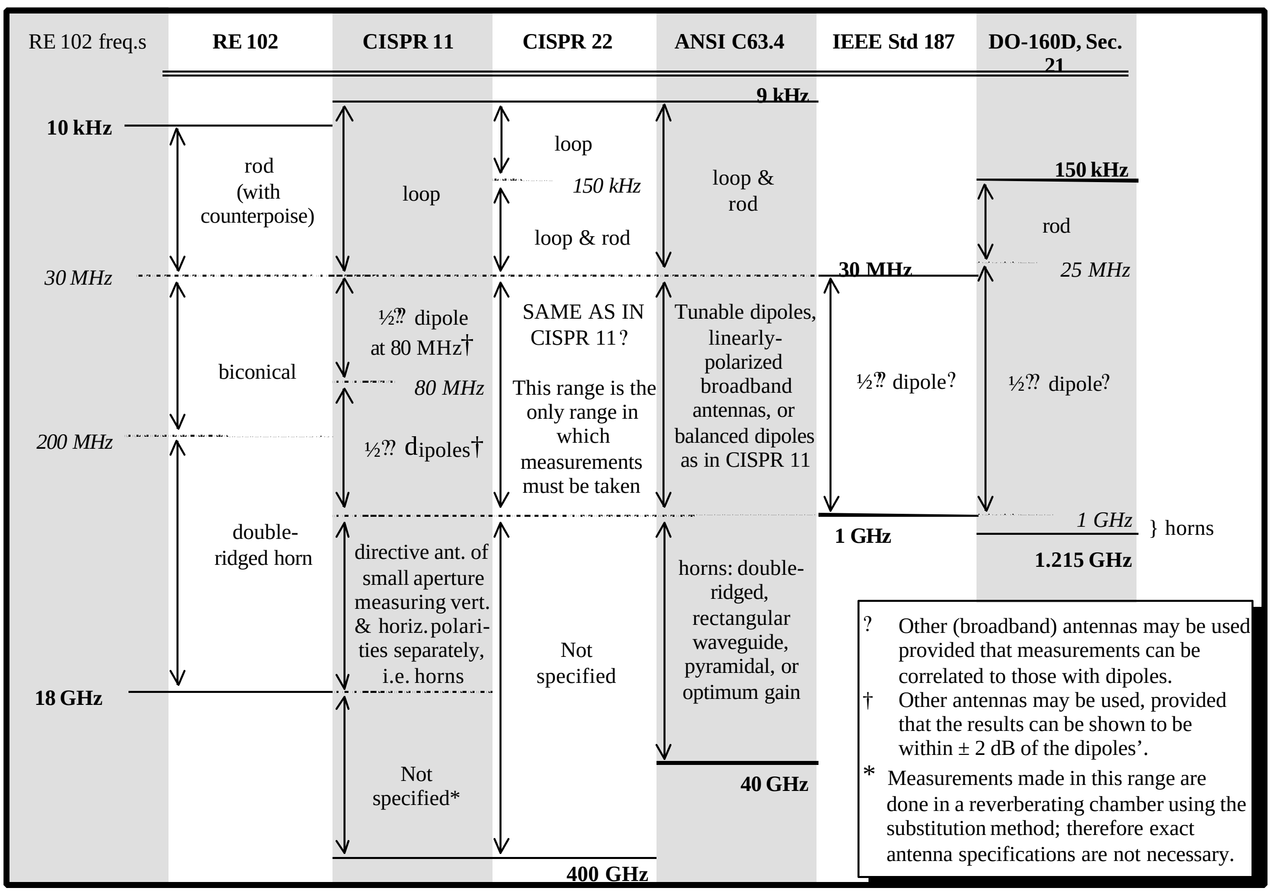
Figure A.9: CISPR 15 vs. Army and Navy Limits

A.10 RE102, Radiated Emissions, Electric Field, 10 kHz to 18 GHz

A.10.1 Instrumentation. We compare antennas, detectors, use of LISNs, and absorbing clamps.

A.10.1.1 Antennas. The most readily apparent differences between the commercial tests (excepting DO-160D) and RE 102 are in the types of antennas employed, summarized below in Table A.10-1. In the table, the frequency ranges are delineated with solid lines whereas intermediate frequencies are the dashed lines.

Table A.10-1: Summary of Antenna Requirements



Experience in civilian practice has shown that below 30 MHz, the magnetic component can be more reliably measured than the electric component, hence the requirement of loop antennas below 30 MHz. Moreover, the magnetic field is expected to be the major source of disturbance below 150 kHz. For the military, magnetic field emissions are covered in RE 101 for the range 10 Hz - 100 kHz; however, RE 101 measurements are made very close to the cabinet: at 7 cm or 50 cm. Nevertheless, in this range, harmonization of RE 102 should be considered in conjunction with that of RE 101 for consistency.

Where both loop and rod antennas are required in the commercial tests, there is no basic difference with RE 102. Where only the loop is required, the magnetic field readings from the loop must be correlated with the electric field readings from the rod. The conversion of field values from (dBµA/m) to (dBµV/m) is usually done with the assumption of a plane wave and the expression:

(Eq. A.10-1) $$\mathbf{E}[\mathrm{dB}(?\mathrm{V/m})] ? \mathbf{H}[\mathrm{dB}(?\mathrm{A/m})] ? 51.5[\mathrm{dB}(?)]$$

where 51.5 dB? = $20\log_{10}(Z_0 = 120?)$. The validity of this assumption and hence the expression above will come into question in the near-field region where the distance between the EUT and the receiving antenna is less than ?/2?, which will occur in the military test (at 1 m) for frequencies below ~ 48 MHz and for the civilian test (at 3 meters) below ~ 16 MHz. In this region the relationship between the **E** & **H** fields will depend on the actual configuration of the EUT and the modes of emission and will be hard to predict. Also, the attenuation rate will not be known in the near-field region unless there is some knowledge of the nature of the source(s). Thus harmonization of loop measurements at 3 meters to rod measurements at 1 meter will be difficult as neither the $1/r$ attenuation relationship nor the above equation will hold.

The antenna difference is most critical in the 30 MHz - 1 GHz range where the biconical and horn antennas are used in the military test in contrast to tunable dipoles in the civilian tests. In order to fully harmonize the antenna requirements in this range with all four civilian tests, the characteristics of the biconical and the horn antennas will have to be compared carefully with those of the dipoles to determine whether their response is within ? 2 dB of each other, a CISPR 11 specification; if this requirement is removed, then a calibration chart can simply be used to correlate measurements made with the biconical and horn antennas to those of the dipoles.

For the high-frequency range 1 GHz - 18 GHz no significant instrumentation differences exist in terms of antenna requirements between the military and civilian tests. A double-ridged horn can be used for CISPR 11 and ANSI C63. For CISPR 22 and IEEE Std 187, measurements in this frequency range are not necessary or specified.

A.10.1.2 Detectors. The CISPR and ANSI standards call for the possibility of using quasi-peak and average detectors. Indeed, the quasi-peak detector is the reference detector for frequencies below 1 GHz. In contrast, the military uses the peak detector exclusively for RE 102. Nevertheless, the peak and the quasi-peak detectors should give the same response, except in cases where EUT emissions are pulsive or intermittent in nature. When such is the case, the quasi-peak response will also depend on the frequency of occurrence. Hence, case-by-case determination of the applicability of quasi-peak detectors will have to be performed if it is suspected that EUT emissions are pulsive or intermittent in nature.

In CISPR 11 and 22, an EUT will be considered in compliance if it meets either:
1) The quasi-peak limits using the quasi-peak detector *and* the average limits using the average detector, or 2) The average limits using the quasi-peak detector. By considering the average along with the (quasi) peak readings, CISPR 11 and 22 provide a more accurate idea of the type of emissions involved. In contrast, by considering only the peak values, RE 102 may be more severe than it need be, especially in the case of pulsed/intermittent EUT emissions.

There are also differences in the –6 dB bandwidth requirements of these detectors. These differences are summarized below in Table A.10-2. For the most part, the bandwidths are comparable, with the exception of DO-160D. This is a minor disagreement and harmonization can be achieved by remembering that the values are intended as minimum bandwidth requirements.

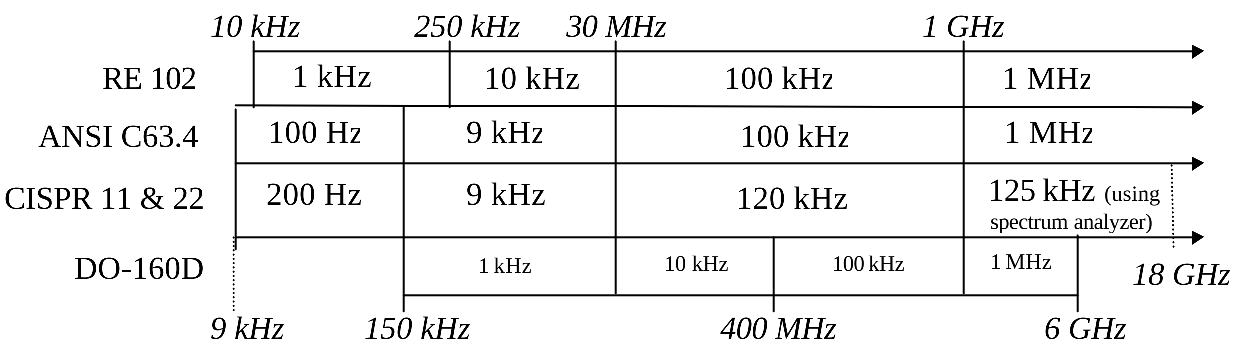


Table A.10-2: ~ 6 dB Bandwidths of Detectors

IEEE 187 uses a field strength meter, which should have selectable functions of peak, quasi-peak and average detection. The FCC limits determine the functions that should be selected (quasi-peak & average); essentially, the IEEE standard uses the same detectors as ANSI and CISPR.

In DO-160D, the detectors are peak detectors as in RE 102 but are also categorized as broadband or narrowband, with the bandwidths as in Figure 1. This will have some impact when the limit levels are compared, the subject of which to be discussed later.

A.10.1.3 <u>Use of LISN's .</u> In RE 102 an LISN is required, whereas in the civilian standards it is optional. There is some concern with the use of an LISN for RE testing if such a device is not used in the installation because of the unknown impedance characteristics of LISNs above 30 MHz and possible resonance effects. Also, the utility of the 50? H inductor comes into question at high frequencies due to possible distributive capacitance effects. The role of an LISN for RE testing is not yet settled and further evaluation may be desirable.

A.10.1.4 <u>Use of absorbing clamp.</u> For certain frequencies (as yet unspecified) and certain EUTs (also unspecified), ANSI C63.4 and the CISPR standards allow the measurements of RF noise power with the absorbing clamp in lieu of field measurements. The rationale for this is documented in CISPR 16-1. The absorbing clamp should be used with care; for example, if the EUT itself approaches 1/4 ? of the measuring frequency, direct cabinet radiation may occur. Also, if more than one cable is radiating, good correlation between the power values and the field strength at the site of measurement will be difficult to obtain. For these reasons, the usage of the absorbing clamp for RE 102 testing should be limited to very simple setups.

A.10.2 Measurement Techniques. Significant differences exist between the military and civilian techniques in requirements on equipment classification, frequency range, test site, test setup, cable treatment, ground plane considerations, scanning in azimuth, antenna height scanning, measuring distance, and multiple antenna positions.

A.10.2.2 Equipment Classification. RE 102 classifies an equipment according to its intended platform and environment: surface ships, submarines, ground (mobile and fixed), and air & space (internal and external — with respect to an electrically conductive structure). In contrast, with the civilian standards, equipment classification is implicit in the documents' scopes. CISPR 11 covers ISM; CISPR 22 covers ITE; C63.4, low-voltage non-ISM equipment; IEEE Std 187, FM and TV receivers; and DO-160D, airborne equipment. Though these categories do not embrace all military equipment, they should be broad enough to encompass all equipment of consequence with regards to RE 102.

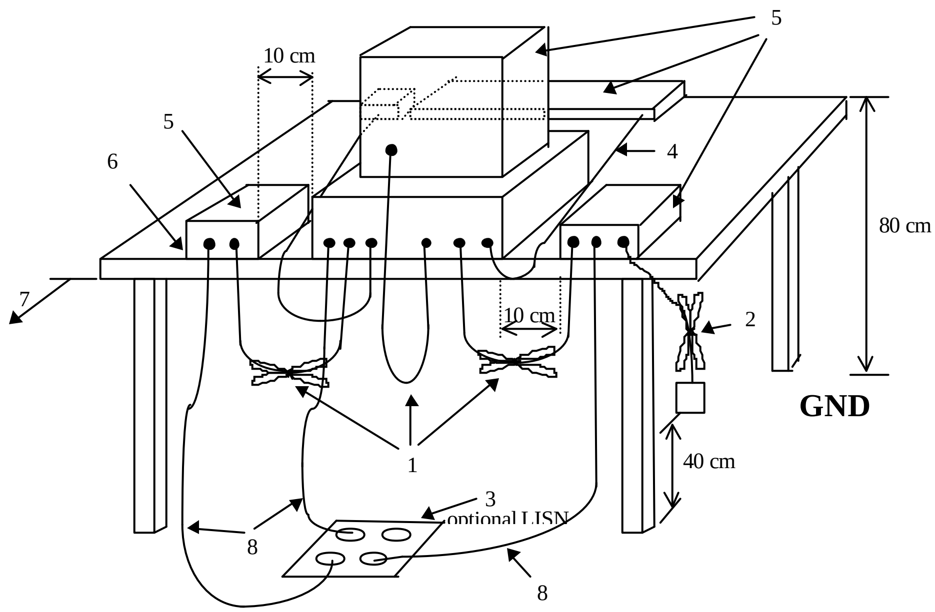
Because C63.4 does not prescribe any limits, it makes no attempt at further classification. The CISPR standards, however, do subdivide their respective equipment. CISPR 11 separates ISM equipment into two Classes, A & B, and two Groups, 1 & 2. Basically, Class A consists of equipment that are not intended for use in homes and Class B consists of equipment so intended; similarly, Group 1 comprises of equipment which uses/generates conducted RF energy while Group 2 equipment uses/generates radiated RF energy. CISPR 22 simply classifies ITE into two Classes, A & B, with Class B covering domestic devices as in CISPR 11, and Class A equipment as those satisfying Class A limits but not Class B limits. In order to correctly compare the associated limit curves, reclassification of military equipment into CISPR Classes and Groups would be necessary. But before such an endeavor is attempted, its suitability should be examined. The stated intent of the prescribed limits in RE 102 is to protect receivers with sensitivities on the order of 1 ?V from degradation. The extent to which the civilian limits may satisfy this goal should first be evaluated.

A.10.2.3 Frequency Range. The frequency ranges of IEEE Std 187 and DO-160D, Section 21 do not encompass that of RE 102. IEEE Std 187 is a special case in that its scope is quite limited in comparison with the others, covering only TV and FM receivers. Harmonization will require the determination whether or not emission from TVs, FM receivers, and representative airborne equipments are appreciable, especially at low and high frequencies.

A.10.2.4 Test Site. The tests in DO-160D and RE 102 are usually performed in shielded rooms, which may or may not be anechoic. In other civilian standards, the tests are performed in an open area test site, and all test sites must be validated. (For IEEE Std 187, validation is optional; a site meeting the description therein is presumed to meet the requirements.) Alternative sites such as anechoic rooms are allowed only if they satisfy the site validation requirement. Since shielded rooms may reflect radiation and introduce errors in measurements (even anechoic rooms may reflect radiation below 30 MHz), a site validation procedure such as that in the ANSI standard is probably desirable for RE 102.

A.10.2.5 Test Setups. There are no basic differences in test setups between RE 102 & DO-160D, Section 21. However, the military does consider two setups that have no counterparts in other civilian tests: the grounded metallic benchtops and bonding of EUTs to the ground plane. With bonding of the EUTs to the ground plane, any radiation will only occur through gaps in the chassis so that chassis radiation is reduced. Furthermore, with the proximity of the ground plane, cable radiation will also be reduced. Radiation levels will also be low with metallic benchtops, whether or not the EUT is bonded to it. Equipments that are normally operated in this fashion cannot be tested with civilian standards, which may result in erroneously high emission readings.

A.10.2.6 Cable Treatment. Cable treatment in DO-160D is very similar to that in RE 102. The military's treatment of cables is covered in MIL-STD 462, Section 4.8.5. In contrast, the civilian treatment of cables is more flexible. This is especially true of the CISPR standards. In CISPR, cables are arranged in any typical manner which maximizes radiation; the only requirement for cables is that excess cables be bundled in ~ 0.4m lengths. C63.4's treatment of cables is a bit more extensive than CISPR's. It, too, allows the rearrangement of cables in any typical manner that maximizes radiation, but it also provides procedures to be followed. The major differences in cable treatment between C63.4 and RE 102 are expected to occur in the case of table-top configurations, summarized below in Figures A.10-1 and A.10-2.



1. Interconnecting cables that hang closer than 40 cm to the ground shall be folded back and forth forming a bundle 30 to 40 cm long, hanging approximately in the middle between ground plane and table.
2. I/O cables that are connected to a peripheral shall be bundled in center. The end of the cable may be terminated if required using correct terminating impedance. The total length shall not exceed 1m.
3. If LISNs are kept in the test setup for radiated emission, it is preferred that they be installed under the ground plane with the receptacle flush with the ground plane.
4. Cables of hand-operated devices, such as keyboards, mouses, etc., have to be placed as close as possible to the controller.
5. Non-EUT components of EUT system being tested.
6. The rear or all components of the system under test shall be located flush with the rear of the table.
7. No vertical conducting wall used.

Figure A.10-1: Table-top Configuration for ANSI C63.4

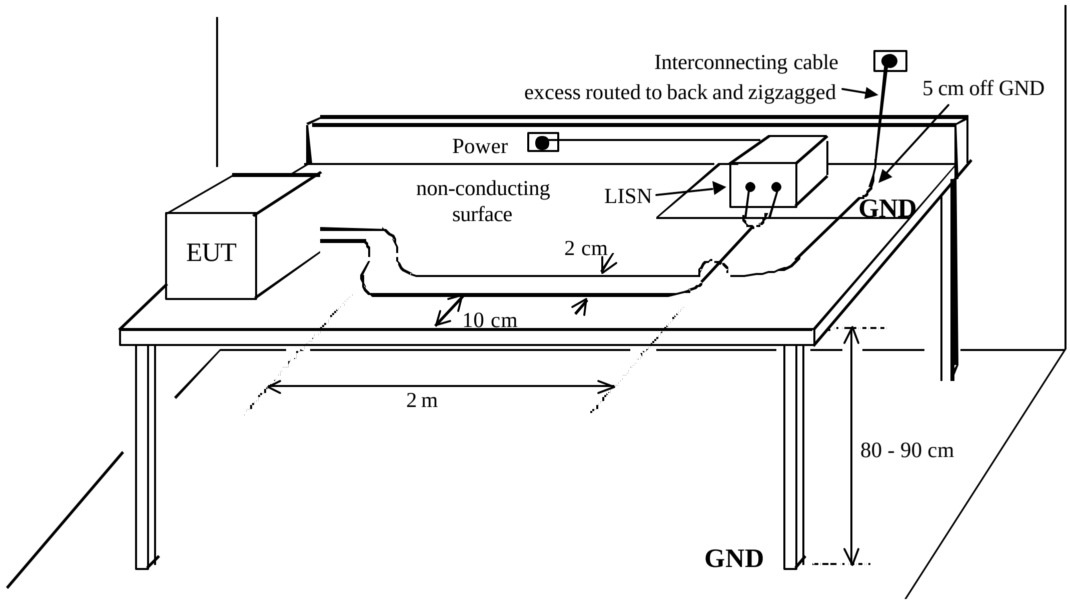


Figure A.10-2: Non-metallic Bench-top Setup for RE 102

Because of cords draping to the ground in Figure A.10-1, the setup effectively forms 160-cm dipoles, and the primary mode of emission is expected to be vertically polarized (although horizontal polarizations are also possible). There is also a possibility of large loops forming with the cable assembly. In RE 102's setup (Figure A.10-2), cables run parallel to the ground and thus vertically polarized modes of emission are mostly eliminated. Furthermore, because excess cables are routed to the back of the testing area, radiation from these parts would be virtually eliminated from consideration. Loop areas are also minimized due to the parallel arrangement of cables, even with multiple EUTs being tested as in Figure A.10-3. (The military would consider each equipment in Figure A.10-1 as an EUT, and multiple EUTs would be set as in Figure A.10-3.) This means that, generally, emission should be greater with the civilian setups. The difference will be exacerbated if metallic bench tops are used in the military setups.

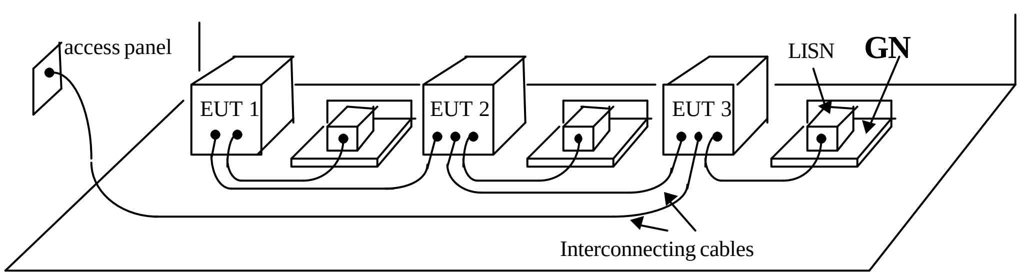


Figure A.10-3: RE 102 Multiple EUT Configuration

A.10.2.7 Ground Plane Considerations. In the case of RE 102 & DO-160D shielded, *non*-anechoic room measurements, there are also vertical ground planes to consider, especially the rear wall (the antenna is at the front of the setup). These are possible sources of reflections. Partial cancellations of the field at the antenna may result due to shifts in the relative phases of the direct and reflected rays. In general, the shielded room introduces variables into the measurement procedure, for example, resonance effects at higher frequencies, the distances to each of the ground planes, etc. The effects of these will not be known if site validation is not performed.

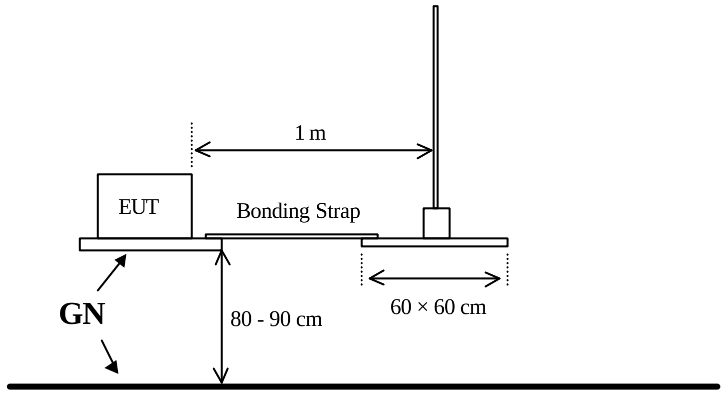


Figure A.10-4: RE 102 Setup Below 30 MHz, Metallic Bench-Top

One interesting case occurs with the military use of a bonding strap between the grounded metallic bench and the counterpoise for a monopole antenna below 30 MHz. (See Figure A.10-4.) In this case reflections from the floor will probably not contribute much to the measurement; therefore it is best to correlate this situation with civilian floor standing EUTs.

A.10.2.8 Azimuthal Scanning for Maximum Radiation. Except for DO-160D, all civilian setups specify the use of a turntable. The EUT setup is then scanned azimuthally for maximum radiation. In contrast, RE 102 only considers only the four sides the EUT. It may very well be that maximum radiation will occur with one of the EUT sides squarely facing the antenna, but a guarantee is needed. This situation, however, is mitigated by the military's use of multiple antenna sites.

A.10.2.9 Antenna Height Scanning (30 MHz - 1 GHz). Except for DO-160D, in all civilian setups between 30 MHz and 1 GHz, the antenna height is scanned, usually from 1 to 4 m. (One exception is CISPR 11, Group 2, Class A - radiative, non-domestic - equipment, where the specified antenna height is 3.0 ? 0.2m; this specification is probably to help minimize test time.) The effect of height scanning is to find the site where the phases of the direct ray and the reflected ray from the ground are such that the fields add. In RE 102, no antenna height scanning is required. Of course, if the measurements are done in a shielded, *non*-anechoic room, then the utility of height scanning can be questioned as there will be the ceiling and vertical ground planes, too, with associated physical limitations and complicated field adding/canceling effects.

A.10.2.10 Measurement Distance. The measurement distances of the tests are as follows:

RE 102	: 1 m
DO-160D, Section 21	: 0.9 m
CISPR 11	: 10 or 30 m preferred, 3 m possible
CISPR 22	: 10 m preferred, 3 m or 30 m possible
IEEE Std 187	: 3, 10, or 30 m

Just from the distances, one would expect higher emission readings with RE 102 (and DO-160D). However, from other considerations, namely antenna height scanning, ground plane proximity, azimuthal scanning, and EUT-cable assembly setups, the civilian readings at 3 m may actually be comparable to military readings at 1 m. (At 10 and 30-meters, the attenuation will probably be the most significant factor so that measurements at these distances may well be within the sensitivity range.)

Complete harmonization of measurement distances will require the analysis of probable attenuation factors. In all the civilian standards, a $1/r$ attenuation factor is used. However, this factor is applicable only down to ~ 16 MHz (for the 3-meter measuring distance) where far-field conditions exist. In the near-field, the attenuation factor is only known as $1/r^n$, where $n > 1$. Harmonization may be difficult since in RE 102 far-field conditions exist only down to 48 MHz; it is made even more difficult by CISPR 11, which does not allow compensation for distances less than those for which limits are given.

A.10.2.11 Multiple Antenna Positions. In RE 102 multiple antenna positions are necessary for setups greater than 3 m wide. This situation will only occur with EUTs measuring greater than 1 m on a side or with multiple EUTs. This requirement is probably an offshoot of the 1-m measuring distance, i.e., the field from distant parts of the setup may not be accounted for with just one measurement. Measurements at 3 m as in civilian testing should eliminate the need for this requirement.

DO-160D does not specify the use of multiple antenna positions or antenna height/azimuthal scanning. As a result, the standard may not detect the true interference potential of large setups.

A.10.2.12 Miscellaneous (measurements with absorbing clamp). Between 1 GHz and 18 GHz in CISPR 11, although the electric field is measured the limit is given in terms of effective radiative power referred to a half-wave dipole (11.7 GHz - 12.7 GHz only, no limits for other frequencies), implying that a substitution method is used. In this method, a half-wave dipole at the approximate geometric center of the setup is driven to obtain the same electric field reading as when the EUT setup is present. The input power (effective radiative power) is then used for determination of compliance. The substitution method is used to discount the effects of antenna gain, which may be difficult to predict in this high frequency range. The power limits will need to be correlated to the field limits of RE 102 for harmonization (as discussed below).

A.10.3 Analysis of Relationship between Measured Quantities. There is no difference in the measured quantities between DO-160D and RE 102. With other civilian standards, meaningful analysis of the relationships between measured quantities can only be achieved when the test site and setups are comparable. Nevertheless, some issues of concern with conversion techniques can be identified.

Below 30 MHz, the **H** field readings obtained will have to be compared with the **E** field readings of RE 102. The difficulty with this comparison is that the conversion formula (Eq. 1) is only valid for the far-field region where the relationship between **E** and **H** is simple. Above 30 MHz, all readings are of the **E** field. Comparison of these readings are straightforward but not necessarily simple due to the imprecisely known attenuation factor.

When radiated power is measured such as by the absorbing clamp in ANSI C63.4, the power readings can be converted to electric field readings for comparison if one assumes that the cable can be viewed as a monopole. However, this will also require the assumption of an omnidirectional radiative pattern, which will certainly not be the case for most setups. Furthermore, radiation from the chassis and other cables are not considered. Good correlation between power and electric field readings will be difficult to obtain for complex setups. Comparisons must therefore be made conservatively.

A.11 Commercial Measurement of Spurious Radiation (Intent Similar to RE103)

Detailed Meaurements are specified by the FCC and ITU.

A.11.1 FCC Measurement Procedure for EPIRBs.

The measurement procedure is described in clause 2.1511 of CFR 47, which covers emissions at both the fundamental frequency as well as spurious emissions

The Commission's Rules require that the peak effective radiated power (PERP) of a Class A, B or S EPIRB not be less than 75 mW under certain specified conditions. The PERP of an EPIRB transmitter is determined by comparing its level to a reference EPIRB generated by a standard quarter-wave monopole antenna located on a one wavelength minimum diameter metal ground plane. The Rules also require that all spurious and harmonic emissions be attenuated by a specified amount with respect to the reference PERP. In addition, there is a limit on the PERP of radiated emissions with the switch in the test mode. These measurements are to be made in accordance with the following procedure.

a) General set-up instructions.

Measurements of radiated electromagnetic emissions (EME) are to be performed on the 30 meter open field test site described in 2.1507 of this part. A receiver, tuned dipole antennas and a calibrated signal generator as described in 2.1505 of this part are required. The EPIRB should be powered by its own internal battery with its standard antenna attached and deployed.

b) Set-up for radiated EME tests.

Step (1) Place a 121.5 MHz quarter-wave vertical antenna element at the center of the ground plane and connect the output of the calibrated signal generator to the antenna.

Step (2) Mount the tuned dipole antenna on the antenna mast, tune the elements to 121.5 MHz and connect the antenna to the receiver.

Step (3) After an appropriate warm up, tune the receiver to the frequency of the test unit, set the detector to peak mode and the bandwith to 100 kHz. (NOTE: It is sometimes helpful to monitor the receiver audio output with a speaker. The EPIRB signal may be identified by its distinctive modulation.)

c) Radiated EME Tests.

Fundamental emissions-peak effective radiated power.

Step (1) Turn on the signal generator and adjust the output to 75 mW at 121.5 MHz.

Step (2) Vary the antenna height from one to four meters in both vertical and horizontal polarization. Record the highest receiver reading in dBm as the reference level.

Step (3) Disconnect the signal generator and replace the quarter-wave vertical element on the round plane with the EPIRB under test. The EPIRB is to be positioned directly on the surface of and in the center of the metal ground plane.

Step (4) Activate the EPIRB.

Step (5) Vary the receive antenna height from one to four meters in both vertical and horizontal polarization. Record the highest receiver reading in dBm and the instrument settings, antenna height and direction for maximum radiation, antenna polarization and conversion factors, if any, associated with that reading.

Step (6) Repeat Step 5 with the EPIRB switch in the test position. Return the switch to the
normal operation position.

Step (7) Rotate the EPIRB 30 degrees and repeat Steps 5 and 6. Repeat this step for all successive 30 degrees segments of a full 360 degree rotation of the EPIRB.

Step (8) Repeat 2.1511(b) and Steps 1 through 7 for 243 MHz.

Step (9) Compute the peak effective radiated power for the maximum level of each measured emission using the following formula:

$$PERP = 75 \times \log_{10}^{-1}[dBm_{meas-dBmref}/10]$$

where:

dBm_{meas} is the measured receiver reading in dBm, and
dBm_{ref} is the reference receiver reading found in step 2 of 2.1511(c)

Step (10) Record the PERP in mW. The FCC limit for minimum power in the normal operation mode (i.e., with the EPIRB switch in the normal operating position) is 75 mW. The FCC limit for maximum power in the test mode is 0.0001 mW.

Spurious emissions.

Step (11) Reset the signal generator to operate at 121.5 MHz.

Step (12) For each spurious and harmonic emission to be measured, retune the receive antenna to the appropriate frequency and repeat Steps 5 and 7.

Step (13) Determine the FCC limit on power for spurious emissions on the frequency of each measured emission as follows: the rules require that spurious emissions be attenuated at least 30 decibels below the transmit power level. Therefore, the maximum received power limit for a spurious emission can be calculated from the formula:

$$dBm_{spur} = dBm_{meas} + AF_{121.5} - AF_{spur\ freq} - 30$$

where:
dBm_{meas} = measured receiver reading (Section 2.1511(c), step 5).
$AF_{121.5}$ = tuned dipole antenna factor at 121.5 MHz.

Step (14) Record in dB below the fundamental emissions the level of all spurious and harmonic emissions within 10 dB of the FCC limits.

A.11.2 ITU-R M.1177 Techniques for Measurement of Spurious Emissions of Radar Systems.

The method is described in much detail. We give here only an abstract of the direct procedure. One indirect procedure measures the power into the antenna and then calculates the emitted field from previously measured or calculated antenna characteristics, however this corresponds to a conducted measurement such as described in MIL-STD test method CE106.

The arrangement for radiated measurement is as follows:

The RF front-end consists of three elements: a variable RF attenuator, a frequency-tuneable bandpass filter (referred to here as a preselector), and a low-noise amplifier (LNA). Each of these elements must have a frequency response range at least as wide as the frequency range to be measured. The RF attenuator provides variable attenuation (e.g. 0-70 dB) in fixed increments (e.g. 10 dB for a 0-70 dB attenuator step). Use of this attenuator during the measurement extends the instantaneous dynamic range of the measurement system by the maximum amount of attenuation available (e.g. 70 dB for a 0-70 dB attenuator). In principle, this attenuator could be manually controlled, but in practice, control via computer is much more practical.

The preselector protects the measurement system from non-linear behaviour due to the high power in the radar signal fundamental frequency when the measurement system is tuned to relatively low-power signals from the radar at extended frequencies in the spurious emission spectrum (e.g. when the radar center frequency is 3050 MHz and the measurement system is tuned to 4800 MHz). This filter could, in principle, be manually tuned. However, as with the attentuator, automatic control, either via computer or an analogue tuned-frequency voltage from the spectrum analyser, is far more practical.

The final element in the RF front-end is an LNA. An LNA installed as the next element in the signal path after the preselector overdrives the noise figure of the rest of the measurement system (e.g. a length of transmission line and a spectrum analyser). Typical spectrum analyser noise figures are 25-45 dB, and transmission line losses may typically be 5-10 dB, depending upon the quality and the length of the line. Use of an LNA after the preselector (and, if required, a cascaded LNA at the spectrum analyser input) can reduce the overall measurement system noise figure to about 10-15 dB.

A.12 RS101, Radiated Susceptibility, Magnetic Field, 30 HZ to 100 kHz.

Combined comparison with IEC 61000-4-8, IEC 61000-4-9, AND IEC 61000-4-10.

A.12.1. Introduction. The methods differ both in the instrumentation and measurement technique used.

A.12.2 Instrumentation.

A.12.2.1 Antennas (loops/coils) Induction. The size and construction of the coils used to produce the magnetic fields are significantly different. RS101 uses are relatively small coil with a diameter of 12 cm. This could is suitable for any equipment under test (EUT) regardless of its size. The coils used with testing are usually larger than the RS101 loop and vary depending on the size of the EUT and the number of turns needed to produce the required field. These coils can be a single coil or double coil (Helmholtz coil). All the standards contain instructions on the design and construction of these coils.

A.12.2.2 Antennas (loops/coils) Calibration Sensor. RS101 calls for the use of a 4 cm diameter loop with specific characteristics. This loop is used to verify the operation of the induction coil used to produce the magnetic field. IEC calls for the use of a “Hall Effect” or multi-turn loop sensor with a diameter of at least one order of magnitude smaller than the induction coil.

A.12.2.3 Test generators. RS101 needs a test generator cable of producing 15 A over the frequency range of 30 Hz to 100 kHz. IEC requires generators with the output waveforms corresponding to the test requirements and output currents capable of producing the required field levels. The standard provides the following values as typical output currents: 1.2 A to 120 A for continuous testing and 350 A to 1200 A for short duration testing.

A.12.2.4 Current Measuring Equipment. All three test procedures call for some type of current measurement equipment to measure the current in the coils. RS101 calls for the use of a measurement receiver and current probe. The IEC standards call for the use of sensors (probes or shunts) and instruments for setting and measuring the current in the induction coil.

A.12.2.5. Auxiliary Instrumentation. RS101 requires the standard MIL-STD 461E test setup using LISNs and the ground plane. The IEC procedures contains a note allowing for the use of the termination networks back filter, etc. on power supply, control and signal lines that are part of the test setup, in order for monitoring test equipment to be protected. They also require that the EUT be placed on a ground plane. This ground plane can be used to complete the induction loop used to generate the test field.

A.12.3 Measurement Techniques. The main difference between the measurement procedures is that RS101 is a proximity test method. The IEC methods are both immersion test methods. The proximity method applies the magnetic field to the EUT, with a relatively small induction coil that is moved over the surface of the EUT, in order to determine particularly sensitive areas that are susceptible. The immersion methods requires the EUT to be positioned in the center of a larger coil and immersing the EUT in the magnetic field.

A.13 RS103, Radiated Susceptibility, Electric Field, 2 MHz to 40 GHz.

A.13.1 SAEJ1113-21. SAE J1113-21 is intended for testing of road vehicles; however, it could be applied elsewhere. A summary comparison of SAE J1113-21 and RS103 is shown in Table A.13-1.

A.13.2 Frequency Range RS103 test frequency ranges from 2 MHz to 40 GHz, depending upon the end platform for the equipment. However, the majority of usage is limited to between 2 MHz and 18 GHz (optional above 18 GHz for all applications). Frequency coverage of J1113-21 is limited to 10 kHz to 18 GHz.

A.13.3 Test Comparison.

Table A.13-1: Main Differences Between RS103 & SAE J1113-21

Parameter	**RS103**	**SAE J1113-21**
Frequency Range	2 MHz-40 GHz	10 kHz – 18 GHz
E-field Measurement Method	Isotropic probe provides feedback during test	Either isotropic probe method or substitution method
Frequency Step Increments	Summarized in Table A.13-3	Summarized in Table A.13-3
Antenna Placement for Physically Large Systems Under Test	Method for multiple test antenna positions based upon beamwidth of antenna	Not addressed
E-Field Modulation	1 kHz square wave	CW and 1 kHz sine wave, 80% AM
LISN	50 ?H	5 ?H
Test Dwell Time	3 sec.	2 sec.
The step sizes used by J1113-21 are four to twenty times larger than those of RS103 (continuous analog rates are not provided in J1113-21).		

A.13.4 Limits. In Table A.13-2 limits are compared between RS103 and J1113-21. Test levels in J1113-21 are provided as examples, with determination of real test levels left to the user.

A.13.5 Conclusions. For most bench size components, J1113-21 can be substituted for RS103 provided that equipment is certified to appropriate limits and associated frequency ranges specified by the procuring activity. However, analysis may need to be conducted to determine possible effects of utilizing J1113-21's larger step sizes and less severe modulation parameters.

Table A.13-2: Comparison of RS103 and J1113-21 E-Field Limits

E-field Strength (V/m)	RS103 Requirements (example)	J1113-21 Test Severity Level
5	Submarines	N.A.
10	Ships (below decks)	N.A.
20	Space	N.A.
25	N.A.	L1
50	Ground	L3
100	N.A.	L6
200	Aircraft	N.A.

Table A.13-3: Comparison of RS103 and J1113-21 Step Sizes

Frequency Range	RS103 Stepped Scans*	SAE J1113-21 Stepped Scans**
10 kHz		10 kHz
100 kHz – 1 MHz		100 kHz
1 MHz – 10 MHz	0.01 *fo*	1 MHz
10 MHz – 30 MHz	0.01 *fo*	2 MHz
30 MHz – 200 MHz	0.005 *fo*	2 MHz
200 MHz-1 GHz	0.005 *fo*	20 MHz
1 GHz – 8 GHz	0.001 *fo*	200 MHz
8 GHz – 18 GHz	0.0005 *fo*	200 MHz
* With minimum dwell time of 3 second ** With minimum dwell time of 2 seconds		

A.14 RS105, Radiated Susceptibility, Transient Electromagnetic Field.

A.14.1 IEC 61000-4-20. In this section we compare the test procedures of RS105 with IEC 61000-4-20. RS105 uses a TEM Cell or parallel plate lines. Commercial TEM Cell testing is covered in IEC 61000-4-20. It is a guide on emission and immunity testing with TEM cells and as such it prescribes no limits. Only the immunity portion is relevant for this report. Presently, IEC 61000-4-20 (still in draft form) only covers continuous-wave (CW) testing; considerations are under way to include a pulse testing technique, which is expected to be very similar to the CW technique

A.14.2 Instrumentation. There are some differences in the instrumentation requirements of RS105 and IEC 61000-4-20. The bandwidth requirement on the monitoring equipment is 200 MHz for RS105 and 120 kHz for IEC 61000-4-20. For the military test, EUT power is supplied through LISNs and terminal protection devices (TPDs) whereas for the civilian test a line filter is used. The last difference is relatively minor: B-dot and D-dot sensors are used with integrators in RS105 to determine the field levels whereas direct field sensors are used in IEC 61000-4-20. The use of these sensors needs further clarification as they are not widely employed in the EMI/EMC community. In particular, the bandwidth of the sensors (the frequency below which they respond to the time derivative of the fields) should be higher than the cut-off frequency of the TEM cell (the frequency above which higher order modes can propagate). For a 10 ns time-to-peak, the bandwidth should be at least 100 MHz, but considering that 10 ns is the longest time-to-peak acceptable for RS105, the bandwidth should be around 1 GHz. This figure should also represent the integrator bandwidth. For such high bandwidths the integrators will most likely be active.

A.14.3 Measurement Techniques.

A.14.3.1 Calibration. There is essentially no difference in the calibration techniques of the military and civilian tests. In both calibration is done without the EUT in place. A field reading is obtained at the various positions within the volume occupied by the EUT and a probe is used to monitor the pulse characteristics.

A.14.3.2 Test Setup. In RS105 all cables are shielded and led directly outside the TEM cell so as to exclude them from the test; only the EUT chassis is considered. Although cables are not treated in detail in IEC 61000-4-25 we make reference to their treatment in IEC 61000-4-20 as probably applicable to IEC 610000-4-25. In IEC 61000-4-20, cables are included in the test and are arranged as in Figure A.14-1. There are numerous issues to be considered in the test procedures, of which the more important issues are discussed in the ensuing material.

Cables are unshielded and 3 m long if unspecified by EUT operations. Since fields will impinge on chassis and cables at the same time, there is a possibility that an equipment may pass both the chassis and cable tests separately (as in RS105 & CS116) but fail if tested together; therefore it is desirable that cables be included in RS testing. The cable layout specification in IEC 61000-4-20 is unclear as it seems to be self-contradictory, that is, cables cannot be "toward the back" as in Figure A.14-1, if the EUT is rotated about the vertical axis. Since TEM cells are sometimes equipped with turntables, the U.S. National Committee (USNC) to the IEC has recommended that all cables be routed towards the center axis of the turntable with EUTs rotated around the axis in a circle. This scheme helps to keep all relative positions fixed during testing and solves the logistical problem of continuous EUT rotation. On the other hand, since IEC 61000-4-20 is also intended to be an alternative technique to IEC 61000-4-3 (or an extension of it to higher frequencies), it is desirable that the layout in IEC 61000-4-3 be kept for TEM cell testing for better correlation of results. The setup of IEC 61000-4-3 is typical of installation with 1 m of cables brought to the front to be illuminated by the uniform field (excess lengths are bundled and/or decoupled), and with one orientation having cables parallel to the electric field. (Four orientations are possible for the four sides of the EUT.) This contradicts both the setups proposed by the USNC and the present IEC 61000-4-20 If the test is also to be a cable test, then cables should be brought to the front (as in IEC 61000-4-3) where there is some confidence of the field levels and not toward the back (as in IEC 61000-4-20. In addition, the 1 m length is more practicable since TEM cells have size limitations. To effect continuous EUT rotation, excess cable lengths can be led to the central axis as in the USNC proposal.

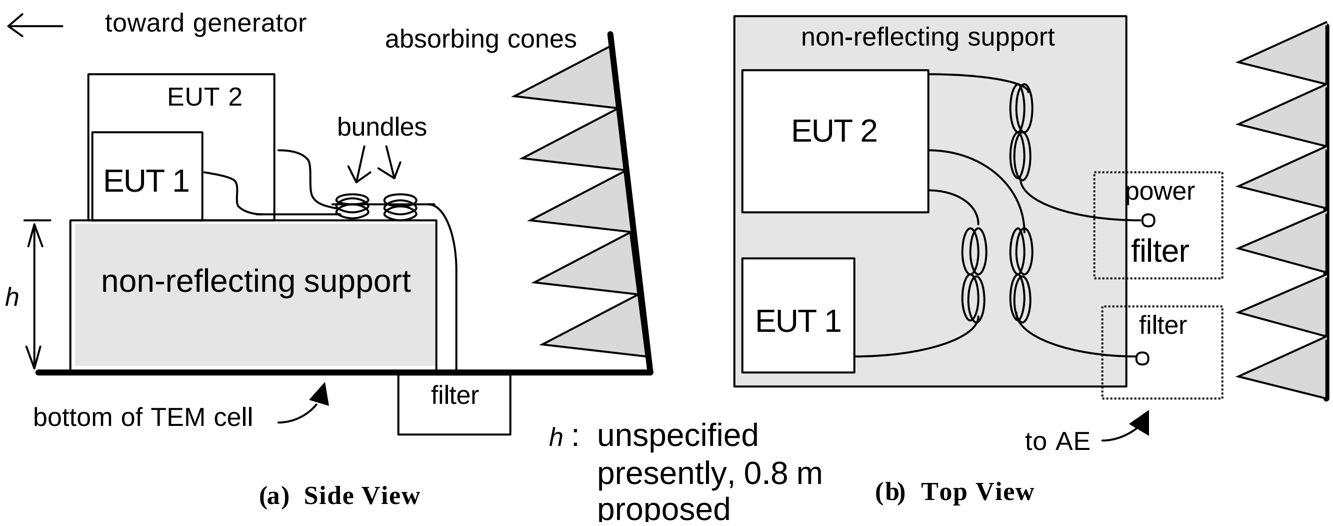


Figure A.14-1 Setup of IEC 61000-4-20, draft 5.95

In IEC 61000-4-3 illumination is achieved by means of an antenna so that the horizontal polarization is easily achieved. Such is not the case for TEM cell testing. One practiced solution is to secure the test configuration to a non-reflective surface and rotate the surface about the three orthogonal axes. This obviously presents a problem with exit cables. Partly for this reason, the USNC has proposed that cables be arranged along an ortho-axis, i.e., along the volumetric diagonal. This technique will require the raising of one end of the TEM cell and tilting it as in Figure A.14-2. In this way, only rotations about the verticle axis are needed. Using the ortho-angle is desirable in that it simplifies testing, however, more detailed analysis is needed to gauge its validity in terms of obtaining correlatable results to IEC 61000-4-3. Theoretically, correlation should be possible since there is a fixed relationship with respect to all the axes about which the EUT can rotate.

Another issue is with filtering. Concerns have been raised that capacitances present in filters may induce currents that are not representative of the disturbance. The use of ferrite sleeves and LISNs have been proposed to mitigate this potential problem.

A.14.3.3 Field Monitoring

In RS105, D-dot and B-dot sensors are used to monitor the rate of change with respect to time of the electric and magnetic fields, respectively, and the integrators are used to obtain the field readings. The integrators are placed in the same shielded room as the oscilloscope, i.e. far from the probes. This setup is questionable in that stray capacitive effects are introduced. Typically, integrators are placed near the base of these sensors. The sensors themselves are placed behind the EUT (away from the generator) at the rear of the usable volume. This placement is also questionable since the field will be significantly distorted by the EUT. Placement at the front plane at one of the points in the calibration grid would be more suitable, preferably as far from the EUT as possible.

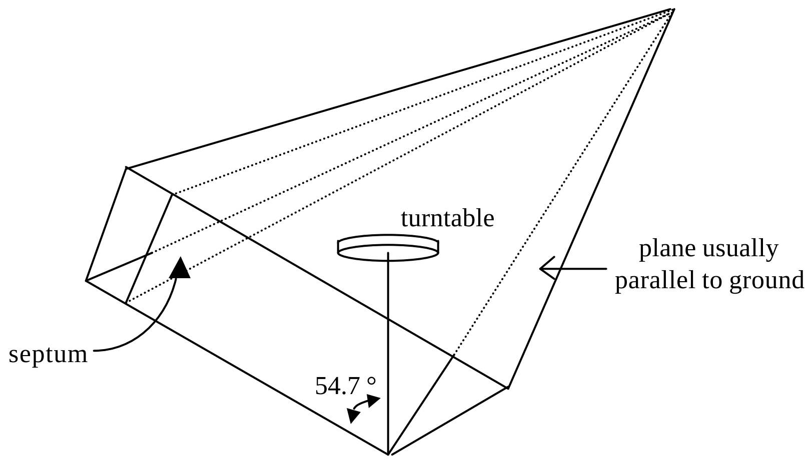


Figure A.14-2: Proposed Ortho-angle Technique

The civilian test has specified no technique for field monitoring but the direct substitution method is proposed. This method assumes that the EUT does not significantly affect the fields, which may not be true for large EUTs.

A.14.3.4 Injected Level

In RS105 the injected level is raised gradually from 10% to 100% of the limit. This specification is intended to protect the EUT from damage. In IEC 61000-4-25 the levels are injected first at two levels below the specified limit and then raised to the limit.

A.14.4 Analysis Of Relationships Between Measured Quantities

There are no differences in the measured quantities between the standards. Both measure the injected voltage and field levels.

Annex B

Tables of Applicable EMC Standards
and
Annotated List of Applicable EMC Standards

Annex B

INTRODUCTION

The purpose of this annex is to serve as a means of readily identifying comparable military and commercial standards. It is divided into two parts. Annex B1 provides lists of standards according to the issuing organization. Annex B2 lists the standards according to the technical area covered, e.g. definitions, environment, basic, product, or system. To clarify the listings annotated remarks are included with some of the listings in Annex B2. In order to increase the usefulness of the listings, the listings in Annex B1 identify, as appropriate, the clause or subclause of Annex B2 which lists a particular standard.

We note here that, because of time limitations only a few of the more important and pervasive commercial standards are compared in the main body of the Guide. Other standards may be of concern in particular procurements. Thus the listings in Annex B may give guidance in identifying and eventually comparing those documents having specialized applicability. It is recognized that the most effective choice can only be decided after any particular document has been examined in detail for its actual content.

The word “standard” is used in this document generically so that this compilation includes not only official “standards” but also related documents having the status of recommended practices and guides, in order to identify all documents that might assist in reaching the desired objectives. The reader should be aware that the exact status of a particular document may not always be clear from the citation.

Annex B1

Tables of Applicable EMC Standards

INDEX OF TABLES OF APPLICABLE EMC STANDARDS

Table 1: IEC Technical Committee Preparing Documents Containing EMC or EMC related Clauses

Document	Title	Part B2 Reference Paragraph
TC1	Terminology: WG161	
	50(161) (1998-08) EMC Definitions	3.1
TC2	Documentation and Graphical Symbols	
	IEC 60034-15 (in preparation) Impulse withstand (Ref. pub. 60060-1)(2(C.O.)587/RVD)	5.27
	IEC 60417 (SC 3C WG1 Revision) Symbol 5140	3.4.3.2
	IEC 60417-2 Ed. 2.0 (in preparation) Graphical symbols for use on equipment. Part 2: Symbol originals (3C/378/RVD)	
TC9	Electric Railway Equipment	
	IEC 60571-1 (1990) Electronic equipment used on rail vehicles: General requirements	5.22
	IEC 60571-3 (1990) Components, programmable electronic equipment and electronic system reliability	5.22
	9(UK)294 (1990) Revision of 60571-1, 2, 3-BRB/RIA specification 13/1987 3.6 interference	5.22
TC13	Equipment for Electrical Energy Measurements & Load Control	
	IEC 61037 (1990) Electronic control receivers for tariff and load control	5.25
	IEC 61038 (1990)Time switches for tariff and load control	5.30
TC17	Switchgear and Controlgear	5.30
	IEC 17A(Sec)304 (1990) Amendment to IEC 60694: Common clauses for high voltage switchgear and controlgear standards. EMC tests	5.30
	IEC 17A(Sec)339 (1991) EMC for secondary systems in gas insulated metal enclosed switchgear for rated voltages of 72.5 kV and above	5.30
	IEC 17A(C.O.)203 (1992) Draft for Appendix F to 947-2 – Part 2: Circuit breakers – F2.1 EMC tests	5.30
	IEC 60730-2-7 (1990) Automatic electrical controls for household and similar use Part 2: Particular requirements for timers and switch time switches	5.30
	IEC 60947-2 Circuit breakers, refers to IEC 61000-4-2, IEC 61000-4-3, IEC 61000-4-4	5.6
	IEC 60947-3 EMC requirements (17B(Sec)414) (1990)	5.30
	IEC 60947-5 (17B(Sec)372) (1990)	5.30
	IEC 60947-5-1 A1 Control circuit devices (SC17B): RF fields, ESD, fast transients, impulse volt.,	5.6
	IEC 60947-5-2 (1992) low voltage switchgear and controlgear Part 5: Control circuit devices and switching elements Section 2: Proximity Switches	5.30

	IEC 61038 (1990) Time switches for tariff and load control	5.30
	IEC 61321-1 (1994) Measurement systems for very fast transient overvoltages generated in gas-insulated metal enclosed substations.	5.30
	IEC 60470 Ed. 2.0 (1999) High voltage alternative current catactors and contactor-based motor-starters	
TC18	Electric Installations of Ships and of mobile and fixed offshore units	
	IEC 60092-304 (in preparation) (Elect. install. in ships) Amendment 1 [calls for limited distortion of power waveform (18/765/RVD)	5.28, 7.7
	IEC 60533 (1982) EMC of electrical and electronic installations in ships and of mobile and fixed off-shore units	7.7
	IEC 60533 Ed. 2.0 (1999) Electrical & electronic installation in ships – EMC (18/870/FDIS)	7.7
	IEC 18(Germ) 526 (1992) Revision of 60533	9.2
	IEC 18(CO) 534 (1994) Revision of 60092-504: Electrical installations in ships Part 504: Special features –Control and instrumentation	9.2
TC22	Power Electronics	
	IEC 60146-1-2 (1996) General requirements Part 1-2 application guide	5.28
	IEC 60478-3 (1989) Stabilized power supplies: dc output, reference levels and measurement of conducted EMI	5.19
	IEC 60478-5 (1993) Stabilized power supplies: measurement of the magnetic component of the reactive near field	5.19
	IEC 61204 (1993) Low-voltage power supply devices dc output – Performance characteristics and safety requirements	5.19
TC23	Electronic Accessories	
	IEC 60669 Ed. 1.0 (in preparation) Switches for households and similar fixed electrical installations – Part 1: General Requirements (23B/578/CD)	5.30
	IEC 60669-2-1 (in preparation) Switches for households and similar fixed electrical installations Part 2: emis. – IEC 60555, CISPR 14: imm. 1000V surges and supply interruptions	5.30
TC28	Insulation Coordination	
	IEC 60664-1 (1991): Insulation co-ordination with low-voltage systems Pt. 1 Principles, requirements, & tests	7.3
	IEC 60664-2-1(1997): Insulation co-ordination with low-voltage systems, Pt. 2 Application Guide, Section 1: Dimensioning procedure worksheets and dimensioning examples	7.3
	IEC 60664-2-2(in preparation): Insulation coordination with low-voltage systems, Pt. 2 Application Guide, Section 2: Interface requirements and transient overvoltage control means (28A(Sec.)88/CD)	7.3
	IEC 60664-2-3(1999): Insulation coordination with low-voltage systems, Pt. 2 Application Guide, Section 3: Explanation to the environmental categories	7.3
	IEC 60664-3(1991): Insulation coordination with low-voltage	7.3

	systems, Pt. 3: Use of coating to achieve insulation coordination of printed board assemblies	
	IEC 60664-4(1997): Insulation coordination with low-voltage systems, Pt. 4: Consideration of high-frequency voltage stress	7.3
	IEC 60664-5(in preparation): Insulation coordination with low-voltage systems, Pt. 5: A comprehensive method for determining clearences and creepage distance up to 2 mm (28A/143/CD)	7.3
TC29	Electroacoustics	
	IEC 29(Secretariat)281 – Immunity of hearing aids (29/317 EMC for hearing aids)	5.14.3
	IEC 60118-0 (in preparation) Hearing aids: electroacoustical characteristics	5.14.3
	IEC 60118-1 (in preparation) Hearing aids with induction pickup coil (29(C.O.)217/RVD)	5.14.3
	IEC 60118-2 (in preparation) Hearing aids with automatic gain control	5.14.3
	IEC 60118-4 (in preparation) Magnetic field strength in audio-frequency induction loops for hearing aids	5.14.3
	IEC 60651 A2 Ed. 1 Amendment to IEC 60651(1979) Sound level meters – Electromagnetic and electrostatic compatibility requirements and test procedures	5.14.3
	IEC 60804 A2 Ed. 1 Amendment to IEC 60804(1995) Integrating averaging sound level meters – Electromagnetic and electrostatic compatibility requirements and test procedures	5.14.3
	IEC 60942 A1 Ed. 2 Amendment to IEC 60942(1997) Sound calibrators – Electromagnetic and electrostatic compatibility requirements and test procedures	5.14.3
	IEC 61252 A2 Ed. 1 Amendment to IEC 61252 (1993) Personal sound exposure meters – Electromagnetic and electrostatic compatibility requirements and test procedures	5.14.3
	IEC 61260(1995) Ed. 1 Amendment to IEC 61260 (1995) Octave-band and fractional octave band filters – Electromagnetic and electrostatic compatibility requirements and test procedures	5.14.3
TC32	Fuses	
	IEC 60269-1 Ed. 3.0 (in preparation) Low voltage fuses (32B/316/RVD)	5.12
	IEC 60282-1 Amendment 2 (1985) High Voltage fuses. Part 1: Circuit limiting fuses	5.12
TC37	Surge Arresters	
	IEC 60099-4 (in preparation) Surge arresters – Part 4: Metal oxide surge arresters w/o gaps for a.c. systems	8.1
	IEC 60099-4 A3(1999) Amendment to IEC 60099-4: EMC considerations (37/220/CD)	8.1
	IEC 37A(Sec)1(1989) Specification for surge arresters for low-voltage distribution systems	7.3, 8.1
TC40	Capacitors and Resistors for Electronic Equipment	

	IEC 60384 (1993)Amendments 1-10	5.5
	IEC 60940 (1988) Filters and filter components	5.11
TC41	Electrical Relays	
	IEC 60255-22-2 Withstand Capability of relay Systems to radiated EMI from Transceivers (Trial Use)	5.24
	IEC 60255-22-3 (1989)ESD disturbance tests for measuring relays and protection equipment	5.24
	IEC 60255-22-4 (1992)Electrical disturbance tests for measuring relays and protection equipment Section 4: Fast transient disturbance test	5.24
	IEC 60041(Sec)80 (1991) Electrical relays, Part 22: ESD tests for measuring relays and protection equipment Section X Limits of radio interference	5.24
	IEC 60041(Sec) 81 (1991) Revision of IEC 60255-22-2 Section 2: ESD tests	5.24
	IEC 60041B(Sec)72 (1990) EMC of measuring relays and protection equipment	5.24
TC42	High Voltage Testing Techniques	
	IEC 60790 (1984) Impulse oscillation	7.3
	IEC 61321-1(1997) High voltage testing technique with very fast impulses. Measuring systems for very fast transient overvoltages generated in gas-insulated metal enclosed substations	3.4.2.2
TC44	Safety of Machinery – Electrotechnical aspects	
TC45	Nuclear Instrumentation	
	IEC 60951-1 (1988) General requirements	5.21
	IEC 61005 (1990) Neutron ambient dose equivalent rate meters for use in radiation protection X, gamma and high energy beta	5.21
	IEC 61225 (1993) Nuclear power plants 0 Instrumentation and control systems important for safety – Requirements for electrical supplies	7.2
	IEC 61283 (in preparation) X, gamma and high energy beta (45B/144/RVD))	5.21
	IEC 61322 (in preparation) Thermal – 15 MeV neutron: volt interrupts, spikes, magnetic and EM fields (45B(C.O.) 136/RVD)	5.21
	IEC 61323 (in preparation) Neutron: external magnetic, EM fields, ESD (45B(Sec.)87)	5.21
	IEC 61225 (1993) Nuclear power plants – Instrumentation and control systems important for safety-Requirements for electrical supplies	7.2
TC46	Cabling, Wires, Waveguides, RF connectors, and accessories for communication and signaling	
	IEC 60169-17(1998) 6.5 mm RF Connectors – Tr. Imp<0.1 ohm	9.3
	IEC 60966-1 (1995) A2 Screening Effectiveness Measurement	9.3
	IEC 61169-1 (in preparation) (46D(Sec)158) RF connectors (SC46D) – Measurement of transfer imp.	9.3
TC56	Reliability and Maintainability Dependability	

	IEC 60605-3-5 (1986) Equipment installed inside ground vehicles	5.18
	IEC 60870-1-2 (1989) Telecontrol equipment and systems Part 1: General considerations Sec. 2: Guide for specification	5.31
	IEC 61085 (1990) Telecommunication services for electric power systems 3.2 EMC	5.31
TC57	Power System Control and Associated Communications	
	IEC 60353 (1994) Line traps for ac power traps	7.3
	IEC 60353 (in preparation) A1 Amendment to 60353 (57/397/CD)	
	IEC 60870-6-2(1995). EMC Telecontrol equipment and systems - Part 6: Telecontrol protocols compatible with ISO standards and ITU-T recommendations - Section 2: Use of basic standards (OSI layers 1-4)	5.31
TC62	Electrical Equipment in Medical Practice	
	IEC 60601-1-2 (in preparation) EMC for medical eq. & info. Tech. eq. used in medical applications (62A/277/CC)	5.14.3
	IEC 60601-2-1 (in preparation) Medical electron accelerators 1 MeV to 50 MeV: General requirements (62C/236/RVD)	5.14.3
	IEC 60601-2-2 (1991) High frequency surgical equipment (in stand-by only) -> CISPR 11)	5.14.3
	IEC 60601-2-3 (1991) Short-wave therapy equipment (-> CISPR 11)	5.14.3
	IEC 60601-2-31 (in preparation) Eternal cardiac pacemakers w/internal power source: ESD (SC62D) (61D(C.O.)81/RVD)	5.14.3
	IEC 60601-2-32 (in preparation) X-ray equipment: -> 601-2-1 (61B(Sec.)132)	5.14.3
TC65	Industrial Process Measurement and Control	
	IEC 60654-2 A1 Operating conditions for industrial process measurement and control equipment, Part 2. Power	5.6
	IEC 60955 (1989) Process data highway, Type C (Proway C) for distributed process control system	5.6
	IEC 61131-2 (1992) Programmable controllers Part 2: Equipment requirements and tests	5.6
	IEC 61131-3 (1998) EMC product standards for power drive systems	5.19
	IEC 61298-3 (in preparation) Measurement & control devices: tests for effects of influence quantities (65B(Sec)198)	5.6
TC72	Automatic Controls for Household Use	
	IEC 72(Sec)159 (1992) Amendment to IEC 60730-2-7: Motor starting relays	5.24
	IEC 60730-1 (1993) Controls for household use: General requirements	5.6
	IEC 60730-1 Ed. 3.0 (in preparation) Automatic electrical controls for household and similar use – Part 1: General requirements (72/417/RVD)	5.3
	IEC 60730-2-3 (1990) . Part 2: Particular requirements for timers and line swatches. Thermal protectors for fluorescent lamps	5.6
	IEC 60730-2-6 A1 . Part 2: Particular requirements for timers and	5.6

	line swatches. Immunity to mains borne perturbations, magnetic and EM interference (TC72)	
	IEC 60730-2-7 (1990) Automatic electrical controls for household & similar use. Part 2: Particular requirements for timers and line swatches. Section 7: Timers and time swatches (72(C.O.)/29)	5.6
	IEC 60730-2-8 . Part 2: Particular requirements for timers and line swatches. Water valves: fast transients (TC72)	5.6
	IEC 60730-2-11 . Part 2: Particular requirements for timers and line swatches. Energy regulators (TC72) (see 2-6 above)	5.6
	IEC 60730-2-15 . Part 2: Particular requirements for timers and line swatches.Water level sensors (TC72) (see 2-6)	5.6
TC74	Safety and Energy Efficiency of its equipement	
TC75	Classification of Environmental Conditions	
	IEC 60721 (1990) Classification of environmental conditions; Part 1. Environmental parameters and their severities Amendment 1(1992)	2.1
	IEC 60721-1(1992)	
	IEC 61000-2-5 Classification of Electromagnetic Environments	2.1
TC76	Optical Radiation Safety and Laser Equipment	
	IEC 60601-2-22 (in preparation) Diagnostic & therapeutic laser equipment: (no requirements present) (76/121/RVD)	5.14.3
TC77	Electromagnetic Compatibility – see separate list	
TC79	Alarm Systems	
	IEC 60839-2-4 (in preparation) Ultrasonic doppler detectors, Environmental tests 79(C.O.)35	5.2
	IEC 60839-2-5 (in preparation) Microwave doppler detectors, Environmental tests 79(C.O.)36	5.2
	IEC 60839-2-7 (in preparation) (TC79) Passive glass-break detectors: spikes, ESD, EM fields 79(C.O.)78	5.2
	IEC 60839-5-2 (1996) General requirements Spike, ESD, EM Fields immunity (see 839-1-3) (79(C.O.)48/)	5.2
	IEC 60839-5-5 (1996) Digital communicator systems using public telephone network, ESD only (79(C.O.)50/)	6.0, 8.0
	IEC 60839-5-6 (1996) Voice communicator systems using public telephone network, ESD only (79(C.O)51/)	6.0, 8.0
TC80	Maritime Navigation and Radio Communication Equipment and Systems	
	IEC 60244-11 (1989) Radiocommunication Transmitting equipment Part 11: Methods of measurement for radio transposers	5.32
	IEC 60244-12-1 (1989) Radiocommunication Transmitting equipement and transposers for sound and television broadcasting	5.32
	IEC 60945 (in preparation) Conducted Audio, & RF; power line transients; EM fields: ESD (80/137/RVD)	5.15
	IEC 61097-2 (in preparation) [Global maritime distress & safety – emergency position. Emis.: see 3.5 of IEC 945. Imm.: see 4.5.8 of IEC 945. (80/101/RVD)	6
	IEC 61097-6 (in preparation) [Global maritime distress & safety] –	6

	Interference and co-channel rejection; intermod. (80/103/RVD)	
TC81	Lighting Protection	
	IEC 61024-1 (1990) General Principles (in revision)	8
	IEC 61024-1-1 (1993) Selection of protection levels	8
	IEC 61312-1 (1995) Protection against lightning electromagnetic impulse – Part 1: General principles	8
TC 84 -	Equipment and Systems in the field of Audio, Video, and Audiovisual Engineering	5.33
	IEC 61237-3 Power supply interference (sc 60-B)	5.33
	EIA Interim Std. No. 16A Immunity of TV receivers and video cassette radio (VCRs) to Direct Radiation from Radio transmissions, 0.5 to 30 MHz	5.33
TC95	Measuring Relays & Protection Equipment	
	IEC 60255-22-2 (in preparation) (95/45/RVD)	5.24
	IEC 60255-22-3 (in preparation)	5.24
	IEC 60255-22-4 (1997)	
TC100	Audio Video and Multimedia Systems & Equipment	
	IEC 60315-7 (1995) Methods of measurement on radio receivers for various classes of emission Part 7: Methods of measurement on digital satellite radio (DSR) receivers	5.23
	IEC 60728-1 A2 (in preparation) Radiation emission memo 30 MHz to 1 GHz	5.4
	IEC 61079-2 (1992) Radiocommunication, receiving equipment – Part 2: Electrical meas. on DBS tuner units	6
	IEC 61114-1 (1992) Methods of measurement on radio receivers for various classes of emission. Part 1: Electrical measurements on DBS receiving antenna	5.23
	IEC 61237-3 (in preparation) Power supply interference (sc 60-B) (60B/172/RVD)	5.33
TC103	Transmitting equipment for radio communication	
	IEC 60244 (1994) Transmitters	5.32
	IEC 60244-5 (1992) Methods of measurement for radio transmitters Part 5: Performance characteristics of television transmitters	5.23, 5.32
	IEC 60244-11 (1989) Radiocommunication transmitting equipment Part 11: Methods of measurement for radio transposers	5.32
	IEC 60244-12-1 (1989) Radio communication transmitting equipment Part 12: Guideline for drawing up descriptive leaflets for transmitters and transposers for sound and television broadcasting	5.32
	IEC 60657 (1979) Non ionizing radiation hazards in the frequency range from 10 MHz to 300,000 MHz	5.20
CISPR	Radio Interference – see separate list	

Table 2: TC77 Standards

NOTE: A bold faced number indicates a series of documents, only the first of which is listed here, dealing with class of equipment. The extent to which EMI phenomena is treated in the various publications of the series depends on the specific equipment being considered and will have to be determined with the appropriate document.

IEC 60725(1981)	Considerations of reference impedances for use in determining the disturbance characteristics from household appliances and similar electrical equipment (77/185/RVS, 725 Ed. 2.0 - 77/178/SR, 77/185/RVS)	2.2
IEC 60816(1984)	Guide on methods of measurement of short duration transients on low-voltage power and signal lines (77/186/RVS, Ed. 2.0 – 77/179/SR, 77/186/SR (1997))	3.2
IEC 60827(1985)	Guide to voltage fluctuation limits for household appliances (relating to IEC Publication 555-3). Note: 555-3 is replaced by 1000-3-3.	4
IEC 60868-0(1991)	Flickermeter – Part 0: Evaluation of flicker severity	2.3
IEC 60868 (1990)	Flickermeter – Fluctuation and design specifications	
IEC 61000-1-1 (1997)	EMC Part 1: General – Section 1: Application and interpretation of fundamental definitions and terms	3.1
IEC 61000-1-2	(in preparation) EMC and Functional Safety (see 77/223/Q)	4.1
IEC 61000-2-1(1990)	EMC Part 2: Environment; Section 1: Description of the environment – Electromagnetic environment for low-frequency conducted disturbances and signaling public power supply systems	2.3
IEC 61000-2-2(1990)	EMC Part 2: Environment; Section 2: Compatibility levels for low-frequency conducted disturbances and signaling in public low-voltage power supply systems (77A(Sec.)85)	2.3
IEC 61000-2-3(1992)	EMC Part 2: Environment; Section3: Description of the environment – Radiated and non-network-frequency-related conducted phenomena	2.4, 2.5
IEC 61000-2-4(1994)	EMC Part 2: Environment; Section 4: Compatibility levels in industrial plants for low-frequency conducted disturbances	2.3
IEC 61000-2-5(1995)	EMC Part 2: Environmental, Section 5: Classification of electromagnetic environments	2.1
IEC 61000-2-6(1995)	Assessment of emission levels in industrial plants	2.3
IEC 61000-2-7	(in preparation) EMC Part 2: Section 7: Low-frequency magnetic fields in various environments (see 77A/151/RVC))	2.4
IEC 61000-2-8	(in preparation) EMC Part 2: Section 8: Voltage dips, short interruptions and statistical measurement results (77A/121/NP)	2.3
IEC 61000-2-9	(in preparation) HEMP – Description: Radiated disturbances (see 77C/34/RVD)	2.6
IEC 61000-2-10	(in preparation) HEMP – Description: Conducted disturbances (see 77C/65/RVD)	2.6
IEC 61000-2-11	(in preparation) HEMP – Classification of HEMP environment (77C/77/FDIS)	2.6

IEC 61000-2-12	(in preparation) EMC Part 2: Section 12: Compatibility levels for low frequency conducted disturbances and signaling in public medium-voltage power supply systems (77A/266/CD)	2.3
IEC 61000-3-1(1982)	Disturbances in supply systems caused by household appliances and similar electrical equipment Part 1: Definitions	3.1
IEC 61000-3-2(1995)	EMC Part 3: Limits- Section 2: Limits for Harmonic Currents Emissions (equipment input current ? 16A per phase)	4
IEC 61000-3-2	Amendments 1 (1997): Air conditioners, professional equipment, vacuum cleaners Amd. 2 (1998) Lighting equipment	5.3, 5.17
IEC 61000-3-3(1994)	EMC Part 3: Limits-Section 3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current ? 16A (77A(Sec)40)	2.3.4, 4
IEC 61000-3-4 (1998)	Limits for harmonic current emissions – harmonic levels > 16A	4
IEC 61000-3-5 (1994)	EMC Part 3: Limits Section 5: Limitations of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 16A	4, 7.3
IEC 61000-3-6(1996)	Harmonic current limits for equipment connected to medium and high voltage power supply systems	4
IEC 61000-3-7(1997)	Voltage fluctuation and flicker limits for equipment connected to medium- and high- voltage power supply systems	4
IEC 61000-3-8(1997)	EMC Part 3: Limits – Section 8: Signaling or low voltage electrical installations – Emission levels, frequency bands and electromagnetic disturbance levels	3.3.2,4, 7.5
IEC 61000-3-9	(in preparation) Emission limits for interharmonics (77A/196/CD, 77A/254/CC)	4
IEC 61000-3-10	(in preparation) EMC Part 3: Section 10: Emission limits 2-9 kHz (77A/137/RVN)	4
IEC 61000-4-1 (1992)	EMC Part 4: Testing and Measurement Techniques Section 1: Overview of immunity tests Basic EMC Publication. (77/200/NP, 77/204/RVN, 77/207/CDV)	3.4.1, 5.6
IEC 61000-4-2 (1995)	EMC Part 4: Testing and Measurement Techniques Section 3: Radiated, radio frequency, EM field immunity tests. Amendment 1: Immunity requirements for components of fire, intruder, and social alarm systems.	3.4.2.1
IEC 61000-4-3 (1995)	EMC Part 4: Testing and Measurement Techniques Section 3: Radiated, radio frequency, EM field immunity test (801-3)	3.4.3
IEC 61000-4-3 (1998)	Amendment 1: Digital Radio Telephones	3.4.3
IEC 61000-4-4 (1995)	EMC Part 4: Testing and Measurement Techniques Section 4: Electrical Fast Transient/burst immunity test (801-4)	3.4.2.2

IEC 61000-4-4	(in preparation) Amendment (see 77B/266/CD)	
IEC 61000-4-5 (1995)	EMC Part 4: Testing and Measurement Techniques Section 5: Surge immunity test	3.4.2.3
IEC 61000-4-5 (1997)	EMC Part 4: Testing and Measurement Techniques Amendment – Surge Testing on telecommunication lines (77B/165/RVN)	
IEC 61000-4-6 (1996)	EMC Part 4: Testing & Measurement Techniques: Section 6: Immunity to conducted disturbances induced by radio-frequency fields	3.4.2
IEC 61000-4-7 (1991)	EMC Part 4: Testing and Measurement Techniques Section 7: General guide on harmonics and interharmonics measurements and instrumentation for power supply systems and equipment connected thereto	3.3.2
IEC 61000-4-7	Amendment (in preparation) see 77A(Secretariat)93; Voltage fluctuations and flicker 16 A to 75 A	3.3.2
IEC 61000-4-8 (1993)	EMC Part 4: Testing and Measurement Techniques Section 8: Power frequency magnetic field immunity test Basic EMC publication	3.4.3, 3.4.3.1
IEC 61000-4-9 (1993)	EMC Part 4: Testing and Measurement Techniques Section 9: Pulse magnetic field immunity test Basic EMC Publication	3.4.3.1
IEC 61000-4-10 (1993)	EMC Part 4: Testing and Measurement Techniques Section 10: Damped oscillatory magnetic field immunity test Basic EMC Publication	3.4.3.1
IEC 61000-4-11 (1994)	EMC Part 4: Testing and Measurement Techniques Section 11: Voltage dips, short interruptions and voltage immunity tests.	3.4.2
IEC 61000-4-12 (1995)	EMC Part 4: Testing and Measurement Techniques Section 12: Oscillatory waves immunity test. Basic EMC Publication	3.4.2.4
IEC 61000-4-13	(in preparation) Tests for immunity to voltage fluctuations, unbalance, variation in power frequency (77A/291/CD))	3.4.2
IEC 61000-4-14	(in preparation) Tests for immunity to voltage fluctuations, unbalance, variation in power frequency (77A/268/RVD)	
IEC 61000-4-15 (1991)	EMC Part 4: Testing and Measurement Techniques Section 15: Flickermeter (formerly IEC 600868)	2.3, 3.2
IEC 61000-4-16 (1998)	(in preparation) EMC Part 4: Testing and Measurement Techniques Section 16: Conducted disturbances in the frequency range DC to 150 kHz immunity	3.4.2
IEC 61000-4-17	(in preparation) EMC Part 4: Testing and Measurement Techniques. Section 17: Tests for immunity to ripple on dc power supply (77A/280/RVD)	3.4.2
IEC61000-4-19 (1995)	EMC Part 4: Testing and Measurement Techniques . Section 19: Guide for the selection of high frequency emission and immunity test sites (in preparation) EMC Part 4: Testing and Measurement Techniques . Section 20: TEM	3.3.1, 3.4.1 3.3.3, 3.4.3

	cells (77B/265/CD)	
IEC 61000-4-21	(in preparation) EMC Part 4: Testing and Measurement Techniques: Section 21: Mode stirred chambers (77B/260/CD)	3.3.3, 3.4.3
IEC 61000-4-22(1999)	EMC Part 4: Testing and Measurement Techniques. Section 22: Guide on measurement methods for EM phenomena (see	2.6
IEC 61000-4-23	(in preparation) EMC Part 4: Testing and Measurement Techniques. Section 23: HEMP Protective devices for radiated disturbances (see 77C/80/RVC)	2.6
IEC 61000-4-24	(in preparation) EMC Part 4: Testing and Measurement Techniques. Section 24: HEMP Protective devices for conducted disturbances (see 77C/40/RVN)	2.6
IEC 61000-4-25	(in preparation) EMC Part 4: Testing and Measurement Techniques. Section 25: HEMP Equipment and systems (77C/81/CD)	2.6
IEC 61000-4-26 (1998)	EMC Part 4: Testing and Measurement Techniques . Section 26: Calibration of probes and associated instruments for measuring electromagnetic fields	3.2
IEC 61000-4-28	(in preparation) EMC Part 4: Testing and Measurement Techniques. Section 28 Variation of power frequency, immunity tests (77A/287/FDIS)	3.4.2
IEC 61000-5-1 (1996)	EMC Part 5: Installation and mitigation guidelines – Section 1: General Considerations	9.1
IEC 61000-5-2 (1997)	EMC Part 5: Installation and mitigation guidelines – Section 2: Earthing and Cabling	9.2, 9.3
IEC 61000-5-3	(in preparation) HEMP Protection concepts – General (see 77C/69/RVC)	2.6
IEC 61000-5-4 (1996)	(EMC) - Part 5: Installation and mitigation guidelines - Section 4: Immunity to HEMP Specification for protective devices against HEMP radiated disturbance. Basic EMC Publication	2.6
IEC 61000-5-5	(in preparation) HEMP Protection concepts for conducted disturbances (see 77C/35/RVD))	2.6
IEC 61000-5-6 (1999)	EMC Part 5: Installation and mitigation guidelines – Section 6: Mitigation of external influences	9.1
IEC 61000-5-7	(in preparation) Mitigation of ESD	
IEC 61000-6-1 (1997)	Generic Standards – Section 1: Immunity for residential, commercial, and light-industrial environments:	4.0
IEC 61000-6-2 (1999)	EMC – Part 6-2: Generic Standards – Immunity for industrial environments	4.0
IEC 61000-6-3 (1996)	EMC – Part 6: Generic Standards – Section 3: Emission standards for residential commercial and light industrial environments	4.0

IEC 61000-6-4 (1997)	EMC – Part 6: Generic Standards – Section 4: Emission standard for industrial environments	4.0
IEC 61000-6-5 Ed. 1	(in preparation) EMC – Part 6-5: General Standards – Immunity for power stations and substation environments (77/215/CD	4.0

Table 3: CENELEC Standards
(note: CENELEC standards have their counterparts in the lists of IEC and ETSI Standards)

SS EN 12015 (1998)	EMC – EMC - Product family standard for lifts, escalators and passengers conveyors – Emissions
SS EN 12016 (1998)	EMC – Product family standard for lifts, escalators and passengers conveyors – Immunity
EN 300 127 (1999)	EMC and Radio Spectrum Matter (ERM); Radiated emission telecommunication system V1.2.1
EN 300 152 (1998)	EMC and Radio Spectrum Matter (ERM); Maritime emergency position indication radio beacons (EPIRB) intended for use on the frequency 121, 5 MHz, or the frequencies 121,5 MHz and 243 MHz for homing purposes only; Technical characteristics and methods of measurement V1.2.1
EN 300 220-1 (1997)	EMC and Radio Spectrum Matter (ERM); Short range devices; Technical characteristics and test methods for radio equipment to be used in the 25 MHz to 1000 MHz frequency range with power levels ranging up to 500 mW; Part 2: Supplementary parameter not intended for regular purposes V1.2.1
EN 300 220-2 (1997)	EMC and Radio Spectrum Matter (ERM); Short range devices; Technical characteristics and test methods for radio equipment to be used in the 25 MHz to 1000 MHz frequency range with power levels ranging up to 500 mW; Part 1: Parameters intended for regular purposes
EN 300 279 (1999)	EMC and Radio Spectrum Matter (ERM); EMC standard for PMR and ancillary equipment (speech and/or non-speech) V1.2.1
EN 300 300	EMC and Radio Spectrum Matter (ERM); SRD; Technical characteristics and test methods for radio equipment in the frequency range 9 kHz to 25 MHz and inductive loop systems in frequency range 9 kHz to 30 MHz V1.2.2
EN 300 339 (1998)	EMC and Radio Spectrum Matters (ERM); General EMC for radio communications equipment
EN 300 385 (1998)	(Draft) EMC and Radio Spectrum Matters (ERM); EMC standard for fixed radio links and ancillary equipment V1.2.1
EN 300 422 (1999)	(Draft) EMC and Radio Spectrum Matter (ERM); Technical characteristics and test methods for wireless microphones in the 25 MHz to 3 GHz frequency range V1.2.1
EN 300 440 (1999)	(Draft) EMC and Radio Spectrum Matters (ERM): Short range devices; technical characteristics and test methods for radio equipment to be used in the 1 GHz to 40 GHz frequency range V1.2.1

EN 300 674 (1999)	EMC and Radio Spectrum Matters (ERM): Road Transport and Traffic Telematics (RTTT); Technical characteristics and test methods for dedicated short range communications (DSRC) transmission equipment (500 kbit/s, 250 kbit/s) operating in the 5,8 GHz industrial, scientific and medical (ISM) band V1.1.1
EN 300 761 (1998)	EMC and Radio Spectrum Matters (ERM): Automatic vehicle identification (AVI) for railways V1.1.1
EN 300 789 (1998)	EMC and Radio Spectrum Matters (ERM); Terrestrial flight telecommunications system (TFTS); Avionic termination radio testing specification V1.1.1
EN 300 793 (1998)	EMC and Radio Spectrum Matters (ERM); Land Mobile Services; presentation of equipment for type testing V1.1.1
EN 300 386-2 (1997)	EMC and Radio Spectrum Matters(ERM); Telecommunication network equipment; EMC requirements; Part 2: Product family standard V1.1.3
EN 300 673 (1999)	(Draft) EMC and Radio Spectrum Matters (ERM) for very small aperture terminal (VSAT), satellite newsgathering (SNG), satellite interactive terminals (SIT), and satellite user terminals (SUT). Earth stations operated in frequency ranges between 4 GHz and 30 GHz in FSS V1.2.1
EN 300 827 (1998)	EMC and Radio Spectrum Matters (ERM); EMC standard for terrestrial trucked radio (TETRA) and ancillary equipment V1.1
EN 300 828 (1998)	EMC and Radio Spectrum Matters (ERM); EMC for radio transmitters and receivers for maritime mobile service operating in VHF bands V1.1.1
EN 300 829 (1997)	(Draft) EMC and Radio Spectrum Matter; EMC for maritime mobile earth stations (MMES) operating in the 1, 5/1, 6 GHz bands providing low bit rate data communications (LBDC) for GMDSS V1.1.1
EN 300 830 (1998)	EMC and Radio Spectrum Matter(ERM); EMC for receive only mobile earth stations (ROMES) operating in the 1,5 GHz band providing data communications V1.1.1
EN 300 831 (1998)	EMC and Radio Spectrum Matters(ERM); EMC for mobile earth stations (MES) used within satellite personal communications networks (S-PCN) operating in the 1, 6/2, 4 GHz and 2 GHz frequency bands V1.1.1
EN 300 832 (1998)	EMC and Radio Spectrum Matters (ERM); EMC for mobile earth stations (MES) providing low bit rate data communications using satellites in low earth orbits operating in frequency bands below 1 GHz V1.1.1
EN 301 011 (1998)	The EMC and Radio Spectrum Matters (ERM); EMC standard for narrow band direct printing (NBDP) navigational information (NAVTEX) receivers operating in the maritime mobile service V1.1.1
EN 301 025 (1998)	EMC and Radio Spectrum Matters (ERM); Technical characteristics and methods of measurement for general communications and

	associated equipment for class "D" digital selective calling (DSC) V1.1.1	
EN 301 033 (1998)	(Draft) EMC and Radio Spectrum Matters (ERM); Technical characteristics and methods of measurement for shipborne watchkeeping receivers for reception of digital selective calling (DSC) in maritime MF, MF/HF and VHF bands V1.1.1	
EN 301 090 (1998)	EMC and Radio Spectrum Matters (ERM); EMC standard for maritime radio telephone watch receiver operators on 2182 kHz V1.1.1	
EN 301 166 (1999)	EMC and Radio Spectrum Matters (ERM); Land mobile service; Technical characteristics and test conditions for radio equipment for analogue and/or digital communications (speech and/or data) and operating on narrowband channels and having on antenna connector V1.1.1	
EN 301 178 (1999)	(Draft) EMC and Radio Spectrum Matters(ERM); Technical characteristics and methods of measurement for portable very high frequency (VHF) radiotelephone equipment for maritime mobile service operating in VHF bands (for non –GMDSS application only) V1.1.1	
EN 301 357 (1999)	(Draft) EMC and Radio Spectrum Matters(ERM); Technical characteristics and test methods for analogue cordless wideband audio devices using integral antennas operating in (CEPT) recommended 863 MHz to 865 MHz frequency range	
EN 301 391 (1998)	(Draft) EMC and Radio Spectrum Matters(ERM); Data communications using short range devices; Access protocol, occupational rules and corresponding technical characteristics for the transmission of data V1.1.1	
EN 50065-1 (1993)	Signaling on LV electronic installation	7.5
EN 50081-1 (1997)	Generic emission standard. Part 1: Domestic, commercial and light industry	4
PREN 50081-2	Generic emission standard. Part 2: Industrial environment	
SSEN 50081-2 (1993)	EMC – General emission standard – Part 2: Industrial environment	
EN 50082-1 (1997)	Generic immunity standard. Part 1: Residential, commercial, and light industry	4
SSEN 50083-2 (1995)	Cabled distribution systems for television, sound and interactive multimedia signals – Part 2: EMC for equipment	
SSEN50083-2A1(1997)	Cabled distribution systems for television, sound and interactive multimedia signals – Part 2: EMC for equipment	
SSEN 50130-4 (1996)	Alarm systems – Part 4: EMC – Product family standard: Immunity requirements for components of fire, intruder and social alarm systems.	
SSEN50130-4A1(1998)	EMC – Product family standard: Immunity requirements for components of fire, intruder, and social alarm systems	
SSEN 50199 (1996)	EMC – Product standard for arcwelding equipment	
SSEN 50199C1 (1998)	EMC – Product standard for arcwelding equipment	

EN 55014-1/A1 (1997)	EMC – Requirement for household appliances, electric tools and similar apparatus – Part 1: Emission - Product family standard	4
EN 55014-2 (1997)	EMC – Requirement for household appliances, electric tools and similar apparatus	4
EN 55015 A1 (1997)		
pr EN 55101-2	ITE (including Telecom) ESD	5.13
pr EN 55101-3	ITE (including Telecom) Radiated fields	5.13
EN 55103-1	EMC – Product family standard for audio, video, audio-visual and entertainment lighting control apparatus for professional use; Part 1: Emission	
EN 55103-2	EMC – Product family standard for audio, video, audio-visual and entertainment lighting control apparatus for professional use; Part 2: Immunity	
SS EN 55104	EMC – Immunity requirements for household appliances, tools, and similar apparatus – Product family standard	
SS EN 55014-2 C1	EMC – Requirements for household appliances, electronic tools and similar apparatus – Part 2: Immunity – Product family standard	
SSEN 60118-13 (1997)	Hearing aids – Part 13: EMC	
EN 60601-1-2 (1993)	Medical electrical equipment – Part 1: General requirement for safety; Section 2: Collateral standard EMC – Requirements and tests	
SSEN60601-1-2C1(98)	Medical Electrical Equipment; Part 1: General requirements for safety – Section 2: Collateral standard: EMC requirements and tests	
EN 60801-2	EMC for industrial – process measurement and control equipment – Part 2: Electrical discharge requirements	
SSEN60870-2-1 (1997)	Telecontrol equipment and systems – Part 2: Operating conditions – Section 1: Power supply and EMC	
EN IEC 61000-2-4	EMC Part 2: Environment – Section 4: Compatibility levels in industrial plants for low frequency conducted disturbances	
EN IEC 61000-2-9	EMC Part 2: Environment – Section 9: Description of HEMP Environment – Radiated disturbance – Basic EMC publication	
SSEN IEC 61000-3-2	(EMC) Part 3: Limits – Section 2: Limits for harmonic current emissions (equipment input current up to and including 16A per phase)	
SSEN IEC 61000-3-2A1 (98)	EMC – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current up to 16A per phase).	
SSEN IEC 61000-3-2A2 (98)	EMC – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current up to 16A per phase).	
EN IEC 61000-3-2/A12	EMC – Part 3: Limits – Section 2: Limits for harmonic current emissions (equipment input current up to and including 16A per phase)	
SSEN IEC 61000-3-	EMC – Part 3-2: Limits – Limits for harmonic current	

2C1(97)	emissions (equipment input current up to 16A per phase).
EN IEC 61000-3-3	EMC – Part 3: Limits – Section 3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current up to and including 16A
SSEN IEC 61000-3-3 (1997)	EMC – Part 3: Limits – Section 3: Limitation of voltage fluctuations and flicker in low voltage supply systems for equipment with rated current equal to or less than 16A
EN IEC 61000-4-1	EMC – Part 4: Testing and measurement – Section 1: Overview of immunity tests – Basic EMC publications
SSEN IEC 61000-4-2	(EMC) Part 4-2: Testing and Measurement Techniques; Electrostatic discharge immunity test – Basic EMC publication
SSEN IEC 61000-4-2A1 (98)	(EMC) Part 4-2: Testing and Measurement Techniques; Electrostatic discharge immunity test
EN IEC 61000-4-3/A1	EMC – Part 4: Testing and measurement – Section 3: Radiated, radio frequency, electromagnetic field immunity test
EN IEC 61000-4-4 T1	EMC – Part 4: Testing and measurement – Section 4 Electrical fast transient/burst immunity test – Basic EMC publication
SS EN IEC 61000-4-4	(EMC) Part 4: Testing and Measurement Techniques; Section 4: Electrical fast transient/burst immunity test – Basic EMC publication
EN IEC 61000-4-5 T1	EMC – Part 4: Testing and measurement – Section 5 Surge immunity test
SS EN IEC 61000-4-5	(EMC) Part 4: Testing and Measurement Techniques; Section 5: Surge immunity test
EN IEC 61000-4-6	EMC – Part 4: Testing and measurement – Section 6: Immunity to conducted disturbances, inducted by radio-frequency fields
SS EN IEC 61000-4-7	(EMC) Part 4: Testing and Measurement Techniques; Section 7: General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected there.
EN IEC 61000-4-8	EMC – Part 4: Testing and measurement – Section 8: Power frequency magnetic field immunity test – Basic EMC publication
EN IEC 61000-4-9	EMC – Part 4: Testing and measurement – Section 9: Pulse magnetic field immunity test – basic EMC publication
EN IEC 61000-4-10	EMC – Part 4: Testing and measurement – Section 10: Damped oscillatory magnetic field immunity test – Basic EMC publication
EN IEC 61000-4-11	EMC – Part 4: Testing and measurement – Section 11: Voltage dips, short interruptions and voltage variations immunity tests
EN IEC 61000-4-12	EMC – Part 4: Testing and measurement – Section 12:

	Oscillatory waves immunity test – Basic EMC publication	
SSEN IEC 61000-4-15 (1998)	(EMC) Part 4: Testing and Measurement Techniques; Section 15: Flickermeter – Functional and design specifications	
SSEN IEC 61000-4-16 (1998)	(EMC) Part 4: Testing and Measurement Techniques; Section 16: Test for immunity to conducted, common mode disturbances in the frequency range – Hz to 150 kHz	
EN IEC 61000-5-5	EMC Part 5: Installation and Mitigation guideline – Section 5: Specification of protective devices of HEMP conducted disturbances - Basic EMC publication.	
SS EN 61543 (1998)	Residual current operated protective devices (RCD) for households and similar use – EMC	
SS EN 61547	Equipment for general lighting purposes – EMC immunity requirements	

Table 4: ETSI Standards
[see 6.0 in Annotated list, Annex B2]

ETS 300 065 (1997)	EMC and Radio Spectrum Matter (ERM); Narrow-band printing telegraph equipment for receiving meteorological or navigational information (NAVTEX) technical characteristics and methods of measurement	
ETS 300 126	EMC Requirements for ISDN	6
ETS 300 127	Radiated emissions testing of physically large systems	6
ETS 300 133-1 (1997)	EMC and Radio Spectrum Matter (ERM); Enhanced radio message system (ERMES); Part 1: General aspects 2nd edition	
ETS 300 133-2 (1997)	EMC and Radio Spectrum Matter (ERM); Enhanced radio message system (ERMES); Part 2: Service aspects 2nd edition	
ETS 300 133-3 (1993)	EMC and Radio Spectrum Matter (ERM); Enhanced radio message system (ERMES); Part 3: Network aspects 2nd edition	
ETS 300 133-4 (1997)	EMC and Radio Spectrum Matter (ERM); Enhanced radio message system (ERMES); Part 4: Air interface specification 2nd edition	
ETS 300 133-5 (1997)	EMC and Radio Spectrum Matter (ERM); Enhanced radio message system (ERMES); Part 5: Receiver conformance specification 2nd edition	
ETS 300 133-6 (1997)	EMC and Radio Spectrum Matter (ERM); Enhanced radio message system (ERMES); Part 6: Base station conformance specification 2nd edition	
ETS 300 133-7 (1997)	EMC and Radio Spectrum Matter (ERM); Enhanced radio message system (ERMES); Part 7; Operations and maintenance aspects 2nd edition	
ETS 300 162 (1998)	EMC and Radio Spectrum Matter (ERM); Radio transmitters and receivers for the maritime mobile service operating in VHF; Technical characteristic and methods	

	of measurement 2nd edition.
ETS 300 224 (1998)	EMC and Radio Spectrum Matter (ERM); On-Site paging service; Technical and functional characteristics for on-site paging systems, including test methods 2nd edition.
ETS 300 279 (1996)	Radio Equipment and Systems (RES); EMC standard for PMR and ancillary equipment (speech or non-speech)
ETS 300 326-1 (1998)	EMC and Radio Spectrum Matter (ERM); Terrestrial flight telecommunications system (TFTS); Facilities and requirements 2nd edition
ETS 300 326-2 (1998)	EMC and Radio Spectrum Matter (ERM); Terrestrial flight telecommunications system (TFTS); Speech Services, radio interface 2nd edition
ETS 300 326-3 (1998)	EMC and Radio Spectrum Matter (ERM); Terrestrial flight telecommunications system (TFTS); Part 3: Speech Services, network aspects 2nd edition
ETS 300 329 (1997)	Radio Equipment and Systems (RES); EMC for digital enhanced cordless telecommunications (DECT) equipment 2nd edition
ETS 300 340 (1994)	Radio Equipment and Systems (RES); EMC for enhanced radio message system (ERMES) paging receivers
ETS 300 342-1 (1997)	Radio Equipment and Systems (RES); EMC for European digital cellular telecommunications systems (GSM 900 MHz and DCS 1 800 MHz) Part 1: Mobile and portable radio and ancillary equipment 2nd edition
ETS 300 345 (1995)	Radio Equipment and Systems (RES); EMC standard for digital fixed radio links and ancillary equipment with data rates at around 2 Mbit/s and above
ETS 300 385 (1996)	Radio Equipment and Systems (RES); EMC standard for digital fixed radio links and ancillary equipment with data rates at around 2 Mbit/s and above
ETS 300 385 A1 (1997)	Radio Equipment and Systems (RES); EMC standard for digital fixed radio links and ancillary equipment with data rates at around 2 Mbit/s and above
ETS 300 386-1 (1994)	Equipment Engineering (EE); Public telecommunication network equipment EMC requirements; Part 1: Product family overview, compliance criteria and test levels
ETS 300 441A1,PRA1 (1997)	EMC and Radio Spectrum Matters (ERM); Technical characteristics and methods of measurement for maritime radiotelephone watch receivers for the distress and calling frequency 2 182 kHz
ETS 300 445 A1 (1997)	Radio Equipment and Systems (RES); EMC standard for wireless microphones and similar RF audio link equipment
ETS 300 447 (1997)	Radio Equipment and Systems (RES); EMC standard for VHF FM broadcasting transmitters
ETS 300 673 (1997)	Radio Equipment and Systems (RES); EMC standard 4/6

	GHz and 11/12/14 GHz very small aperture terminal (VSAT) equipment and 11/12/14 GHz SNG TES Equipment
ETS 300 680-1 (1997)	Radio equipment and systems (RES); EMC standard for CB radio and ancillary equipment (speech and/or non-speech); Part 1: Angle-Modulated
ETS 300-680-2 (1997)	Radio Equipment and Systems (RES), EMC standard for CB radio and ancillary equipment (speech and/or non-speech); Part 2: DSB and/or SSB
ETS 300 682 (1997)	Radio Equipment and Systems (RES); EMC standard for on-site paging equipment
ETS 300 683 (1997)	Radio Equipment and Systems (RES); EMC standard for SRD operating on frequencies between 9 kHz and 25 GHz

Table 5: CISPR Standards

CISPR 10 (1992)	Organization, rules and procedures of the CISPR (Ed. 4.0)	
CISPR 11 (1990)	Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific and medical radio-frequency equipment. EN 55011 (Ed. 3.1 1996)	5.14.1
CISPR 12 (1990)	Limits and methods of measurement of radio interference characteristics of vehicles, motor boats and spark-ignited engine driven devices (Ed. 4.0 1997)	5.18
CISPR 13 (1990)	Limits and methods of measurement of radio interference characteristics of sound and television broadcast receivers and associated equipment. Amendment No. 1(1992)	5.23
CISPR 14-1 (1993)	EMC – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission product family standard	5.3
CISPR 14-1 A1 (96)	Amendment 1	5.3
CISPR 14-1 A2 (98)	Amendment 2	5.3
CISPR 14-2 (1997)	EMC – requirements for household appliances, electric tools and similar apparatus – Part 2: Immunity – Product family standard	5.3
CISPR 15 (1992)	Limits and methods of measurement of radio interference characteristics of fluorescent lamps and luminaries. Amendment No. 1 (1989), EN 55015	5.3
CISPR 16-1 (1993)	CISPR specifications for radio disturbance and immunity measuring apparatus and methods. Part 1: Radio disturbance and immunity measuring apparatus	3.2
CISPR 16-2 (1999)	Methods of disturbance and immunity measurements(in preparation)	3.3.1
CISPR 16-3	(TBP)	
CISPR 17 (1981)	Methods of measurement of the suppression characteristics of passive radio interference filters and suppression components	5.11
CISPR 18	Radio interference characteristics of overhead power lines and	

	high voltage equipment	
CISPR 18-1 (1982)	Radio interference characteristics of overhead power lines and high voltage equipment Part 1: Description of phenomena	2.4, 7.3
CISPR 18-2 (1986)	Radio interference characteristics of overhead power lines and high voltage equipment Part 2: Methods of measurement and procedure for determining limits	3.3.3, 7.3
CISPR 18-3 (1986)	Radio interference characteristics of overhead power lines and high voltage equipment Part 3: Code of practice for minimizing the generation of radio noise	7.3
CISPR 19 (1983)	Guidance on the use of the substitution method for method of measurements of radiation from microwave ovens for frequencies above 1 GHz	5.16
CISPR 20 (1990)	Limits and methods of measurement of immunity characteristics of sound and television broadcast receivers and associated equipment.	5.13, 5.23
CISPR 21 (1985)	Interference to mobile radio communications in the presence of impulsive noise; methods judging degradation and measures to improve performance	5.23
CISPR 22 (1985)	Limits and methods of measurement of radio interference characteristics of information technology equipment. EN 55022	5.13
CISPR 23 (1987)	Determination of limits for industrial, scientific and medical equipment	5.14.1
CISPR 24 (1992)	Immunity of ITE: ESD requirements (see CISPR G/93/CDV)	5.13
CISPR 25 (1995)	Limits of measurement of radio disturbance characteristics for the protection of receivers used on board vehicles	5.23
CISPR 28 (1997)	Industrial scientific and medical equipment (ISM) – Guidelines for emission levels within the bands designated by the ITU	5.14.1
CISPR 28-1	Generic emission standard: Residential	4
CISPR 28-2	Generic emission standard: Industrial	4

Table 6: Current C63 Standards

ANS C63.2-1987	Standard for instrumentation – Electromagnetic noise and field strength, 10 kHz to 40 GHz – Specifications	3.2
ANS C63.4-1992	Standard for EMC – Radio noise emissions from low-voltage electrical and electronic equipment in the range of 10 kHz to 1 GHz – Methods of measurement	3.3.1
ANS C63.5-1988	Standard for EMC – Radiated emission measurements in electromagnetic interference (EMI) Control – calibration of antennas	3.2
ANS C63.6-1988	Standard for EMC – Open areas test site measurements – Guide for the computation of errors	3.2, 3.3.1
ANS C63.7-1988	Guide for the construction of open area test sites for performing radiated emission measurements	3.3.1
ANS C63.12-1987	Standard for EMC limits – Recommended practice	4
ANS C63.13-1991	American National Standard Guide on the application and	7.3, 9.5

	evaluation of EMI power line filters for commercial use	
ANS C63.14-1992	Dictionary for technologies for EMC, EMP and ESD	3.1
	Conducted Immunity (CI) Tests	
	CI-1 Power line immunity, 30 Hz to 50 kHz , Different Mode	3.4.2
	CI-2 Power line immunity, 50 kHz to 400 MHz, Differential Mode – (line to ground)	3.4.2
	CI-3 Power line conducted immunity, 50 kHz to 50 MHz, Differential mode	3.4.2
	CI-4 RF power line conducted immunity, 50 kHz to 50 MHz, Common mode	3.4.2
	CI-5 Communications receiver antenna input immunity (receivers other than broadcast), 30 Hz to 10 GHz	3.4.2
	CI-6 Receiver antenna input immunity for TVs and VCR's, 0.5 MHz	3.4.2
	CI-7 Signal line immunity, interconnected cables, 15 kHz to 50 MHz	3.4.2
	CI-8 Power line surge voltage and fast trANSent test	3.4.2.2, 3.4.2.3
	CI-9 Telecommunications terminal equipment line immunity, 10 kHz to 30 MHz	3.4.2
ANS C63.14-1998	ANS for technology of EMC, EMP and ESD	
ANS C63.15-	(Draft), Immunity Measurement Techniques (last updated 8/19/99)	3.4.1
	Radiated Immunity (RI) Tests	
	RI-1 Uniform magnetic field immunity, helmholtz coil, 30 Hz to 30 kHz	3.4.3
	RI-2 Magnetic field immunity, point source, 30 Hz to 30 kHz	3.4.3
	RI-3 Power frequency magnetic induction field	3.4.3
	RI-4 Spikes, inductive field immunity	3.4.3
	RI-5 Electronic field immunity, 10 kHz to 80 MHz	3.4.3
	RI-6 Electric field immunity, 80 MHz to 10 GHz	3.4.3
ANS C63.16-1994	ESD: Guide for electrostatic discharge methodologies criteria	8, 3.4.2.1
ANS C63.17-	Methods of measurement of electromagnetic & operational compatibility of unlicensed personal communication services (UPCS) devices	6.0

Table 7: Other ANSI EMC Related Standards

C37.90.2 1995	Withstand capacity of relay systems to radiated electromagnetic interference from transceivers (trial use)	5.24
C62.2 1987	Application of gapped sic surge arresters	8

C62.41 1990	Guide for surge voltages in low-voltage AC power circuits	2.3, 3.4.2.3
C62.45 1987	Guide on surge testing for equipment connected to low-voltage AC power circuits	3.4.2.3
C95.1 1991	Limits for human exposure 3 kHz to 300 GHz	4
C95.3 1991	Rec. practices – measurements of hazardous fields	3.4.3.2
NFPA 77-1993	Static Electricity	8
NFPA 78-1989	Lighting protection code	8

Table 8 – (FCC) Federal Communications Commission

CFR 15	RF Devices	4
CFR 18	Industrial scientific and medical equipment	4
Part 68	Telephone Interconnect	5.31
MP-5		

Table 9: Institute of Electrical and Electronics Engineers Standards

Electromagnetic Compatibility Society Standards

IEEE 139-1993	Measurement of RF emission from industrial, scientific, and medical (ISM) equipment installed on user's premises	5.14.1
IEEE 140-1990	Minimization of interference from RF heating equipment	5.14.2
IEEE 187-1990	Open field method of measurement of spurious radiation from FM and TV broadcast receivers.	5.23
IEEE 211-1990	Definitions of terms for Radio Wave propagation (APS) (SH13904)	3.1
IEEE 213-1993	Measuring conducted emissions in the range of 300 kHz to 25 MHz from TV and FM broadcast receivers to power lines	5.23
IEEE 291-1969	Report on Meas. field strength in Radio Wave Propagation (APS) (SH018000)	3.3.1
IEEE 299-1991	Measurement of shielding effectiveness of high-performance shielding enclosures	5.8
IEEE 368-1977	Recommended Practice for meas. of electrical noise and harmonic filter performance of high voltage direct current systems (SH07021)	7.3
IEEE 376-1975	Standard for the measurement of impulse strength and impulse bandwidth	
IEEE 377-1986	Measurement of spurious emissions from land-mobile communications transmitters	5.32
IEEE 473-1985	Recommended practice for an electromagnetic site survey (10 kHz – 10 GHz)	5.29
IEEE 475-1983	Measurement procedure for field disturbance sensor	5.10

IEEE 518-1990	Guide for the installation of electrical equipment to minimize electrical noise inputs to controllers from external sources	5.6
IEEE 587-1990	Power Line Transients	7.3

Communications Society

IEEE 367-1987	Recommended practice for determining the electric power station ground potential rise and induced voltage from a power fault	5.6
IEEE 368-1977	Recommended practice for the measurement of electrical noise and harmonic filter performance of high voltage direct current systems	7.3
IEEE 377-1986	Measurement emission from LM communication trans.	5.32
IEEE 776-1993	Guide for inductive coordination of electric supply and communication lines	7.3

Industrial Control Committee

IEEE 518-1982	Guide for the installation of electrical equipment to minimize noise inputs to controllers from external sources	

Power Engineering Society

IEEE 376-1993	Measurement of impulse strength and bandwidth	3.2
IEEE 430-1991	Procedures for the measurement of radio noise from overhead power lines and substations	7.3
IEEE 469-1988	Recommended practice for voice-frequency electrical-noise tests for distribution transformers (COMSOC) (SH12328)	
IEEE 539-1990	Definitions and terms relating to overhead power lines corona radio noise	3.1
IEEE 539a-1984	Supplement to IEEE Std. 539-1979. (PES) [SH09530]	
IEEE 644-1987	Procedures for measurement of power frequency electric and magnetic fields from AC power lines	7.3
IEEE 1027-1984	Draft trial use method for meas. the magnetic field intensity around a telephone receiver (COMSOC) (SH9497)	5.31
IEEE 1140		

Table 10: SAE (formerly – Society of Automotive Engineers)

Standards:

SAE J551d (1990)	Measurement of electromagnetic radiation from a motor vehicle or other combustion – powered device	5.18
SAE J551-1 (1996)	Performance levels and methods of measurement of EMC of vehicles and devices (60 Hz to 18 GHz)	5.18
SAE J551-17 (1997)	Vehicle electromagnetic immunity ~ Power line magnetic fields (Ref. J551-1)	5.18
SAE J1113 (1987)	Rec. Practice on electromagnetic susceptibility procedures for vehicle components	5.18
SAE J1113-1 (1995)	EMC Measurement procedures and limits for vehicle components (except aircraft) (60 Hz to 18 GHz)	5.18

SAE J1113-2 (1996)	EMC Measurement procedures and limits for vehicle components (except aircraft) – conducted immunity, 30 Hz to 250 kHz – All leads	5.18
SAE J1113-3 (1995)	Conducted immunity, 250 kHz to 5000 MHz, Direct injection of radio frequency (RF) Power	5.18
SAE J1113-4 (1998)	Immunity to radiated electromagnetic fields ~ Bulk current injection method	5.18
SAE J1113-13 (1997)	EMC measurement procedure for vehicle components ~ Part 13 ~ Immunity to electrostatic discharge	5.18
SAE J1113-21 (1998)	EMC measurement procedure for vehicle components ~ Part 21 ~ Immunity to electromagnetic fields, 10 kHz to 18 GHz absorber – Lined chamber	5.18
SAE J1113-22 (1996)	EMC measurement procedure for vehicle components – Part 22 ~ Immunity to radiated magnetic fields	5.18
SAE J1113-23 (1995)	EMC measurement procedure for vehicle components – Part 23 ~ Immunity to radiated electromagnetic fields, 10 kHz to 200 MHz, Strip line method	5.18
SAE J1113-25 (1999)	EMC measurement procedure for vehicle components – Part 25 ~ Immunity to radiated electromagnetic fields, 10 kHz to 500 MN_2 ~ Trio-plate method	5.18
SAE J1113-26 (1995)	EMC measurement procedure for vehicle components – Part 26 ~ Measurement procedure for vehicle components ~ Immunity to AC power line electric fields	5.18
SAE J1113-27 (1995)	EMC measurement procedure for vehicle components – Part 27 ~ Immunity to radiated electromagnetic fields	5.18
SAE J1338 (1981)	Open field whole vehicle radiated susceptibility 10kHz-18GHz	5.18
SAE J1407 (1988)	Vehicle electromagnetic susceptibility testing using a large TEM cell	5.18
SAE J1448 (1995)	Electromagnetic susceptibility measurements of vehicle components using TEM cells (14 kHz – 200 MHz) (cancelled: 01 Jul 1995)	5.18
SAE J1547 (1995)	Electromagnetic susceptibility procedure for common mode injection (1 ~ 400 MHz), Module Testing (cancelled: 01 July 1995)	5.18
SAE J1752-1 (1997)	EMC measurement procedure for integrated circuits – Integrated circuit EMC measurement procedures – General and Definitions	5.18
SAE J1752-2 (1995)	EMC measurement procedures for integrated circuits – integrated circuit radiated emissions diagnostic procedure 1 MN2 to 1000 MHz Magnetic field – Loop probe	5.18
SAE J1752-3 (1995)	EMC measurement procedures for integrated circuits – Integrated circuit radiated emissions measurement procedure 150 kHz – 1000 MHz TEM cell	5.18
SAE J1812 (1996)	Functional performance status classification for EMC susceptibility testing of automotive electronic and electrical	5.18

	devices	
SAE JIS W 2009	Bonding electrical and lighting protection for aero systems	7.8
SAE JIS W 7005 (84)	EMC requirements for aero system	7.8
SAE HS 3600 (1997)	SAE surface vehicle EMC standards manual	

Recommended Practices:

ARP 935	Control plan/technical construction file	9.1
ARP 936 (1989)	Rf capacitors for EMI measurements	5.5
ARP 958 (1992)	Broadband antenna calibration	3.2
ARP 1172 (1972)	Interference reduction filters, General specification	5.11
ARP 1267 (1973)	Impulse generators, calibration requirements and techniques	3.2
ARP 1285	Test procedure for measuring shielding effectiveness of electrical connectors and associated hardware	3.5
ARP 1393	EMC and interface control for rapid transit vehicles	
ARP 1705 (1981)	Coaxial test procedure to measure the RF shielding characteristics for EMI gasket materials	3.5
ARP 1870 (1991)	Aero. systems electrical bonding and grounding for EMC and safety	9.2
ARP 1870 (1987)	Aero. bonding and grounding for EMC and safety	7.8
ARP 1972 (1986)	Recommended measurement practices and procedures for EMC testing; Section): Conducted susceptibility, damped sinewave	3.3.1
ARP 4242 (1999)	EMC Control Requirement Systems	7.8
ARP 4043	Flight line grounding and bonding of aircraft	

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AIR 1147	EMI on A/C from jet engine charging	5.9
AIR 1173 (1975)	Test procedures to measure the RF shielding characteristics of EMI gaskets	3.5
AIR 1209 (1974)	Construction and calibration of parallel plate transmission line for EMI susceptibility testing	3.3.3, 3.4.3
AIR 1221 (1971)	EMC system design checklist	
AIR 1255 (1971)	Spectrum analyzers for EMI measurement	3.2
AIR 1394 (1978)	Cabling guidelines for EMC	9.3
AIR 1404 (1976)	DC Resistivity vs. RF impedance of EMI gaskets	9.4
AIR 1406 (1976)	Lighting protection and ESD	8
AIR 1423 (1977)	EMC on gas turbines engines for aircraft propulsion	5.9
AIR 1425 (1978)	Achieving EMC of gas turbines accessories	5.9
AIR 1425A	Methods of achieving EMC of gas turbine engine accessories for self propelled vehicles	
AIR 1499 (1992)	Commercial product susceptibility guide	3.4.2, 8
AIR 1509 (1978)	EMC antennas and antenna factors	3.2
AIR 1662A	Minimization of electrostatic hazards in aircraft fuel systems	8.0
AIR 1700A	Upper frequency measurement boundary for evaluation shielding effectiveness in cylindrical systems	9.4

AIR 5060 (1978)	Electrical engine control design guide for electromagnetic environmental effects	3.2
AIR 50040	Certification of aircraft .. for operation in the high intensity field (HIRF) environment	2.7

Table 11: Electronic Industries Association (EIA)

ANS/EIA-152C (98)	Minimum standards for land mobile communication, FM or PM transmitters, 25 to 866 MHz	5.18
ANS/EIA-544(1989)	Immunity of TV and VCR tuners to internally generated harmonic interference from signals in the band 535 kHZ to 30 MHz	5.23
EIA 361 (1990)	Feed through RI capacitors	5.5
EIA 378 (1970)	Spur. rad. from FM and TV broadcast rcvrs.	5.23
EIA 416 (1981)	RI filters	5.11
EIA 544 (1989)	Immunity of TV and VCR tuners to internally generated harmonic interference from signals in the band 535 kHz to 30 MHz	5.23
EIA RS 378 (1970)	Measurement of spurious radiation from FM and TV broadcast receivers in the frequency range of 100 to 1000 MHz	5.23
EIA TIA 204D (1989)	Minimum standards for LM Com FM or PM receivers	5.23
EIA TIA 316C (1990)	Pers radio trans.	5.32
EIA TSB 10E (1990)	Int. criteria microwave systems	6
Interim Std. 16A	Immunity of television receivers and video cassette recorders (VCRs) to direct radiation from radio transmissions, 0.5 to 30 MHz	5.23, 5.33
Interim Std. 31(1987)	Recommended design guideline, rejection of educational interference to channel 6 television reception, August 1987	5.23
TEP-171 (1981)	Recommended practice for the measurement and warning of radio frequency leakage from microwave tubes	5.16
TIA 204D (1989)	Minimum standards for LM Com FM or PM receivers	5.23
TIA 316C (1990)	Pers. radio trans.	5.32
TR 8.10	Ignition interference susceptibility, measurement correlation	5.18
TSB-10-E (1990)	Interference criteria for microwave systems in the private radio services	6

Table 12: Aeronautical Radio (ARINC)

Project 650	Modular avionics packaging and interfacing	7.8
Project 654	Design guidelines	7.8, 9.4, 9.5

Table 13: Radio Technical Committee for Aeronautics

DO-160D	Environmental conditions and test procedures for airborne equipment	3.3.1, 7.8

DO-160D-15	Environmental conditions and test procedures for airborne equipment: Section 15 - Magnetic Effect	3.4.2
DO-160D-17	Environmental conditions and test procedures for airborne equipment: Section 17: Voltage spike	3.4.2.2
DO-160D-18	Environmental conditions and test procedures for airborne equipment: Section 18: Audio frequency conducted susceptibility power inputs	3.4.2
DO-160D-19	Environmental conditions and test procedures for airborne equipment: Section 19: Induced signal susceptibility	3.4.3
DO-160D-20	Environmental conditions and test procedures for airborne equipment: Section 20: Radio frequency susceptibility	3.4.2, 3.4.3
DO-160D-21	Environmental conditions and test procedures for airborne equipment: Section 21: Emission of radio frequency energy	3.4.2
DO-160D-22	Environmental conditions and test procedures for airborne equipment: Section 22: Lightning induced transient susceptibility	3.4.2.4
DO-160D-23	Environmental conditions and test procedures for airborne equipment: Section 23: Lightning direct effects (under development)	3.4.2.4
DO-160D (1997)	Environmental conditions and test procedures for airborne equipment:	7.8
	Section 15 Magnetic Effect	3.4.2
	Voltage Spike	3.4.2.2
	Audio frequency conducted susceptibility – Power Inputs	3.4.2
	Induced signal susceptibility	3.4.3
	Radio frequency susceptibility (radiated and conducted)	3.4.2, 3.4.3
	Emission of radio frequency energy	3.3.2, 3.3.3
	Lighting induced transient susceptibility	3.4.2.4
	Lighting direct effects (under development)	3.4.2.4
DO-163 (1976)	Minimum performance standards of high frequency radio communications transmitting and receiving equipment operating within the radio frequency range of 1.5 MHz to 30 MHz	6
DO-176 (1984)	FM int. to airborne comm.	6
DO-189 (1985)	Minimum operational performance standards for airborne distance measuring equipment operating in the frequency range of 960-1215 MHz	7.4

Table 14: National Electrical Manufacturers Associatin

NEMA 107	Radio Influence of HV, Measurement method	7.3
NEMA ICS 11 (1995)	EMC for industrial process measurement and control equipment	5.14.1
NEMA WD2	Semiconductor Dimmers for Incandescent Lamps	5.28

Table 15: U.S. Postal Service

MIL-STD-461, 462		
	CS01, power line ripple	
	CS06, transient	
	RS03, radiated field, 10 kHz-1 GHz, 1 V/m to 10 V/m (above 30 MHz)	
IEEE STD 587	(C62.41) power line transients	7.3
FCC Part 68	telephone interconnect	5.31

Table 16 – (CSA) Canadian Standards Association

CSA B72 (1987)	Install code for lightning protection systems	8
CSA C22.2 #0.4 M82	Bonding and grounding of electrical equipment (1993)	9.2
CSA C22.2 #41 M82	Bonding and grounding equipment (1993)	9.2
CSA C108.1.1 (1980)	CISPR type measurement inst. amend. 1	3.2
CSA C108.3.1-M84	Limits and measurement methods of electromagnetic noise from a AC power systems, 0.15-30 MHz (1993)	7.3
CSA C108.4-M92	Motor vehicles (1992)	5.18
CSA C108.6-M91	Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific, and medical (ISM) radio – frequency equipment	5.14.1
CSA C108-8 (1983)	Electromagnetic emissions from data processing equipment and electronic office machines	7.1
CSA C108.9-M91	Sound and television broadcasting receivers and associated equipment limits and methods of measurement of immunity characteristics	5.23
CSA E1000-2-1 (97)	EMC Part 2; Environment; Section 1: Description of the Environment – Electromagnetic Environment for low frequency conducted disturbances and signalling in public power supply systems	2.3
CSA E1000-2-2 (97)	EMC Part 2: Environment; Section 2: Compatibility levels for low frequency conducted disturbances and signalling in public low voltage power supply systems	2.3
CSA Pkg. 3300 (1998)	Telecommunications package	6.0
CSA RIR-2	Radio interference regulations of Canada	6.0
CSA T512-M91	Functional and compatibility requirements for private branch exchange (PBX) switching equipment for voiceband applications	6.0

Table 17: (DIN-VDE) German Standards Association

DIN-VDE 0185-1	Lighting protection system; general	8
DIN-VDE 0185-2	Lighting protection system, installation	8

DIN-VDE 0185-100	Lighting protection structures	8
DIN VDE 0871	ISM	5.14.1, 8
DIN VDE 0871-1	ISM	5.14.1
DIN VDE 0871-2 A2	ISM	5.14.1
DIN VDE 0871-11	ISM	5.14.1
DIN VDE 0871-100	ITE	5.13
DIN VDE 0872-1	Receivers	5.23
DIN VDE 0872-1 A1	Receivers	5.23
DIN VDE 0872-4-87	Interference immunity requirement for video equipment	5.13
DIN VDE 0872-1-88	Appliance interference	5.3
DIN VDE 0875-3-88	Radio interference of electrical system and special electrical appliances	7.5
DIN VDE 0875-208-89	Portable tools interference	5.3
DIN VDE 0877-1-89	Measurement of radio interference and voltages	3.3.1
DIN VDE 0877-2-85	Measurement of radio interference and field strength	3.3.1
DIN VDE 0877-3-80	Measurement of radio interference and power on leads	3.3.1
DIN VDE 0878-1-86	Radio interference suppression of telecommunications systems and apparatus	6
DIN VDE 0878 30-89	ITE	5.13
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Table 18: (BSI) British Standards Institution

BS 800-1988	Specification for radio interference limits and measurements for household appliances, portable tools and other electrical equipment causing similar types of interference	5.3
BS 833-1985	Radio interference limits and measurements for the electrical ignition systems of internal combustion engines	5.18
BS 1597-1985	Specification for limits and methods of measurement of electromagnetic interference generated by marine equipment and installations	7.7
BS 4809-1981	Radio interference limits and measurements for radio frequency heating equipment	5.14.2
BS 5049-1981	Methods of measurement of radio noise from power supply apparatus for operation at 1 kV and above	5.19
BS 5406-1988	Dist. in supplies systems by appliances – harmonics	5.19
BS 5260-1975	Code of practice for RI suppression on marine installations	7.7
BS 6299-1982	Measurement of RI filters	5.11
BS 6345-1983	Methods for measurement of radio interference terminal voltage of lighting equipment	5.3

BS 6527-1988	Specification for limits and measurement of radio interference characteristics of information technology equipment	7.1
BS 6667-1985	EMC requirements for industrial process control instrumentation	5.14.4
BS 9121-1988	RI Suppression filters	5.11
3G 100-1980	Specification for general requirements for equipment for use in aircraft; Part 4: Section 2, Electromagnetic interference at radio and audio frequencies	7.8

Table 19: (ISO) International Standards Organization

ISO 7637-0-1990	Road vehicles EM disturbances Part 0: Definitions and general	5.18
ISO 14982-1988	Agriculture and forestry machinery – EMC Test methods and acceptable criteria	5.18
ISO DIS 10296-1990	Aircraft hybrid remote power controllers	5.6

Table 20: (CEPT) European Commission of Post and Telecommunications

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Table 21: Military Standards

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MIL A 9094A	Lightning arresters	8
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MIL B 5087B	Bonding, electrical & lighting protection for aerospace systems	9.2
MIL B 85584 (1999)	Battery relay control unif, aircraft	7.8
MIL C 11693C (1992)	Feed through capacitors	5.5
MIL F 15733G (1993)	RFI filters and capacitors	5.5
MIL DTL 62062D	Blower, Generator cooling 28 Volt DC	5.14.2
MIL E 6051D	Systems EMC requirements	4.0
MIL HDBK 235 (1993)	Environment considerations for design and procurement	2.7
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MIL HDBK 237A	EMC management guide for platforms, systems, and equipments	7.7
MIL HDBK 237B (1997)	Electromagnetic environment effects on platforms, systems, and equipment (1997)	7.7
MIL HDBK 241B	EMI reduction in power supplies	5.19
MIL HDBK 253	Protection against EM energy	7.7

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MIL HDBK 293 (1987)	Countermeasures in radar system acquisition	7.4
MIL HDBK 294 (1986)	Countermeasures in naval communications systems	7.7
MIL HDBK 335 (1992)	Em radiation hardness for airlauched ordinance systems	7.8
MIL HDBK 419A	Grounding, bonding and shielding for electronic equipment and facilities	9.2
MIL HDBK 1763 (1998)	Aircraft/stores compatibility systems engineering data requirements and test procedures	9.2
MIL S 6451E	Shields	9.4
MIL STD 108E	Enclosures	5.8
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MIL STD 285	EM shielding measurements	
MIL STD 449D	Emission spectrum characteristics	4
MIL STD 461E	Requirements for the control of EMI characteristics of subsystems and equipment.	4
MIL STD 464 (1997)	Electromagnetic environmental effects requirements for systems	4.0
MIL STD 469B (1999)	Radar engineering interface requirements, EMC metric	7.4
MIL STD 704E (1991)	Electrical Power	7.3
MIL STD 1310G	Shipboard bonding, grounding, and other techniques for EMC and safety	7.7, 9.2
MIL STD 1377	Shielding effectiveness measurements cables, connectors, and weapons enclosures	5.20
MIL STD 1397C (1998)	Digital data interfaces	7.1
MIL STD 1399-300A (92)	Shipboard electric power systems	7.7
MIL STD 1399A-408	HERP	7.7
MIL STD 1512	Electro-explosive systems	4.0
MIL STD 1541A	EMC requirements for space systems	7.8
MIL STD 1542B	EMC & grounding requirements for space system facilities	7.8, 9.2
MIL STD 1605	Shipboard EMI surveys	7.7
MIL STD 1686B (1973)	ESD	3.4.2.1
MIL STD 1757A	Lighting qual. tests for aerospace systems & hardware	7.8, 8
MIL STD 1766B	Nuclear hardness and survivability program requirements for ICBM weapon system	8
MIL STD 1795A	Lighting protection of aerospace vehicles & hardware	8
MIL STD 1857 (1998)	Grounding, bonding & shielding design practices	9.2
MIL STD 2169	HEMP	2.6

Table 22: NATO Standards

STANAG 1233	Procedures for RADHAZ control in ports and the Territorial Sea (CU:FR)	4.0
STANAG 1305	RADHAZ procedures for receiving aircraft of other nations on NATO air capable ships (CU:FR)	4.0, 7.7
STANAG 1307	Maximum NATO naval operational E.M. environment produced by radar and radio (CU:IT)	2.7
STANAG 1308	RADHAZ to ships personnel during helicopter (and VSTOL aircraft) operations on ships (CU:FR)	4.0, 7.7
STANAG 1379	NATO RADHAZ warning sign (CU:CA)	4.0
STANAG 1380 AECP-2	Naval interoperational procedures to control the radio and radar radiation hazards	4.0, 7.4
STANAG 1397	RADHAZ classification of munitions and weapons	4.0
STANAG 3516 AE	Electromagnetic interference and test methods for aircraft electrical and electronic equipment	7.8
STANAG 3614 AE	Electromagnetic Compatibility (EMC) of aircraft systems Ed. 3	7.8
STANAG 3659 AE	Electrical bonding requirements for metallic aircraft	7.8, 9.2
STANAG 3731 AE	Bibliography on electromagnetic compatibility (Ed 1 Amd. 1, Ed 2 Amd. 0, Ed 2 Amd. 1, Ed 2 Amd. 2, Ed 2 Amd. 3, Ed 2 Amd. 4, Ed 3 Amd. 0, Ed 3 Amd. 2 – Archive/Historical)	1.1
STANAG 3856 AE	Protection of aircraft crew and subsystems in flight against the effects of electrostatic charges – AEP 29	7.8, 8.0
STANAG 3968 AE	NATO glossary of electromagnetic terminology	1.1
STANAG 3991	Design criteria to minimize generation of static electricity within aircraft fuel systems	8.0
STANAG 4145	Nuclear survivability criteria for armed forces material and installation – AEP –4, 31-10-79	2.6
STANAG 4234	EM radiation (RF) 200 kHz – 40 GHz environment – affecting the design of material for use by NATO forces	2.5, 4.0
STANAG 4235	Electrostatic/environment conditions – affecting design of material for use by NATO forces	8.0
STANAG 4236	Lighting	5.3
STANAG 4237	EEDs	4.0
STANAG 4238	Design principles for hardening munitions/weapon systems against EME	4.0, 9.4
STANAG 4239	ESD test procedures	8.0
STANAG 4273	Standard NATO survivability design threat	2.6
STANAG 4274	Standard description for the presentation of vulnerability analysis	4.0
STANAG 4324	EM radiation (RF) test information to determine the safety and suitability for service of EEDs and associated electronic systems in weapons and munitions systems	4.0
STANAG 4327	Lightning test procedures	8.0

STANAG 4332	General criteria and common procedure for protection against damage caused by EMP on warships. Ratif requested 17-2-86	8.0
STANAG 4370-502	AECTP 502: Special requirements	3.3.1
STANAG 4370-503	AECTP 503: Radiated susceptibility	3.4.3
STANAG 4370-504	AECTP 504: Conducted susceptibility	3.4.2
STANAG 4370-505	AECTP 505: Radiated Emission	3.3.3
STANAG 4370-506	AECTP 506: Conducted emission	3.3.2
STANAG 4370-507	AECTP 507: Susceptibility to transients from switching	3.4.2.2
STANAG 4370-508	AECTP 508: Susceptibility to transients from NEMO induction	3.4.2.4
STANAG 4370-509	AECTP 509: Susceptibility to transients from lightning	3.4.2.3
STANAG 4370-510	AECTP 510: Magnetic susceptibility	3.4.3
STANAG 4370-511	AECTP 511: Electrostatic discharge susceptibility (System Testing)	3.4.2.1
STANAG 4370-520	AECTP 520: Special requirements	3.3.1
STANAG 4370-521	AECTP 521: Radiated susceptibility	3.4.3
STANAG 4370-522	AECTP 522: Conducted susceptibility	3.4.2
STANAG 4370-523	AECTP 523: Radiated susceptibility	3.4.3
STANAG 4370-524	AECTP 524: Shielding effectiveness	9.4
STANAG 4370-525	AECTP 525: Self-compatibility	4.0
STANAG 4370-526	AECTP 526: Susceptibility to transients from NEMP induction	3.4.2.3
STANAG 4370-527	AECTP 527: Susceptibility to transients from lightning	3.4.2.3
STANAG 4370-528	AECTP 528: Magnetic susceptibility	3.4.3
STANAG 4370-529	AECTP 529: Electronic discharge susceptibility	3.4.2.1
STANAG 4416	EMP test procedures containing EEDs	8.0
STANAG 4435	(1993) Electromagnetic compatibility testing procedure and requirements for Naval electrical and electronic equipment (surface ships, metallic hull)	7.7
STANAG 4436	Electromagnetic compatibility testing procedure and requirements for naval electrical and electronic equipment (surface ships, non-metallic hull)	7.7
STANAG 4437	(1994) Electromagnetic compatibility testing procedure and requirements for naval electrical and electronic equipment (submarines)	7.7

Annex B2

Annotated List of Applicable EMC Standards

Annex B2

TABLE OF CONTENTS

1.0 Introduction

The standards are grouped in the following major classes:

1) Environment
2) Basic (measurement techniques)
3) Generic (limits)
4) Product
5) Communications related
6) Systems
7) Lightning
8) Installation

Except in the product and application listings the coverage of a particular standard is identified by whether it covers emission or immunity, whether it deals with measurement techniques or limits, and whether it covers low frequencies (generally below 10 kHz, or high frequencies (above 10 kHz).

1.1 Source Documents

A number of documents are available which list the various standards referred to in this compilation, and admittedly there is considerable duplication in some of the listings here with those documents. This duplication was not intentional. However the objective, i.e. the ordering of the material so that comparable documents can be readily identified is unique to this publication. However in order to prepare the cross listing of documents it has been considered necessary to, in some degree, compile similar lists of standards. Some of the source documents contain some amount of content description, but, as mentioned previously, it will be necessary to consult the actual standards to identify specific coverages.

The two general reference documents are:

a) Electromagnetic Compatibility (EMC) Standards Handbook; W.C.Carter, ECAC-HDBK-94-088, July 1994

b) EMC Documents Reference Catalog, Space and Naval Warfare Systems Command, Department of the Navy, Washington, DC 20363-5100.

c) STANAG 3731 AE Bibliography on electromagnetic compatibility (Ed 1 Amd. 1, Ed 2 Amd. 0, Ed 2 Amd. 1, Ed 2 Amd. 2, Ed 2 Amd. 3, Ed 2 Amd. 4, Ed 3 Amd. 0, Ed 3 Amd. 2 – Archive/Historical)

d) STANAG 3968 AE NATO glossary of electromagnetic terminology

2.0 Environment Standards

These standards are primarily concerned with describing conditions that may appear either generally or in specific locations where electromagnetic phenomena may be observed.

Historically IEC 721 sets up a system for specifying climatic environmental conditions for shipping, or use, of equipment in various locations world-wide. Only recently has the responsible Technical Committee (TC75) classified electromagnetic conditions (according to parameters set defined by TC77). Documents discussing compatibility levels in the 1000-2-series are probably the most useful documents for obtaining quantitative estimates of the levels of electromagnetic parameters to be found in locations of interest, especially for conducted phenomena. Document 1000-2-3 is probably less reliable for selecting parameter values.

TC 77 has recently examined the magnetic field environment, especially the power frequency field due to large industrial equipments.

2.1 General

IEC 60721-1 (1990)	Classification of environment conditions; Part 1. Environmental parameters and their severities Amend 1(1992)
IEC 61000-2-5	Classification of Electromagnetic Environments

2.2 Network Impedance

IEC 60725	Reference impedances for household appliances

2.3 Low frequency conducted environment

ANS C62.41 (1990)	Guide for Surge Voltages in Low-voltage AC Power Circuits
CSA E1000-2-1 (97)	EMC Part 2; Environment; Section 1: Description of the Environment – Electromagnetic Environment for low frequency conducted disturbances and signaling in public power supply systems
CSA E1000-2-2 (97)	EMC Part 2: Environment; Section 2: Compatibility levels for low frequency conducted disturbances and signaling in public low voltage power supply systems
IEC 60868-0 (1991) (new IEC 61000-4-15-0)	Flickermeter: Evaluation of flicker severity
IEC 61000-2-1	LF conducted disturbances
IEC 61000-2-2	Compatibility levels in public networks
IEC 61000-2-4	Compatibility levels in industrial plants
IEC 61000-2-6	Conducted emission levels in industrial plants
IEC 61000-2-8	Voltage dips and interruptions

IEC 61000-2-12	Compatibility levels for medium LV networks (see 77A/128/FDIS)
IEC 61000-3-3	Voltage fluctuations & flicker in LV supply systems

2.4 Low frequency magnetic fields

CISPR 18-1	Emission characteristics of overhead power lines
IEC 61000-2-3	Radiated and non-network-frequency-related conducted phenomena.
IEC 61000-2-7	Magnetic fields in various environments

2.5 High frequency environment

IEC 61000-2-3	Radiated and non-network-frequency-related conducted phenomena.
STANAG 4234	EM radiation (RF) 200 kHz – 40 GHz environment – affecting the design of material for use by NATO forces

2.6 HEMP Environment

IEC 61000-2-9	Description of HEMP environment: radiated
IEC 61000-2-10	Description of HEMP environment: conducted
IEC 61000-2-11	Classification of HEMP environment
IEC61000-4-2 (1999)	EMC Part 4: Testing and Measurement Techniques. Section 22: Guide on measurement methods for EM phenomena (see
IEC 61000-4-23	(in preparation) EMC Part 4: Testing and Measurement Techniques. Section 23: HEMP Protective devices for radiated disturbances (see 77C/80/RVC)
IEC 61000-4-24	(in preparation) EMC Part 4: Testing and Measurement Techniques. Section 24: HEMP Protective devices for conducted disturbances (see 77C/40/RVN)
IEC 61000-4-25	(in preparation) EMC Part 4: Testing and Measurement Techniques. Section 25: HEMP Equipment and systems (77C/81/CD)
IEC 61000-5-3	(in preparation) HEMP Protection concepts – General (see 77C/69/RVC)
IEC61000-5-4 (1996)	(EMC) – Part 5: Installation and mitigation guidelines - Section 4: Immunity to HEMP Specification for protective devices against HEMP radiated disturbance. Basic EMC Publication
IEC 61000-5-5	(in preparation) HEMP Protection concepts for conducted disturbances (see 77C/35/RVD))
MIL-STD-2169B	HEMP
NATO STANAG 4145	
NATO STANAG 4273	

2.7 HIRF

MIL-HDBK-235	Environment Considerations for Design and Procurement
MIL-STD-464	Table ID
NATO STANAG 1307	Maximum NATO Naval EME Produced by Radios & Radars
SAE ARD 50040	Certification of Aircraft for Operation in the High Intensity Field (HIRF) Environment

3.0 Basic Standards

Basic standards are those that have general applicability. Basic measurement standards are applicable to of a wide variety of equipment types. Typically they do not specify limits but may contain limit classifications from which the user may choose an appropriate set. Vocabulary documents are also included as "basic" standards.

3.1 Definitions

Documents C63.14 and IEC 50(161) broadly cover EMC definitions but C63.14 contains more terms, many of which are also in the communications field. Where there is direct overlap an effort has been made to keep them identical. The other documents are specialized, but 1000-1-1 explains the basic concepts in sometimes extensive detail.

ANS C63.14 (1992)	Dictionary for Technologies of EMC, EMP, ESD
IEC 60050(161)	EMC Definitions
IEC 61000-1-1 (1997)	EMC Part 1: General – Section 1: Application and interpretation of fundamental definitions and terms
IEC 61000-3-1 (555-1-1982)	Disturbances in supply systems caused by household appliances and similar electrical equipment: Definitions
IEEE 211-90	Definitions of terms for Radio Wave propagation (APS) [SH13904]
IEEE 539-90	Corona definitions of terms

3.2 Instrumentation and Calibration

Traditionally measurements of electromagnetic disturbances have been made with a radio interference meter built according to specifications prepared by ANSI (in the United States) and the CISPR (for international use). Other countries have prepared specifications that are identical, or similar, to the international standards.

On the other hand measurements for military purposes have been made using a rather conventional spectrum analyzer having a minimum of required characteristics although instrumentation conforming to Accredited Standard C63.2 is referenced. The major difference between military and commercial requirements is the use of the peak detector for military measurements, whereas the quasi-peak detector is required for most commercial measurements.

Methods of antenna calibration are generally more rigorous for commercial use than for the military, probably because of the legal consequences of inaccurate measurements It should be noted that measurement accuracy (and antenna calibration) is under intensive discussion at the present time.

SAE recommended practices cover various topics of concern in instrumentation calibration and use.

ANS C63.2-1987	Instrumentation 10 kHz to 40 GHz
ANS C63.5-1988	Antenna calibration
ANS C63.6-1988	Standard for EMC – OATS Measurements – Guide for the computation of errors
CISPR 16	Instrumentation & measurement methods (will be withdrawn when CISPR 16-2 is completed)
CISPR 16-1	Instrumentation 9 kHz to 1 GHz
CSA C108.1.1-1980	CISPR type measurement instrumentation, Amend. 1
IEC 60816	Transients
IEC 60868 (new IEC 61000-4-15)	Flickermeter
IEC 61000-4-26	Probe calibration (see 77B/169/RVN)
IEEE 376-93	Measurements of impulse strength and bandwidth
SAE AIR 1255-71	Spectrum analyzers for EMI measurements
SAE AIR 1509-78	Antenna factors & how to use them
SAE ARP 958-92	Antenna calibration
SAE ARP 1267-73	Impulse generators

3.3 Emission Measurement Procedures

Emission measurement procedures are covered in detail in documents dealing with particular product or product families. Measurement procedures in a general way in several documents which are identified in clause 3.3.1 Also listed in that clause is material on test site calibration, which is considered to be of general applicability even though it is only related to radiated emission testing.

3.3.1 General

ANS C63.4-1992	EMI Measurements 9 kHz to 40 GHz
ANS C63.7-1988	Guide for Construction of Open Area Test Site for Performing Radiated Emission Meas.

CISPR 16-2	CISPR measurement methods (in preparation)
DIN-VDE 0877 PT 1-89	Measurement of Radio Interference and Voltages
DIN-VDE 0877 PT 2-85	Measurement of Radio Interferences and Field Strength
DIN-VDE 0877 PT 3-80	Measurement of Radio Interference and Power on Leads
IEC 1000-4-19	Guide on selection of test sites (see 77B(Sec)117/NP)
IEEE 291-1969 (Reaff 1981)	Report on Meas. field strength in Radio Wave Propagation (APS) [SH01800]
RTCA DO-160D	Environmental conditions & test procedures for airborne equipment
SAE ARP 1972-86	Meas. pract. & proc. for EMC testing
STANAG 4370-502	AECTP 502: Special requirements
STANAG 4370-520	AECTP 520: Special requirements

3.3.2 Conducted

IEC 61000-3-8	Signaling on LV electrical installations
IEC 61000-4-7	Guide on harmonics and interharmonics
MIL-STD-461E: CE106	Antenna Terminal, 10 kHz to 40 GHz
RTCA DO-160D, Section 21	Emission of Radio Frequency Energy
STANAG 4370-506	AECTP 506: Conducted emission

3.3.3 Radiated

CISPR 18-2	EMI char. Of overhead power lines: meas. Tech.
IEC 61000-4-20	TEM cells (see 77B/153/CD)
IEC 61000-4-21	Mode stirred chambers (see 77B(Secretariat)140)
MIL-STD-461E: RE101	Magnetic Field, 30 Hz to 100 kHz
MIL-STD-461E: RE102	Electric Field, 10 kHz to 18 GHz
MIL-STD-461E: RE103	Antenna Spurious and Harmonic Outputs, 10 kHz to 40 GHz
RTCA DO-160D, Section 21	Emission of Radio Frequency Energy
SAE AIR 1209-74	TEM Field Measuring Techniques - Parallel plate trans. line
STANAG 4370-505	AECTP 505: Radiated Emission

3.4 Immunity Measurement Procedures

IEC Publication 1000-4-1 contains a collection of immunity testing procedures along with general suggestions for limits to be adopted. ANS C63.15 also contains a collection of test procedures but that document is still in preparation. IEC 1000-4-19 (also in preparation) is planned to deal with both emission and immunity test sites.

3.4.1 General overview

ANS C63.15	Immunity meas. techniques
IEC 61000-4-1	Overview of immunity tests
IEC 61000-4-19	Guide on selection of test sites (see 77B(Secretariat)117/NP)

3.4.2 Conducted measurement

ANS C63.15: CI-1	Power Line Immunity, 30 Hz to 50 kHz, Diff. Mode
ANS C63.15: CI-2	Power Line Immunity, 50 kHz to 400 MHz, Diff. Mode (line to ground)
ANS C63.15: CI-3	Power Line Conducted Immunity, 50 kHz to 50 MHz, Common Mode
ANS C63.15: CI-4	RF Power Line Conducted Immunity, 50 kHz to 50 MHz, Common Mode
ANS C63.15: CI-5	Communications Receiver Antenna Input Immunity (Receivers Other than Broadcast), 30 Hz to 10 GHz.
ANS C63.15: CI-6	Receiver Antenna Input Immunity for TVs and VCRs. 0.5 MHz.
ANS C63.15: CI-7	Signal Line Immunity, Interconnected Cables, 15 kHz to 50 MHz.
ANS C63.15: CI-9	Telecommunications Terminal Equipment Line Immunity, 10 kHz to 30 MHz.
IEC 728-1	Cabled distribution systems (sound & tv)
IEC 61000-4-6	Immunity to RF induced currents
IEC 61000-4-11	Voltage dips, interruptions and variation
IEC 61000-4-13 (77A/291/CD)	Harmonics, interharmonics
IEC 61000-4-16 1997	DC to 150 kHz (of particular concern in systems utilizing carrier current DC and sine wave voltage immunity)
IEC 61000-4-17 1999	Ripple on D.C. power supply
IEC 61000-4-28	Power frequency variance
MIL-STD-461E: CS101	Power Leads, 30 Hz to 50 kHz
MIL-STD-461E: CS103	Antenna Port, Intermodulation, 15 kHz to 10 GHz
MIL-STD-461E: CS104	Antenna Port, Rejection of Undesired Signals, 30 Hz to 20 GHz
MIL-STD-461E:	Antenna Port, Cross-Modulation, 30 Hz to 20 GHz

CS105	
MIL-STD-461E: CS109	Structure Current, 60 Hz to 100 kHz
MIL-STD-461E: CS114	Bulk Cable Injection, 10 kHz to 400 MHz
RTCA DO-160D	
Section 15	Magnetic Effect
Section 18	Audio Frequency Conducted Susceptibility-Power Inputs;
Section 20	Radio Frequency Susceptibility
SAE AIR 1499 (1992)	5 kHz – 400 MHz
STANAG 4370-504	AECTP 504: Conducted susceptibility
STANAG 4370-522	AECTP 522: Conducted susceptibility

3.4.2.1 ESD

While ESD phenomena have been of concern for many years, generally recognized test procedures are of relatively recent vintage. IEC 1000-4-2 is probably the most popular standard, but C63.16 discusses some of the problems encountered in getting reproducible results. Current research is leading to a better understanding of this phenomenon and its impact on sensitive semiconductor devices.

ANS C63.16 (1994)	Guide for Electrostatic Discharge Test Methodologies and Criteria
IEC 61000-4-2	Electrostatic Discharge Requirements
IEC 15 (Sec) 39	Guide to ESD
IEC 15D/47	Specification for the protection of protective devices: General Requirements
IEC 15D/48	Specification for the protection of protective devices: User Guide
IEC 15D/52	Component testing: Human Body Model (to be included in IEC 1340-4-3)
IEC 15D/53	Component testing: Machine Model (to be included in IEC 1340-4-3)
IEC 15D/54	Component testing: Charged Device Model (to be included in IEC 1340-4-3)
MIL-HDBK-263A	ESD control
MIL-STD-1686B	ESD
STANAG4370-511	AECTP 511: Electrostatic discharge susceptibility (System Testing)
STANAG4370-529	AECTP 529: Electronic discharge susceptibility

3.4.2.2 Fast Transients

Fast transients occur when switches are opened on individual equipments which contain a large equivalent inductance in series with the switch. They consist of a rapid series of very fast rise time pulses having a high peak voltage. In contrast surges arise on high voltage lines either from lightning (either a direct hit or a near miss, of from high voltage switching that may occur or not because of lightning. The rise time is slower than that of the fast transient and it may occur only once as the result of a single incident. Oscillatory waves may be associated with surge phenomena when there are points on the transmission line at which significant reflections can occur.

ANS C63.15: CI-8	Power Line Surge Voltage and Fast Transient Test
IEC 60255-22-4 (1992)	Electrical disturbance tests for measuring relays and protection equipment Section 4: Fast transient disturbance test
IEC 61000-4-4 (801 PT 4-88 Part 4)	Electrical Fast Transient/Burst Requirements
IEC 61321-1	Fast transient overvoltages in gas-insulated metal enclosed substations.
MIL-STD-461E: CS115	Bulk cable injection, impulse excitation
RTCA DO-160D, Section 17	Voltage Spike
STANAG 4370-507	AECTP 507: Susceptibility to transients from switching

3.4.2.3 Surges

ANS C62.41 (1990)	Guide for Surge Voltages in Low-voltage AC Power Circuits
ANS C62.45 (1987)	Guide on Surge Testing for Equipment Connected to Low-voltage AC Power circuits.
ANS C63.15: CI-8	Power Line Surge Voltage and Fast Transient Test
IEC 61000-4-5	Surge Immunity Test
STANAG 4370-509	AECTP 509: Susceptibility to transients from lightning
STANAG 4370-526	AECTP 526: Susceptibility to transients from NEMP induction
STANAG 4370-527	AECTP 527: Susceptibility to transients from lightning

3.4.2.4 EMP

The two major sources of EMP considered in the standards are lightning & nuclear detonation. Both deliver a large amount of energy in an initial pulse and smaller amounts in subsequent pulses, with slight differences in the frequency spectrum between the two. 1000-5-3 compares protection concepts for the two sources and concludes that they are about the same. 1000-4-25 is still under development and it is expected to refer to 1000-4-12 for the conducted test and 1000-4-20 for the radiated test.

IEC 61000-4-12	Oscillatory Waves Immunity Test
IEC 61000-4-25	EMP requirements for equipment & systems
IEC 61000-5-3	EMP protection concepts
MIL-STD-461E: CS116	Damped Sinusoidal Transients, Cables and Power Leads, 10 kHz to 100 MHz

RTCA DO-160D	
Section 22	Lightning Induced Transient Susceptibility
Section 23	Lightning Direct Effects (under development)
STANAG 4370-508	AECTP 508: Susceptibility to transients from NEMO induction

3.4.2.5 Radiated measurements

ANS C63.15: RI-1	Uniform Magnetic Field Immunity, Helmholtz Coil, 30 Hz to 30 kHz
ANS C63.15: RI-2	Magnetic Field Immunity, Point Source, 30 Hz to 30 kHz
ANS C63.15: RI-3	Power frequency Magnetic Induction Field
ANS C63.15: RI-4	Spikes, Inductive Field Immunity
ANS C63.15: RI-5	Electric Field Immunity, 10 kHz to 80 MHz
ANS C63.15: RI-6	Electric Field Immunity, 80 MHz to 10 GHz
IEC 61000-4-3	Radiated Electromagnetic Field
IEC 61000-4-8	Power frequency
IEC 61000-4-20	TEM cells (see 77B/153/CD)
IEC 61000-4-21	Mode stirred chambers (see 77B(Secretariat)140)
MIL-STD-461E: RS101	Magnetic Field, 30 Hz to 100 kHz
MIL-STD-461E: RS103	Electric Field, 10 kHz to 40 GHz
MIL-STD-461E: RS105	Transient Electromagnetic Field
RTCA DO-160D	
Section 19	Induced Signal Susceptibility
Section 20	Radio Frequency Susceptibility
SAE AIR 1209-74	Parallel plate trans. line

3.4.3 Radiated measurements

STANAG 4370-503	AECTP 503: Radiated susceptibility
STANAG 4370-510	AECTP 510: Magnetic susceptibility
STANAG 4370-521	AECTP 521: Radiated susceptibility
STANAG 4370-523	AECTP 523: Radiated susceptibility
STANAG 4370-528	AECTP 528: Magnetic susceptibility

3.4.3.1 EMP

See comments in the conducted section.

IEC 61000-4-20	EMP radiated tests
IEC 61000-4-25	EMP requirements for equipment & systems
IEC 61000-5-3	EMP protection concepts

3.4.3.2 Hazardous Fields

Hazardous Fields are those that can have a deleterious effect on biological matter or cause detonation or ignition of life threatening armaments or other hazardous materials. The C95 publications are concerned with biological effects, whereas the IEC publication specifies a warning sign to be placed on equipment capable of generating such fields.

ANS C95.3-91	Rec practice-meas. of hazardous fields
IEC 417L	Symbol 5140
NUSC Technical Memo 901219	A Compendium of Biological Effects of ELF Fields

3.5 Shielding and Filtering

SAE AIR 1173-75	Shielding chars. of EMI gaskets
SAE ARP 1285	Test procedure for meas. shielding effectiveness of electrical connectors and associated hardware
SAE ARP 1705-81	Meas. of shielding properties of EMI gasket mat'ls

4.0 Generic & other Broadly Applicable Limit Standards

Generic standards usually specify limit values that are to be applied if there are no specific equipment standards. The measurement techniques, where possible, are chosen from, or adaptations of, Basic standards. Other broadly applicable standards are characteristic of many emission limit standards typically generated by the CISPR and TC77. In some cases they may be identified as Product-Family standards and as such may be listed here or, if of a more restricted applicability, under specific products in Section 5 of this listing.

ANS C63.12	Limits-Recommended practice
ANS C95.1-91	Limits for human exposure 3 khz to 300 GHz
CISPR 28-1	Generic Emission Standard: Residential
CISPR 28-2	Generic Emission Standard: Industrial
CLC EN 50081-1	Generic Emission Standard: Residential, Commercial, and Light Industry
CLC EN 50081-2	Generic Emission Standard: Heavy Industry
CLC EN 50082-1	Generic Immunity Standard: Residential, Commercial, and Light Industry
CLC EN 50082-2	Generic Immunity Standard: Heavy Industry
DoD-STD 1463	Munitions to EM Fields, Requirements for evaluation of
FCC CFR 15	RF Devices
FCC CFR 18	Industrial Scientific & Medical Equipment

IEC 60827 (1985)	Guide to voltage fluctuations limits for household appliances (relating to IEC 1000-3-3)
IEC 61000-1-2	(in preparation) EMC and Functional Safety (see 77/223/Q)
IEC 61000-3-2	Power frequency harmonics (<16A)
IEC 61000-3-3	Voltage fluctuations (<16A)
IEC 61000-3-4	Harmonic limits > 16 A
IEC 61000-3-5	Voltage fluctuations (S 16A)
IEC 61000-3-6 (see 77A/135/CDV)	Harmonic limits: medium, and high voltage equipment
IEC 61000-3-7 (see 77A/136/CDV)	Voltage fluctuation limits: medium, and high voltage equipment
IEC 61000-3-8 (77B/170/CDV)	Signaling on LV power lines
IEC 61000-3-9	Interharmonics
IEC 61000-3-10	Limits 2-9 kHz
IEC 61000-6-3	Generic Emission Standard: Residential
IEC 61000-6-1	Generic Immunity Standard: Residential
IEC 61000-6-2	Generic Immunity Standard: Industrial
IEC 61000-6-3	Generic Emission Standard: Industrial
IEC 61000-6-1(1997)	Generic Standards – Section 1: Immunity for residential, commercial, and light-industrial environments:
IEC 61000-6-2(1999)	EMC – Part 6-2: Generic Standards – Immunity for industrial environments
IEC 61000-6-3(1996)	EMC – Part 6: Generic Standards – Section 3: Emission standards for residential commercial and light industrial environments
IEC 61000-6-4(1997)	EMC – Part 6: Generic Standards – Section 4: Emission standard for industrial environments
IEC 61000-6-5 Ed. 1	(in preparation) EMC – Part 6-5: General Standards – Immunity for power stations and substation environments (77/215/CD
MIL E 6051D	Systems EMC requirements
MIL-STD-449D	Emission spectrum characteristics
MIL-STD-461E	Emission and Susceptibility Limits
MIL STD 464 (1997)	Electromagnetic environmental effects requirements for systems
MIL STD 1512	Electro-explosive systems
STANAG 1233	Procedures for RADHAZ control in ports and the Territorial Sea (CU:FR)
STANAG 1305	RADHAZ procedures for receiving aircraft of other nations on NATO air capable ships (CU:FR)
STANAG 1308	RADHAZ to ships personnel during helicopter (and VSTOL aircraft) operations on ships (CU:FR)
STANAG 1379	NATO RADHAZ warning sign (CU:CA)
STANAG 1380 AECP-2	Naval interoperational procedures to control the radio and radar radiation hazards

STANAG 1397	RADHAZ classification of munitions and weapons
STANAG 4234	EM radiation (RF) 200 kHz – 40 GHz environment – affecting the design of material for use by NATO forces
STANAG 4237	EEDs
STANAG 4238	Design principles for hardening munitions/weapon systems against EME
STANAG 4274	Standard description for the presentation of vulnerability analysis
STANAG 4324	EM radiation (RF) test information to determine the safety and suitability for service of EEDs and associated electronic systems in weapons and munitions systems
STANAG 4370-525	AECTP 525: Self-compatibility

5.0 Product Standards

5.1 Agricultural & forestry machines

ISO/FDIS 14982	Agricultural & forestry machines – EMC

5.2 Alarm Systems

CISPR 14-1 (1993)	EMC – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission product family standard
IEC 60839-2-4	Ultrasonic doppler detectors, Environmental tests
IEC 60839-2-5	Microwave doppler detectors, Environmental tests
IEC 60839-2-7 (TC79)	Passive glass-break detectors: spikes, ESD, EM fields
IEC 60839-5-2	Gen'l req'ts Spike, ESD, EM Fields immunity (see 839-1-3)
IEC 60839-5-5	Digital communicator systems using public telephone network, ESD only
IEC 60839-5-6	Voice communicator systems using public telephone network, ESD only

5.3 Appliances & Lighting Equipment

CISPR 14 & 15 are widely used and are often referred to in other IEC standards for measurement techniques.

BS 800-1988	Specification for radio interference limits and

	measurements for household appliances, portable tools and other electrical equipment causing similar types of interference
BS 6345-1983	Methods for measurement of radio interference terminal voltage of lighting equipment
CISPR 14-1 A1 (96)	Amendment 1
CISPR 14-1 A2 (98)	Amendment 2
CISPR 14-2 (1997)	EMC – requirements for household appliances, electric tools and similar apparatus – Part 2: Immunity – Product family standard
CISPR 15	Lighting equipment
DIN-VDE 0872 PT 1-88	Appliance Interference
DIN-VDE 0875 PT 208-89	Portable Tools Interference
IEC 60730-1 Ed. 3.0 (in preparation)	Automatic electrical controls for household and similar use – Part 1: General requirements (72/417/RVD)
IEC 61000-3-2 Amend. 1	Air conditioners, vacuum cleaners
IEC 61000-3-3	Lighting equipment
MIL STD 1337B	Suppression requirements for portable tools
STANAG 4236	Lighting

5.4 Cabled Distribution Systems

728-1 Amend. 2 describes measurement procedures for sound & tv systems

IEC 60728-1 Amend. 2	Radiation emission memo 30 MHz to 1 GHz

5.5 Capacitors

EIA 60361-90	Feed through RI capacitors
IEC 60384-14 & Amend. 1 (1995)	Fixed capacitors for EMI suppression and connection to the supply mains
MIL-C-11693C	Feed through capacitors
MIL-F-15733G	RFI Filters and capacitors
SAE ARP 936-89	RF Capacitor for EMI meas.

5.6 Controls

The main standards are 730-1, 947-5-1, and 1131-2 for programmable controllers. The 801-x series for industrial measurement & control process equipment are now replaced by the 1000-4-x Basic EMC series. See section 3 for descriptions of the 1000-4-x series.

IEC 60654-2, Amend. 1	Operating conditions for industrial-process measurement and control equipment. Power
IEC 60730-1 (1993)	Controls for household use: General requirements
IEC 60730-2-3 (1990)	Thermal protectors for fluorescent lamps
IEC 60730-2-6, Amend 1	Immunity to mains borne perturbations, magnetic and

	EM interference (TC72)
IEC 60730-2-7 (1990)	Timers and time switches
IEC 60730-2-8	Water valves: fast transients (TC72)
IEC 60730-2-11	Energy regulators (TC72) (see 2-6 above)
IEC 60730-2-15	Water level sensors (TC72) (see 2-6)
IEC 60947-2	Circuit breakers, refers to 1000-4-2, -4-3, -4-4
IEC 60947-5-1	Appendix H: Electromechanical control circuit devices (SC17B): RF fields, ESD, fast transients, impulse volt.
IEC 60947-5-2 (1992)	LV Proximity Switches
IEC 60955 (1989)	Process data highway, Type C (Proway C) for distributed process control system
IEC 61131-2 (1992)	Programmable controllers: Equipment requirements and tests
IEC 61225 (1993)	Nuclear power plants - Instrumentation and control systems important for safety –Requirements for electrical supplies
IEC 61298-3 (65B(Sec)198)	Measurement & control devices: tests for effects of influence quantities
IEEE 367-1987	Recommended Practice for determining the electric power station ground potential Rise and induced voltage from a power fault
IEEE 518-90	guide on minimization of noise to controllers
ISO/DIS 10296 (1990)	Aircraft hybrid remote power controllers

5.7 Earth-moving machinery

ISO/DIS 13766	Earth moving machinery – EMC

5.8 Enclosures

IEEE 299-91	Meas. of SE of shielding enclosures
MIL-STD-108E	Enclosures

5.9 Engines

SAE AIR 1147	EMI on A/C from jet engine charging
SAE AIR 1423-77	EMC on gas turbine engines
SAE AIR 1425-78	Achieving EMC of gas turbine accessories

5.10 Field Disturbance Sensors

IEEE 475-83	Field dist. sensors

5.11 Filters

ANS C63.13-1991	Guide on the application and evaluation of EMI power line Filters for Commercial Use.
BSI BS-6299-1982	Meas. of RI Filters
BSI BS-9121-1988	RI suppression filters
CISPR 17 (1981)	Methods of meas. of the suppressed characteristics of passive radio interference filters and suppression components.
EIA 416-81	RI filters
IEC 60384-14-1 (1993)	Fixed capacitors for EMI suppression: Blank detail specification
IEC 60940-88	Filters and Filter Components
MIL-F-28861B	EMI Filters
SAE ARP 1172-72	Filters for EMI reduction

5.12 Fuses

IEC 60269-1 Amend. 1	EMC Requirements
IEC 60282-1 Amend 2 (1985)	High voltage fuses. Part 1: circuit limiting fuses
MIL-STD-331B	Fuses

5.13 ITE

ITE does not include equipment which primarily transmits or receives according to the ITU Radio Regulations. Information equipment which are intended for use in the medical services are also covered in IEC 601-1-2.

CISPR 20	Immunity char. of sound & TV
CISPR 22	Disturbance char. Of ITE
CISPR 24 (1992)	Immunity of ITE: ESD requirements
[CISPR-G(CO)20]	
CISPR G/93/CDV	Amendment to CISPR 22
CLC pr EN 55101-2	ITE (including Telecom): ESD
CLC pr EN 55101-3	ITE (including Telecom): Radiated fields
DIN VDE 0871 PT 100	ITE
DIN-VDE 0872 PT 4-87	Interference Immunity Requirements for Video Equipment
DIN-VDE 0878 PT 30-89	ITE
IEC 60601-1-2	EMC for medical eq. & Info. Tech. Eq. used in medical applications

5.14 ISM

5.14.1 General ISM

CISPR 11 describes measurements primarily from 150 kHz to 1 GHz and is frequently referred to by other standards. CISPR 23 describes the rationale behind the limits and deals only with frequencies outside the ITU bands and does not include consideration of data processing equipment.

CISPR 11	EMI from ISM
CISPR 23	Determination of limits for ISM
CISPR 28 (1997)	Industrial scientific and medical equipment (ISM) – Guidelines for emission levels within the bands designated by the ITU
CSA C108.6-M91	Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific, and medical (ISM) radio – frequency equipment
DIN VDE 0871	ISM
DIN VDE 0871 PT1	ISM
DIN VDE 0871 PT 2A2	ISM
DIN VDE 0871 PT 11	ISM
IEEE 139-93	Meas. ISM emissions
NEMA ICS 11 (1995)	EMC for industrial process measurement and control equipment

5.14.2 Industrial Equipment

BS 4809-1981	Radio interference limits and measurements for radio frequency heating equipment
MIL DTL 62062D	Blower, Generator cooling 28 Volt DC
IEEE 140-90	Minimization of interference fm RF heating equip.

5.14.3 Medical equipment

IEC 601-1-2 contains general EMC requirements for electromedical equipment. Typically, emission standards are those called out in CISPR 1. Immunity requirements cover EM fields in the range 26 MHz to 1 GHz, transients, ESD, pulses, bursts, clicks, and voltage surges.

IEC 60118-1	Hearing aids with induction pickup coil
IEC 60118-2	Hearing aids with automatic gain control
IEC 60118-13	Hearing aids – Part 13: EMC
IEC 60601-1-2	EMC for medical eq. & info. Tech. eq. used in medical applications
IEC 60601-2-1	Medical electron accelerators 1 MeV to 50 MeV: General requirements
IEC 60601-2-2 (1991)	High frequency surgical equipment (in stand-by only)(–>

	CISPR 11)
IEC 60601-2-3 (1991)	Short-wave therapy equipment (–> CISPR 11)
IEC 60601-2-22	Diagnostic & therapeutic laser equipment: (no requirements present)
IEC 60601-2-31	External cardiac pacemakers w/internal power source: ESD (SC62D)
IEC 60601-2-32	X-ray equipment: –> 601-2-1
IEC 29/303	EMC for TC 29 Standards
IEC 60651 A2 Ed. 1	Amendment to IEC 60651(1979) Sound level meters – Electromagnetic and electrostatic compatibility requirements and test procedures
IEC 60804 A2 Ed. 1	Amendment to IEC 60804(1995) Integrating averaging sound level meters – Electromagnetic and electrostatic compatibility requirements and test procedures
IEC 60942 A1 Ed. 2	Amendment to IEC 60942(1997) Sound calibrators – Electromagnetic and electrostatic compatibility requirements and test procedures
IEC 61252 A2 Ed. 1	Amendment to IEC 61252 (1993) Personal sound exposure meters – Electromagnetic and electrostatic compatibility requirements and test procedures
IEC 61260(1995) Ed. 1	Amendment to IEC 61260 (1995) Octave-hand and fractional octave band filters – Electromagnetic and electrostatic compatibility requirements and test procedures

5.14.4 Scientific Equipment

BS 6667-1985	EMC requirements for industrial process control instrumentation
IEC 61000-3-3 Amend.	professional equipment

5.15 Marine Navigational Equipment

IEC 60945 (TC80)	conducted audio, & RF; power line transients; EM fields: ESD
IEC 61097-2 *	(sat. emergency position)
IEC 61097-4 *	(INMARSAT-C)
IEC 61097-6 *	(Glob. Mar. Distress & Safety):(TC80)

* All Ref. IEC 945

5.16 Microwave Ovens

TEP-171 (1981)	Recommended practice for the measurement and warning of radio frequency leakage from microwave tubes
CISPR 19 (1983)	Guidance on the use of the substitution method for method of measurements of radiation from microwave ovens for frequencies above 1 GHz.

5.17 Motors

IEC 60034-15	Impulse voltage withstand levels of AC machines with form-wound stator coils
IEC 61000-3-2 Amend.	

5.18 Motor Vehicles

ANS/EIA-152C (98)	Minimum standards for land mobile communication, FM or PM transmitters, 25 to 866 MHz
BS 833-1985	Radio interference limits and measurements for the electrical ignition systems of internal combustion engines
CISPR 12	EMI of vehicles, boats, & spark-ignited engines
CISPR 25	Limits & Meas. Methods of EMI for protection of receivers used on vehicles
CSA C108.4-M92	Motor vehicles
DIN-VDE 0879 PT 1-88	Ignition Interference
DIN-VDE 0879 PT 3-81	Interference to On-board Reception
IEC 60605-3-5 (1986) [IEC 56(CO)120]	Equipment installed inside ground vehicles
ISO 7637-0: 1990	Road vehicles – Electrical disturbance by conduction & coupling – Part 0: defs. & general
ISO 7637-1: 1990	Road vehicles – Electrical disturbance by conduction & coupling – Part 1: Passenger cars & light commercial vehicles with nominal 12V supply (electrical transient conduction along supply lines only)
ISO 7637-2: 1990	Road vehicles – Electrical disturbance by conduction & coupling – Part 2: Commercial vehicles with nominal 24V supply (electrical transient conduction along supply lines only)
ISO 7637-3: 1995	Road vehicles – Electrical disturbance by conduction & coupling – Part 3: Vehicles with nominal 12V or 24V supply (transient transmission by capapcitive and inductive coupling via lines other than supply lines)
ISO/TR 10305: 1992	Road vehicles – Generation of standard EM fields for calibration of power density meters (20 kHz – 1000 MHz)
ISO 11451-1: 1995	Road vehicles – Electrical disturbances by narrowband radiated EM energy – Vehicle test methods – Part 1: General & definitions
ISO 11451-2: 1995	Road vehicles – Electrical disturbances by narrowband radiated EM energy – Vehicle test methods – Part 2: Off-vehicle radiation source
ISO 11451-3: 1995	Road vehicles – Electrical disturbances by narrowband radiated EM energy – Vehicle test methods – Part 3: On-board transmitter simulation
ISO 11451-4: 1995	Road vehicles – Electrical disturbances by narrowband

	radiated EM energy – Vehicle test methods – Part 4: Bulk current injection
ISO 11452-1: 1995	Road vehicles – Electrical disturbances by narrowband radiated EM energy – Component test methods – Part 1: General & defs.
ISO 11452-2: 1995	Road vehicles – Electrical disturbances by narrowband radiated EM energy – Component test methods – Part 2: Absorber-lined chamber
ISO 11452-3: 1995	Road vehicles – Electrical disturbances by narrowband radiated EM energy – Component test methods – Part 3: TEM cell
ISO 11452-4: 1995	Road vehicles – Electrical disturbances by narrowband radiated EM energy – Component test methods – Part 4: Bulk current injection
ISO 11452-5: 1995	Road vehicles – Electrical disturbances by narrowband radiated EM energy – Component test methods – Part 5: Stripline
ISO 11452-6: 1995	Road vehicles – Electrical disturbances by narrowband radiated EM energy – Component test methods – Part 6: Parallel plate antenna
ISO 11452-7: 1995	Road vehicles – Electrical disturbances by narrowband radiated EM energy – Component test methods – Part 7: Direct RF power injection
SAE ARP 1393	EMC and Interference Control for Rapid Transit Vehicles
SAE J551-2	Limits & Meas. Methods of interference from vehicles, motorboats, and spark-ignited engine driven devices
SAE J551-4	Limits & Meas. Methods of interference from vehicles & devices broadband & narrowband (150 kHz – 1000 MHz)
SAE J551-5	Performance levels & Methods of Meas. of magnetic & electric vehicles, broadband 9 kHz – 30 MHz
SAE J551-11	Vehicle EM Immunity: Off-vehicle source
SAE J551-12	Vehicle EM Immunity: On board transmitter simulation
SAE J551-13	Vehicle EM Immunity: Bulk current cable injection
SAE J551-14	Vehicle EM Immunity: Reverberation chamber
SAE J551-15	Vehicle EM Immunity: ESD
SAE J1113-87	Immunity meas. proc. vehicle components Emissions – Parts 1,21,42 Immunity – Parts 2-4,11-13,22-27
SAE J1338-81	Whole vehicle radiated susceptibility
SAE J1407-88	Vehicle susc. testing using TEM cell
SAE J1816-87	Meas. of radiation from vehicles and device
SAE J551-1(1996)	Performance levels and methods of measurement of EMC of vehicles and devices (60 Hz to 18 GHz)
SAE J551-17(1997)	Vehicle electromagnetic immunity ~ Power line magnetic fields (Ref. J551-1)
SAE J1448 (1995)	Electromagnetic susceptibility measurements of vehicle

	components using TEM cells (14 kHz – 200 MHz) (cancelled: 01 Jul 1995)
SAE J1547 (1995)	Electromagnetic susceptibility procedure for common mode injection (1 ~ 400 MHz), Module Testing (cancelled: 01 July 1995)
SAE J1752-1 (1997)	EMC measurement procedure for integrated circuits – Integrated circuit EMC measurement procedures – General and Definitions
SAE J1752-2 (1995)	EMC measurement procedures for integrated circuits – integrated circuit radiated emissions diagnostic procedure 1 MN2 to 1000 MHz Magnetic field – Loop probe
SAE J1752-3 (1995)	EMC measurement procedures for integrated circuits – Integrated circuit radiated emissions measurement procedure 150 kHz – 1000 MHz TEM cell
SAE J1812 (1996)	Functional performance status classification for EMC susceptibility testing of automotive electronic and electrical devices
TR 8.10	Ignition Interference Susceptibility, Measurement Correlation

5.19 Power Supplies

BS 5049-1981	Methods of measurement of radio noise from power supply apparatus for operation at 1 kV and above
BSI BS-5406-1988	Dist. in supplies systems by appliances--harmonics
CIS/B(Sec)62	Requirements for power supply devices
IEC 61131-3 (IEC 22G/31)	EMC product standards for power drive systems
IEC 61204 (1993)	Low-voltage power supply devices dc output-Performance characteristics and safety requirements
IEC 60478-3 (1989)	Stabilized power supplies: dc output, reference levels and measurement of conducted EMI
IEC 60478-5 (1993)	Stabilized power supplies: measurement of the magnetic component of the reactive near field
MIL-HDBK-241-B	EMI reduction in power supplies

5.20 Radiation Hazards

IEC 60657-79	Non-Ionizing Radiation Hazards in the Frequency Range from 10 MHz to 300,000MHz
IEC 12C/222	Measurement of Exposure to EM fields 100 k – 1 GHz.
MIL-STD-1377	Test methods for hazards to ordinance

5.21 Radiation Monitors (SC45B)

IEC 60951-1 (1988)	General requirements
IEC 61005 (1990)	neutron ambient dose equivalent rate meters for use in radiation protection
IEC 61171 (1992)	Monitoring of airborne radioactive iodines 6. 10-Electrical interference
IEC 61283	X, gamma and high energy beta
IEC 61322	Thermal - 15 MeV neutron: volt interrupts, spikes, magnetic and EM fields
IEC 61323	Neutron: external magnetic, EM fields, ESD

5.22 Rail Vehicles

IEC 60571-1 (1990)	Electronic equipment used on rail vehicles: General requirements
IEC 60571-3 (1990)	Components, programmable electronic equipment and electronic system reliability
IEC 9(UK)294 (1990)	Revision of 571-1,2,3-BRB/RIA specification 13/1987 3.6 interference

5.23 Receivers

CISPR 13	EMI from sound & TV receivers
CISPR 20	Immunity meas. for sound & TV receivers
CISPR 21 (1985)	Interference to mobile radio communications in the presence of impulsive noise
CISPR 25	Limits & methods of meas. of EMI for the protection of receivers used on board vehicles
CSA C108.9-M91	Sound and television broadcasting receivers and associated equipment limits and methods of measurement of immunity characteristics
EIA 378-70	Spur. rad. from FM and TV broadcast rcvrs.
EIA 544-1989	Immunity of TV and VCR Tuners to internally generated harmonic interference from signals in the band 535 kHz to 30 MHz
EIA Interim Std no 16A.	Immunity of TV receivers and video cassette recorders (VCRs) to Direct Radiation from Radio transmissions, 0.5 to 30 MHz.
EIA Interim Std no. 31 (1987)	Design Guidelines, Rejection of Educational Interference to Channel 6 TV reception
EIA TIA 204D-89	Min. stds for LM Com FM or PM rcvrs
DIN VDE 0872 PT 1	Rcvrs
DIN VDE 0872 PT 1A1	Rcvrs
IEC 60244-5 (1992)	Methods of measurement for radio transmitters Part 5: Performance characteristics of television transmitters

IEC 60315-7 (1995)	Methods of measurement on radio receivers for various classes of emission Part 7: Methods of measurements on digital satellite radio (DSR) receivers
IEC 60728 A1 (1992)	Cabled distribution primarily intended for sound and television signals operating between 30 MHz and 1 GHz
IEC 61114-1 (1992)	Methods of measurement on radio receivers for various classes of emission. Part 1: Electrical measurements on DBS receiving antenna.
IEEE 187-90	Open field meas. of rcvr. emissions
IEEE 213-93	Cond. rcvr. emission meas. 300 kHz to 25 MHz

5.24 Relays

ANS C37.90.2	Withstand Capability of relay Systems to radiated EMI from Transceivers (Trial Use)
IEC60041(Sec)80 (1991)	Electrical relays, Part 22: ESD tests for measuring relays and protection equipment Section X Limits of radio interference
IEC60041(Sec)81 (1991)	Revision of IEC 60255-22-2 Section 2: ESD tests
IEC60041B(Sec)72 (1990)	EMC of measuring relays and protection equipment
IEC 60255-22-1	Measuring relays & protection eq.: 1 MHz bursts
IEC 60255-22-2	Measuring relays & protection equipment: ESD
IEC 60255-22-3 (1989)	Measuring relays & protection equipment: Radiated EM fields
IEC 60255-22-4 (1992)	Measuring relays & protection equipment: Fast transients
IEC 60730-2-7 A1 (1994)	Motor starting relays
IEC 41B(Sec)80 (1991) (TC 95)	Measuring Relays & protection equipment: Limits of radio interference
IEC 95/14 (1991)	Revision of IEC 255-22-2: ESD tests
ISO 5867-1: 1996	Aircraft: Electromagnetic relays & contactors, Part 1: General Requirements

5.25 Ripple Control Receivers

IEC 61037 (1990)	Electronic control receivers for tariff and load control

5.26 Robots

ISO/TR 11062: 1994	Manipulating industrial robots – EMC test methods and performance evaluation criteria – guidelines.

5.27 Rotating Electrical Machines

IEC 60034-15	Impulse withstand (Ref. pub 60-1)

5.28 Semiconductor convertors

IEC 60092-304	(Elect. install. in ships) Amend.1 [calls for limited distortion of power waveform
IEC 60146-1-2	General requirements Part 1-2 Application guide
IEC 60870-6-2(1995).	EMC Telecontrol equipment and systems - Part 6: Telecontrol protocols compatible with ISO standards and ITU-T recommendations - Section 2: Use of basic standards (OSI layers 1-4)
NEMA WD2	Semiconductor dimmers for incandescent lamps

5.29 Site survey

IEEE 473-85

5.30 Switches

IEC 60669-1	(household -- SC23B) no requirem'nts !
IEC 60694 Ed. 2.0	Common specifications for high voltage switchgear and control gear standards
IEC 60694 Amend. 3 (1995)	Common clauses for high voltage switchgear and control gear standards. EMC tests
IEC 60669-2-1 (SC23B)	Electronic: emis. – IEC 555, CISPR 14: imm. 1000V surges & supply interruptions
IEC 60730-2-7 (1990)	Automatic electrical controls for household and similar use Part 2: Particular requirements for timers and time switches
IEC 60947-2	Circuit breakers, Appendix F: EMC tests
IEC 60947-3 [17B(Sec)414] (1990)	Switches, disconnectors, fuse combination units: EMC requirements
IEC 60947-5-1 (1994)	Electromechanical control circuit devices
IEC 60947-5-2 (1992)	low voltage switchgear and controlgear Part 5. Control circuit devices and switching elements Section 2: Proximity Switches
IEC 61038 (1990)	Time switches for tariff and load control
IEC 61321-1 (1994)	Meas. systems for very fast transient overvoltages generated in gas-insulated metal enclosed substations.

5.31 Telephone and Telecom Equipment

FCC Part 68,	telephone interconnect

IEC 60870-1-2 (1989)	Telecontrol equipment and systems Part 1: General consideration Sec 2: Guide for specification
IEC 60870-2-1 (1995)	Telecontrol power supply & EMC
IEC 61085 (1990)	Telecommunication services for electric power systems 3.2 EMC
IEEE 1027-1984	Draft Trial Use Method for meas. the magnetic field Intensity around a telephone receiver (COMSOC) [SH09497]

5.32 Transmitters

EIA TIA 316C-90	Pers radio trans.
IEC 60244	Transmitters
IEC 60244-5 (1992)	Radio transmitters: Performance characteristics of television transmitters
IEC 60244-11 (1989)	Radiocommunication Transmitting equipment: Methods of meas. for radio transposers
IEEE 377-86	meas. emission from LM communication trans.

5.33 Video tape recorders

EIA Interim Std no 16A.	Immunity of TV receivers and video cassette recorders (VCRs) to Direct Radiation from Radio transmissions, 0.5 to 30 MHz.
IEC 61237-3	Power supply interference (SC 60-B)

5.34 Wheelchairs

ISO/WD 7176-21	Wheelchairs – Part 21: Requirements & test methods for EMC of powered wheelchairs and motorized scooters

6.0 Communication Related Standards

CEPT T/R 70-01E 72	Mutual int bet. broadcast & mobile service
CLC ETS 300126	EMC requirements for ISDN
CLC ETS 300127	Radiated emissions testing of physically large systems
CSA Pkg. 3300 (1998)	Telecommunications package
CSA RIR-2	Radio interference regulations of Canada
CSA T512-M91	Functional and compatibility requirements for private branch exchange (PBX) switching equipment for voiceband applications
DIN-VDE 0878 PT 1-86	Radio Interference Suppression of Telecommunications Systems and Apparatus

DIN-VDE 0878 PT 200-87	Radio Interference Suppression of Telecommunications Systems and Equipment
EIA TSB 10E-90	Int. criteria microwave systems
IEC 60489-2	Mobile radio eq.: transmitters employing A3E, F3E, G3E emissions
IEC 60489-3	Mobile radio eq.: receivers A3E, F3E, G3E
IEC 60489-4	Mobile radio eq.: transmitters single-sideband emissions (R3E, H3E, J3E)
IEC 60489-5	Mobile radio eq.: receivers (R3E, H3E, J3E)
IEC 61079-2 (1992)	Radiocommunication, Receiving equipment-Part 2: Electrical meas. on DBS tuner units
IEC 61097-2 (TC80)	[Global maritime distress & safety - emergency position. Emis.: see 3.5 of IEC 945. Imm.: see 4.5.8 of IEC 945.
IEC 61097-6	[Global maritime distress & safety] -- Interference and co-channel rejection; Intermod. (TC80)
IEC 61149 TR2 (1995)	Guide for safe handling and operation of mobile radio equip.
IEC 61733-1 (1995)	Measuring relays & protection eq.: protection communication interfacing, general info.
ANS C63.17-	Methods of measurement of electromagnetic & operational compatibility of unlicensed personal communication services (UPCS) devices
DO-163 (1976)	Minimum performance standards of high frequency radio communications transmitting and receiving equipment operating within the radio frequency range of 1.5 MHz to 30 MHz
RTCA DO-176-84	FM int. to airborne comm.

Additional ETSI Standards may be found in Table 4 of Annex B1

7.0 Systems Standards

The primary standards covering military systems are

CSA C108-8 (1983)	Electromagnetic emissions from data processing equipment and electronic office machines
MIL-STD-464	Interface Standard for E3 Requirements for Systems

At the present time there are no comparable commercial system standards except at the product specific level

7.1 Digital Systems

BS 6527-1988	Specification for limits and measurement of radio interference characteristics of information technology equipment
MIL HDBK 272A	Nuclear weapon systems, safety design and evaluation criteria for

MIL-STD-1397C	Digital data interfaces

7.2 Nuclear Systems

IEC 61225 (1993)	Nuclear power plants - Instrumentation and control systems important for safety-Requirements for electrical supplies

7.3 Power Systems

ANS C63.13 (1991)	Guide on the application and evaluation of EMI power line Filters for Commercial Use.
CSA C108.3.1-M84	Limits and measurement methods of electromagnetic noise from a AC power systems, 0.15-30 MHz (1993)
CISPR 18-1 (1982)	Radio interference characteristics of overhead power lines and high voltage equip. Part 1:Description of phenomena
CISPR 18-2 (1986)	Part 2: Methods of measurements and procedures for determining limits
CISPR 18-3 (1986)	Part 3: Code of practice for minimizing the generation of radio noise.
IEC 60353 (1989)	Line traps for ac power traps
IEC 60664-1 (1991)	Insulation co-ordination with low-voltage systems Pt. 1 Principles, requirements, & tests
IEC 60664-2-1(1997)	Insulation co-ordination with low-voltage systems, Pt. 2 Application Guide, Section 1: Dimensioning procedure worksheets and dimensioning examples
IEC60664-2-2 (in preparation)	Insulation co-ordination with low-voltage systems, Pt. 2 Application Guide, Section 2: Interface requirements and transient overvoltage control means (28A(Sec.)88/CD)
IEC 60664-2-3(1999)	Insulation co-ordination with low-voltage systems, Pt. 2 Application Guide, Section 3: Explanation to the environmental catagories
IEC 60664-3(1991)	Insulation co-ordination with low-voltage systems, Pt. 3: Use of coating to achieve insulation coordination of printed board assemblies
IEC 60664-4(1997)	Insulation co-ordination with low-voltage systems, Pt. 4: Consideration of high-frequency voltage stress
IEC60664-5 (in preparation)	Insulation co-ordination with low-voltage systems, Pt. 5: A comprehensive method for determining clearances and creepage distance up to 2 mm (28A/143/CD)
IEC 60664-1	Insulation co-ordination with low-voltage systems
IEC 60664-3	Use of coatings to achieve insulation co-ordination
IEC 60722 (1982)	Guide to lightning impulse & switching impulse testing of power transformers & reactors
IEC 60790 (1984)	Impulse oscillations
IEC 61000-3-5	Limitations on Flicker for equipment with current >16A.
IEC 61643-12 Ed. 1.0	Specification for surge arresters for LV distribution systems (37A/69/CDV)
IEC 61644-1 (Draft)	Surge protection devices connected to telecommunication

	and signaling networks
IEC 42(CO)43 (1990)	Digital Recorders for HV impulse tests
IEEE 368-1977	Recommended Practice for the meas. of electrical noise and harmonic filter performance of high-voltage direct current systems [SH07021]
IEEE 430-91	Int meas. overhead power lines
IEEE 469-1988	Recommended Practice for voice-frequency electrical-noise tests of distribution transformers (COMSOC) [SH12328]
IEEE 587 (ANS C62.41)	power line transients
IEEE 644-87	Meas. of fields from power lines
IEEE 776-1993	Guide for inductive coordination of electric supply and communication lines.
MIL-STD-704E	Electrical Power
NEMA 107	Radio Influence Voltage of HV Apparatus, Measurement method

7.4 Radar Systems

DO-189 (1985)	Minimum operational performance standards for airborne distance measuring equipment operating in the frequency range of 960-1215 MHz
MILHDBK293 (1987)	Countermeasures in radar system acquisition
MILSTD469B (1999)	Radar engineering interface requirements, EMC metric
STANAG1380 AECP-2	Naval interoperational procedures to control the radio and radar radiation hazards

7.5 Signaling Systems

CLC EN 50065-1	Signaling on LV elect install.
DIN-VDE 0875 PT 3-88	Radio Interference of Electrical Systems and Special Electrical Appliances
IEC 61000-3-8	(see 77B/170/CDV) signaling on mains systems

7.6 SAE AIR 1221-71 EMC system design checklist

7.7 Ships Systems

IEC 60533 Ed. 2.0 (1999)	Electrical & electronic installation in ships – EMC (18/870/FDIS)
BS 1597-1985	Specification for limits and methods of measurement of electromagnetic interference generated by marine equipment and installations
BSI BS-5620-1975	Code of pract. for RI suppression of marine vehicles
IEC 60092-504	Electrical installations in ships: Control and instrumentation

IEC 60092-304	[see semiconductor convertors]
IEC 60533	EMC of electrical & electronic systems in ships
MIL-HDBK-235-1A	EMI free system procurement
MILHDBK237B (1997)	Electromagnetic environment effects on platforms, systems, and equipment (1997)
MIL-HDBK-253	EMI design for prot. against EM energy
MIL-HDBK-294 (1986)	Countermeasures in naval communications systems
MIL-STD-1310G	Shipboard bonding, grounding, and other techniques for EMC and safety
MIL-STD-1399-300A	Shipboard electric power systems
MIL-STD-1399A-408	HERP
MIL-STD-1605	EMI survey
STANAG 1305	RADHAZ procedures for receiving aircraft of other nations on NATO air capable ships (CU:FR)
STANAG 1308	RADHAZ to ships personnel during helicopter (and VSTOL aircraft) operations on ships (CU:FR)
STANAG 4435	(1993) Electromagnetic compatibility testing procedure and requirements for Naval electrical and electronic equipment (surface ships, metallic hull)
STANAG 4436	Electromagnetic compatibility testing procedure and requirements for naval electrical and electronic equipment (surface ships, non-metallic hull)
STANAG 4437	(1994) Electromagnetic compatibility testing procedure and requirements for naval electrical and electronic equipment (submarines)

7.8 Air & Space Systems

The primary military standard covering airborne , ground and support systems is MIL-STD-464 (formerly MIL-STD-1818). It places general requirements on overall systems including the application of MIL-STD 461E to equipment, grounding, lightning protection, static discharge protection, etc. It also requires the establishment of EMC Advisory Boards to oversee the application of the proper control techniques. It also specifies the EM environment in which the systems shall operate.

In the commercial arena DO-160D is probably the most similar specification, along with documentation produced by ARINC. The ARINC documents specify limit values referenced to DO-160D with especially high values of electric fields for some exposed components, and also construction practices to achieve optimum performance.

ARINC Project No. 650	Modular Avionics Packaging & Interfacing
ARINC Project No. 654	Design Guidelines
JIS W 2009	Bonding elect. & lightning protection for aero, systems
JIS W 7005	EMC requirements for aero. systems
MIL B 85584 (1999)	Battery relay control unif, aircraft

MIL HDBK 274 (1990)	Grounding for aircraft safety
MIL HDBK 335 (1992)	Em radiation hardness for airlauched ordinance systems
MIL-STD-464	Interface Standards for E3 Requirements for Systems
MIL STD 1541A	EMC requirements for space systems
MIL STD 1542B	EMC & grounding requirements for space system facilities
MIL-STD-1757A	Lightning qualification test techniques for aerospace vehicles and hardware
RTCA DO-160D	
SAE ARP 1870-87	Aero. bonding & grounding for EMC and safety
SAE ARP 4242	
STANAG 3516 AE	Electromagnetic interference and test methods for aircraft electrical and electronic equipment
STANAG 3614 AE	Electromagnetic Compatibility (EMC) of aircraft systems Ed. 3
STANAG 3659 AE	Electrical bonding requirements for metallic aircraft
STANAG 3856 AE	Protection of aircraft crew and subsystems in flight against the effects of electrostatic charges – AEP 29

8.0 Lightning, EMP, & ESD

ANS C62.2-87	Appl.of gapped SiC Surge arresters
ANS C63.16	Guide for ESD Methodologies Criteria
CSA B72-87	Install code for lightning prot. systems
DIN-VDE 0185 PT 1	Lightning protection system; general
DIN-VDE 0185 PT100	Lightning protection structures
DIN-VDE 0185 PT 2	Lightning protection system; installation
IEC 60099-2-62	Lightning Arresters
IEC 60099-4 (in preparation)	Surge arresters – Part 4: Metal oxide surge arresters w/o gaps for a.c. systems
IEC 60099-4 A3(1999)	Amendment to IEC 60099-4: EMC considerations (37/220/CD)
IEC37A(Sec)1 (1989)	Specification for surge arresters for low-voltage distribution systems
IEC 61000-4-2	ESD
IEC 61024-1 (1990)	Protection of structures against lightning; Part 1: General principles
IEC 61024-1-1 (1993)	Protection of structures against lightning; Part 1: General principles - Section 1: Selection of protection levels
IEC 61312-1 (1995)	Protection against lightning EMP (TC81)
IEC 61312-2(1999)	EM fields inside structures from direct & nearby lightning strikes
IEC 61312-3	(in preparation)Surge arrester requirements against LEMP (81/120/CDV)
IEC 81/70	Protection of fiber optic telecom lines against lightning
AIR 1662A	Minimization of electrostatic hazards in aircraft fuel systems

MIL-A-9094A	Lightning arresters
MIL-HDBK-273	EMP survivability
MIL-STD-1757A	Lightning qualification test techniques for aerospace vehicles and hardware
MIL-STD-1766B	Nuclear hardness and survivability program requirements for ICBM weapon systems
MIL-STD-1795A	Lighting protection of aerospace vehicles & hardware
NFPA 77-93	ESD rec. practice
NFPA 78-89	Lightning protection code
SAE AIR 1406-76	Lightning protection & ESD
SAE AIR 1499	Commercial Product Susceptibility Guide
STANAG 3856 AE	Protection of aircraft crew and subsystems in flight against the effects of electrostatic charges – AEP 29
STANAG 3991	Design criteria to minimize generation of static electricity within aircraft fuel systems
STANAG 4235	Electrostatic/environment conditions – affecting design of material for use by NATO forces
STANAG 4239	ESD test procedures
STANAG 4327	Lighting test procedures
STANAG 4332	General criteria and common procedure for protection against damage caused by EMP on warships. Ratif requested 17-2-86
STANAG 4416	EMP test procedures containing EEDs

9.0 Installation Standards and Practices

9.1 General

IEC 61000-5-1	(see 77B/155/CDV) General considerations
IEC 61000-5-6	mitigation of external influences (see 77B/157/CD)
MIL-HDBK-274 (1990)	Grounding for aircraft safety
MIL-STD-1857 (1998)	Grounding, bonding & shielding design practices
ARP 935	Control plan/technical construction file

9.2 Grounding and Bonding

CSA C22.2 NO 0.4 M1982	BONDING & GROUNDING OF ELEC. Equip
CSA C22.2 NO 41-M1982	Bonding & grounding equipment
IEC 60092-504	Electrical installations in ships: Control and instrumentation
IEC 61000-5-1	EMC installation & mitigation guidelines: general considerations
IEC 61000-5-2	EMC installation & mitigation guidelines: Earthing and cabling (see 77B/168/CDV)

IEC 18(Germ)526 (1992)	Revision of 533: EMC of electrical and electronic installations in ships and of mobile and fixed off-shore units
ARP 1870 (1991)	Aero. systems electrical bonding and grounding for EMC and safety
MIL B 5087B	Bonding, electrical & lighting protection for aerospace systems
MIL-HDBK-419A	Grounding bonding & shielding for equipment & facilities
MIL-STD-188-124B	Grounding, Bonding, and Shielding
MIL STD 1310G	Shipboard bonding, grounding, and other techniques for EMC and safety
MIL STD 1542B	EMC & grounding requirements for space system facilities
STANAG 3659 AE	Electrical bonding requirements for metallic aircraft cabling and connecting

9.3 Cabling & Connecting

IEC 60169-17	6.5 mm RF Connectors -- Tr. Imp<0.1 ohm
IEC 60966-1, Amend. 2	Screening Effectiveness Measurement
IEC 61000-5-1 (77B/155)	EMC installation & mitigation guidelines: general considerations
IEC 61000-5-2	Earthing and cabling (see 77B/168/CDV)
IEC 61169-1	RF Connectors (SC46D) -- Meas of Transfer imp.
DOD-STD-2133	Cable arrangement minimum stray mag.field
SAE AIR 1394-78	Cabling guidelines for EMC

9.4 Shielding & Absorbing (see also Grounding and Bonding)

ARINC 654	
AIR 1700A	Upper frequency measurement boundary for evaluation shielding effectiveness in cylindrical systems
MIL A 17161D	RF absorbers
MIL-S-6451E	Shields
SAE AIR 1404-76	DC resistivity vs RF impedance of EMI gaskets
STANAG 4238	Design principles for hardening munitions/weapon systems against EME
STANAG 4370-524	AECTP 524: Shielding effectiveness

9.5 Filtering

ARINC 654	
ANS C63.13-1991	Guide on the Application and Evaluation of EMI Power Line Filters for Commercial Use
SAE ARP 4244	Recommended Insertion Loss Test Methods for EMI Power Line Filters

Annex C

Acronyms

A	Ampere
AC	Alternating Current
AE	Auxiliary Equipment
AF	Air Force
AM	Amplitude Modulation
ANS	American National Standard
ANSI	American National Standards Institute
ASC	Accredited Standards Committee
ASW	Anti-Submarine Warfare
BCI	Bulk Cable Injection
CDN	Coupling/Decoupling Network
CE	Conformite Europeenne or Conducted Emissions
CEMA	Consumer Electronics Manufacturers Association
CENELEC	European Committee for Electrotechnical Standardization
CFR	Code of Federal Regulations
C-I	Common Impedance
CI	Commercial Items
CISPR	International Special Committee for Radio Interference
CM	Common Mode
CS	Conducted Susceptibility
CW	Continuous Wave
CRT	Cathode Ray Tube
DC	Direct Current
DIESC	DoD/Industry E3 Standards Committee
DISA	Defense Information Systems Agency
DM	Differential Mode
DoD	Department of Defense
DTRA	Defense Threat Reduction Agency
E3	Electromagnetic Environmental Effects
EEC	European Economic Community
EIA	Electronics Industries Association
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EME	Electromagnetic Environment
EMI	Electromagnetic Interference
EMP	Electromagnetic Pulse
EPIRB	Emergency Position Indicating Radio Beacon
EPS	Engineering Practice Study
ESD	Electrostatic Discharge
EUT	Equipment Under Test
FCC	Federal Communications Commission
FM	Frequency Modulation
GND	Ground
HEMP	High Altitude Electromagnetic Pulse
HF`	High Frequency
HIRF	High Intensity Radiated Field

IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
ISM	Industrial, Scientific and Medical
ISO	International Organization for Standardization
ITE	Information Technology Equipment
L	Line
LISN	Line Impedance Stabilization Network
MIL-STD	Military Standard
N	Neutral
NASA	National Aeronautics and Space Administration
NEMA	National Electrical Manufacturers Association
PM	Program Manager
PO	Program Office
QP	Quasi-Peak
RE	Radiated Emissions
RF	Radio Frequency
RMS	Root Mean Square
RS	Radiated Susceptibility
RTCA	Radio Technical Commission for Aeronautics
SAE	Society of Automotive Engineers
SD	Standardization Document
TCF	Technical Construction File
TEM	Transverse Electromagnetic
TV	Television
V	Volt
VAC	Volt Alternating Current
VLF	Very Low Frequency
VDT	Video Display Terminal
W	Watt