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METRIC
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11 JANUARY 1993

SUPERSEDING
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4 AUGUST 1986

DEPARTMENT OF DEFENSE INTERFACE STANDARD

REQUIREMENTS FOR THE CONTROL OF ELECTROMAGNETIC INTERFERENCE EMISSIONS AND SUSCEPTIBILITY

AMSC: N6852

AREA: EMCS

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FOREWORD

1. This military standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Space and Naval Warfare Systems Command, Attn: SPAWAR 2243, Washington, DC, 20363-5100, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

3. The stated requirements represent the minimum considered necessary to provide reasonable confidence that a particular subsystem or equipment complying with these requirements will function within their designated design tolerances when operating in their intended electromagnetic environment. Test methods to be used to demonstrate compliance to this document are contained in MIL-STD-462.

4. Substantial changes have been made from previous editions. Some requirements have been eliminated, others significantly changed, and new requirements added. An appendix has been introduced which provides the rationale and background for each paragraph.

5. The requirements contained in this document may be tailored by the procuring activity for each application and intended operational Electromagnetic Environment (EME).

6. A joint committee consisting of representatives of the Army, Air Force, Navy, and Industry prepared this document.

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1. SCOPE

1.1 Purpose. This standard establishes the design requirements for the control of the electromagnetic emission and susceptibility characteristics of electronic, electrical, and electromechanical equipment and subsystems designed or procured for use by activities and agencies of the Department of Defense. Such equipment and subsystems may be used independently or as an integral part of other subsystems or systems. Data item requirements are also included.

1.2 Application.

1.2.1 General applicability. The applicability of the emission and susceptibility requirements is dependent upon the types of equipment or subsystems and their intended installations as specified herein.

1.2.2 Tailoring of requirements. Application-specific environmental criteria may be derived from operational and engineering analyses on equipment or subsystems being procured for use in specific systems or platforms. When analyses reveal that the requirements in this standard are not appropriate for that procurement, the requirements may be tailored and incorporated into the request-for-proposal, specification, contract, order, and so forth.

1.3 Emission and susceptibility designations. The emissions and susceptibility requirements in this standard and corresponding test methods of MIL-STD-462 are designated in accordance with an alpha-numeric coding system. Each method is identified by a two letter combination followed by a three digit number. The number is for reference purposes only. The meaning of the individual letters are as follows:

C = Conducted
R = Radiated
E = Emission
S = Susceptibility

a. Conducted emissions tests are designated by "CE---."
b. Radiated emissions tests are designated by "RE---."
c. Conducted susceptibility tests are designated by "CS---."
d. Radiated susceptibility test are designated by "RS---."
e. "---" = numerical order of test from 101 to 199.

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2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

STANDARD

MILITARY

MIL-STD-462 - Measurement of Electromagnetic Interference Characteristics

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, ATTN: NPODS, 700 Robbins Avenue, Philadelphia, PA 19111-5093.)

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

DODISS	-	Department of Defense Index of Specifications and Standards
DOD Federal Acquisition Regulation Supplement, Part 27	-	Data Requirements.
DOD 5010.12-L	-	DOD Acquisition Management Systems and Data Requirement Control List (AMSDL).
DOD 5000.37-M	-	DOD Non Developmental Items Acquisition Manual

(Copies of the DOD 5010.12-L on a subscription basis and DOD 5000.37M are available from the Commanding Officer, Naval Publications and Forms Center, 700 Robbins Avenue, Philadelphia, PA 19111-5093. Copies of the DOD Federal Acquisition Regulation

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Supplements are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-0001. Copies of DODISS are available on a yearly subscription basis either from the Government Printing Office for hard copy, or microfiche copies are available from the Director, Navy Publications and Printing Service Office, 700 Robbins Avenue, Philadelphia, PA 19111-5093.)

2.2 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C63.14	-	Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD).
ANSI/IEEE 268	-	Metric Practice. (DOD adopted)

(Application for copies should be addressed to the IEEE Service Center, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 380	-	Standard for Metric Practice. (DOD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

(Non-government standards are generally available for reference from libraries. They are also distributed among non-government standards bodies and using Federal agencies.)

2.3 Order of precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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3. DEFINITIONS

3.1 General. The terms used in this standard are defined in ANSI C63.14. In addition, the following definitions are applicable for the purpose of this standard.

3.2 Acronyms used in this standard.

a. ASW - Anti-submarine Warfare

b. EMC - Electromagnetic Compatibility

c. EME - Electromagnetic Environment

d. EMI - Electromagnetic Interference

e. EMICP - Electromagnetic Interference Control Procedures

f. EMITP - Electromagnetic Interference Test Procedures

g. EMITR - Electromagnetic Interference Test Report

h. EUT - Equipment Under Test

i. GFE - Government Furnished Equipment

j. ISM - Industrial, Scientific and Medical

k. NDI - Non-Developmental Item

l. RMS - Root Mean Square

3.3 Above deck. An area on ships which is generally in the open air.

3.4 Below deck. An area on ships which is surrounded by a metallic structure, or an area which provides significant attenuation to electromagnetic radiation, such as the metal hull or superstructure of a surface ship, the hull of a submarine and the screened rooms in non-metallic ships.

3.5 External installation. An equipment location on a platform which is exposed to the external electromagnetic environment, such as an aircraft cockpit which does not use electrically conductive treatments on the canopy or windscreen.

3.6 Flight-line equipment. Any support equipment that is attached to or used next to an aircraft during pre-flight or

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post-flight operations, such as uploading or downloading data, maintenance diagnostics, or equipment functional testing.

3.7 Internal installation. An equipment location on a platform which is totally inside an electrically conductive structure, such as a typical avionics bay in an aluminum skin aircraft.

3.8 Metric units. Metric units are a system of basic measures which are defined by the International System of Units based on "Le System International d'Unites (SI)", of the International Bureau of Weights and Measures. These units are described in ASTM E 380 and ANSI/IEEE 268.

3.9 Non-developmental item. Non-developmental item is a broad, generic term that covers material available from a wide variety of sources with little or no development effort required by the Government.

3.10 Safety critical. A category of subsystems and equipment whose degraded performance could result in loss of life or loss of vehicle or platform.

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4. GENERAL REQUIREMENTS

4.1 General. Electronic, electrical, and electromechanical equipment and subsystems shall comply with the applicable requirements in 4.2 through 4.8. The requirements are in addition to the applicable emission and susceptibility requirements defined in other portions of this standard.

4.2 Joint procurement. Equipment or subsystems procured by one DOD activity for multi-agency use shall comply with the requirements of the user agencies.

4.3 Filtering (Navy only). The use of line-to-ground filters for EMI control shall be minimized. Such filters establish low impedance paths for structure (common-mode) currents through the ground plane and can be a major cause of interference in systems, platforms, or installations because the currents can couple into other equipment using the same ground plane. If such a filter must be employed, the line-to-ground capacitance for each line shall not exceed 0.1 microfarads (μF) for 60 Hertz (Hz) equipment or 0.02 μF for 400 Hz equipment. For submarine DC-powered equipment and aircraft DC-powered equipment, the filter capacitance from each line-to-ground at the user interface shall not exceed 0.075 μF/kW of connected load. For loads less than 0.5 kW, the filter capacitance shall not exceed 0.03 μF. The filtering employed shall be fully described in the equipment or subsystem technical manual and the Electromagnetic Interference Control Procedures (EMICP) (See 6.3).

4.4 Self-compatibility. The operational performance of an equipment or subsystem shall not be degraded, nor shall it malfunction when all of the units or devices in the equipment or subsystem are operating together at their designed levels of efficiency or their design capability.

4.5 Non-Developmental Items (NDI). In accordance with the guidance provided by DOD 5000.37-M, the requirements of this standard shall be met when applicable and warranted by the intended installation and platform requirements.

4.5.1 Commercial off-the-shelf equipment.

4.5.1.1 Selected by contractor. When it is demonstrated that a commercial item selected by the contractor is responsible for equipment or subsystems failing to meet the contractual EMI requirements, either the commercial item shall be modified or replaced or interference suppression measures shall be employed, so that the equipment or subsystems meet the contractual EMI requirements.

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4.5.1.2 Specified by procuring activity. When it is demonstrated by the contractor that a commercial item specified by the procuring activity for use in an equipment or subsystem is responsible for failure of the equipment or subsystem to meet its contractual EMI requirements, the data indicating such failure shall be included in the Electromagnetic Interference Test Report (EMITR) (See 6.3). No modification or replacement shall be made unless authorized by the procuring activity.

4.5.2 Procurement of equipment or subsystems having met other EMI requirements. Procurement of equipment and subsystems electrically and mechanically identical to those previously procured by activities of DOD or other Federal agencies, or their contractors, shall meet the EMI requirements and associated limits, as applicable in the earlier procurement, unless otherwise specified by the Command or agency concerned.

4.6 Government Furnished Equipment (GFE). When it is demonstrated by the contractor that a GFE is responsible for failure of an equipment or subsystem to meet its contractual EMI requirements, the data indicating such failure shall be included in the EMITR (See 6.3). No modification shall be made unless authorized by the procuring activity.

4.7 Testing requirements. The testing requirements and procedures of MIL-STD-462 shall be used to determine compliance with the applicable emission and susceptibility requirements of this standard. Data gathered as a result of performing tests in one electromagnetic discipline may be sufficient to satisfy requirements in another. Therefore, to avoid unnecessary duplication, a single test program should be established with tests for similar requirements conducted concurrently whenever possible. Equipment that are intended to be operated as a subsystem shall be tested as such to the applicable emission and susceptibility requirements whenever practical. Formal testing is not to commence without approval of the Electromagnetic Interference Test Procedures (EMITP) (See 6.3) by the Command or agency concerned.

4.8 Switching transients. Switching transient emissions that result at the moment of operation of manually actuated switching functions are exempt from the requirements of this standard. Other transient type conditions, such as automatic sequencing following initiation by a manual switching function, shall meet the emissions requirements of this standard.

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5. DETAILED REQUIREMENTS

5.1 General. Table I is a list of emissions and susceptibility requirements established by this standard. General test methods for these requirements are contained in MIL-STD-462 as implemented by the Government approved EMITP (See 6.3). All results of tests performed to demonstrate compliance with the requirements are to be documented in the EMITR (See 6.3) and forwarded to the Command or agency concerned for evaluation prior to acceptance of the equipment or subsystem. Design procedures and techniques for the control of EMI shall be described in the EMICP (See 6.3). Approval of design procedures and techniques described in the EMICP does not relieve the supplier of the responsibility of meeting the contractual emission, susceptibility, and design requirements.

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TABLE I. Emission and susceptibility requirements.

Requirement	Description
CE101	Conducted Emissions, Power Leads, 30 Hz to 10 kHz
CE102	Conducted Emissions, Power Leads, 10 kHz to 10 MHz
CE106	Conducted Emissions, Antenna Terminal, 10 kHz to 40 GHz
CS101	Conducted Susceptibility, Power Leads, 30 Hz to 50 kHz
CS103	Conducted Susceptibility, Antenna Port, Intermodulation, 15 kHz to 10 GHz
CS104	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals, 30 Hz to 20 GHz
CS105	Conducted Susceptibility, Antenna Port, Cross-Modulation, 30 Hz to 20 GHz
CS109	Conducted Susceptibility, Structure Current, 60 Hz to 100 kHz
CS114	Conducted Susceptibility, Bulk Cable Injection, 10 kHz to 400 MHz
CS115	Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation
CS116	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads, 10 kHz to 100 MHz
RE101	Radiated Emissions, Magnetic Field, 30 Hz to 100 kHz
RE102	Radiated Emissions, Electric Field, 10 kHz to 18 GHz
RE103	Radiated Emissions, Antenna Spurious and Harmonic Outputs, 10 kHz to 40 GHz
RS101	Radiated Susceptibility, Magnetic Field, 30 Hz to 100 kHz
RS103	Radiated Susceptibility, Electric Field, 10 kHz to 40 GHz
RS105	Radiated Susceptibility, Transient Electromagnetic Field

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5.1.1 Units of frequency domain measurements. All frequency domain limits are expressed in terms of equivalent Root Mean Square (RMS) value of a sine wave as would be indicated by the output of a measurement receiver using peak envelope detection.

5.2 EMI control requirements versus intended installations. Table II summarizes the requirements for equipment and subsystems intended to be installed in, on, or launched from various military platforms or installations. When an equipment or subsystem is to be installed in more than one type of platform or installation, it shall comply with the most stringent of the applicable requirements and limits. An "A" entry in the table means the requirement is applicable. An "L" entry means the applicability of the requirement is limited as specified in the appropriate requirement paragraphs of this standard; the limits are contained herein. An "S" entry means the procuring activity must specify the applicability and limit requirements in the procurement specification. Absence of an entry means the requirement is not applicable.

TABLE II. Requirement matrix.

Equipment and Subsystems Installed In, On, or Launched From the Following Platforms or Installations	Requirement Applicability															
	CE101	CE102	CE106	CS101	CS103	CS104	CS105	CS109	CS114	CS115	CS116	RE101	RE102	RE103	RS101	RS103	RS105
Surface Ships	A	A	L	A	S	S	S		A		A	A	A	L	A	A	L
Submarines	A	A	L	A	S	S	S	L	A		A	A	A	L	A	A	L
Aircraft, Army, Including Flight Line	A	A	L	A	S	S	S		A	A	L	A	A	L	A	A	L
Aircraft, Navy	L	A	L	A	S	S	S		A	A	A	L	A	L	L	A	L
Aircraft, Air Force		A	L	A	S	S	S		A	A	A		A	L		A	
Space Systems, Including Launch Vehicles		A	L	A	S	S	S		A	A	A		A	L		A	
Ground, Army		A	L	A	S	S	S		A	L	L		A	L	L	A	
Ground, Navy		A	L	A	S	S	S		A		A		A	L	L	A	L
Ground, Air Force		A	L	A	S	S	S		A	L	A		A	L		A	

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5.3 Emission and susceptibility requirements and limits.

5.3.1 CE101 (Conducted emissions, power leads, 30 Hz to 10 kHz).

5.3.1.1 CE101 applicability. This requirement is applicable as follows for power leads, including returns, that obtain power from other sources not part of the EUT.

a.	Not applicable	Air Force
b.	AC leads only	Ships
c.	AC and DC leads . . .	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.

5.3.1.2 CE101 limits. Conducted emissions on power leads shall not exceed the applicable values shown on Figures CE101-1 through CE101-3, as appropriate, for ships and submarines and Figure CE101-4 for Army aircraft (including flight line) and Navy ASW aircraft.

5.3.2 CE102 (Conducted emissions, power leads, 10 kHz to 10 MHz).

5.3.2.1 CE102 applicability. 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.

5.3.2.2 CE102 limits. Conducted emissions on power leads shall not exceed the applicable values shown on Figure CE102-1.

5.3.3 CE106 (Conducted emissions, antenna terminal, 10 kHz to 40 GHz).

5.3.3.1 CE106 applicability. This requirement is applicable to the antenna terminals of transmitters and receivers. The requirement is not applicable to equipment designed to operate into a non-removable antenna. The transmitter (transmit mode) portion of this requirement is not applicable within either the EUT necessary bandwidth or ±5

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percent of the fundamental frequency. Depending on the operating frequency range of the EUT, the start frequency of the test is as follows:

Operating Frequency Range (EUT)	Start Frequency of Test
10 kHz to 3 MHz	10 kHz
3 MHz to 300 MHz	100 kHz
300 MHz to 3 GHz	1 MHz
3 GHz to 40 GHz	10 MHz

The end frequency of the test is 40 GHz or twenty times the highest generated or received frequency within the EUT, whichever is less. For equipment using waveguide, the requirement does not apply below eight-tenths of the waveguide's cutoff frequency. Requirement RE103 may be used as an alternative for CE106 for testing transmitters with their operational antennas.

5.3.3.2 CE106 limits. Conducted emissions at the EUT antenna terminal shall not exceed the values given below.

a. Receivers: 34 dBµV

b. Transmitters (standby mode): 34 dBµV

c. Transmitters (transmit mode): Harmonics, except the second and third, and all other spurious emissions shall be at least 80 dB down from the level at the fundamental. The second and third harmonics shall be suppressed 50 + 10 log p (where p = peak power output in watts, at the fundamental) or 80 dB, whichever requires less suppression.

5.3.4 CS101 (Conducted susceptibility, power leads, 30 Hz to 50 kHz).

5.3.4.1 CS101 applicability. 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 50 kHz. If the EUT is AC operated, this requirement is applicable starting from the second harmonic of the EUT power frequency and extending to 50 kHz.

5.3.4.2 CS101 limit. The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the

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individual equipment or subsystem specification, when subjected to a test signal with levels as specified in Figure CS101-1. The requirement is also met under the following condition: when the power source specified in MIL-STD-462, adjusted to dissipate 80 watts in a 0.5 ohm load, cannot develop the required voltage at the EUT power input terminals, and the EUT is not susceptible to the output of the signal source.

5.3.5 CS103 (Conducted susceptibility, antenna port, intermodulation, 15 kHz to 10 GHz).

5.3.5.1 CS103 applicability. This receiver front-end susceptibility requirement is applicable to equipment and subsystems, such as communications receivers, RF amplifiers, transceivers, radar receivers, acoustic receivers, and electronic warfare receivers as specified in the individual procurement specification.

5.3.5.2 CS103 limit. The EUT shall not exhibit any intermodulation products beyond specified tolerances when subjected to the limit requirement provided in the individual procurement specification.

5.3.6 CS104 (Conducted susceptibility, antenna port, rejection of undesired signals, 30 Hz to 20 GHz).

5.3.6.1 CS104 applicability. This receiver front-end susceptibility requirement is applicable to equipment and subsystems, such as communications receivers, RF amplifiers, transceivers, radar receivers, acoustic receivers, and electronic warfare receivers as specified in the individual procurement specification.

5.3.6.2 CS104 limit. The EUT shall not exhibit any undesired response beyond specified tolerances when subjected to the limit requirement provided in the individual procurement specification.

5.3.7 CS105 (Conducted susceptibility, antenna port, cross modulation, 30 Hz to 20 GHz).

5.3.7.1 CS105 applicability. This receiver front-end susceptibility requirement is applicable only to receivers that normally process amplitude-modulated RF signals, as specified in the individual procurement specification.

5.3.7.2 CS105 limit. The EUT shall not exhibit any undesired response, due to cross modulation, beyond specified tolerances when subjected to the limit requirement provided in the individual procurement specification.

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5.3.8 CS109 (Conducted susceptibility, structure current, 60 Hz to 100 kHz).

5.3.8.1 CS109 applicability. 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.

5.3.8.2 CS109 limit. The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to the values shown on Figure CS109-1.

5.3.9 CS114 (Conducted susceptibility, bulk cable injection, 10 kHz to 400 MHz).

5.3.9.1 CS114 applicability. 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.	10 kHz to 2 MHz . .	all
b.	2 MHz to 30 MHz . .	all
c.	30 MHz to 200 MHz . .	aircraft (Air Force and Army); space systems; and optional* for all others
d.	200 MHz to 400 MHz . .	optional* for all

*Required only if specified in the procurement specification

5.3.9.2 CS114 limit. The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to a test signal with calibration levels as shown in Figure CS114-1. The appropriate limit curve in Figure CS114-1 shall be selected from Table III. The requirements are also met if the following currents are induced in the cable under test and the EUT is not susceptible:

Curve 5: 115 dBμA
Curve 4: 103 dBμA
Curve 3: 95 dBμA
Curve 2: 89 dBμA
Curve 1: 83 dBμA

TABLE III. CS114 limit curves.

FREQ. RANGE / PLATFORM		LIMIT CURVE # FROM FIGURE CS114-1							
		AIRCRAFT (EXTERNAL OR SAFETY CRITICAL)	AIRCRAFT (INTERNAL)	ALL SHIPS (ABOVE DECKS)	SHIPS (METALLIC) (BELOW DECKS)	SHIPS (NON-METALLIC) (BELOW DECKS)	SUB-MARINES	GROUND	SPACE
10 kHz ↓ 2 MHz	A	5	5	2	2	2	1	3	3
	N	5	3	2	2	2	1	2	3
	AF	5	3	–	–	–	–	2	3
2 MHz ↓ 30 MHz	A	5	5	5	2	4	1	4	3
	N	5	5	5	2	4	1	2	3
	AF	5	3	–	–	–	–	2	3
30 MHz ↓ 200 MHz	A	5	5	5	2	2	1	4	3
	N	–	–	5	2	2	1	2	3
	AF	5	3	–	–	–	–	2	3
200 MHz ↓ 400 MHz	A	5	5	5	2	2	1	4	3
	N	–	–	5	2	2	1	2	3
	AF	5	3	–	–	–	–	2	3

KEY: A = Army
N = Navy
AF= Air Force

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5.3.10 CS115 (Conducted susceptibility, bulk cable injection, impulse excitation).

5.3.10.1 CS115 applicability. This requirement is applicable to all aircraft and space system interconnecting cables, including power cables. The requirement is also applicable for Army and Air Force ground subsystems and equipment when specified by the procuring activity.

5.3.10.2 CS115 limit. The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystems specification, when subjected to a calibrated test signal as specified in Figure CS115-1 at a 30 Hz rate for one minute.

5.3.11 CS116 (Conducted susceptibility, damped sinusoidal transients, cables and power leads, 10 kHz to 100 MHz.

5.3.11.1 CS116 applicability. This requirement is applicable to all interconnecting cables, including power cables, and individual power leads. Power returns need not be tested individually. For Air Force ground subsystems and equipment, this requirement is applicable only for power cables and individual power leads. The requirement is also applicable for Army ground subsystems and equipment, including flight line, when specified by the procuring activity.

5.3.11.2 CS116 limit. The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to a signal having the waveform shown in Figure CS116-1 and having a maximum current as specified in Figure CS116-2. As a minimum, compliance shall be demonstrated at the following frequencies: .01, .1, 1, 10, 30, 100 MHz, and resonant frequencies as determined in accordance with MIL-STD-462. The test signal repetition rate shall be no greater than one pulse per second and no less than one pulse every two seconds. The pulses shall be applied for a period of five minutes.

5.3.12 RE101 (Radiated emissions, magnetic field, 30 Hz to 100 kHz).

5.3.12.1 RE101 applicability. This requirement is applicable for radiated emissions from equipment and subsystem enclosures, and all interconnecting 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

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equipment. The requirement does not apply to radiation from antennas. For Navy aircraft, this requirement is applicable only for aircraft with an ASW capability.

5.3.12.2 RE101 limit. Magnetic field emissions shall not be radiated in excess of the levels shown in Figures RE101-1 and RE101-2 at the specified distances of 7 centimeters and 50 centimeters.

5.3.13 RE102 (Radiated emissions, electric field, 10 kHz to 18 GHz).

5.3.13.1 RE102 applicability. This requirement is applicable for radiated emissions from equipment and subsystem enclosures, and all interconnecting cables. The requirement does not apply at the transmitter fundamental frequencies or to radiation from antennas. 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 1 GHz
d.	Aircraft (Army)	10 kHz to 18 GHz
e.	Aircraft (Air Force and Navy)	2 MHz 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.

5.3.13.2 RE102 limits. Electric field emissions shall not be radiated in excess of those shown in Figures RE102-1 through RE102-3. Above 30 MHz, the limits shall be met for both horizontally and vertically polarized fields.

5.3.14 RE103 (Radiated emissions, antenna spurious and harmonic outputs, 10 kHz to 40 GHz).

5.3.14.1 RE103 applicability. 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. The requirement is not applicable within either the EUT necessary bandwidth or ±5 percent of the fundamental frequency. Depending on the operating frequency range of the EUT, the start frequency of the test is as follows:

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Operating Frequency Range (EUT)	Start Frequency of Test
10 kHz to 3 MHz	10 kHz
3 MHz to 300 MHz	100 kHz
300 MHz to 3 GHz	1 MHz
3 GHz to 40 GHz	10 MHz

The end frequency of the test is 40 GHz or twenty times the highest generated frequency within the EUT, whichever is less. For equipment using waveguide, the requirement does not apply below eight-tenths of the waveguide's cutoff frequency.

5.3.14.2 RE103 limits. Harmonics, except the second and third, and all other spurious emissions shall be at least 80 dB down from the level at the fundamental. The second and third harmonics shall be suppressed 50 + 10 log p (where p = peak power output in watts, at the fundamental) or 80 dB, whichever requires less suppression.

5.3.15 RS101 (Radiated susceptibility, magnetic field, 30 Hz to 100 kHz).

5.3.15.1 RS101 applicability. This requirement is applicable to equipment and subsystem enclosures, and all interconnecting cables. 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 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.

5.3.15.2 RS101 limit. The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to the magnetic fields shown in Figures RS101-1 and RS101-2.

5.3.16 RS103 (Radiated susceptibility, electric field, 10 kHz to 40 GHz).

5.3.16.1 RS103 applicability. This requirement is applicable to equipment and subsystem enclosures and all interconnecting cables. The requirement is applicable as follows:

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a.	10 kHz to 2 MHz . . .	Army aircraft, including flight line; and optional* for all others
b.	2 MHz to 30 MHz . . .	Army ships; Army aircraft, including flight line; Navy; and optional* for all others
c.	30 MHz to 1 GHz . . .	all
d.	1 GHz to 18 GHz . . .	all
e.	18 GHz to 40 GHz . . .	optional* for all

*Required only if specified in the procurement specification

The requirement is not applicable at the tuned frequency of an antenna-connected receiver unless otherwise specified by the procuring activity.

5.3.16.2 RS103 limit. The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to the radiated electric fields specified in Table IV. Up to 30 MHz, the requirement shall be met for vertically polarized fields. Above 30 MHz, the requirement shall be met for both horizontally and vertically polarized fields. Circular polarized fields are not acceptable.

TABLE IV. RS103 limits.

FREQ. RANGE / PLATFORM		LIMIT LEVEL (VOLTS/METER)							
		AIRCRAFT (EXTERNAL OR SAFETY CRITICAL)	AIRCRAFT (INTERNAL)	ALL SHIPS (ABOVE DECKS)	SHIPS (METALLIC) (BELOW DECKS)	SHIPS (NON-METALLIC) (BELOW DECKS)	SUB-MARINES	GROUND	SPACE
10 kHz ↓ 2 MHz	A	200	200	10	10	10	5	20	20
	N	200	20	10	10	10	5	10	20
	AF	200	20	-	-	-	-	10	20
2 MHz ↓ 30 MHz	A	200	200	200	10	50	5	50	20
	N	200	200	200	10	50	5	10	20
	AF	200	20	-	-	-	-	10	20
30 MHz ↓ 1 GHz	A	200	200	200	10	10	5	50	20
	N	200	200	200	10	10	5	10	20
	AF	200	20	-	-	-	-	10	20
1 GHz ↓ 18 GHz	A	200	200	200	10	10	5	50	20
	N	200	200	200	10	10	5	50	20
	AF	200	60	-	-	-	-	50	20
18 GHz ↓ 40 GHz	A	200	200	200	10	10	5	50	20
	N	200	60	200	10	10	5	50	20
	AF	200	60	-	-	-	-	50	20

KEY: A = Army
N = Navy
AF= Air Force

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5.3.17 RS105 (Radiated susceptibility, transient electromagnetic field).

5.3.17.1 RS105 applicability. 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 for 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.

5.3.17.2 RS105 limit. The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to a test signal having the waveform and amplitude shown on Figure RS105-1. At least five pulses shall be applied at the rate of not more than one pulse per minute.

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6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This standard is intended for use in the acquisition cycle of equipment and subsystems to specify the electromagnetic emission and susceptibility requirements for the control of EMI.

6.2 Issue of DODISS. When this standard is used in acquisition, the applicable issue of the DODISS must be cited in the solicitation (see 2.1.1 and 2.2).

6.3 Data requirements. The following Data Item Descriptions (DID's) must be listed, as applicable, on the Contract Data Requirements List (DD Form 1423) when this standard is applied on a contract, in order to obtain the data, except where DOD FAR Supplement 27.475-1 exempts the requirement from a DD Form 1423.

Referenced Paragraph	DID Number	DID Title
5.1	DI-EMCS-80199A	Electromagnetic Interference Control Procedures (EMICP)
5.1	DI-EMCS-80201A	Electromagnetic Interference Test Procedures (EMITP)
5.1	DI-EMCS-80200A	Electromagnetic Interference Test Report (EMITR)

The above DID's were those cleared as of the date of this standard. The current issue of DOD 5010,12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DID's are cited on the DD Form 1423.

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6.4 Subject term (key word) listing.

EMC
EMI
Electromagnetic compatibility
Electromagnetic emission
Electromagnetic interference
Electromagnetic susceptibility
Test Limits, EMI
Test Methods, EMI

6.5 International standardization agreements. Certain provisions of this standard may be the subject of international standardization agreements. When amendment, revision, or cancellation of this standard is proposed which will modify the international agreement concerned, the preparing activity will take appropriate action through international standardization channels, including departmental standardization offices to change the agreement or make other appropriate accommodation.

6.6 Changes from previous issue. Marginal notations are not used in the revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

6.7 Technical points of contact. Requests for additional information or assistance on this standard can be obtained from the following:

a. Commander, U.S. Army, CECOM
AMSEL-RD-C3-EM-F
Ft. Monmouth, NJ 07703-5203
DSN 995-4220; Commercial (908) 544-4220

b. Commander, Space and Naval Warfare Systems Command
SPAWAR 2243
Washington, DC 20363-5100
DSN 332-0559; Commercial (703) 602-4396

c. ASC/ENACE
Wright Patterson AFB, OH 45433-6503
DSN 785-5078; Commercial (513) 255-5078

Any information relating to Government contracts must be obtained through contracting officers.

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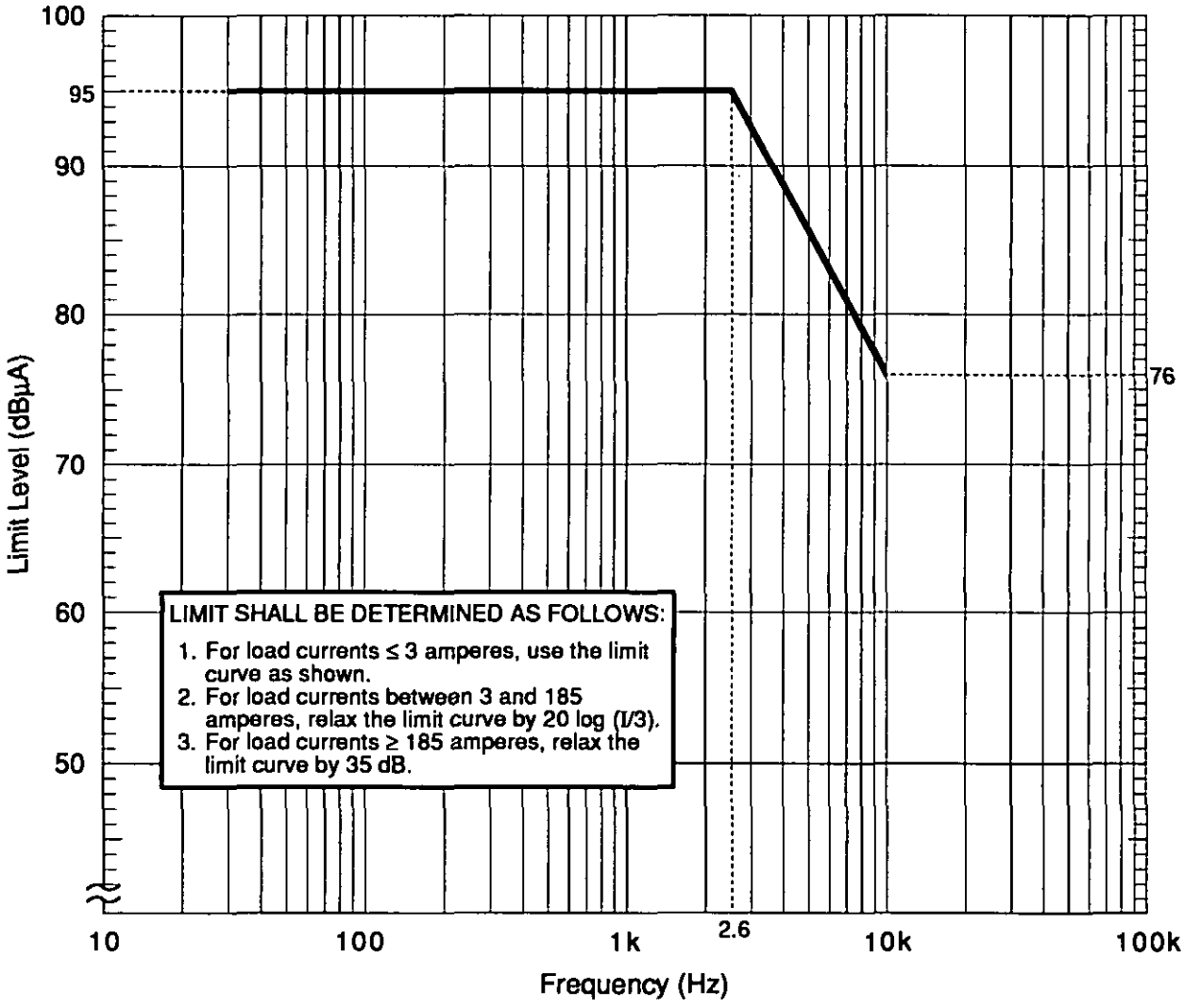

FIGURE CE101-1. CE101 limit (EUT power leads, DC only) for submarine applications.

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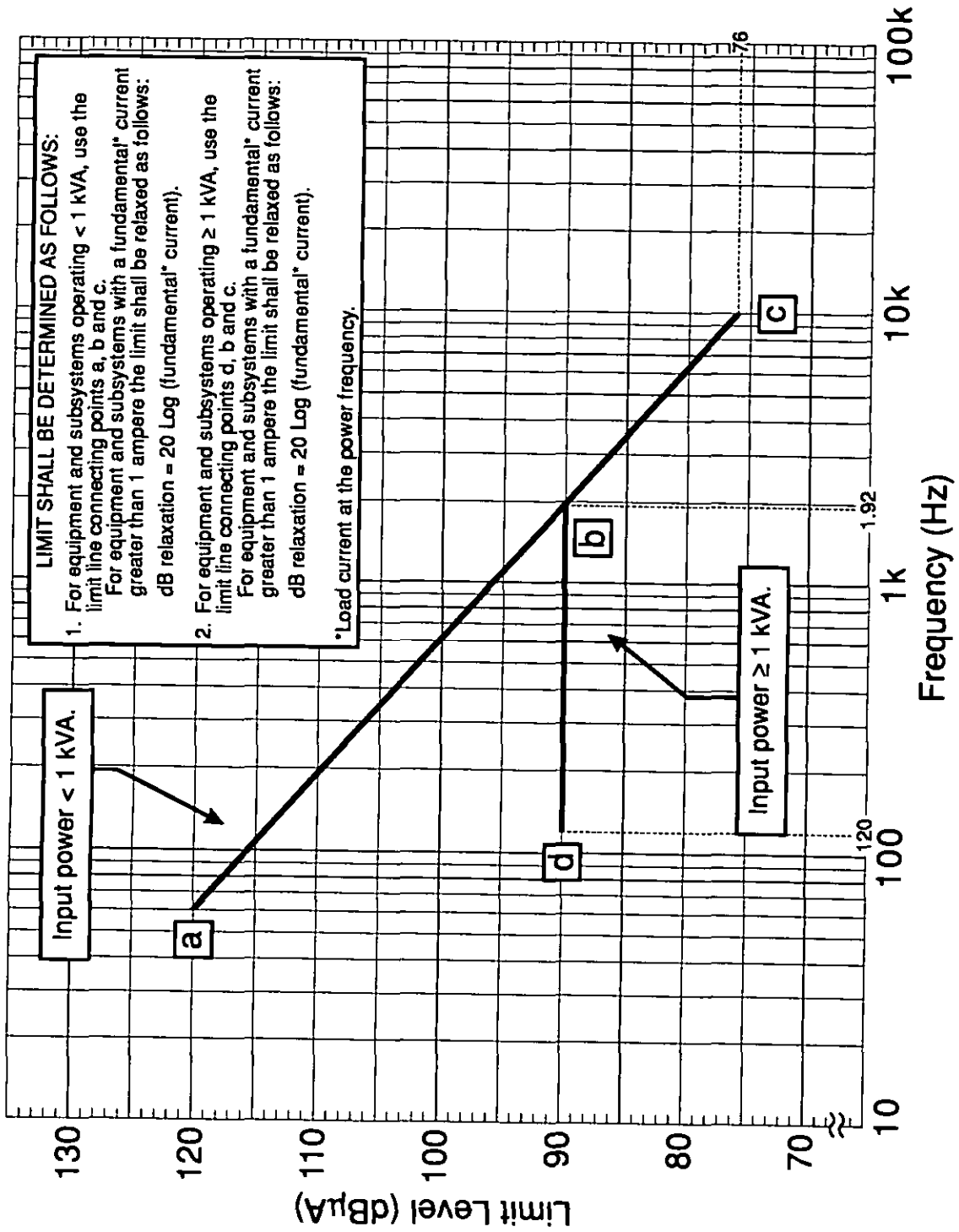

FIGURE CE101-2. CE101 limit for surface ship and submarine applications, 60 Hz.

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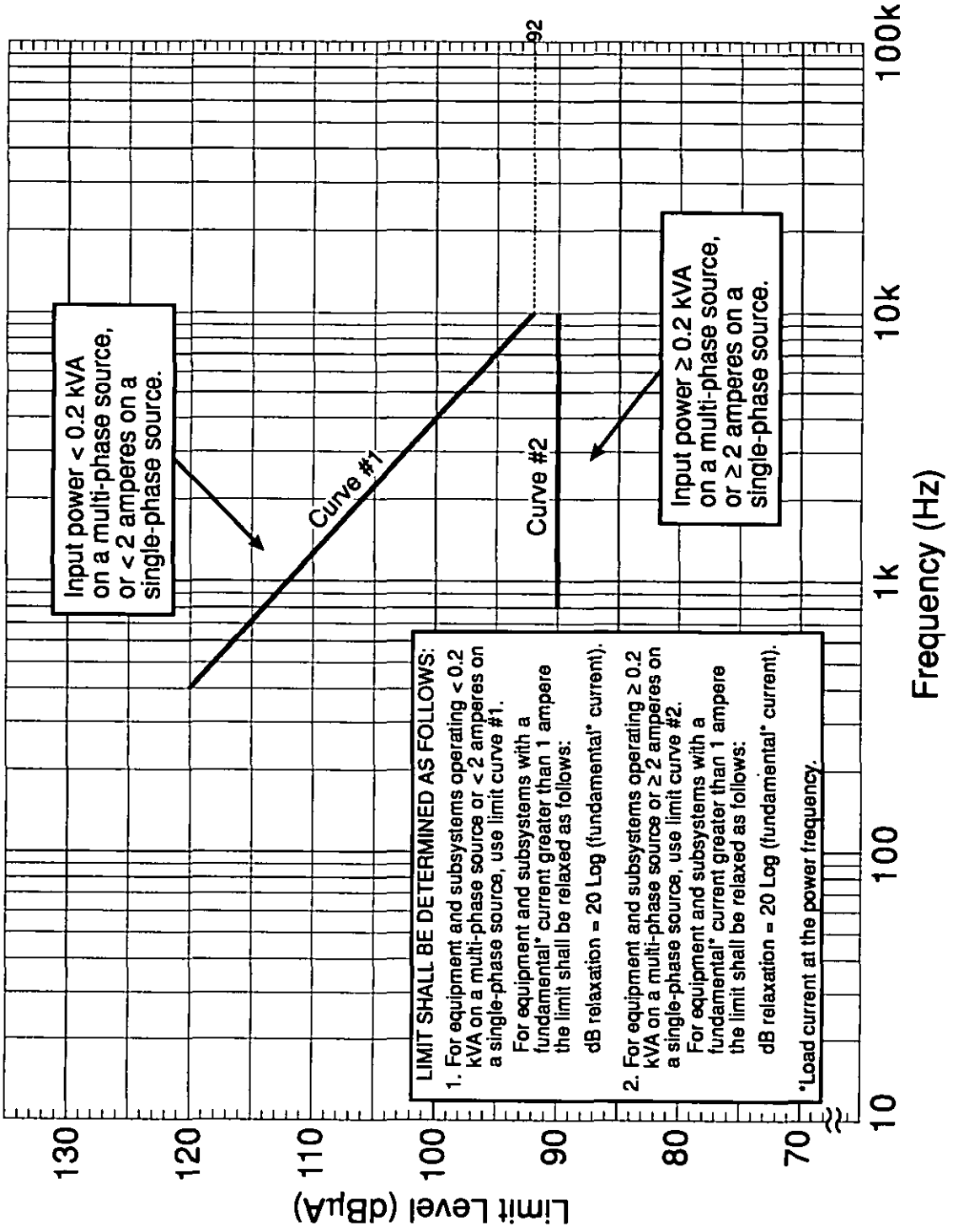

FIGURE CE101-3. CE101 limit for surface ship and submarine applications, 400 Hz.

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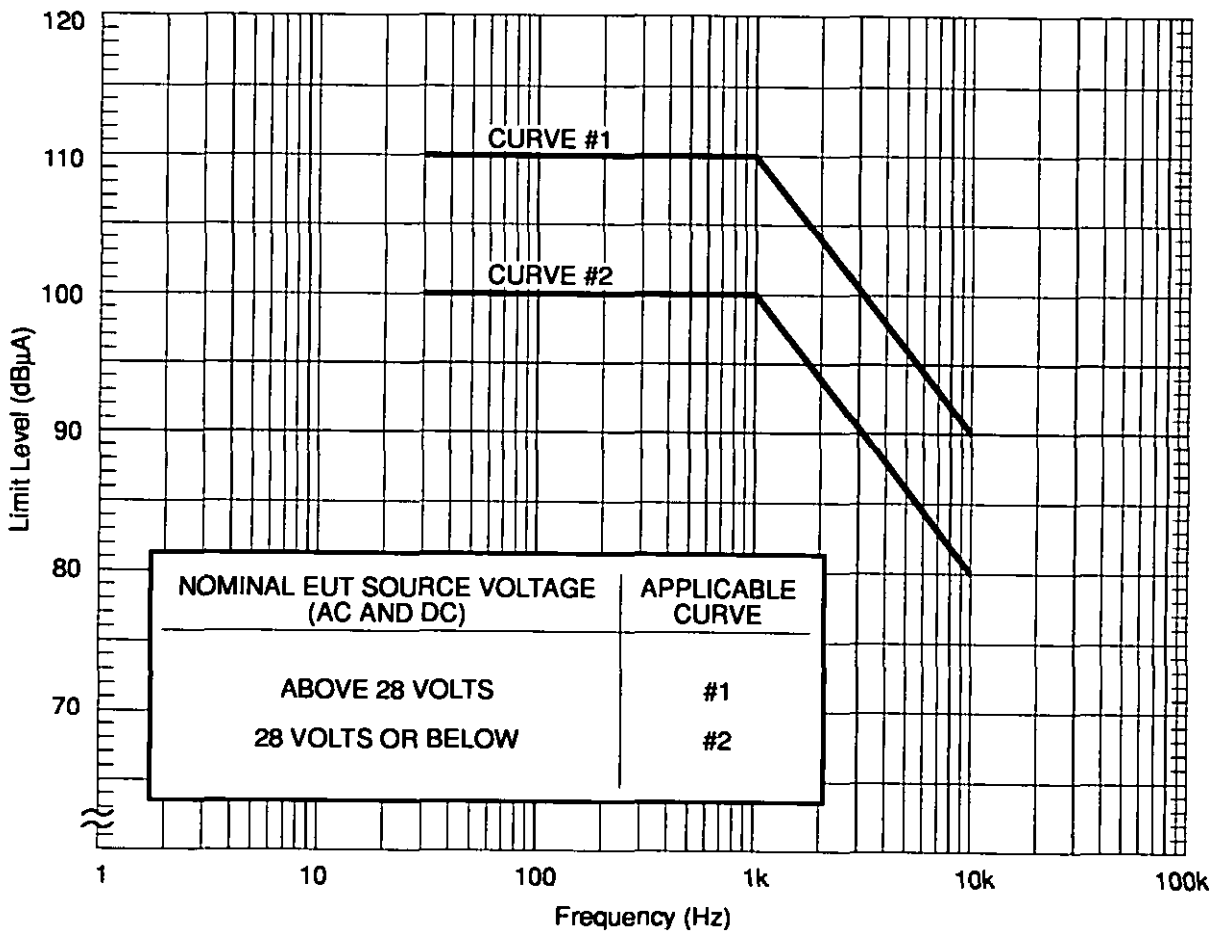

FIGURE CE101-4. CE101 limit (EUT power leads, AC and DC) for Navy ASW and Army aircraft (including flight line) applications.

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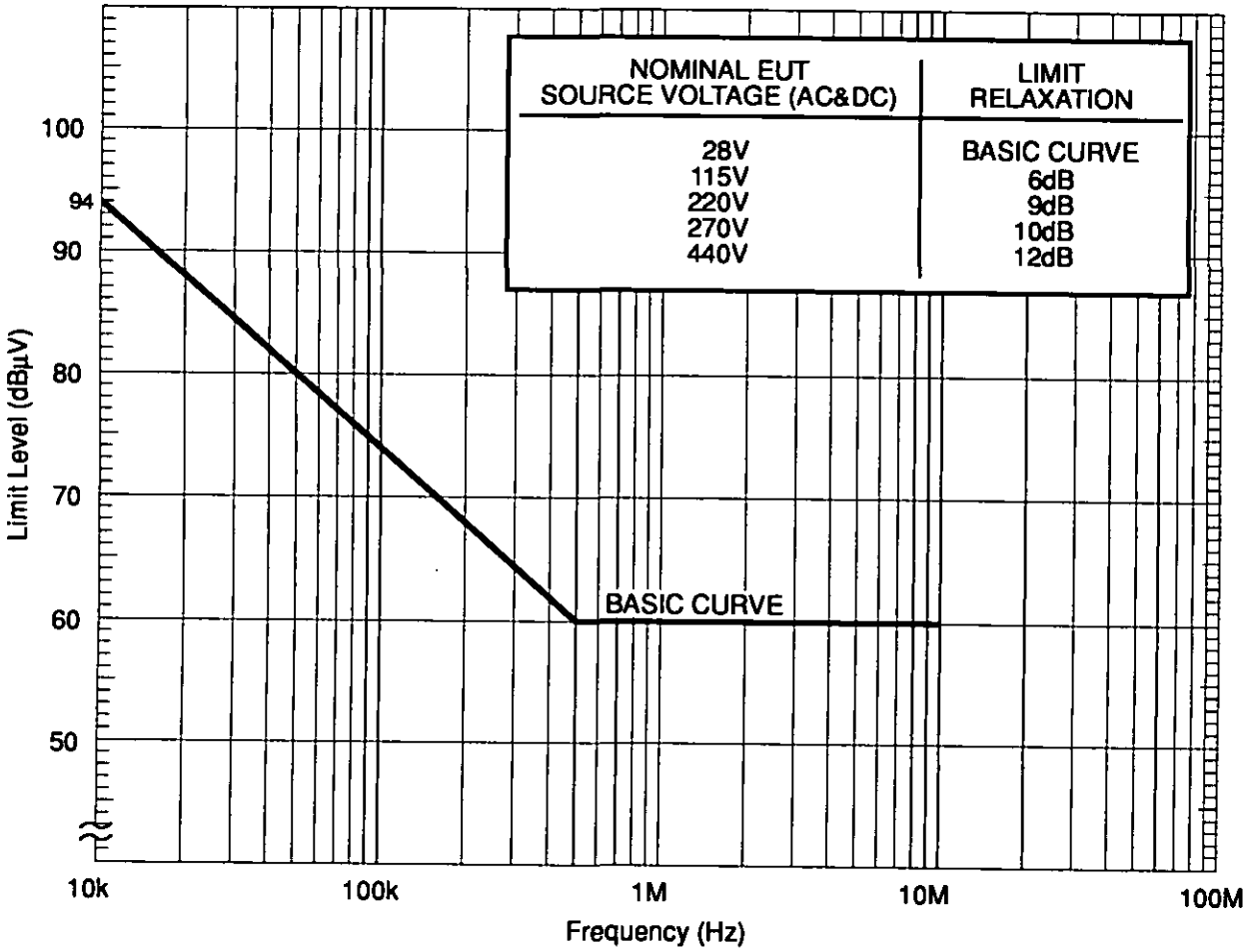

FIGURE CE102-1. CE102 limit (EUT power leads, AC and DC) for all applications.

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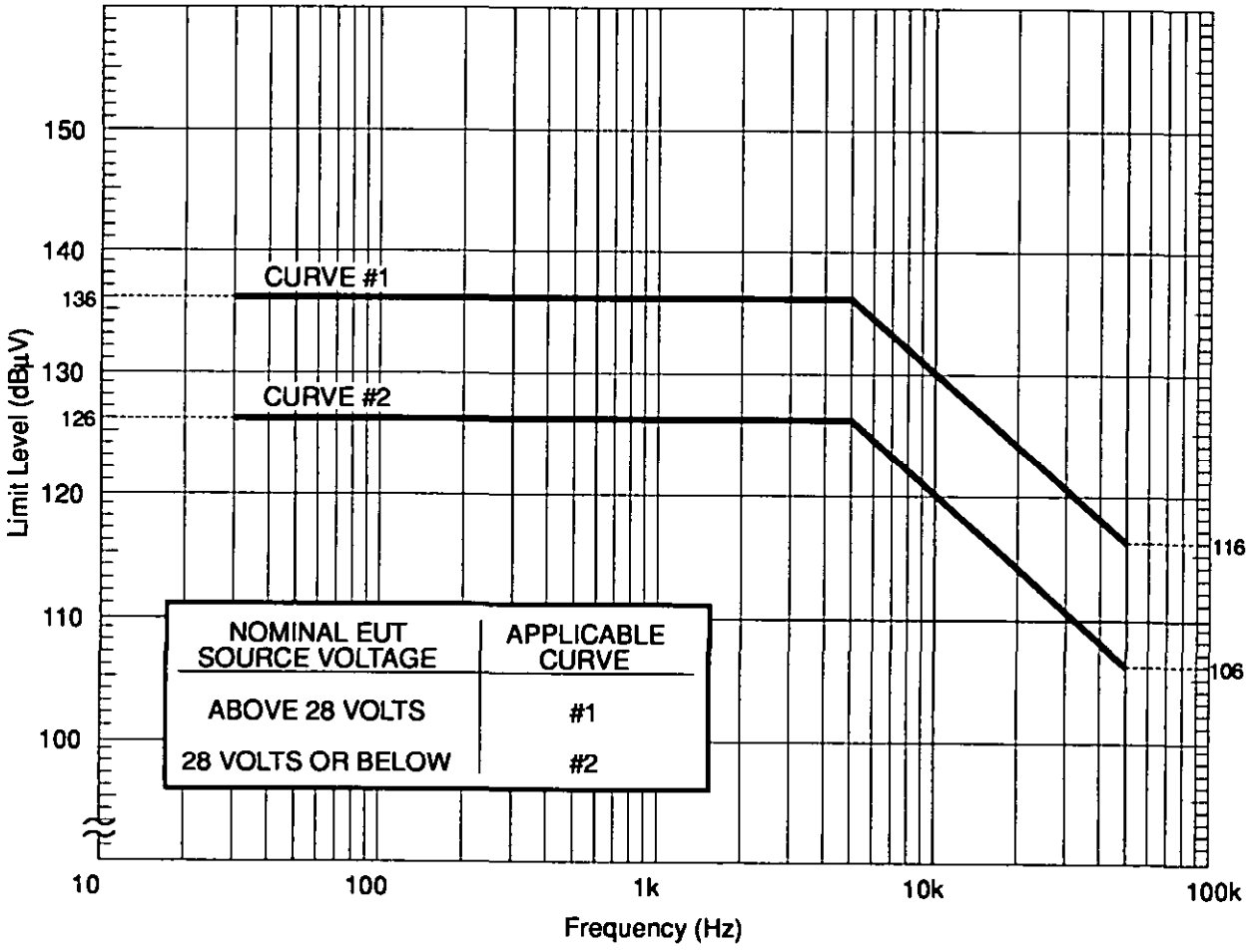

FIGURE CS101-1. CS101 limit (EUT power leads, AC and DC) for all applications.

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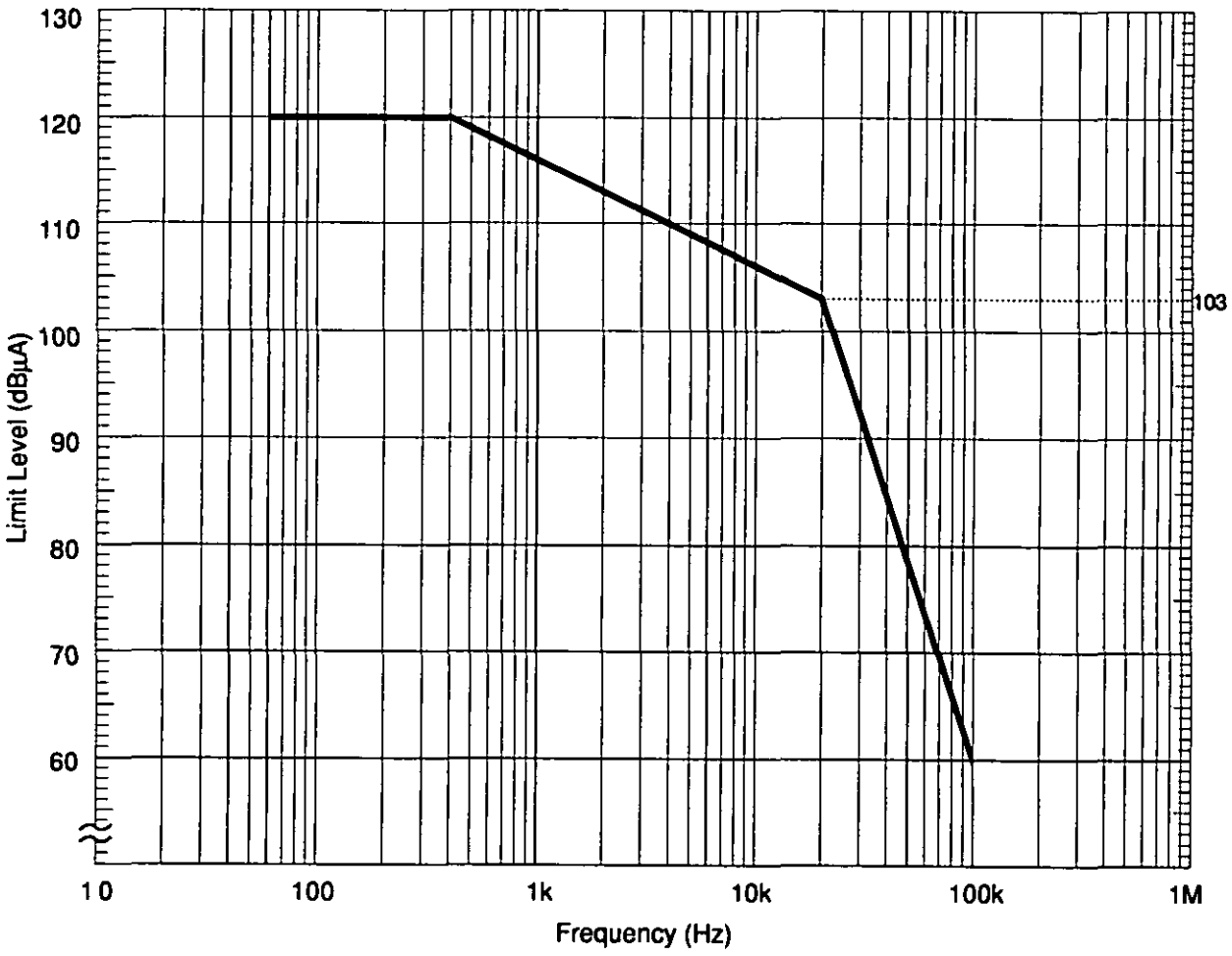

FIGURE CS109-1. CS109 limit for all applications.

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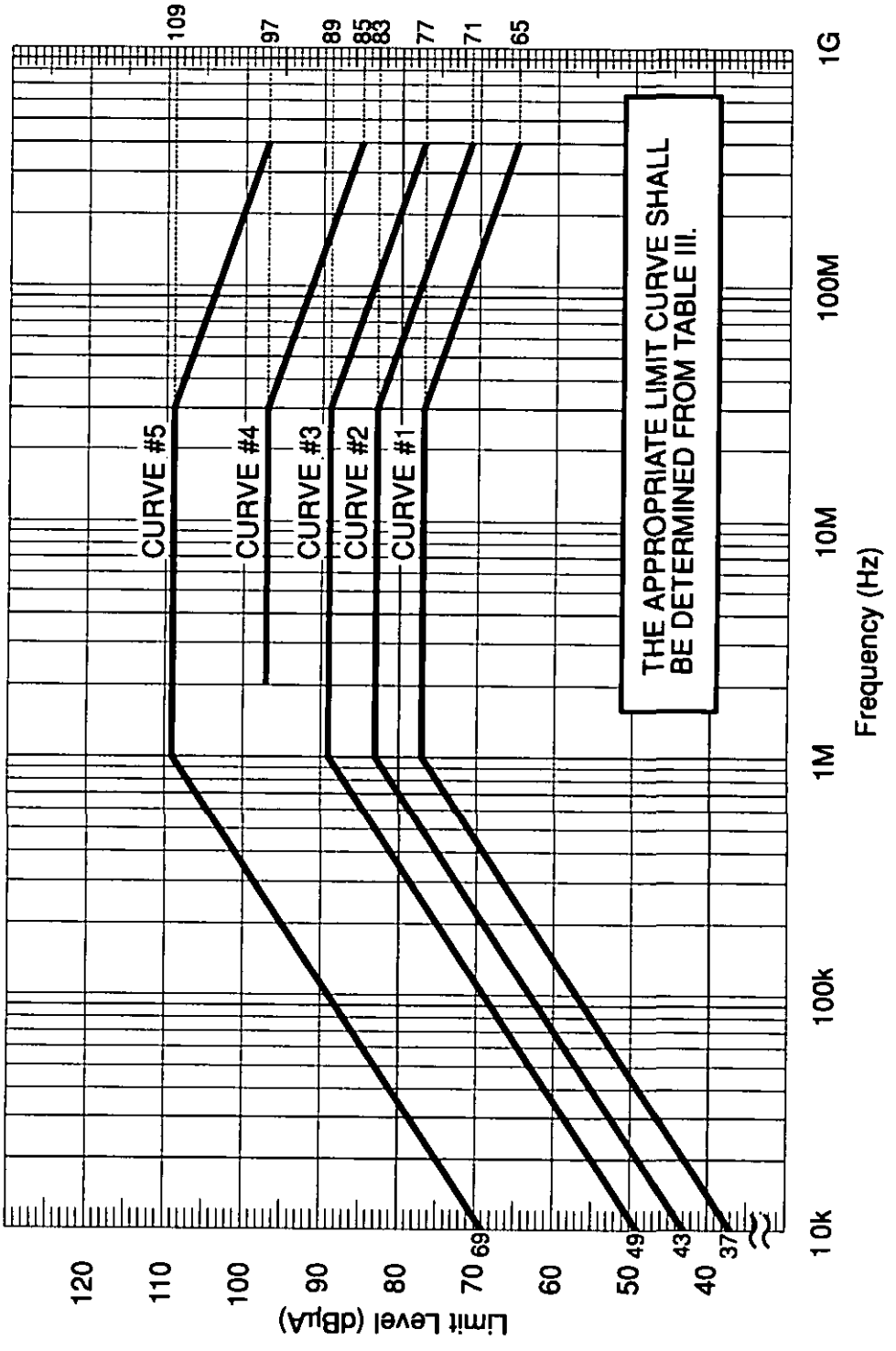

FIGURE CS114-1. CS114 calibration limit for all applications.

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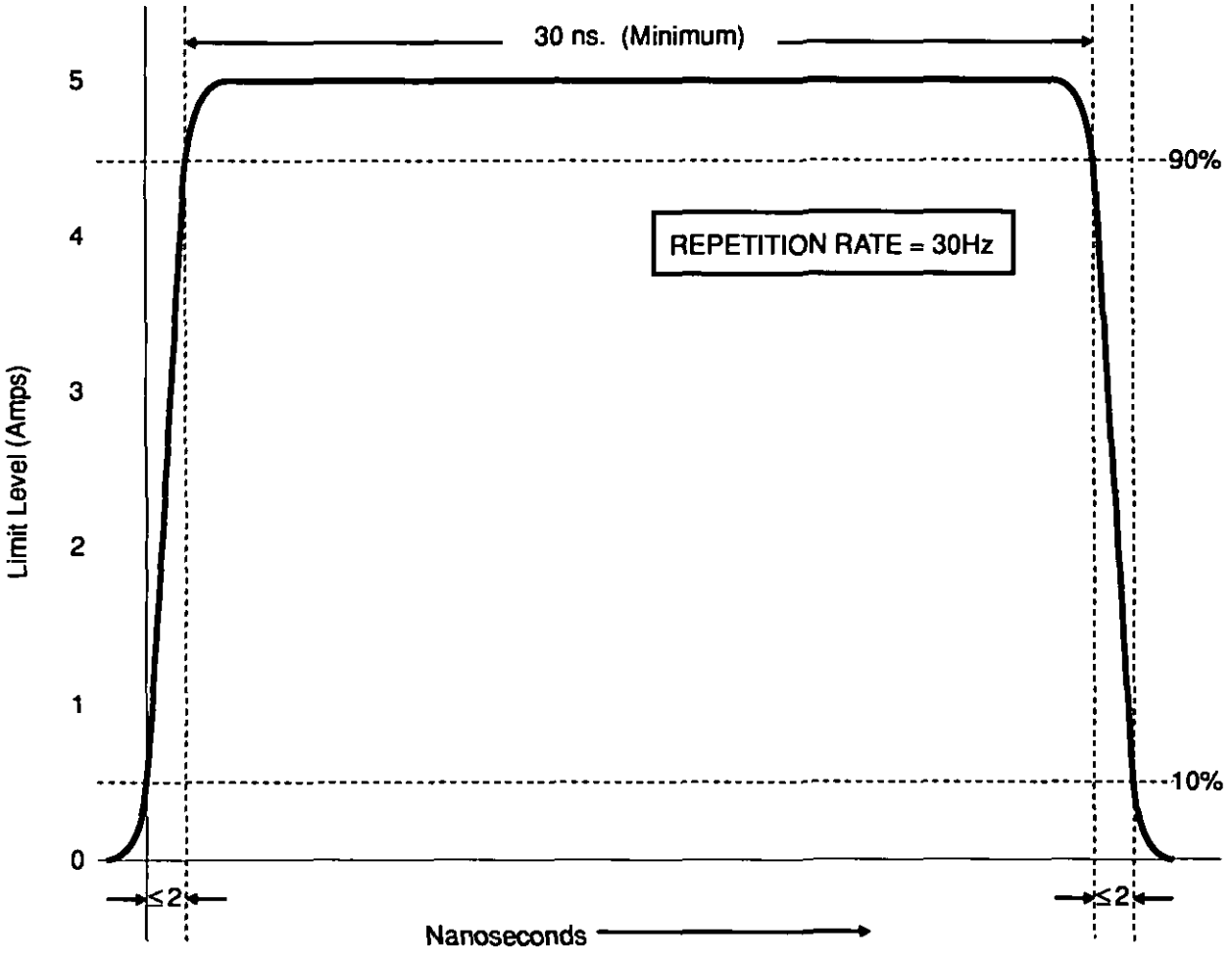

FIGURE CS115-1. CS115 calibrated signal source characteristics for all applications.

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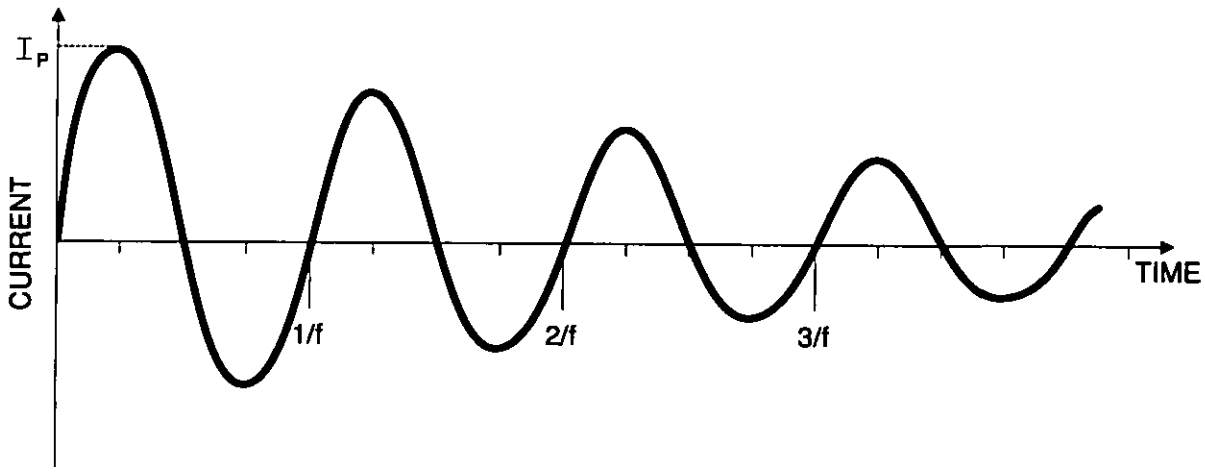

NOTES: 1. Normalized waveform: $e^{-(\pi ft)/Q}\sin(2\pi ft)$

Where:
f = Test frequency (Hz)
t = Time (sec)
Q = Damping factor, 15 ± 5

2. Damping factor (Q) shall be determined as follows:

$$Q = \frac{\pi(N - 1)}{\ln(I_P/I_N)}$$

Where:
Q = Damping factor
N = Cycle number (i.e. N = 2, 3, 4, 5,...)
I_P = Peak current at 1st cycle
I_N = Peak current at Nth cycle
ln = Natural log

3. I_P as per figure CS116-2

FIGURE CS116-1. Typical CS116 damped sinusoidal waveform.

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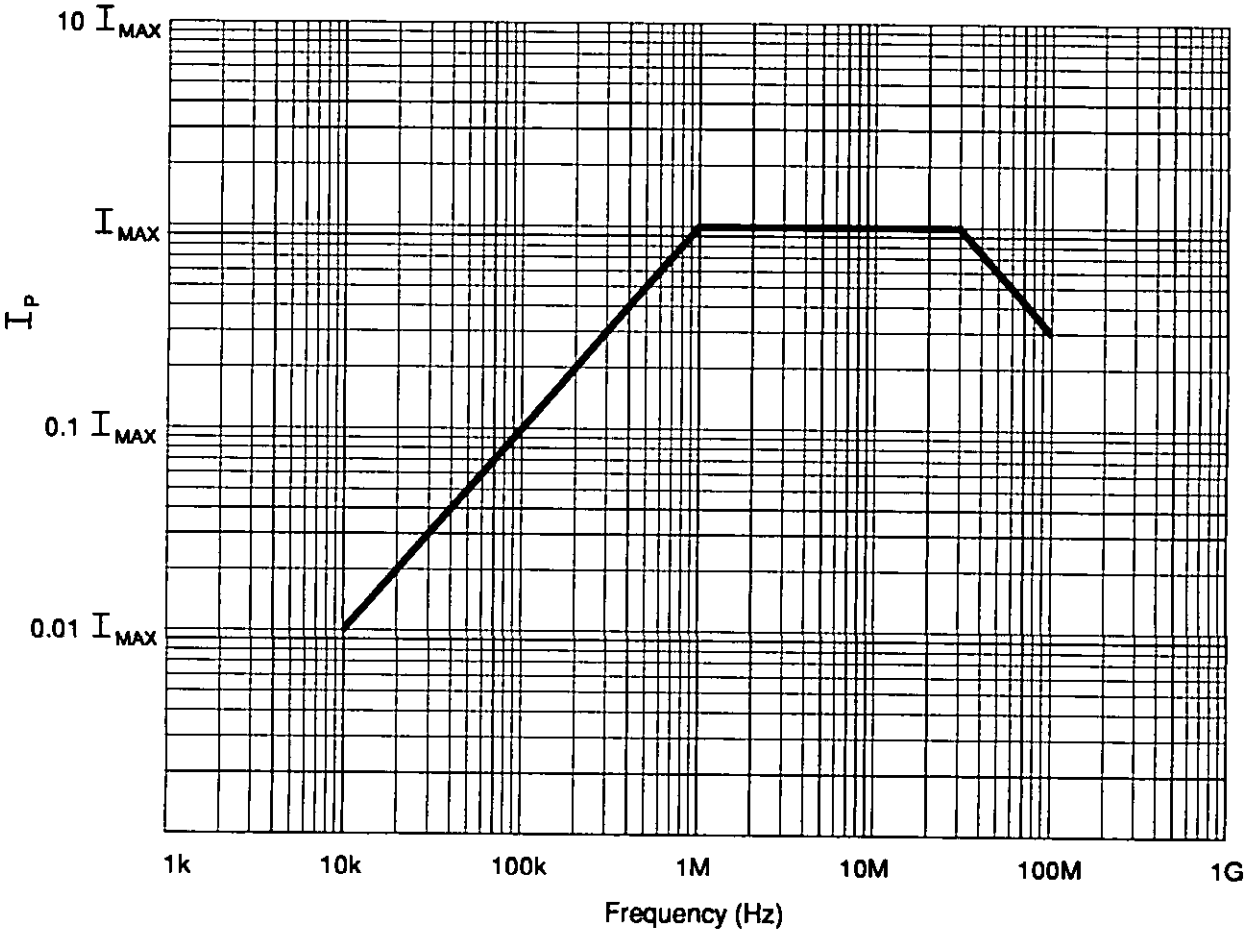

NOTE:

1. For Army and Navy procurements, I_{MAX} = 10 amperes
2. For Air Force procurements, I_{MAX} = 5 amperes

FIGURE CS116-2. CS116 limit for all applications.

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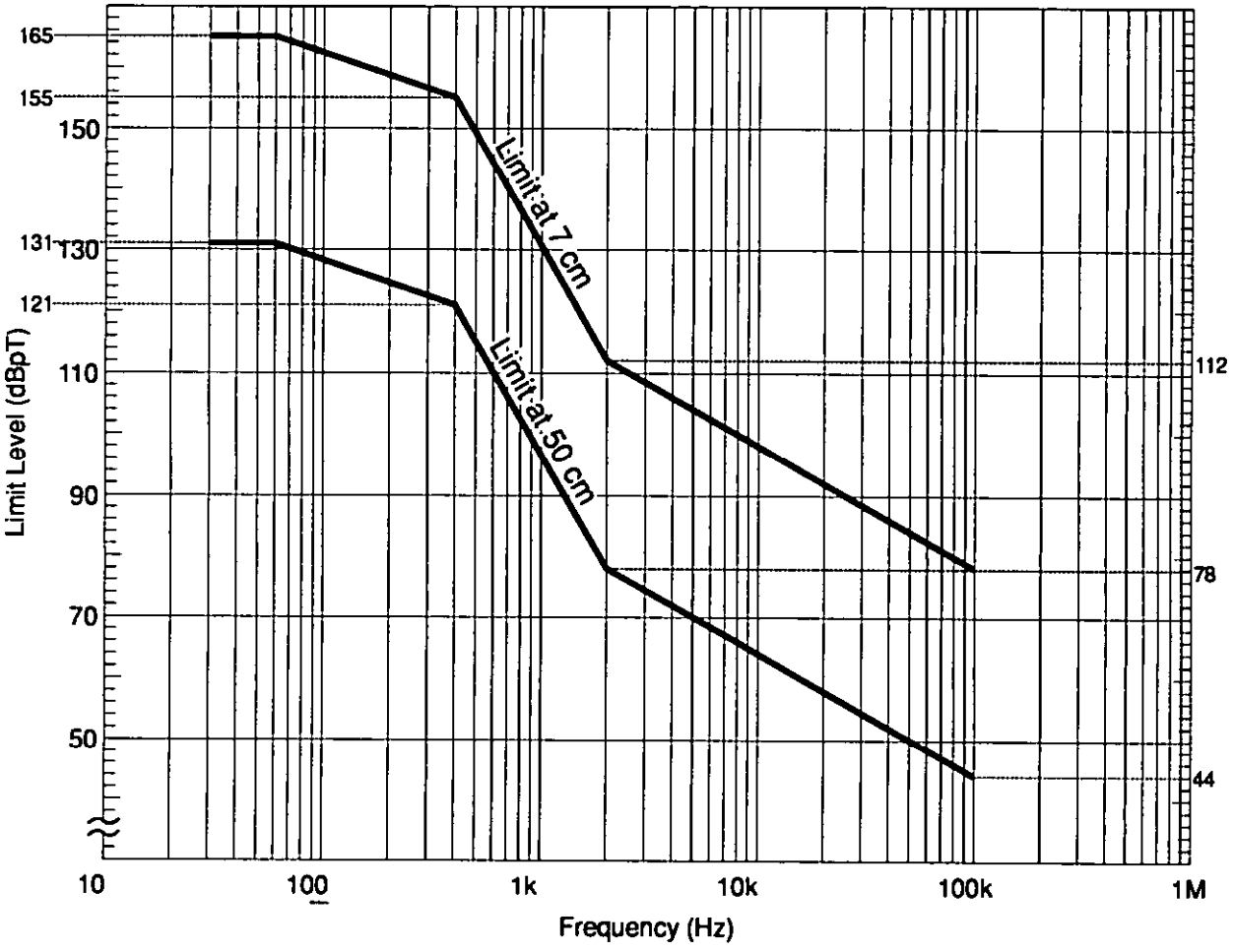

FIGURE RE101-1. RE101 limit (Navy only) for all applications.

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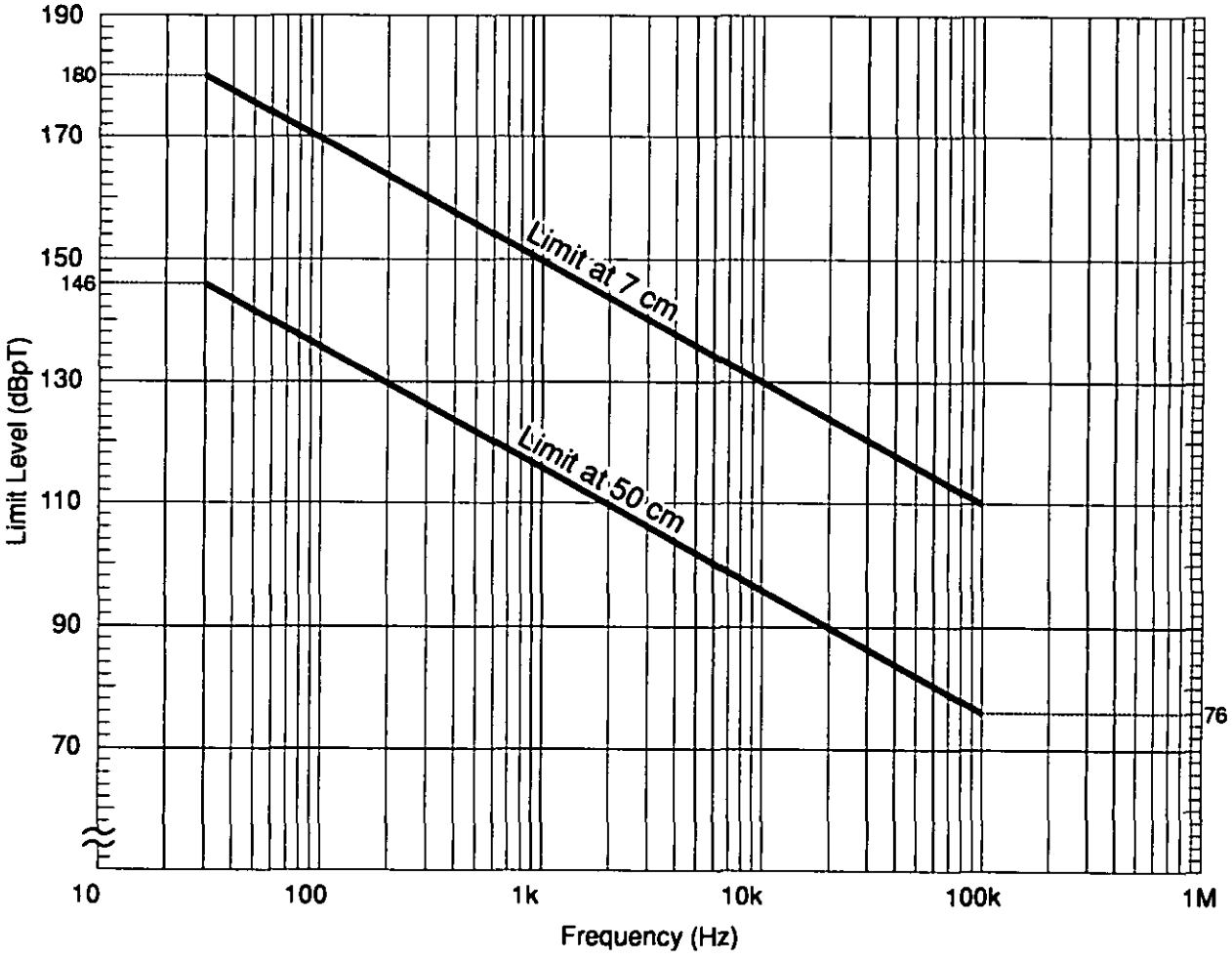

FIGURE RE101-2. RE101 limit (Army only) for all applications.

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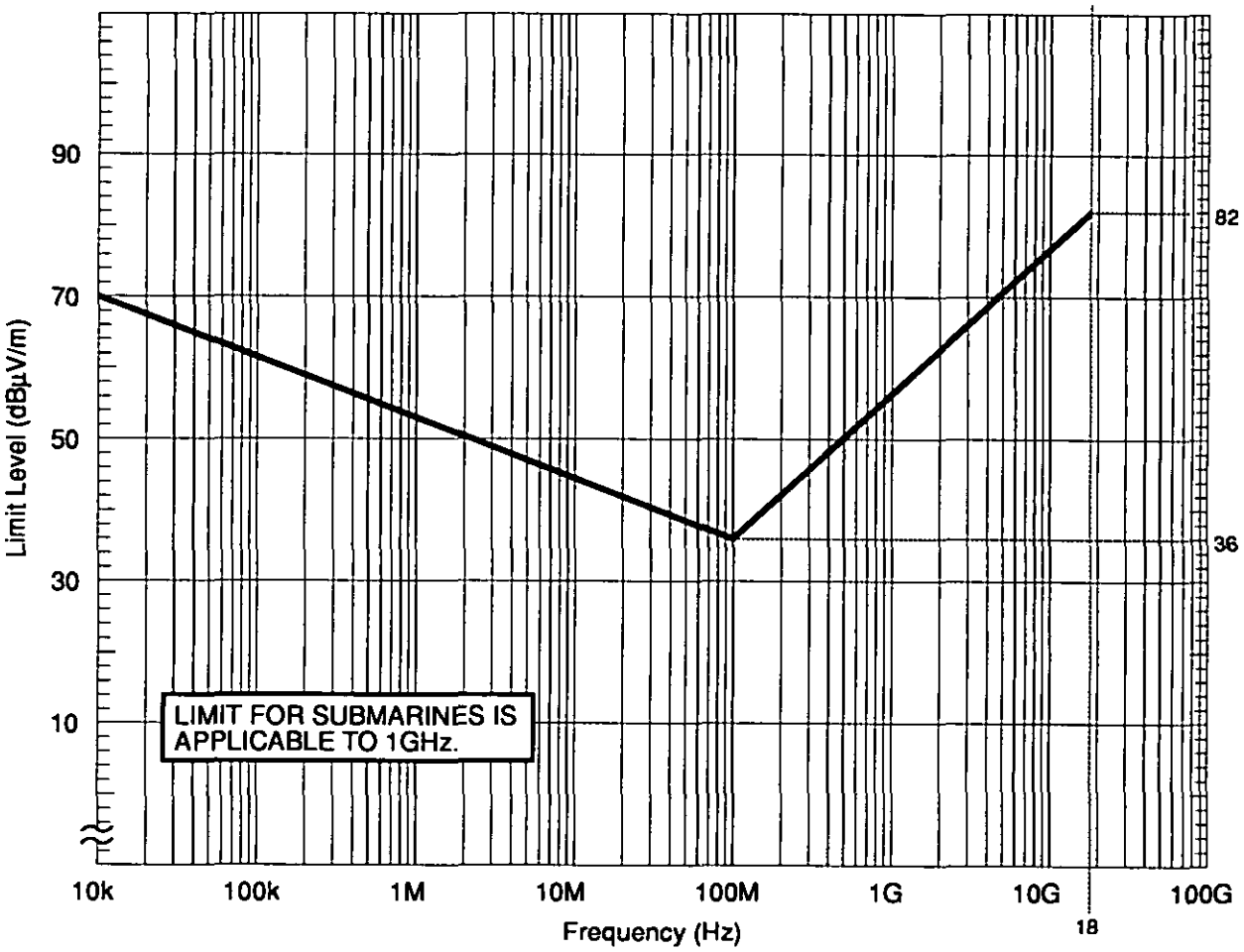

FIGURE RE102-1. RE102 limit for surface ship and submarine applications.

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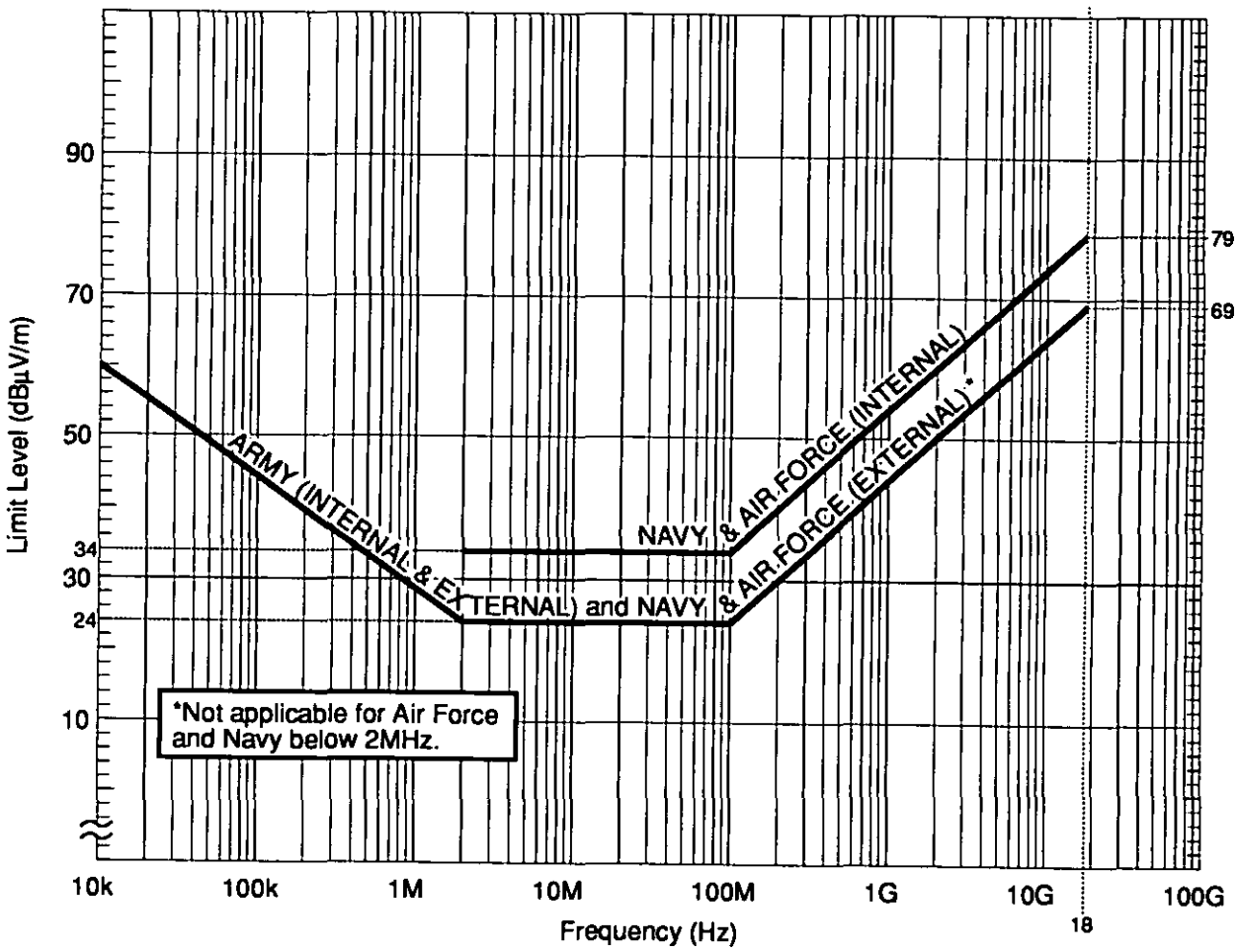

FIGURE RE102-2. RE102 limit for aircraft and space system applications.

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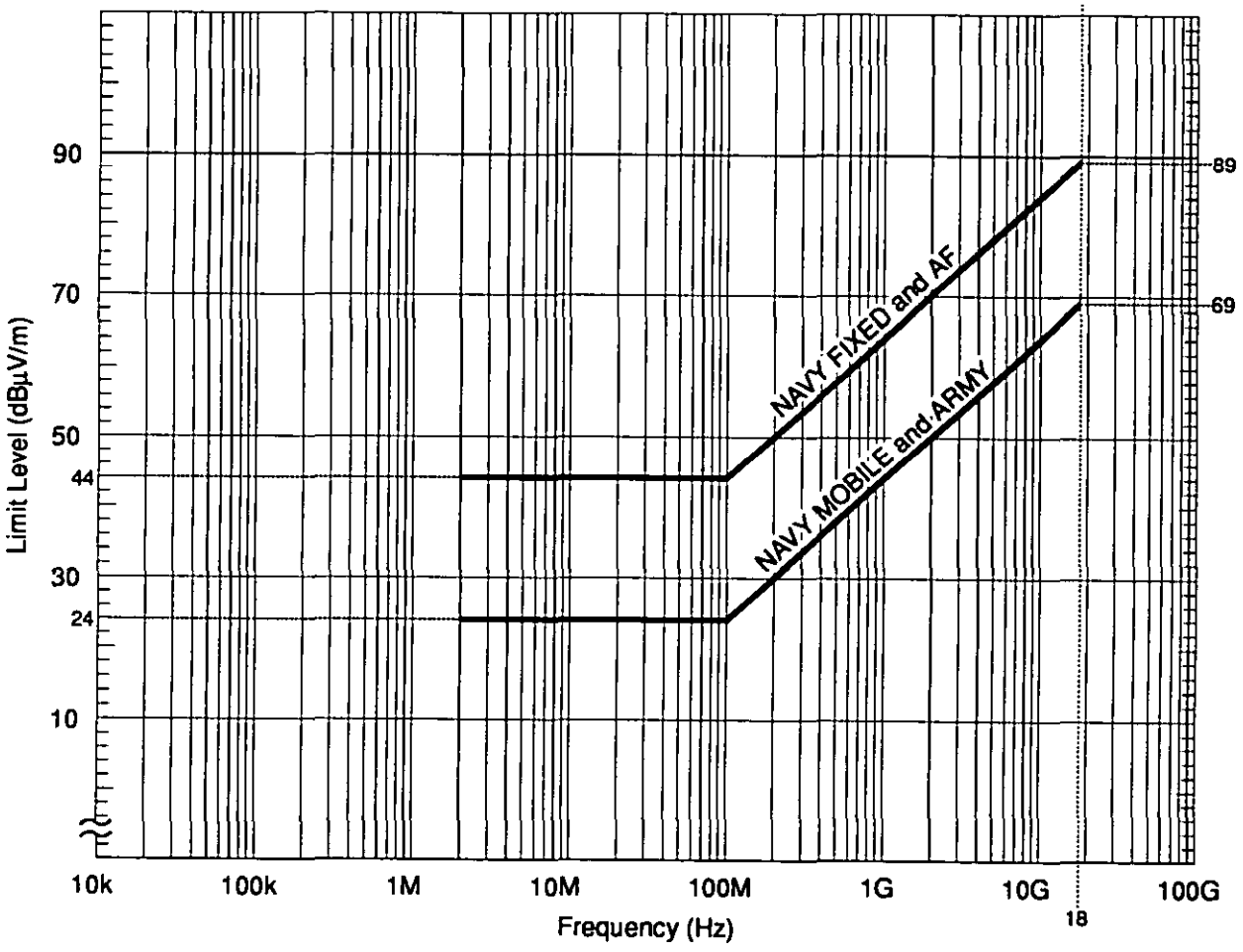

FIGURE RE102-3. RE102 limit for ground applications.

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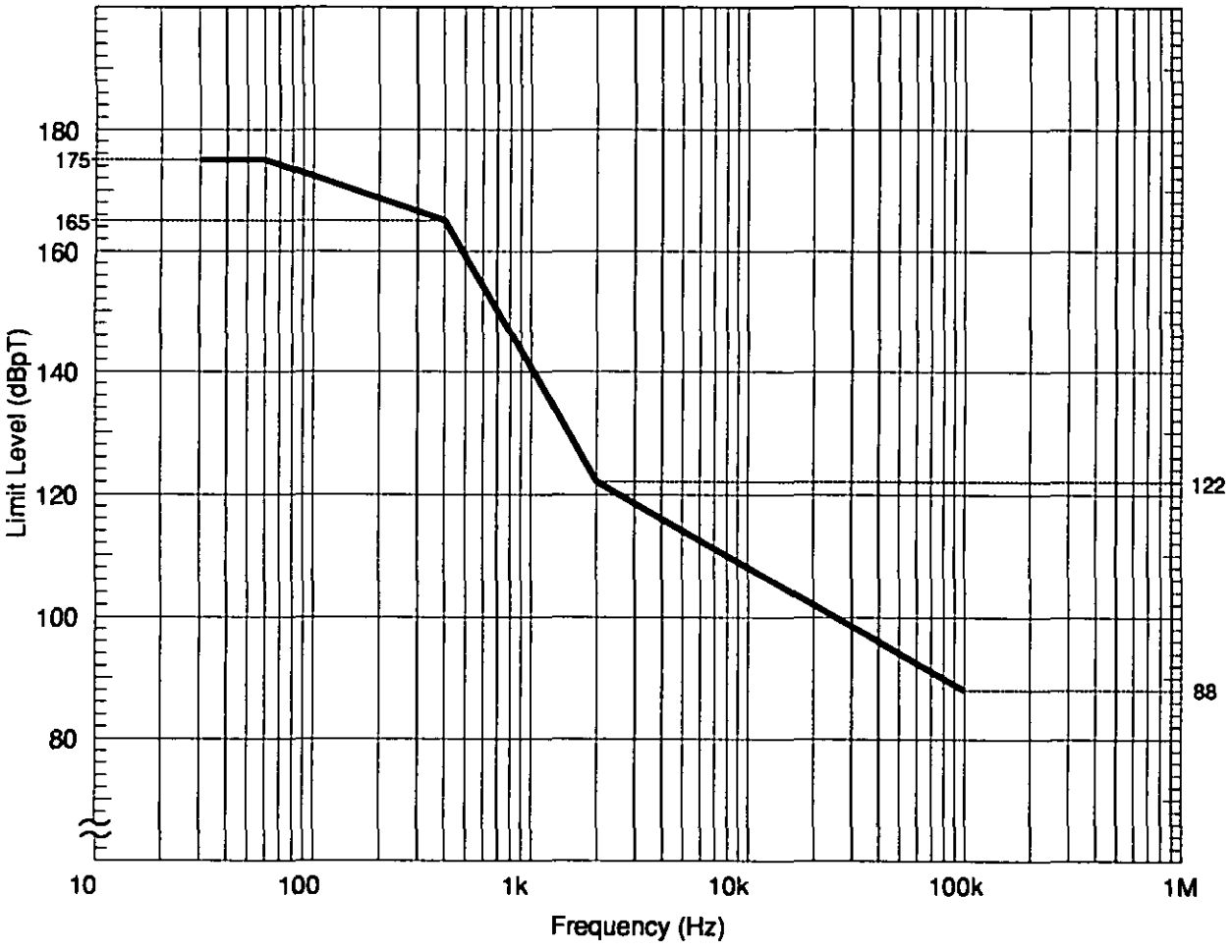

FIGURE RS101-1. RS101 limit (Navy only) for all applications.

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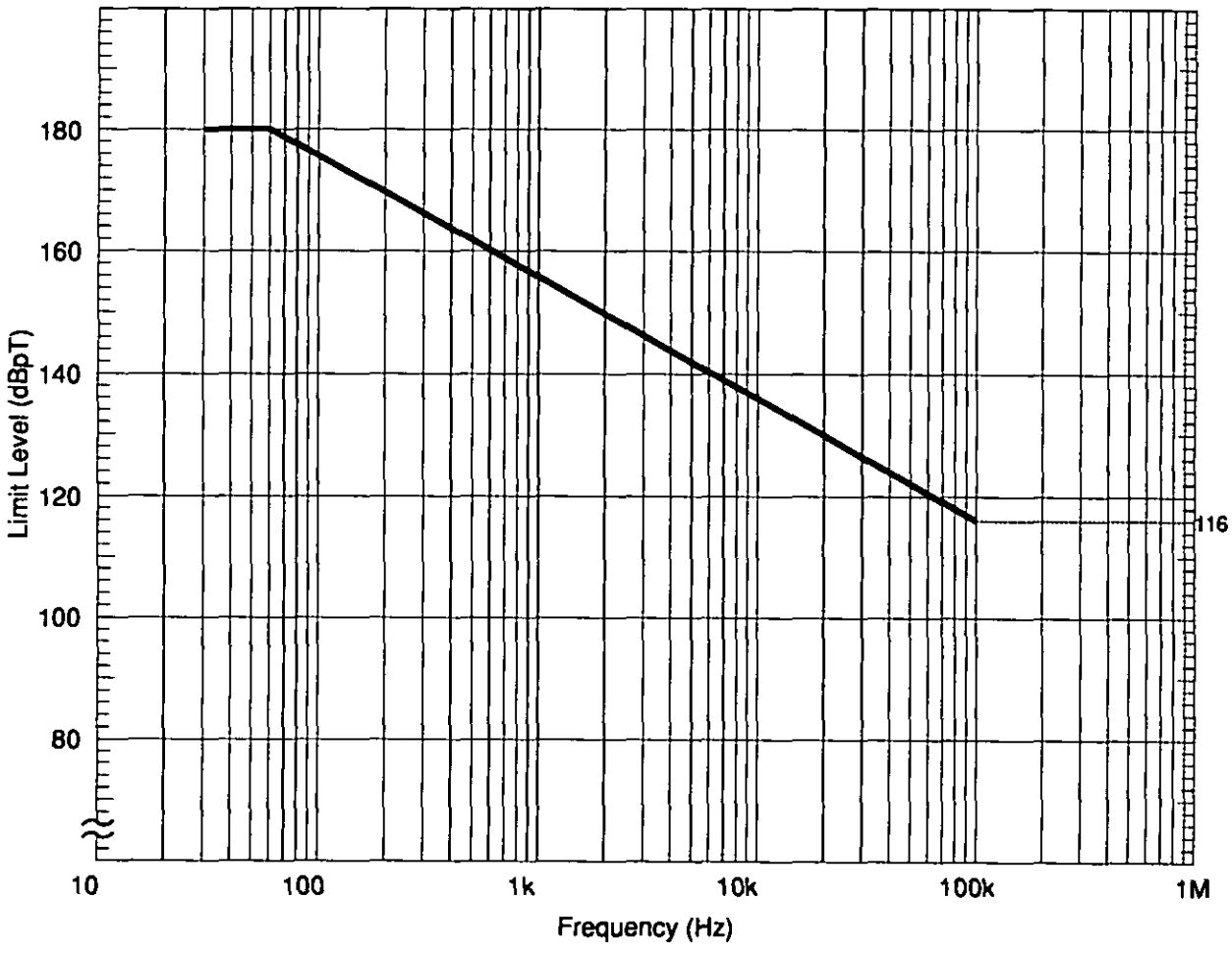

FIGURE RS101-2. RS101 limit (Army only) for all applications.

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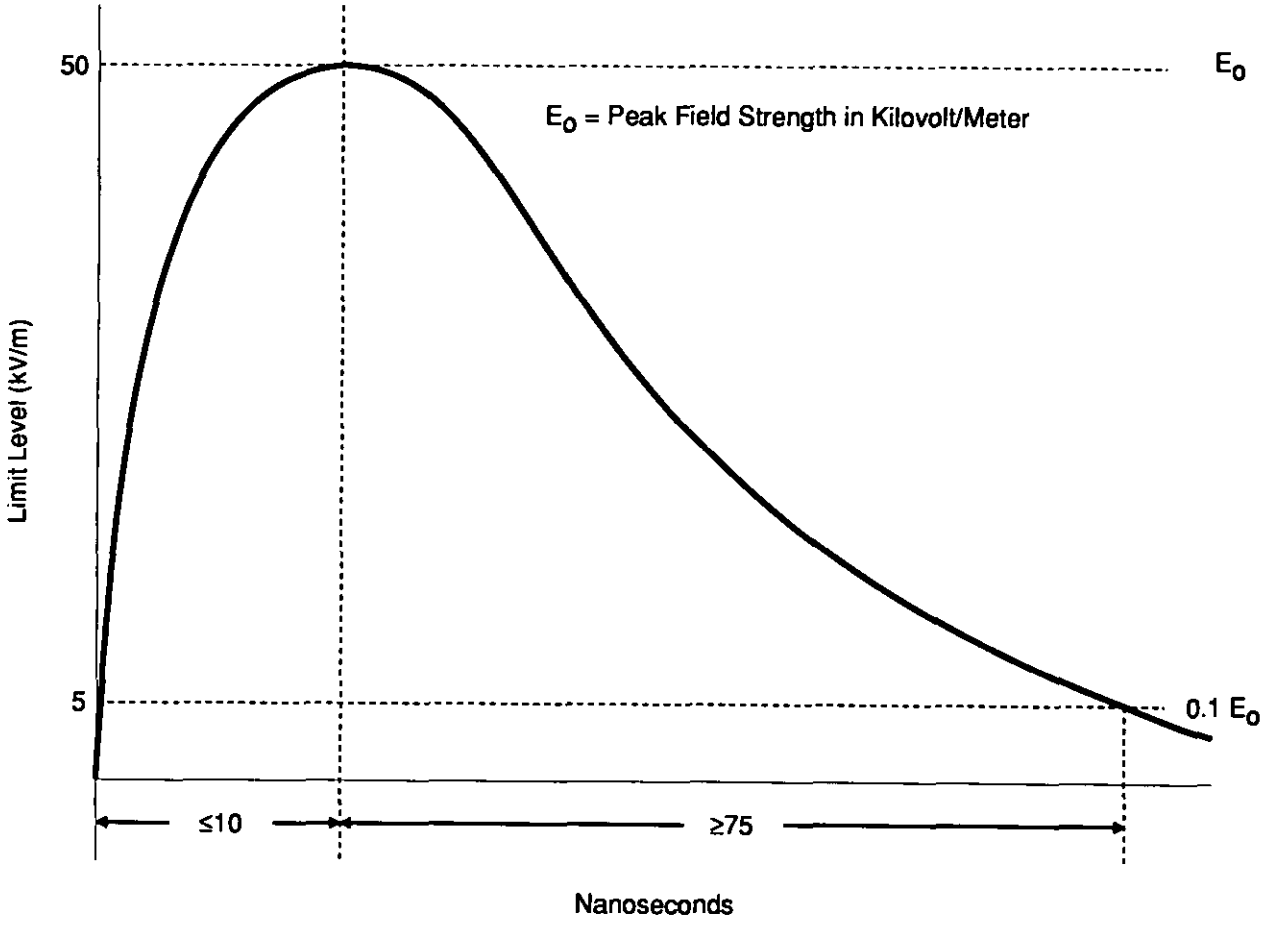

FIGURE RS105-1. RS105 limit for all applications.

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CONCLUDING MATERIAL

Custodians

Army - CR
Air Force - 11

Preparing Activity:
Navy - EC
(Project EMCS - 0133)

Review Activities

Army - MI, AV, TE
Navy - SH, OS, AS, YD, MC, CG, TD
Air Force - 13, 15, 17, 19, 99
NSA

User Activities:

Air Force - 84
Army - AT, ME, CL, CE, MD
DISA
DODECAC
DNA

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APPENDIX

MIL-STD-461D
APPLICATION GUIDE

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10. GENERAL

10.1. Scope. This appendix provides background information for each requirement in the main body of the standard. This information includes rationale for requirements, guidance in applying the requirements and lessons learned from platform experience. This information should help users understand the intent behind the requirements and should aid the procuring activity in tailoring requirements as necessary for particular applications. This handbook is provided for guidance purposes and, as such, should not be interpreted as providing contractual requirements.

10.2 Structure. This appendix follows the same general format as the main body of the standard. A "DISCUSSION" paragraph is provided for each requirement contained in the standard. Main body paragraph numbers corresponding to each requirement are included in parentheses.

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20. APPLICABLE DOCUMENTS

20.1 Government documents.

20.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issue of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

SPECIFICATIONS

MILITARY

MIL-E-6051	-	Electromagnetic Compatibility Requirements, Systems

STANDARDS

MILITARY

MIL-STD-462	-	Measurement of Electromagnetic Interference Characteristics
MIL-STD-704	-	Aircraft Electric Power Characteristics
MIL-STD-1275	-	Characteristics of 28 Volt DC Electrical Systems in Military Vehicles
MIL-STD-1377	-	Effectiveness of Cable, Connector and Weapon Enclosure Shielding and Filters in Precluding Hazards of Electromagnetic Radiation to Ordnance, Measurement of
MIL-STD-1385 (NAVY)	-	Preclusion of Ordnance Hazards in Electromagnetic Fields, General Requirements for
MIL-STD-1399 (NAVY) Section 300	-	Interface Standard for Ship Systems, Section 300, Electric Power, Alternating Current

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MIL-STD-1512 (USAF)	-	Electroexplosive Subsystems, Electrically Initiated, Test Methods and Design Requirements
MIL-STD-1539 (USAF)	-	Electric Power, Direct Current, Space Vehicle Design Requirements
MIL-STD-1541 (USAF)	-	Electromagnetic Compatibility Requirements for Space Systems
MIL-STD-1542 (USAF)	-	Electromagnetic Compatibility (EMC) and Grounding Requirements for Space Systems Facilities
MIL-STD-1757	-	Lightning Qualification Test Techniques for Aerospace Vehicles and Hardware
MIL-STD-1795	-	Lightning Protection of Aerospace Vehicles and Hardware
MIL-STD-1818	-	Electromagnetic Effects Requirements for Systems

HANDBOOKS

MILITARY

MIL-HDBK-235	-	Electromagnetic (Radiated) Considerations for Design and Procurement of Electrical and Electronic Equipment
MIL-HDBK-237	-	Electromagnetic Compatibility Management Guide for Platforms, Systems and Equipment
MIL-HDBK-241	-	Design Guide for EMI Reduction in Power Supplies
MIL-HDBK-253	-	Guidance for the Design and Test of Systems Protected Against the Effects of Electromagnetic Energy

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (ATTN: NPODS, 5801 Tabor Avenue, Philadelphia PA 19120-5099.))

20.1.2 Other Government documents, drawings, and publications. The following other Government documents,

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drawings, and publications form a part of this standard to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

PUBLICATIONS

AIR FORCE SYSTEMS COMMAND (AFSC)

AFSC DH 1-4	-	Air Force Systems Command Design Handbook, EMC

FEDERAL COMMUNICATIONS COMMISSION

CFR Title 47	-	Parts 2, 15, and 18

DEPARTMENT OF DEFENSE (DOD)

DODISS	-	Department of Defense Index of Specifications and Standards
DOD 5000.37-M	-	DOD Non Developmental Items Acquisition Manual

US ARMY AMC MATERIEL READINESS SUPPORT ACTIVITY

AMC Pamphlet 706-235	-	Hardening Weapon Systems Against RF Energy
AMC Pamphlet 706-410	-	Engineering Design Handbook, EMC

US ARMY AVIATION SYSTEMS COMMAND

ADS-37	-	Electromagnetic Environmental Effects (E^3) Management, Design and Test Requirements

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

NAVSEA OD 30393	-	Design Principles and Practices for Controlling Hazards of Electromagnetic Radiation to Ordnance

(Copies of publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

20.2. Non-Government publications. The following documents form a part of this document to the extent specified herein.

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Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C63.12	-	American National Standard for Electromagnetic Compatibility Limits - Recommended Practice
ANSI C63.14	-	Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD)
ANSI/IEEE 268	-	Metric Practice. (DOD adopted)

(Application for copies should be addressed to the IEEE Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 380	-	Standard for Metric Practice. (DOD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

RADIO TECHNICAL COMMISSION FOR AERONAUTICS

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

(Applications for copies should be addressed to Radio Technical Commission for Aeronautics Secretariat, One McPherson Square, Suite 500, 1425 K Street, NW, Washington DC 20005.)

(Non-government standards are generally available for reference from libraries. They are also distributed among non-government standards bodies and using Federal agencies.)

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30. DEFINITIONS

30.1 General. The terms used in this appendix are defined in ANSI C63.14. In addition, the following definitions are applicable for the purpose of this appendix.

30.2 Acronyms used in this appendix.

a. ASW - Anti-submarine Warfare

b. EMC - Electromagnetic Compatibility

c. EME - Electromagnetic Environment

d. EMI - Electromagnetic Interference

e. EMICP - Electromagnetic Interference Control Procedures

f. EMITP - Electromagnetic Interference Test Procedures

g. EMITR - Electromagnetic Interference Test Report

h. EMP - Electromagnetic Pulse

i. EUT - Equipment Under Test

j. GFE - Government Furnished Equipment

k. LISN - Line Impedance Stabilization Network

l. NDI - Non-Developmental Item

m. NOE - Nap-of-the-earth

n. RF - Radio Frequency

o. RMS - Root Mean Square

p. VFR - Visual Flight Rules

30.3 Below deck. An area on ships which is surrounded by a metallic structure, or an area which provides significant attenuation to electromagnetic radiation, such as the metal hull or superstructure of a surface ship, the hull of a submarine and the screened rooms in non-metallic ships.

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30.4 External installation. An equipment location on a platform which is exposed to the external electromagnetic environment, such as an aircraft cockpit which does not use electrically conductive treatments on the canopy or windscreen.

30.5 Internal installation. An equipment location on a platform which is totally inside an electrically conductive structure, such as a typical avionics bay in an aluminum skin aircraft.

30.6 Metric units. Metric units are a system of basic measures which are defined by the International System of Units based on "Le System International d'Unites (SI)", of the International Bureau of Weights and Measures. These units are described in ASTM E 380 and ANSI/IEEE 268.

30.7 Non-developmental item. Non-developmental item is a broad, generic term that covers material available from a wide variety of sources with little or no development effort required by the Government.

30.8 Safety critical. A category of subsystems and equipment whose degraded performance could result in loss of life or loss of vehicle or platform.

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40. GENERAL REQUIREMENTS

40.1 (4.1) General. Electronic, electrical, and electromechanical equipment and subsystems shall comply with the applicable requirements in 4.2 through 4.8. The requirements are in addition to the applicable emission and susceptibility requirements defined in other portions of this standard.

DISCUSSION: The requirements in this paragraph are universally applicable to all subsystems and equipment. Separate emission and susceptibility requirements which are structured to address specific concerns with various classes of subsystems and equipment are contained in other portions of this standard.

This document is concerned only with specifying technical design requirements for controlling electromagnetic interference (EMI) emissions and susceptibility at the subsystem-level and equipment-level. The requirements in this document are not intended to be directly applied to subassemblies of equipment such as modules or circuit cards. The basic concepts can be implemented at the subassembly level; however, significant tailoring needs to be accomplished for the particular application. The requirements included herein are intended to be used as a baseline. Placement of the limits is based on demonstrated performance typically required for use on existing platforms in order to achieve electromagnetic compatibility (EMC). System-level requirements dealing with integration of subsystems and equipment are contained in documents such as MIL-E-6051, MIL-STD-1818, MIL-STD-1541 and MIL-STD-1542. The procuring activity and system contractors should review the requirements contained herein for possible tailoring based on system design and expected operational environments.

Guidance and techniques which are helpful in designing to meet the requirements of this standard are contained in MIL-HDBK-241, MIL-HDBK-253, AFSC DH 1-4, and AMC Pamphlet 706-410. MIL-HDBK-237 provides guidance for management of EMC efforts. ADS-37 provides additional guidance for Army equipment located or operated on fixed-wing aircraft and helicopters. MIL-HDBK-235 provides information on land, air, and sea based RF emitters, both hostile and friendly, which contribute to the overall electromagnetic environment. MIL-STD-1818 specifies the total electromagnetic environment (external RF, EMP, and lightning) for complete systems for Air Force applications.

An area related to EMI control is design requirements of electroexplosive subsystems and electroexplosive devices. MIL-STD-1512 specifies requirements for Air Force applications. MIL-STD-1385 specifies ordnance design requirements for the NAVY

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with OD 30393 providing design guidance. MIL-STD-1377 contains techniques for evaluating the effectiveness of cable, connector, and weapon enclosure shielding.

Another related area is lightning requirements. MIL-STD-1795 specifies design requirements for protecting aerospace vehicles and hardware from the effects of lightning. MIL-STD-1757 provides test techniques for evaluating aerospace vehicles and hardware to the lightning threat.

40.2 (4.2) Joint procurement. Equipment or subsystems procured by one DOD activity for multi-agency use shall comply with the requirements of the user agencies.

DISCUSSION: When the government procures equipment that will be used by more than one service or agency, a particular activity is assigned responsibility for overall procurement. The responsible activity must address the concerns of all the users. Conflicts may exist among the parties concerned. Also, imposition of more severe design requirements by one party may adversely affect other performance characteristics required by the second party. For example, severe radiated susceptibility levels on an electro-optical sensor may require aperture protection measures which compromise sensitivity. It is important that these issues be resolved to the satisfaction of all parties and that all genuine requirements be included.

40.3 (4.3) Filtering (Navy only). The use of line-to-ground filters for EMI control shall be minimized. Such filters establish low impedance paths for structure (common-mode) currents through the ground plane and can be a major cause of interference in systems, platforms, or installations because the currents can couple into other equipment using the same ground plane. If such a filter must be employed, the line-to-ground capacitance for each line shall not exceed 0.1 microfarads (µF) for 60 Hertz (Hz) equipment or 0.02 µF for 400 Hz equipment. For submarine DC-powered equipment and aircraft DC-powered equipment, the filter capacitance from each line-to-ground at the user interface shall not exceed 0.075 µF/kW of connected load. For loads less than 0.5 kW, the filter capacitance shall not exceed 0.03 µF. The filtering employed shall be fully described in the equipment or subsystem technical manual and the Electromagnetic Interference Control Procedures (EMICP) (See 6.3).

DISCUSSION: The power systems for Navy ships and submarines are ungrounded. The primary AC power, both 60 Hz and 400 Hz are three-phase, ungrounded, delta configuration systems. The primary DC power for submarines is a two-wire ungrounded system. The capacitance-to-ground of power line filters provides a path for conducting current into the hull structure. The Navy uses very sensitive low frequency radio and sonar receivers. At low

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frequencies, currents flowing through the installation structure and across surfaces of electronic enclosures will penetrate to the inside of the enclosure. The magnetic fields created by these currents can couple into critical circuits and degrade performance. At higher frequencies (greater than 100 kHz), the combination of power line filter capacitance-to-ground limitation, skin effect of equipment enclosures and reduced harmonic currents tend to minimize the problems associated with structure currents.

40.4 (4.4) Self-compatibility. The operational performance of an equipment or subsystem shall not be degraded, nor shall it malfunction when all of the units or devices in the equipment or subsystem are operating together at their designed levels of efficiency or their design capability.

DISCUSSION: The EMI controls imposed by this standard apply to subsystem-level hardware with the purpose of insuring compatibility when various subsystems are integrated into a system platform. In a parallel sense, a subsystem can be considered to be an integration of various assemblies, circuit cards, and electronics boxes. While specific requirements could be imposed to control the interference characteristics of these individual items, this standard is concerned only with the overall performance characteristics of the subsystem after integration. Therefore, the subsystem itself must exhibit compatibility among its various component parts and assemblies.

40.5 (4.5) Non-developmental items (NDI). In accordance with the guidance provided in DOD 5000.37-M, the requirements of this standard shall be met when applicable and warranted by the intended installation and platform requirements.

DISCUSSION: NDI refers to any equipment which is already developed and ready for use including both commercial and military items. DOD 5000.37-M provides guidance on EMC issues relating to the use of NDI. DOD 5000.37-M states concerns with proper operation in the mission environment and the need for compatibility with existing operational equipment. The document includes cautions that acceptance in the commercial marketplace does not mean that EMC requirements are met, that modifications to correct EMC problems can be costly and time consuming, and that EMC problems can be potentially hazardous. DOD 5000.37-M states that quantitative EMC requirements should be developed and that valid data needs to be gathered during a market investigation for performance of analysis to determine the suitability of the NDI. Testing may be required if there is insufficient data. An EMC board is recommended to provide alternatives to decision makers.

40.5.1 (4.5.1) Commercial off-the-shelf equipment.

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DISCUSSION: The use of commercial off-the-shelf equipment presents a dilemma between the need for EMI control with appropriate design measures implemented and the desire to take advantage of existing designs which may exhibit undesirable EMI characteristics. Paragraphs 4.5.1.1 and 4.5.1.2 address the specific requirements for the two separate cases of contractor selection versus procuring activity specification of commercial equipment.

For some applications of commercially developed products, such as commercial transport aircraft, EMI requirements similar to those in this standard are usually imposed on equipment. Most commercial aircraft equipment is required to meet the EMI requirements in RTCA DO-160 or an equivalent contractor in-house document. Revisions to RTCA DO-160 in 1989 and planned changes in the early 1990s are making the document more compatible with this standard. Equipment qualified to RTCA DO-160 is often suitable for military aircraft applications.

EMI requirements on most commercial equipment are more varied and sometimes nonexistent. The Federal Communication Commission (FCC) is responsible for regulating "Non-Licensed Radio Frequency Devices" in the commercial and residential environment to control interference to radio reception. Requirements are imposed in FCC Rules, Parts 2, 15, and 18. The FCC does not control susceptibility (referred to as immunity in the commercial community) characteristics of equipment. The most widely applied requirement is Part 15 which requires that any "digital device" comply with the following conducted and radiated emission limits for commercial environments (Class A) and residential environments (Class B).

CONDUCTED EMISSIONS

FREQUENCY (MHz)	CLASS A (dBμV)	CLASS B (dBμV)
0.45 - 1.705	60	48
1.705 - 30	70	48

RADIATED EMISSIONS

FREQUENCY (MHz)	CLASS A (dBμV/m at 10 meters)	CLASS B (dBμV/m at 3 meters)
30 - 88	39	40
88 - 216	44	44
216 - 960	46	46
above 960	50	54

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These requirements are typically less stringent than military requirements of a similar type. Also, there is difficulty in comparing levels between commercial and military testing due to differences in measurement distances, different types of antennas, and near-field conditions.

The commercial community is moving toward immunity standards. The basis for immunity control is given in ANSI C63.12. There is also activity in the international area. The European Community is imposing mandatory standards and the International Electrotechnic Commission is working on standards. A comparison of various proposed limits are as listed below:

RF Radiated Immunity:	1, 3, or 10 V/m 0.15 to 1,000 MHz
RF Conducted Immunity:	1 to 7 Vrms 10 kHz to 400 MHz
Transient Immunity:	600 V 0.01 µs/1 µs, 50 Ohm source

40.5.1.1 (4.5.1.1) Selected by contractor. When it is demonstrated that a commercial item selected by the contractor is responsible for equipment or subsystems failing to meet the contractual EMI requirements, either the commercial item shall be modified or replaced or interference suppression measures shall be employed, so that the equipment or subsystems meet the contractual EMI requirements.

DISCUSSION: The contractor retains responsibility for complying with EMI requirements regardless of the contractor's choice of commercial off-the-shelf items. The contractor can treat selected commercial items as necessary provided required performance is demonstrated.

40.5.1.2 (4.5.1.2) Specified by procuring activity. When it is demonstrated by the contractor that a commercial item specified by the procuring activity for use in an equipment or subsystem is responsible for failure of the equipment or subsystem to meet its contractual EMI requirements, the data indicating such failure shall be included in the EMITR (See 6.3). No modification or replacement shall be made unless authorized by the procuring activity.

DISCUSSION: The procuring activity retains responsibility for EMI characteristics of commercial items which the procuring activity specifies to be used as part of a subsystem or equipment. The procuring activity will typically study trade-offs between the potential of system-level problems and the

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benefits of retaining unmodified commercial equipment. The procuring activity needs to provide specific contractual direction when modifications are considered to be necessary.

40.5.2 (4.5.2) Procurement of equipment or subsystems having met other EMI requirements. Procurement of equipment and subsystems electrically and mechanically identical to those previously procured by activities of DOD or other Federal agencies, or their contractors, shall meet the EMI requirements and associated limits, as applicable in the earlier procurement, unless otherwise specified by the Command or agency concerned.

DISCUSSION: In general, the government expects configuration controls to be exercised in the manufacturing process of equipment and subsystems to ensure that produced items continue to meet the particular EMI requirements to which the design was qualified. The latest version of MIL-STD-461 reflects the most up-to-date environments and concerns. Since the original EMI requirements may be substantially different than the latest version of MIL-STD-461, they may not be adequate to assess the suitability of the item in a particular installation. This situation most often occurs for equipment susceptibility tests related to the radiated electromagnetic environment. Procuring activities need to consider imposing additional test requirements on the contractor to gather additional data to permit adequate evaluation. The Navy and Army have found this additional testing to be especially necessary for their applications.

Testing of production items has shown degraded performance of the equipment from that previously demonstrated during development. One problem area is engineering changes implemented for ease of manufacturing which are not adequately reviewed for potential effects on EMI control design measures. Specific problems have been related to treatment of cable and enclosure shields and electrical grounding and bonding.

40.6 (4.6) Government furnished equipment (GFE). When it is demonstrated by the contractor that a GFE is responsible for failure of an equipment or subsystem to meet the contractual EMI requirements, the data indicating such failure shall be included in the EMITR (see 6.3). No modification shall be made unless authorized by the procuring activity.

DISCUSSION: GFE is treated the same as commercial items specified by the procuring activity.

40.7 (4.7) Testing requirements. The testing requirements and procedures of MIL-STD-462 shall be used to determine compliance with the applicable emission and susceptibility requirements of this standard. Data gathered as a result of performing tests in one electromagnetic discipline may be

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sufficient to satisfy requirements in another. Therefore, to avoid unnecessary duplication, a single test program should be established with tests for similar requirements conducted concurrently whenever possible. Equipment that are intended to be operated as a subsystem shall be tested as such to the applicable emission and susceptibility requirements whenever practical. Formal testing is not to commence without approval of the Electromagnetic Interference Test Procedures (EMITP) (See 6.3) by the Command or agency concerned.

DISCUSSION: MIL-STD-462 is a parallel document to MIL-STD-461. MIL-STD-461 specifies design requirements and MIL-STD-462 specifies general test methodology together with detailed methods to demonstrate compliance with MIL-STD-461.

Electromagnetic disciplines (electromagnetic compatibility (EMC), electromagnetic pulse (EMP), lightning, RF compatibility, frequency allocation, etc.) are integrated to differing levels in various government and contractor organizations. There is often a common base of requirements among the disciplines. It is more efficient to have unified requirements and complete and concise testing. For example, the EMC, EMP and lightning areas all pertain to electronic hardness to transients. The transient requirements in MIL-STD-461 and MIL-STD-462 should satisfy most concerns or should be adapted as necessary to do so.

Testing integrated equipment at the subsystem-level is advantageous because the actual electrical interfaces are in place rather than electrical load or test equipment simulations. When simulations are used, there is always doubt regarding the integrity of the simulation and questions arise whether emission and susceptibility problems are due to the equipment under test or the simulation.

Test procedures provide a mechanism to interpret and adapt MIL-STD-461 and MIL-STD-462 as they are applicable to a particular subsystem or equipment and to detail the test agency's facilities and instrumentation and their use. It is important that the procedures are available to the procuring activity early so that the procuring activity can approve the test procedures prior to the start of testing. Agreement needs to exist between the procuring activity and the contractor on the interpretation of test requirements and methodology, thereby minimizing the possible need for retesting.

40.8 (4.8) Switching transients. Switching transient emissions that result at the moment of operation of manually actuated switching functions are exempt from the requirements of this standard. Other transient type conditions, such as automatic sequencing following initiation by a manual switching function, shall meet the emissions requirements of this standard.

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DISCUSSION: Proper treatment of manually actuated switching functions has long been a dilemma. Platform experience has shown that switching of electronics equipment subjected to EMI requirements rarely causes electromagnetic compatibility problems. On this basis, there are no requirements included in this standard. "On-off" switching has been of particular interest. On-off switching has occasionally caused power quality type problems. These problems are associated with voltage regulation difficulties from a large load being switched on a power bus; however, such power quality issues are not addressed by this standard.

Platform problems have also been observed from switching of items not normally subjected to EMI requirements such as unsuppressed inductors (valves, relays, etc.), motors, and high current resistive loads. These types of problems are more related to coupling of transients onto platform wiring through electric and magnetic fields than direct conduction of the interference. There are substantial requirements included in the standard to protect against susceptibility to transients. This statement is not intended to imply that inductive devices and other transient producers should not be suppressed as a normal good design practice. For example, some integrating contractors routinely require vendors to provide diode suppression on inductors.

In earlier versions of EMI standards, manually actuated functions were measured using frequency domain techniques. Although measured emission levels were often 40-70 dB above the limit, no platform problems were observed. This technique was largely abandoned in later versions of the standards in favor of a time domain requirement on power leads (CE07). Except for some above limit conditions associated with on-off functions, equipment rarely have had any problems with the requirement. Testing of on-off functions has often been controversial because of the need to often use a switch external to the equipment. A number of issues arise regarding placement of the switch, where the transient should be measured, whether the switch or the equipment causes the transient, and whether the switch can be suppressed.

The exemption is applicable only for transient effects occurring at the moment of manual switch operation. Many other transient type effects occur during the operation of electronics. An argument could be made that the operation of microprocessor controlled electronics produces continuous transients with every change of state. There are certain transient effects which occur infrequently that could be presented to the procuring activity as events similar to the action of a manual switch with a request for an exemption. An example is a heater circuit which functions intermittently dependent upon a sensed temperature.

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Other documents such as MIL-STD-704 and MIL-E-6051 for aircraft impose transient controls at the system-level.

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50. DETAILED REQUIREMENTS

50.1 (5.1) General. Table I is a list of emissions and susceptibility requirements established by this standard. General test methods for these requirements are contained in MIL-STD-462 as implemented by the Government approved EMITP (see 6.3). All results of tests performed to demonstrate compliance with the requirements are to be documented in the EMITR (see 6.3) and forwarded to the Command or agency concerned for evaluation prior to acceptance of the equipment or subsystem. Design procedures and techniques for the control of EMI shall be described in the EMICP (see 6.3). Approval of design procedures and techniques described in the EMICP does not relieve the supplier of the responsibility of meeting the contractual emission, susceptibility, and design requirements.

DISCUSSION: The applicability of individual requirements in Table I for a particular equipment or subsystem is dependent upon the platforms where the item will be used. The electromagnetic environments present on a platform together with potential degradation modes of electronic equipment items play a major role regarding which requirements are critical to an application. For example, emissions requirements are tied to protecting antenna-connected receivers on platforms. The operating frequency ranges and sensitivities of the particular receivers on-board a platform, therefore, influence the need for certain requirements.

The EMICP, EMITP, and EMITR are important elements in documenting design efforts for meeting the requirements of this standard, testing approaches which interpret the generalized test methods in MIL-STD-462, and reporting of the results of testing. The EMICP is a mechanism instituted to help ensure that contractors analyze equipment design for EMI implications and include necessary measures in the design for compliance with requirements. Approval of the document does not indicate that the procuring activity agrees that all the necessary effort is stated in the document. It is simply a recognition that the design effort is addressing the correct issues.

The susceptibility limits are the upper bound on the range of values for which compliance is required. The EUT must also provide required performance at any stress level below the limit. For example, if the limit for radiated susceptibility to electric fields is 10 volts/meter, the EUT must also meet its performance requirements at 5 volts/meter or any other field less than or equal to 10 volts/meter. There have been cases where equipment has met its EMI requirements at the limit, but it has failed elsewhere.

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50.1.1 (5.1.1) Units of frequency domain measurements. All frequency domain limits are expressed in terms of equivalent root mean square (RMS) value of a sine wave as would be indicated by the output of a measurement receiver using peak envelope detection.

DISCUSSION: A detailed discussion is provided on peak envelope detection in the MIL-STD-462 appendix for paragraph 4.10.1. A summary of output of the detector for several input waveforms is as follows. For an unmodulated sine wave, the output simply corresponds to the RMS value of the sine wave. For a modulated sine wave, the output is the RMS value of an unmodulated sine wave with the same absolute peak value. For a signal with a bandwidth greater than the bandwidth of the measurement receiver, the output is the RMS value of an unmodulated sine wave with the same absolute peak value as the waveform developed in the receiver bandpass.

50.2 (5.2) EMI control requirements versus intended installations. Table II summarizes the requirements for equipment and subsystems intended to be installed in, on ,or launched from various military platforms or installations. When an equipment or subsystem is to be installed in more than one type of platform or installation, it shall comply with the most stringent of the applicable requirements and limits. An "A" entry in the table means the requirement is applicable. An "L" entry means the applicability of the requirement is limited as specified in the appropriate requirement paragraph of this standard. An "S" entry means the procuring activity must specify the applicability and limit requirements in the procurement specification. Absence of an entry means the requirement is not applicable.

DISCUSSION: Discussion on each requirement as it relates to different platforms is contained in the sections on the individual requirements.

50.3 (5.3) Emission and susceptibility requirements and limits.

50.3.1 (5.3.1) CE101 (Conducted emissions, power leads, 30 Hz to 10 kHz).

DISCUSSION: The requirements are applicable to leads that obtain power from sources which are not part of the EUT. There is no requirement on output leads from power sources. Since power quality standards are normally used to govern the characteristics of output power, there is no need for separate EMI requirements on output leads.

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The limits are in terms of current because of the difficulty in controlling the power source impedance in test facilities at lower frequencies. This type of control would be necessary to specify the limits in terms of voltage. Emission current levels will be somewhat independent of power source impedance variations as long as the impedance of the emission source is large relative to the power source impedance.

For Navy surface ships and submarines, the intent of this requirement is to control the effects of conducted emissions peculiar to the shipboard power distribution system. Harmonic line currents are limited for each electrical load connected to the power distribution system. Power quality for ships is controlled by MIL-STD-1399, Section 300.

The ship service power distribution system (ship's primary power) supplied by the ship's alternators is 440 VAC, 60 Hz, 3-phase, 3-wire, delta-connected, ungrounded. Although ship's primary power is ungrounded, there exists a virtual alternating current (AC) ground at each electrical load due to capacitance to chassis. The unbalance between the virtual grounds at each electrical load causes AC currents to flow in the hull of the ship. These hull currents can degrade the performance of electronic equipment, upset ground detectors, and counteract degaussing.

Hull currents are controlled by limiting the amplitude of harmonic currents conducted on the power distribution system wiring for each electrical load. The limit is based on maintaining total harmonic distortion of the ship power distribution system within 5% of the supply voltage with the contribution from any single harmonic being less than 3%. In addition to the hull current concern, total harmonic distortion greater than 5% is above the tolerance of most electronic equipment, induction motors, magnetic devices, and measuring devices.

For Army aircraft, the primary concern is to ensure that the EUT does not corrupt the power quality (allowable voltage distortion) on the power busses present on the platform. The Army aircraft limits are based on relating the allowable current flowing into a 1.0 ohm impedance to MIL-STD-704 requirements on voltage distortion. The Army limit includes approximately a 20 dB margin with respect to MIL-STD-704 to allow for contributions from multiple emission sources.

For Navy aircraft, the requirement is applicable for installations using anti-submarine warfare (ASW) equipment. The primary mission of ASW aircraft is to detect and locate submarines. Unacceptable levels of emission currents in the frequency range of this test would limit the detection and

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processing capabilities of the Magnetic Anomaly Detection (MAD) and Acoustic Sensor systems. The MAD systems must be able to isolate a magnetic disturbance in the earth's magnetic field of less than one part in 50,000. In present aircraft, the full sensitivity of the MAD systems is not available due to interference produced by onboard equipment. Low frequency interference effects in the 30 Hz to 10 kHz can be a problem for Acoustic Sensor systems.

The Air Force has not generally imposed this type of requirement in the past (particularly in the case of aircraft), and no platform problems have resulted. This situation is probably due to the low source impedances present in Air Force power generation systems at the lower frequencies. Also, the Air Force does not usually utilize tuned receivers operating in the frequency range of the requirement.

Possible tailoring of the requirements by the procuring activity is to impose the requirement if sensitive receivers operating in the frequency range of the requirement are to be installed on a platform or to modify the limit based on the particular characteristics of the power system onboard the platform.

50.3.2 (5.3.2) CE102 (Conducted emissions, power leads, 10 kHz to 10 MHz).

DISCUSSION: The requirements are applicable to leads that obtain power from sources which are not part of the EUT. There is no requirement on output leads from power sources.

The basic concept in the lower frequency portion of the requirement is to ensure that the EUT does not corrupt the power quality (allowable voltage distortion) on the power busses present on the platform. Examples of power quality documents are MIL-STD-704 for aircraft, MIL-STD-1399 for ships, MIL-STD-1539 for space systems, and MIL-STD-1275 for military vehicles.

Since power quality standards govern allowable distortion on output power, there is no need for separate EMI requirements on output leads. The output power leads are treated no differently than any other electrical interface. This standard does not directly control the spectral content of signals present on electrical interfaces. Waveform definitions and distortion limits are specified in documents such as interface control documents. In the case of output power, the quality of the power must be specified over an appropriate frequency range so that the user of the power can properly design. This situation is true whether the power source is a primary source such as 115 volts, 400 Hz, or a $\pm$ 15 VDC low current supply. A significant indirect control on spectral content exists in the RE102 limits

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which essentially require that appropriate waveform control and signal transmission techniques be used to prevent unacceptable radiation (see discussion on CE102 limit placement and RE102 relationship below). An important issue, which is often ignored, is that some requirements such as CS114 and RS103 will induce substantial voltage and current levels on electrical interfaces. Controlling directly conducted interference to low levels can be a poorly directed effort if the interfacing equipment can tolerate the much higher stresses associated with the susceptibility tests.

Since voltage distortion is the basis for establishing power quality requirements, the CE102 limit is in terms of voltage. The use of a standardized line impedance over the frequency range of this test provides for the convenient measurement of the voltage as developed across this impedance. In previous versions of MIL-STD-461, a current measurement into a 10 microfarad feedthrough capacitor was specified. The intent of the capacitor was to provide an RF short of the power lead to the ground plane. It was difficult to interpret the significance of the current limit with respect to platform applications. The presence of a standardized impedance is considered to reflect more closely the electrical characteristics of the power busses in platforms.

Of the power quality documents reviewed, MIL-STD-704 is the only one with a curve specifying an amplitude versus frequency relationship for the allowable distortion. The CE102 limits require that amplitude decays with increasing frequency similar to the requirements of MIL-STD-704. Common requirements are specified for all applications since the concerns are the same for all platforms.

The basic limit curve for 28 volts is placed approximately 20 dB below the power quality curve in MIL-STD-704. There are several reasons for the placement. One reason is that a number of interference sources present in different subsystems and equipments on a platform may be contributing to the net interference voltage present at a given location on the power bus. Assuming that the interference sources are not phase coherent, the net voltage will be the square root of the sum of the squares of the voltages from the individual sources. A second reason is that the actual impedance in an installation will vary from the control impedance with actual voltages being somewhat higher or lower than that measured during the test. Therefore, some conservatism needs to included in the limit.

The relaxation for other higher voltage power sources is based on the relative levels of the power quality curves on ripple for different operating voltages.

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At higher frequencies, the CE102 limit serves as a separate control from RE102 on potential radiation from power leads which may couple into sensitive antenna-connected receivers. The CE102 limits have been placed to ensure that there is no conflict with the RE102 limit. Emissions at the CE102 limit should not radiate above the RE102 limit. Laboratory experiments on coupling from a 2.5 meter power lead connected to a line impedance stabilization network have shown that the electric field detected by the RE102 rod antenna is flat with frequency up to approximately 10 MHz and is approximately equal to (X-40) dBμV/m, where X is the voltage expressed in dBμV. For example, if there is a signal a level of 60 dBμV on the lead, the detected electric field level is approximately 20 dBμV/m.

Tailoring of the requirements in contractual documents may be desirable by the procuring activity. Adjusting the limit line to more closely emulate a spectral curve for a particular power quality standard is one possibility. Contributions from multiple interference sources need to be considered as noted above. If antenna-connected receivers are not present on the platform at the higher frequencies, tailoring of the upper frequency of the requirement is another possibility. The requirement is limited to an upper frequency of 10 MHz due to the allowable 2.5 meter length of power lead in the test setup approaching resonance. Any conducted measurements become less meaningful above this frequency. If tailoring is done to impose the requirement at higher frequencies, the test setup should be modified for CE102 to shorten the allowable length of the power leads.

50.3.3 (5.3.3) CE106 (Conducted emissions, antenna terminal, 10 kHz to 40 GHz).

DISCUSSION: The requirement is applicable for transmitters and receivers. 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 which provides reasonable assurance of compatibility with other equipment. Common requirements are specified for all applications since the concerns are the same for all platforms.

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

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that the transmitter second harmonic at 300 MHz must be down 50 + 10 log 10 = 60 dB. The free space loss equation $P_R/P_T = (\lambda^2 G_T G_R)/(4\pi R)^2$ indicates an isolation of 42 dB between the two antennas.

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

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 which 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 which could be a difficult task. Harmonic relationships can sometimes be addressed through frequency management actions to avoid problems.

Assessing the 34 dBµV (-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

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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.

50.3.4 (5.3.4) CS101 (Conducted susceptibility, power leads, 30 Hz to 50 kHz).

DISCUSSION: The requirement is applicable to power input leads that obtain power from other sources which are not part of the EUT. There is no requirement on power output leads. The basic concern is to ensure that equipment performance is not degraded from ripple voltages associated with allowable distortion of power source voltage waveforms.

The required signal is applicable only to the high sides on the basis that the concern is developing a differential voltage across the power input leads to the EUT. The series injection technique in MIL-STD-462 results in the voltage dropping across the impedance of the EUT power input circuitry. The impedance of the power return wiring is normally insignificant with respect to the power input over most of the required frequency range. Common mode voltages evaluations are addressed by other susceptibility tests such as CS114 and RS103. Injection on a power return will result in the same differential voltage across the power input; however, the unrealistic condition will result in a large voltage at the return connection to the EUT with respect to the ground plane.

Similar to CE102, the limits are based on a review of the power quality standards with emphasis toward the spectral content curves present in MIL-STD-704. Rather than having a separate curve for each possible power source voltage, only two curves are specified. The voltage amplitude specified is approximately 6 dB above typical power quality limits, although the limit has been somewhat generalized to avoid complex curves. The margin between the limit and the power quality standard is necessary to allow for variations in performance between manufactured items.

The difference between the limits for CE102 and CS101 of approximately 26 dB should not be viewed as a margin. The CE102 limit is placed so that ripple voltages do not exceed that allowed by the power quality standards due to interference contributions from multiple EUTs. Therefore, the power quality standard is the only valid basis of comparison.

The primary tailoring consideration for the procuring activity for contractual documents is adjustment of the limit to follow more closely a particular power quality standard.

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50.3.5 (5.3.5) CS103 (Conducted susceptibility, antenna port, intermodulation, 15 kHz to 10 GHz).

DISCUSSION: The intent of this requirement is to control the response of antenna-connected receiving subsystems to in-band signals resulting from potential intermodulation products of two signals outside of the intentional passband of the subsystem produced by non-linearities in the subsystem. The requirement can be applied to receivers, transceivers, amplifiers, and the like. Due to the wide diversity of subsystem designs being developed, the applicability of this type of requirement and appropriate limits need to be determined for each procurement. Also, requirements need to be specified that are consistent with the signal processing characteristics of the subsystem and the particular test methodology to be used to verify the requirement.

One approach for determining levels required for the out-of-band signals is from an analysis of the electromagnetic environments present and characteristics of receiving antennas. However, levels calculated by this means will often place unreasonable design penalties on the receiver. For example, if an external environment of 200 volts/meter is imposed on a system, an isotropic antenna at 300 MHz will deliver 30 dBm to the receiver. This level represents a severe design requirement to many receivers. An alternative approach is to simply specify levels which are within the state-of-the-art for the particular receiver design.

This requirement is most applicable to fixed frequency, tunable, superheterodyne receivers. Previous versions of this standard required normal system performance with the two out-of-band signals to be 66 dB above the level required to obtain the standard reference output for the receiver. One signal was raised to 80 dB above the reference in the 2 to 25 MHz and 200 to 400 MHz bands to account for transmissions from HF and UHF communication equipment. Maximum levels for both signals were limited to 10 dBm. As an example, conventional communication receivers commonly have sensitivities on the order of -100 dBm. For this case, the 66 dB above reference signal is at -34 dBm and the 80 dB above reference signal is at -20 dBm. Both are substantially below the 10 dBm maximum used in the past.

For other types of receivers, application of this requirement is often less straightforward and care must be taken to ensure that any applied requirements are properly specified. Many receivers are designed to be interference or jam resistant and this feature may make application of this requirement difficult or inappropriate.

One complicating factor is that one of the out-of-band signals typically is modulated with a waveform normally used by

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the receiver. For receivers that process a very specific modulation, the issue exists whether an out-of-band signal can reasonably be expected to contain that modulation. Another complicating factor is related to the potential intermodulation products resulting from two signals. Responses from intermodulation products can be predicted to occur when $f_o = mf_1 \pm nf_2$ where f_o is the operating frequency of the receiver, m and n are integers, and f_1 and f_2 are the out-of-band signals. For receivers which continuously change frequency (such as frequency agile or frequency hopping), the relationship will be true only for a portion of the operating time of the receiver, unless the out-band-signals are also continuously tuned or the receiver operating characteristics are modified for the purpose of evaluation.

50.3.6 (5.3.6) CS104 (Conducted susceptibility, antenna port, rejection of undesired signals, 30 Hz to 20 GHz).

DISCUSSION: The intent of this requirement is to control the response of antenna-connected receiving subsystems to signals outside of the intentional passband of the subsystem. The requirement can be applied to receivers, transceivers, amplifiers, and the like. Due to the wide diversity of subsystem designs being developed, the applicability of this type of requirement and appropriate limits need to be determined for each procurement. Also, requirements need to be specified that are consistent with the signal processing characteristics of the subsystem and the particular test methodology to be used to verify the requirement.

One approach for determining levels required for the out-of-band signal can be determined from an analysis of the electromagnetic environments present and characteristics of receiving antennas. However, levels calculated by this means will often place unreasonable design penalties on the receiver. For example, if an external environment of 200 volts/meter is imposed on a system, an isotropic antenna at 300 MHz will deliver 30 dBm to the receiver. This level represents a severe design requirement to many receivers. An alternative approach is to simply specify levels which are within the state-of-the-art for the particular receiver design.

This requirement is most applicable to fixed frequency, tunable, superheterodyne receivers. Previous versions of this standard required normal system performance for a 0 dBm signal outside of the tuning range of the receiver and a signal 80 dB above the level producing the standard reference output within the tuning range (excluding the receiver passband within the 80 dB points on the selectivity curve). As an example, a conventional UHF communication receiver operating from 225 MHz to 400 MHz commonly has a sensitivity on the order of -100 dBm. For

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this case, the 0 dBm level applies below 225 MHz and above 400 MHz. Between 225 MHz and 400 MHz (excluding the passband), the required level is -20 dBm.

For other types of receivers, application of this requirement is often less straightforward and care must be taken to ensure that any applied requirements are properly specified. Many receivers are designed to be interference or jam resistant and this feature may make application of this requirement difficult or inappropriate.

This requirement is usually specified using either one or two signals. With the one signal requirement, the signal is out-of-band to the receiver and is modulated with a waveform normally used by the receiver. No in-band signal is used. For receivers that process a very specific modulation, the issue exists whether an out-of-band signal can reasonably be expected to contain that modulation. An alternative is to specify the requirement for two signals. An in-band signal can be specified which contains the normal receiver modulation. The out-off-band signal can be modulated or unmodulated with the criterion being that no degradation in reception of the intentional signal is allowed.

50.3.7 (5.3.7) CS105 (Conducted susceptibility, antenna port, cross modulation, 30 Hz to 20 GHz).

DISCUSSION: The intent of this requirement is to control the response of antenna-connected receiving subsystems to modulation being transferred from an out-of-band signal to an in-band signal. This effect results from a strong, out-of-band signal near the operating frequency of the receiver which modulates the gain in the front-end of the receiver and adds amplitude varying information to the desired signal. The requirement should be considered only for receivers, transceivers, amplifiers, and the like, which extract information from the amplitude modulation of a carrier. Due to the wide diversity of subsystem designs being developed, the applicability of this type of requirement and appropriate limits need to be determined for each procurement. Also, requirements need to be specified that are consistent with the signal processing characteristics of the subsystem and the particular test methodology to be used to verify the requirement.

One approach for determining levels required for the out-of-band signal can be determined from an analysis of the electromagnetic environments present and characteristics of receiving antennas. However, levels calculated by this means will often place unreasonable design penalties on the receiver. For example, if an external environment of 200 volts/meter is imposed on a system, an isotropic antenna at 300 MHz will deliver 30 dBm to the receiver. This level represents a severe design

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requirement to many receivers. An alternative approach is to simply specify levels which are within the state-of-the-art for the particular receiver design.

This requirement is most applicable to fixed frequency, tunable, superheterodyne receivers. Previous versions of this standard required normal system performance with an out-of-band signal to be 66 dB above the level required to obtain the standard reference output for the receiver. The maximum level for the signal was limited to 10 dBm. As an example, conventional communication receivers commonly have sensitivities on the order of -100 dBm. For this example, the 66 dB above reference signal is at -34 dBm which is substantially below the 10 dBm maximum used in the past.

For other types of receivers, application of this requirement is often less straightforward and care must be taken to ensure that any applied requirements are properly specified. Many receivers are designed to be interference or jam resistant and this feature may make application of this requirement difficult or inappropriate.

One complicating factor is that one of the out-of-band signals typically is modulated with a waveform normally used by the receiver. For receivers that process a very specific modulation, the issue exists whether an out-of-band signal can reasonably be expected to contain that modulation. Another factor is that the out-of-band signal is normally specified to be close to the receiver operating frequency. For receivers which continuously change frequency (such as frequency agile or frequency hopping), an appropriate relationship may be exist for only short periods for a fixed frequency out-of-band signal.

50.3.8 (5.3.8) CS109 (Conducted susceptibility, structure current, 60 Hz to 100 kHz).

DISCUSSION: This requirement is specialized and is intended to be applied only for very sensitive equipment (1 μV or better) such as tuned receivers operating over the frequency range of the test. The basic concern of the requirement is to ensure that equipment does not respond to magnetic fields caused by currents flowing in platform structure and through EUT housing materials. The magnetic fields are sufficiently low that there is no concern with most circuitry.

An estimate can be made of induced voltages that may result from the required CS109 currents. Magnetic fields act by inducing voltages into loop areas in accordance with Faraday's law ($V = -d\phi/dt$). For a constant magnetic field perpendicular to a given loop area, Faraday's law reduces to $V = -2\pi fBA$ where

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f = Frequency of Interest B = Magnetic Flux Density

A = Loop Area

Since Faraday's law indicates that these voltages are proportional to frequency, the maximum voltage from the CS109 currents will result at the 20 kHz knee of the curve for a given loop area. A drop of 20 dB/decade would result in a constant voltage. Since the curve is dropping at only 10 dB/decade below 20 kHz, the induced voltage will rise as frequency increases. The sharp drop off above 20 kHz results in decreasing voltages with increasing frequency.

If the 103 dBμA current at 20 kHz specified in the requirement is assumed to spread uniformly over a cross-sectional dimension of 10 cm, the surface current density and the resulting magnetic field intensity at the surface would be 1.41 amperes/meter. In air, this value corresponds to magnetic flux density of $(1.77)(10^{-6})$ Tesla. If it is further assumed that this magnetic field is uniform over a circuit loop area of 0.001 m^2 (such as 20 cm by 0.5 cm) within the enclosure, Faraday's Law predicts an induced voltage of 222 μV.

Similar calculations at 400 Hz and 100 kHz yields values of 31 μV and 8 μV, respectively.

It is apparent that design considerations such as proper grounding techniques, minimizing of loop areas, and common mode rejection concepts need to be implemented to prevent potential problems with very sensitive circuits used in submarines such as low frequency tuned receivers. However, these levels are well below the sensitivity of typical circuits used in other equipment.

The limit is derived from operational problems due to current conducted on equipment cabinets and laboratory measurements of response characteristics of selected receivers.

No tailoring is recommended.

50.3.9 (5.3.9) CS114 (Conducted susceptibility, bulk cable injection, 10 kHz to 400 MHz).

DISCUSSION: The requirements are applicable to all electrical cables interfacing with the EUT enclosures. The basic concept is to simulate currents which will be developed on platform cabling from electromagnetic fields generated by antenna transmissions both on and off the platform.

An advantage of this type of requirement is that it provides data which can be directly related to induced current levels

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measured during platform-level evaluations. An increasingly popular technique is to illuminate the platform with a low level, relatively uniform field while monitoring induced levels on cables. Then, either laboratory data can be reviewed or current injection done at the platform with the measured currents scaled to the full threat level. This same philosophy has been applied to lightning and electromagnetic pulse testing.

Due to size constraints and available field patterns during radiated susceptibility testing (such as RS103), it has long been recognized that cabling cannot be properly excited to simulate platform effects at lower frequencies. The most notable example of this situation is experience with HF (2 - 30 MHz) radio transmissions. HF fields have caused numerous problems in platforms through cable coupling. However, equipment items rarely exhibit problems in this frequency range during laboratory testing.

The limits are primarily derived from testing on aircraft which were not designed to have intentionally shielded volumes. The basic structure is electrically conductive; however, there was no attempt to ensure continuous electrical bonding between structure members or to close all apertures. The shape of the limit reflects the physics of the coupling with regard to resonant conditions, and the cable length with respect to the interfering frequency wavelength. At frequencies below resonance, coupling is proportional to frequency (20 dB/decade slope). Above resonance, coupled levels are cyclic with frequency with a flat maximum value. The 10 dB/decade decrease in the limit level at the upper frequency portion is based on actual induced levels in the aircraft testing data base when worst-case measurements for the various aircraft are plotted together. From coupling theory for a specific cable, the decrease would be expected to be cyclic with frequency with an envelope slope of 40 dB/decade.

The basic relationship for the limit level in the resonance (flat) portion of the curve is 1.5 milliamperes per volt/meter which is derived from worst-case measurements on aircraft. For example, 110 dBμA corresponds to 200 volts/meter. At resonance, the effective shielding effectiveness of the aircraft can be zero. Application of these results to other platforms is reasonable.

The frequency coverage varies dependent on application. A basic issue is the required upper frequency. In some of the applications, the requirement stops at 30 MHz. This frequency is specified under the assumption that RS103 adequately provides any required performance at higher frequencies. The requirement is continued to 200 MHz for aircraft applications primarily for reasons of clearing aircraft as safe to fly. These results are

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used as the basis of comparison to induced levels measured during system-level testing in the presence of external environments.

Possible tailoring by the procuring activity for contractual documents is a curve amplitude based on the expected field intensity for the installation and a breakpoint for the curve based on the lowest resonance associated with the platform. Tailoring of the frequency of application can be done based on the operating frequencies of antenna-radiating equipment. Tailoring should also include transmitters that are not part of the platform. For equipment used in benign environments, the requirement may not be necessary.

50.3.10 (5.3.10) CS115 (Conducted susceptibility, bulk cable injection, impulse excitation).

DISCUSSION: The requirements are applicable to all electrical cables interfacing with EUT enclosures. The basic concern is to protect equipment from fast rise and fall time transients that may be present due to platform switching operations and external transient environments such as lightning and electromagnetic pulse. The requirement is intended to replace "chattering relay" type requirements (RS06 in the previous version of MIL-STD-461) commonly used in procurements of equipment for aircraft applications in the past. The chattering relay has been criticized as unscientific and non-repeatable. The CS115 requirement has a defined waveform and a repeatable coupling mechanism.

The 2 nanosecond rise time is consistent with rise times possible for the waveforms created by inductive devices interrupted by switching actions. The 30 nanosecond pulse width standardizes the energy in individual pulses. In addition, it separates the rising and falling portions of the pulse so that each may act independently. Also, each portion may affect different circuits. The 5 ampere amplitude (500 volts across 100 ohm loop impedance calibration fixture) covers most induced levels that have been observed during system-level testing of aircraft to transient environments. The 30 Hz pulse rate is specified to ensure that a sufficient number of pulses are applied to provide confidence that the equipment will not be upset.

Many circuit interfaces are configured such that potential upset is possible for only a small percentage of the total equipment operating time. For example, a microprocessor may sequentially poll various ports for input information. A particular port may continuously update information between polling intervals. If the transient occurs at the time the port is accessed, an upset condition may result. At other times, no effect may occur.

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Possible tailoring by the procuring activity for contractual documents is lowering or raising the required amplitude based on the expected transient environments in the platform. Another option is to adjust the pulse width based on a particular environment onboard a platform or for control of the energy content of the pulse.

50.3.11 (5.3.11) CS116 (Conducted susceptibility, damped sinusoid transients, cables and power leads, 10 kHz to 100 MHz).

DISCUSSION: The requirements are applicable to all electrical cables interfacing with each EUT enclosure and also individually on each power lead. The basic concept is to simulate electrical current and voltage waveforms occurring in platforms from excitation of natural resonances.

When a platform is exposed to an external environment such as electromagnetic pulse or lightning, induced current and voltage waveforms within the platform are frequently damped sine waves or combinations of damped sine waves due to natural resonances. Transients caused from switching actions within the platform can also result in similar waveforms. Transient effects from platform switching actions on a particular power lead can cause a differential signal. Transients caused by external environments or coupled effects within the platform will cause common mode signals to be developed on cable interfaces. Both switching and external environment effects are addressed by the requirement.

A consideration for the requirement is whether momentary upsets are allowable if the EUT is capable of self-recovery to normal operation. Some upsets may occur that are not even noticed by an operator due to self-correcting mechanisms in the equipment. There may be cases where longer term upset is acceptable which may possibly require action by an operator to reset the equipment. The EMITP should address any instances where the contractor proposes that observable upsets be accepted.

A limited set of damped sine waves is specified to address a sampling of the various ringing frequencies that may be present in the platform. The additional resonant frequencies determined during testing are to evaluate the EUT at points of development of maximum current and voltage. An advantage of using a set of damped sine waves is that different circuit types are evaluated for various waveform attributes that may cause worst-case effects. Some circuits may respond to peak amplitude while others may respond to total energy or rate of rise.

The current limits are set at levels that cover most induced levels found in platforms during system-level testing to external

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transient environments. The level for aircraft also typically allows for designs which do not require the use of terminal protection devices. These items are generally undesirable due to concerns with hardness maintenance/hardness surveillance and the ability to assess whether protection remains effective. The lower frequency breakpoints are at worst-case platform resonant frequencies below which the response will fall off at 20 dB/decade. The upper frequency breakpoint is located where the spectral content of the transient environments fall off.

Possible tailoring of the requirements by the procuring activity in contractual documents is adjustment of the curve amplitude either higher or lower based on the degree of protection provided in the area of the platform where the equipment and interconnecting cabling will be located. A caution with this particular requirement based on past experiences is that the platform designer should be required to share in the burden of the hardening process by providing stress reduction measures in the platform. The equipment should not be expected to provide the total protection. Protection against transients generated internal to the platform needs to remain a consideration. Another potential tailoring area is adjusting the lower frequency breakpoint to be more consistent with the lowest resonance of a particular platform.

50.3.12 (5.3.12) RE101 (Radiated emissions, magnetic field, 30 Hz to 50 kHz).

DISCUSSION: This requirement is specialized and is intended primarily to control magnetic fields for applications where equipment is present in the installation which is potentially sensitive to magnetic induction at lower frequencies. The most common example is a tuned receiver which operates within the frequency range of the test.

RS101 is a complimentary requirement imposed on equipment to ensure compatibility with the anticipated magnetic fields. The RS101 limits have the same shape as the RE101 limits; however, the RS101 limits are 10 dB higher for Navy applications and 6 dB higher for Army aircraft applications. These differences are necessary to allow for variations in performance between manufactured items and to account for the possibility that the emissions from the EUT may couple into a larger physical area than that evaluated under the RS101 procedures in MIL-STD-462.

The Navy RE101 limits were derived by taking into account the allowable user equipment power line harmonic content (CE101), applicable cable types, shielding effectiveness of typical equipment cabinets, maximum anticipated power consumption of the user equipment, magnetic field radiation from current

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carrying cables, case and cable coupling contributions, and equipment circuit sensitivity.

Since the RE101 emissions of an EUT are usually related to its power consumption, relaxations similar to those for the Navy CE101 requirement were considered as a possibility for this standard. However, the many variables used to establish the RE101 limit makes any relaxations complex and a single limit is necessary. The specified limit is based on the maximum expected magnetic field emissions from most well-designed EUTs. Limits are specified at both 7 and 50 cm distances to allow for assessment of potential impacts in the actual installation. There may be instances where physical separation from potentially sensitive equipment is sufficient that a 50 cm control is adequate.

Some of the considerations in the limit are described below. Emissions at the lower frequencies are equipment related with regard to power type (60 Hz or 400 Hz, single or polyphase), EUT power load, and the shielding effectiveness of the enclosure. Emissions at the upper frequencies, above 1020 Hz for 60 Hz equipment and 12.8 kHz for 400 Hz equipment, are for the most part the result of magnetic field emissions from cabling. The type of cabling used in shipboard installations is driven by the power type and load and intentional signal parameters to be carried by the cables.

Note that the limit does not take into account magnetic effects from equipment such as magnetic launchers, magnetic guns and the like.

An estimate can be made of the types of induced levels which will result in circuitry from the limits. Magnetic fields act by inducing voltages into loop areas in accordance with Faraday's law ($V = -d\phi/dt$). For a uniform magnetic field perpendicular to the loop area, the induced voltage from Faraday's law reduces to $V = -2\pi fBA$.

f = Frequency of Interest B = Magnetic Flux Density

A = Loop Area

The Army aircraft RE101 limit is based on preventing induction of more than 2.5 millivolts (5 millivolts for RS101) in a 12.7 centimeter (5 inch) diameter loop. Since magnetic induction is proportional to frequency and the limit falls off at 20 dB/decade, the induced voltage in a given loop area is constant. Since the Army limit is greater than or equal to the Navy limit at all frequencies, this induced level represents the worst-case. The primary concerns are potential effects to

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engine, flight and weapon turret control systems and sensors which have sensitivities in the millivolt range.

The RE101 limits in this version of the standard are substantially relaxed from previous versions of the standard. Previous limits typically resulted in tens of microvolts being induced in loop areas. As noted above the present limits can result in a few millivolts worst-case. For many types of applications, this type of control has not been considered necessary in the past and has not been applied. Platform problems have not been observed in these situations.

There are certain limited applications in the Air Force where an RE101 requirement needs to be considered. These applications are primarily when a subsystem will be installed in an aircraft in close proximity to an antenna connected to a VLF/LF receiver. An appropriate limit needs to be chosen based upon distances between the equipment and the antenna.

For Army applications, possible tailoring is increasing the limit for single-use equipment that will be located a sufficient distance from any potentially susceptible systems or waiving of the requirement.

50.3.13 (5.3.13) RE102 (Radiated emissions, electric field, 10 kHz to 18 GHz).

DISCUSSION: The requirements are applicable to electric field emissions from the EUT and associated cables. The basic intent of the requirement is to protect sensitive receivers from interference coupled through the antennas associated with the receiver. Many tuned receivers have sensitivities on the order of one microvolt and are connected to an intentional aperture (the antenna) which are constructed for efficient reception of energy in the operating range of the receiver. The potential for degradation requires relatively stringent requirements to prevent platform problems.

There is no implied relationship between this requirement and RS103 which addresses radiated susceptibility to electric fields. Attempts have been made quite frequently in the past to compare electric field radiated emission and susceptibility type requirements as a justification for deviations and waivers. While RE102 is concerned with potential effects with antenna-connected receivers, RS103 simulates fields resulting from antenna-connected transmitters.

Often, the same equipment item will be involved in influencing both requirements. A 30 watt VHF-AM radio with a typical blade antenna operating at 150 MHz can easily detect a 40 dBµV/m electric field (approximately -81 dBm developed at

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receiver input) while in the receive mode. When this same piece of equipment transmits at the same 150 MHz frequency, it will produce a field of approximately 150 dBμV/m (32 volts/meter) at a 1 meter distance. The two field levels are 110 dB apart.

The limit curves are based on experience with platform-level problems with antenna-connected receivers and the amount of shielding typically between antennas and equipment and associated wiring.

The Air Force and Navy limit curve for equipment in internal installations is placed for an aircraft that is not designed to have intentionally shielded volumes which are effective across the frequency range of the test. Some minimal shielding is present. The curve for equipment in external installations is 10 dB more stringent because even this minimal shielding is not available.

The Air Force and Navy limit for internal equipment for the 30 to 400 MHz band, in particular, has been validated as being properly placed. Army investigations with aircraft have also shown the validity of the Army limit. It has become standard practice on some aircraft programs to use spectral analysis equipment wired to aircraft antennas to assess degradation due to radiated emissions from onboard equipment. Many problems due to out-of-limit conditions in this band have been demonstrated. It has also been determined that equipment meeting the limit generally do not cause problems. Most of this experience is on fighter size aircraft. The 20 dB/decade increase in the limit above 100 MHz is due to the aperture size of a tuned antenna ($G\lambda^2/(4\pi)$) decreasing with frequency. The coupled power level from an isotropic tuned antenna will remain constant. The curve breaks at 100 MHz because of difficulty with maintaining a tuned antenna due to increasing physical size and the lower likelihood of coupling to the antenna with longer wavelengths.

No Air Force and Navy limit is specified below 2 MHz. There are antennas on some aircraft that operate below 2 MHz; however, these antennas are usually magnetic loops which have an electrostatic shield. These antennas have very short electrical lengths with respect to the wavelength of frequencies below 2 MHz and any electric field coupling will be inefficient. With the exception of Army aircraft, there is no known history of coupling problems to these antennas or to cabling despite substantial above limit conditions with respect to past MIL-STD-461 requirements. The Army has had problems with low frequency automatic direction finding receivers primarily attributed to their use of helicopters which are physically small and have many larger apertures. The inefficient coupling to cabling at lower frequencies has been demonstrated innumerable times in MIL-STD-462 testing.

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The limits for Navy mobile and all Army ground equipment are the same. Also, the limits for Navy fixed and all Air Force ground equipment are identical. The 20 dB difference between the limits exists because of the general situations where the equipment is deployed. The Navy mobile is primarily oriented toward the Marines which operate in a fashion similar to the Army. Equipment is often very close to unprotected antennas such as installations in jeeps or tents or near physically small helicopter aircraft. The Navy fixed and most Air Force installations have less critical coupling situations with regard to antenna coupling.

The limit for ships is based on numerous documented incidents of case and cable radiation coupling to receiver antennas. The use of hand-held type transceivers below deck within a ship is increasing and can be plagued by excessive levels of interference below deck. The limit is more stringent than corresponding electric field radiation emissions requirements contained in military-related international agreements and standards such as those used by NATO.

Another issue is that there have been substantial conflicts between allowed radiated levels implied by the power quality limits of MIL-STD-704 and previous MIL-STD-461 requirements. For example, MIL-STD-704 allows approximately 0.63 volt RMS on 115 volt, 400 Hz, AC power busses at 15 kHz. Based on laboratory testing, this level will radiate at approximately 76 dBμV/m. This level is 31 dB above the previous MIL-STD-461 limit for aircraft equipment. It is interesting to note that if the rod antenna in the MIL-STD-462 setup were usable down to 400 Hz, an approximate 1 volt/meter level would be indicated because of the power source waveform.

Possible tailoring by the procuring activity for contractual documents is as follows. The limits could be adjusted based on the types of antenna-connected equipment on the platform and the degree of shielding present between the equipment, associated cabling, and the antennas. For example, substantial relaxations of the limit may be possible for equipment and associated cabling located totally within a shielded volume with known shielding characteristics. It may be desirable to tailor the frequency coverage of the limit to include only frequency bands where antenna-connected receivers are present. Some caution needs to be exercised in this regard since there is always the chance the equipment will be added in the future. For example, it is not uncommon to add communications equipment (such as HF radio) onboard an aircraft as different missions evolve.

Based on the above discussion concerning MIL-STD-704, relaxing of RE102 limits for aircraft should be considered at

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lower frequencies for power generation equipment to avoid conflicts between the two sets of requirements.

50.3.14 (5.3.14) RE103 (Radiated emissions, antenna spurious and harmonic outputs, 10 kHz to 40 GHz).

DISCUSSIONS: The requirements are essentially identical with CE106 for transmitters in the transmit mode. There are no requirements for receivers or transmitters in the standby mode. Most of the discussion under CE106 also applies to RE103. A distinction between the requirements is that RE103 testing in MIL-STD-462 includes effects due to antenna characteristics. The test itself is considerably more difficult.

50.3.15 (5.3.15) RS101 (Radiated susceptibility, magnetic fields, 30 Hz to 50 kHz).

DISCUSSION: This requirement is specialized and intended primarily to ensure that performance of equipment potentially sensitive to low frequency magnetic fields is not degraded. RE101 is a complimentary requirement governing the radiated magnetic field emissions from equipment and subsystems. The RE101 discussion is also applicable to this requirement.

The RS101 limits have the same shape as the RE101 limits; however, the RS101 limits are 10 dB higher for Navy applications and 6 dB for Army aircraft applications. These differences are necessary to allow for variations in performance between manufactured items and to account for the possibility that the emissions from the EUT may couple into a larger physical area than that evaluated under the RS101 procedures in MIL-STD-462.

The Navy limits are based on the maximum expected magnetic field emissions from equipment and subsystems, including interconnecting cabling. The Army limits are based on 5 millivolts (independent of frequency) being induced in a 12.7 centimeter (5 inch) diameter loop.

50.3.16 (5.3.16) RS103 (Radiated susceptibility, electric field, 10 kHz to 40 GHz).

DISCUSSION: The requirements are applicable to both the EUT enclosures and EUT associated cabling. The basic concern is to ensure that equipment will operate without degradation in the presence of electromagnetic fields generated by antenna transmissions both onboard and external to the platform.

There is no implied relationship between this requirement and RE102. The RE102 limit is placed primarily to protect antenna-connected receivers while RS103 simulates fields resulting from antenna transmissions.

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The limits specified for different platforms are simply based on levels expected to be encountered during the service life of the equipment. They do not necessarily represent the worst-case environment to which the equipment may be exposed. RF environments can be highly variable, particularly for emitters not located on the platform. The limits are placed at levels which are considered to be adequate to cover most situations.

An example which demonstrates the variability of environments for ground installations and the need for effective tailoring of requirements is the installation of equipment in a large ground-based radar facility. Some of these facilities transmit power levels over one megawatt and the back lobes from the antennas can be substantial. Suitable design levels for equipment which will be used in the facility or nearby need to be imposed.

For aircraft and ships, different limits are specified depending on whether the equipment receives protection from platform structure. This distinction is not made for Army ground systems, such as tanks, because the same equipment used inside a structure is often used in other applications where protection is not available.

The 200 volt/meter requirement for Army aircraft regardless of the location or criticality of the equipment is based on the use of Army aircraft. Portions of the external environment accepted for most of the Army's aircraft is higher than 200 volts/meter. Army aircraft, especially rotary wing, have flight profiles which are almost exclusively nap-of-the-earth (NOE). The NOE profiles allow for much closer, and longer duration, encounters with high power emitters. This approach is similar to the FAA approach which recommends that Visual Flight Rules (VFR) helicopters be qualified to levels higher than fixed wing aircraft.

Circularly polarized fields are not allowed due to problems with using the spiral conical antennas specified in previous versions of MIL-STD-462. Circularly polarized fields were convenient since they avoided the need to rotate a linearly polarized antenna to obtain both polarizations of the radiated field. However, problems existed with this antenna. At some frequencies, the antenna pattern of the conical log spiral is not centered on the antenna axis. Also, the circular polarization of the conical log spiral creates confusion in its proper application. The EUT and associated cabling can be expected to respond more readily to linearly polarized fields. If a second spiral conical were used to calibrate the field radiated from the first spiral conical antenna, it would indicate an electric field 3 dB higher than a linearly polarized antenna. The question arises whether a 3 dB higher field should be used for a spiral

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conical transmit antenna to obtain response characteristics similar to a linearly polarized field. Similarly, if a spiral conical antenna were used to calibrate a linearly polarized field, the indication would be 3 dB below the true electric field strength.

Possible tailoring by the procuring activity for contractual documents is to modify the required levels and required frequency ranges based on the emitters on and near a particular installation. Actual field levels can be calculated from characteristics of the emitters, distances between the emitters and the equipment, and intervening shielding. MIL-HDBK-235 provides information on land, air, and sea based RF emitters, both hostile and friendly, which contribute to the overall electromagnetic environment. The possible use of the equipment in other installations and the potential addition or relocation of RF emitters needs to be considered. Other possible tailoring is to change from the standard 1 kHz, square wave, modulation or use additional modulations based on actual platform environments.

50.3.17 (5.3.17) RS105 (Radiated susceptibility, transient, electromagnetic field).

DISCUSSION: This requirement has limited applicability. It is primarily intended for equipment located outside platform structure exposed to incident transient electromagnetic fields. This requirement is applicable only for EUT enclosures. The electrical interface cabling should be protected in shielding conduit. Potential equipment responses due to cable coupling are controlled under CS116.

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