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DEPARTMENT OF DEFENSE HANDBOOK

MILITARY OPERATIONAL ELECTROMAGNETIC ENVIRONMENT PROFILES

PART 1D

GENERAL GUIDANCE

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FOREWORD

1. This handbook is approved for use by all Departments and Agencies of the Department of Defense (DoD).

2. This handbook provides composite electromagnetic environment (EME) profiles for military operations. Each part is provided on a separate CD that contains tables that define the various military operational EME profiles and their dominant emitter sources. The tables are presented as electronically linked Microsoft Excel spreadsheets. This handbook is only for guidance and cannot be cited as a requirement.

3. MIL-HDBK-235 Part 1D is unclassified and available at the ASSIST Online Website: https://assist.dla.mil/. MIL-HDBK-235 Parts 7D and 10D are restricted in distribution and authorized for release only to DoD personnel and defense contractors. MIL-HDBK-235 Parts 2D through 6D, 8, and 9D are classified. The procedures for requesting MIL-HDBK-235 Parts 2D through 10D are as follows:

a. DoD Components. Defense agencies and organizations may obtain copies of MIL-HDBK-235 Parts 7D and 10D upon request. MIL-HDBK-235 Parts 2D through 6D, 8, and 9D are available upon request after verification of access to an approved security container.

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1) Statement of “need-to-know.”

2) Government sponsor, contract number, and program nomenclature.

3) Copy of DD Form 254, “DoD Contract Security Classification Specification,” to document access to approved storage container.

4) Specific part(s) of MIL-HDBK-235 being requested.

c. In addition to the requirements stated above, requests from non-DoD Government, contractor, and civilian personnel should be endorsed by and submitted through the responsible Government agency, program manager, contracting officer, or sponsor.

d. The required information for requesting MIL-HDBK-235 Parts 2D through 10D should be forwarded to:

Defense Information Systems Agency (DC5)
Joint Spectrum Center
Attn: M. Shellman, Jr. (J5)
2004 Turbot Landing
Annapolis, MD 21402-5064

4. The point of contact for additional information is Mr. Marcus Shellman, Jr., at commercial (410) 919-2749 and e-mail marcus.shellman.civ@mail.mil.

5. Data Handling and Releasability. The classified parts of this handbook may be used to define the military operational EME or interface performance requirements. In addition, the handbook may be used to prepare proposals in response to an invitation-for-bid in accordance with the conditions of DoD Instructive 5200.01 (Information Security Program Regulation and Protection of Sensitive Compartmented Information). The following guidance is applicable.

a. Contracting Officers and Security Managers should ensure that the following requirements are included specifically in the contract itself, invitation-for-bid, or in the Contract Security Classification Specification (DD Form 254):

1) The classified parts of this handbook should not be released to foreign nationals or immigrant aliens who may be employed by the contractor, regardless of their security clearance level.

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3) Bidders and contractors should not release the classified parts of this handbook to any activity or person of the contractor's organization not directly engaged in providing services under the contract or to another contractor (including subcontractors), Government agency, private individual, or organization.

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5) The bidder and contractor should maintain such records as will permit them to furnish on demand the names of individuals having access to foreign intelligence material in their custody.

b. While data from the EME tables contained in MIL-HDBK-235 Parts 2D through 10D may be extracted and incorporated into the Joint Capabilities Integration and Development System and other acquisition documentation (including the request-for-proposal, specification, contract, order, and so forth), it should be done with care. The EME tables may contain or are linked electronically with a combination of classified and unclassified data elements, and the extracted data should be marked properly according to their classification.

5. Comments, recommendations, additions, or deletions and any other pertinent data that may improve this document should be e-mailed to marcus.shellman.civ@mail.mil or addressed to:

Defense Information Systems Agency (DC5)
Joint Spectrum Center
Attn: M. Shellman, Jr. (J5)
2004 Turbot Landing
Annapolis, MD 21402-5064

The currency of this address information may be verified by using the ASSIST Online database at https://assist.dla.mil/.

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CONTENTS

1. SCOPE

1.1 Purpose

This handbook provides information for use in tailoring and supplementing the electromagnetic environment (EME) levels specified in MIL-STD-464 and the radiated susceptibility (RS) RS103 requirement of MIL-STD-461. Both standards may be imposed to ensure adequate consideration of the EME in the design, development, procurement, and evaluation of Department of Defense (DoD) platforms, systems, subsystems, or equipment. This handbook is applicable to any electrical and electronic equipment, subsystem, system, or platform that may be exposed to the EME during its life cycle, including ground, ship, aircraft, aerospace and weapons systems and their associated subsystems and equipment, ordnance, and support and checkout equipment and instruments. It is intended for use by DoD personnel responsible for requirements generation and acquisition life-cycle processes, including test and evaluation of these end items. See 6.5 for tailoring guidance.

1.2 Background

The threat presented by radio frequency (RF) emitters around the world is becoming increasingly prevalent. Increased multinational military operations, proliferation of both friendly and hostile weapons systems, and the expanded use of the spectrum worldwide have resulted in operational EMEs not previously encountered. The EME can include the electromagnetic (EM) emissions from mission-essential systems as well as contributions from foreign systems, military as well as civilian systems, friendly as well as hostile systems, and Government as well as commercial systems.

General EME profiles for platforms/systems and subsystems/equipment can be obtained from MIL-STD-464 and MIL-STD-461, respectively. These documents define external RF EME levels that may be encountered by land-based, ship-based, airborne, and space systems and ordnance. These EME levels can be very high and can degrade operational performance if they are not addressed properly. Even relatively low-power personal communication system items such as cellular phones used in close proximity to sensitive electronic items can create EM fields sufficient to degrade performance. This handbook may be used to tailor the EME levels in the standards.

Since each platform, system, subsystem, or equipment has its own requirements and characteristics, the general EME levels specified in these documents may not be adequate. These EME profiles should be tailored (adapted or modified) to the specific missions in which the system or equipment will participate, and to the characteristics and operational requirements of the item under development, to avoid unnecessary design costs associated with stringent EME levels. The tailored electromagnetic environmental effects (E3) requirements and EME levels should be incorporated into the Joint Capabilities Integration and Development System (JCIDS) and acquisition documentation, including the request-for-proposal, specification, contract, order, and so forth. See MIL-HDBK-237 for guidance on incorporating E3 into JCIDS and other acquisition documents.

1.3 Use

The information contained herein is intended for use in tailoring requirements when implementing DoD policies and meeting contractual requirements, or when specified in the Statement of Work. Tailoring of requirements should not violate International agreements. In the event that there are essential reasons for nonconformance with such an agreement, the Signatory Nations should be consulted, as required by the agreement. Care should be taken to ensure that tailoring does not restrict the use of a platform, system, subsystem, or equipment. Extracting data from the EME tables found in the other parts of this handbook should be done with care. The EME tables may contain or are linked electronically with a combination of classified and unclassified data, and the extracted data should be marked properly according to their classification.

1.4 Format

This handbook is issued in 10 parts. Part 1D gives general information on the EME and some of the rationale and assumptions used to derive the EME levels in the other parts of this handbook. The other parts (except Part 8) contain tables describing the EME levels that may be encountered from friendly emitters, as well as emitter characteristics. EME levels in Part 8 are based on friendly and hostile sources. The parts are formatted to mirror the EME tables in MIL-STD-464 (see Table 1D-I.). Table 1D-II is an index of the EME tables in the other parts of this handbook. In addition, the comparable MIL-STD-464 tables are annotated in the table.

TABLE 1D-I. MIL-HDBK-235 parts

PART #	PART TITLE
2D	(U) External EME Levels for U.S. Navy Surface Ship Operations
3D	(U) External EME Levels for Space and Launch Vehicle Systems
4D	(U) External EME Levels for Ground Systems
5D	(U) External EME Levels for Rotary-Wing Aircraft, Excluding U.S. Shipboard Operations
6D	(U) External EME Levels for Fixed-Wing Aircraft, Excluding U.S. Shipboard Operations
7D	External EME Levels for Ordnance
8	(U) External EME Levels from High Power Microwave (HPM) Systems
9D	(U) External EME Levels for Other U.S. Ships (Coast Guard, Military Sealift Command, and Army Ships)
10D	External EME Levels for Submarine Operations

TABLE 1D-II. Index of EME tables in MIL-HDBK-235

TABLE	TITLE
Part 2D	
2D-IA	(U) Maximum external EME for deck operations on U.S. Navy ships (MIL-STD-464 table I)
2D-IB	(U) Operational external EME for deck operations on U.S. Navy ships
2D-IIA	(U) Maximum external EME for ship operations in the main beam of transmitters (MIL-STD-464 table II)
2D-IIB	(U) Operational external EME for ship operations in the main beam of transmitters
2D-III	(U) Composite combatant EME
2D-IV	(U) Composite amphibious EME
2D-V	(U) CVN 68 Class EME
2D-VI	(U) LCC 19 Class EME
2D-VII	(U) CG 47 Class EME
2D-VIII	(U) DDG 51 FLT I and II Class EME
2D-IX	(U) DDG 51 FLT IIA Class EME
2D-XI	(U) LHA 1 Class EME
2D-XII	(U) LHD 1 Class EME
2D-XIV	(U) LPD 17 Class EME
2D-XV	(U) LSD 41 and 49 Classes EME
2D-XVI	(U) MCM 1 Class EME
2D-XVII	(U) PC 1 Class EME
2D-XVIII	(U) LCS 1 Class EME
2D-XIX	(U) CG 47 Class measured EME
2D-XX	(U) CVN 68 Class measured EME
2D-XXI	(U) DDG 51 FLT I and II Classes measured EME
2D-XXII	(U) DDG 51 FLT IIA Class measured EME
2D-XXIV	(U) LHA 1 Class measured EME
2D-XXV	(U) LHD 1 Class measured EME
2D-XXVII	(U) LPD 17 Class measured EME
2D-XXVIII	(U) LSD 41 and 49 Classes measured EME
2D-XXIX	(U) LCC 19 Class measured EME
2D-XXX	(U) MCM 1 Class measured EME
2D-XXXI	(U) PC 1 Class measured EME
2D-XXXII	(U) LCS 1 Class measured EME
2D-XXXIII	(U) Calculated weather-deck EME (all ships)
2D-XXXIV	(U) CG 47 Class calculated flight-deck and in-flight aircraft EME
2D-XXXV	(U) CVN 68 Class calculated flight-deck and in-flight aircraft EME
2D-XXXVI	(U) DDG 51 FLT I and II Class calculated flight-deck and in-flight aircraft EME
2D-XXXVII	(U) DDG 51 FLT IIA Class calculated flight-deck and in-flight aircraft EME
2D-XXXIX	(U) LHA 1 Class calculated flight-deck and in-flight aircraft EME
2D-XL	(U) LCC 19 Class calculated flight-deck and in-flight aircraft EME
2D-XLI	(U) LHD 1 Class calculated flight-deck and in-flight aircraft EME

TABLE 1D-II. Index of EME tables in MIL-HDBK-235 - Continued

TABLE	TITLE
2D-XLIII	(U) LPD 17 Class calculated flight-deck and in-flight aircraft EME
2D-XLIV	(U) LSD 41 and 49 Classes calculated flight-deck and in-flight aircraft EME
2D-XLV	(U) MCM 1 Class calculated flight-deck and in-flight aircraft EME
2D-XLVI	(U) PC 1 Class calculated flight-deck and in-flight aircraft EME
2D-XLVII	(U) LCS 1 Class calculated flight-deck and in-flight aircraft EME
2D-XLVIII	(U) Escort ship calculated EME (all ships)
2D-XLIX	(U) Emitter specifications
2D-L	(U) PEL considerations
Part 3D	
3D-I	(U) Maximum external EME for space and launch vehicle systems (MIL-STD-464 table III)
3D-II	(U) EME levels for low orbital space systems @ 100 nm altitude
3D-III	(U) Composite EME levels for launch and recovery space systems @ 1 km altitude
3D-IV	(U) EME levels 1 km above Cape Canaveral launch pad
3D-V	(U) EME levels 1 km above Wallops Island launch pad
3D-VI	(U) EME levels 1 km above Vandenberg launch pad
3D-VIII	(U) Space transmitter antenna specifications
3D-IX	(U) Launch and recovery transmitter antenna specifications
Part 4D	
4D-I	(U) Maximum external EME for ground systems (MIL-STD-464 table IV)
4D-II	(U) EME levels from mobile and portable platforms
4D-III	(U) EME levels at fixed and transportable sites
4D-IV	(U) Emitter specifications
Part 5D	
5D-IA	(U) Maximum external EME for rotary-wing aircraft, excluding U.S. shipboard operations (MIL-STD-464 table V)
5D-IB	(U) Operational external EME for rotary-wing aircraft, excluding U.S. shipboard operations
5D-II	(U) EME levels for rotary-wing aircraft in flight
5D-III	(U) EME levels from civilian airfields during landing and taking off
5D-IV	(U) EME levels for military airfield operations (rotary)
5D-V	(U) EME levels for expeditionary airfields
5D-VI	(U) HIRF levels in Europe
5D-VII	(U) Emitter specifications
Part 6D	
6D-I	(U) Maximum external EME for fixed-wing aircraft, including UAVs, excluding shipboard operations (MIL-STD-464 table VI)
6D-II	(U) EME levels for fixed-wing aircraft in flight
6D-III	(U) EME levels from civil airfields during landing and taking off
6D-IV	(U) EME levels during military airfield operations
6D-V	(U) EME levels during expeditionary airfield operations
6D-VI	(U) EME levels for ferry
6D-VII	(U) EME levels for formation escort

TABLE 1D-II. Index of EME tables in MIL-HDBK-235 - Continued

TABLE	TITLE
6D-VIII	(U) EME levels during low-altitude ingress and egress
6D-IX	(U) EME levels during in-flight refueling
6D-X	(U) EME levels for air-to-ground employment
6D-XI	(U) EME levels for hostile intercept (information only)
6D-XII	(U) Emitter specifications
6D-XIII	(U) Emitter specifications for hostile intercept
Part 7D	
7D-IA	Maximum external EME levels for ordnance (MIL-STD-464 table IX)
7D-IB	External EME levels for ordnance
7D-II	HERO EME levels for the S4 phases
Part 8	
8-I	(U) Combined external EME for narrowband HPM
8-II	(U) Combined external EME for wideband HPM
8-III	(U) Formal HPM threats – general descriptions
8-IVA	(U) Characteristics of HPM threats – characteristics of HPM sources 1-11, 14, and 15
8-IVB	(U) Characteristics of HPM threats – characteristics of HPM sources 12 and 13
8-V	(U) Wideband HPM environments – broad-band E-field distribution (mV/m/MHz @ 100m)
8-VI	(U) Narrowband HPM threats – aircraft example
8-VII	(U) Wideband HPM threats – aircraft example
8-VIII	(U) Given standoff distances – aircraft example
8-IX	(U) Tailored narrowband threat environment – aircraft example
8-X	(U) Tailored wideband threat environment – aircraft example
Part 9D	
9D-IA	(U) Maximum external EME for deck operations (all USCG, MSC, and Army ships) (for tailoring of MIL-STD-464 table I)
9D-IB	(U) Maximum external EME for operations in the main beam (all USCG, MSC, and Army ships) (for tailoring of MIL-STD-464 table II)
9D-IIA	(U) Maximum external EME for deck operations on all USCG ships
9D-IIB	(U) Maximum external EME for operations in the main beam of USCG ships' transmitters
9D-IIIA	(U) Maximum external EME for deck operations on all MSC and Army ships
9D-IIIB	(U) Maximum external EME for operations in the main beam of MSC and Army ships' transmitters
9D-IV	(U) WMSL 750 Class EME
9D-V	(U) WHEC 715 Class EME
9D-VI	(U) WMEC 901 Class EME
9D-VII	(U) T-AKE 1 Class EME
9D-VIII	(U) T-AOE 6 Class EME
9D-IX	(U) T-AE 26 Class EME
9D-X	(U) T-AO 187 Class EME
9D-XI	(U) T-ARS 50 Class EME
9D-XII	(U) WMSL 750 Class measured EME

TABLE 1D-II. Index of EME tables in MIL-HDBK-235 - Continued

TABLE	TITLE
9D-XIII	(U) T-AKE 1 Class measured EME
9D-XIV	(U) T-AOE 6 Class measured EME
9D-XV	(U) T-AE 26 Class measured EME
9D-XVI	(U) T-AO 187 Class measured EME
9D-XVII	(U) T-ARS 50 Class measured EME
9D-XVIII	(U) WMSL 750 Class calculated EME
9D-XIX	(U) WHEC 715 Class calculated EME
9D-XX	(U) WMEC 901 Class calculated EME
9D-XXI	(U) T-AKE 1 Class calculated EME
9D-XXII	(U) T-AOE 6 Class calculated EME
9D-XXIII	(U) T-AE 26 Class calculated EME
9D-XXIV	(U) T-AO 187 Class calculated EME
9D-XXV	(U) T-ARS 50 Class calculated EME
9D-XXVI	(U) Emitter specifications
Part 10D	
10D-IA	Maximum external EME for submarine operations (for tailoring of MIL-STD-464 tables I and II)
10D-IB	Operational EME levels for submarine operations
10D-II	SSN 688 Class EME
10D-III	SSBN 726 Class EME
10D-IV	SSGN 726 Class EME
10D-V	SSN 774 Class EME
10D-VI	SSN 688 Class calculated weather-deck, main-beam, and in-flight aircraft EME
10D-VII	SSBN 726 Class calculated weather-deck, main-beam, and in-flight aircraft EME
10D-VIII	SSGN 726 Class calculated weather-deck, main-beam, and in-flight aircraft EME
10D-IX	SSN 774 Class calculated weather-deck, main-beam, and in-flight aircraft EME
10D-X	SSGN 726 Class measured EME
10D-XI	SSN 774 Class measured EME

2. APPLICABLE DOCUMENTS

2.1 Government Documents

2.1.1 Specifications, Standards, and Handbooks

The following standards form a part of this document to the extent specified herein.

Department of Defense

MIL-HDBK-235-2D (CLASSIFIED)	(U) External Electromagnetic Environment (EME) Levels for U.S. Navy Surface Ship Operations
MIL-HDBK-235-3D (CLASSIFIED)	(U) External EME Levels for Space and Launch Vehicle Systems
MIL-HDBK-235-4D (CLASSIFIED)	(U) External EME Levels for Ground Systems
MIL-HDBK-235-5D (CLASSIFIED)	(U) External EME Levels for Rotary-Wing Aircraft, Excluding U.S. Shipboard Operations
MIL-HDBK-235-6D (CLASSIFIED)	(U) External EME Levels for Fixed-Wing Aircraft, Excluding U.S. Shipboard Operations
MIL-HDBK-235-7D	External EME Levels for Ordnance
MIL-HDBK-235-8 (CLASSIFIED)	(U) External EME Levels from High Power Microwave (HPM) Systems
MIL-HDBK-235-9D (CLASSIFIED)	(U) External EME Levels for Other U.S. Ships (Coast Guard, Military Sealift Command, and Army Ships)
MIL-HDBK-235-10D	External EME Levels for Submarine Operations
MIL-HDBK-237	Electromagnetic Environmental Effects and Spectrum Supportability Guidance for the Acquisition Process
MI-HDBK-240	Hazards of Electromagnetic Radiation to Ordnance (HERO) Test Guide
MIL-STD-461	Interface Standard, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-464	Interface Standard, Electromagnetic Environmental Effects Requirements for Systems

(Copies of the unclassified documents are available online at https://assist.dla.mil/ from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.) For copies of the classified documents, see Foreword.

2.1.2 Other DoD Documents and Publications

The following other DoD documents and publications form a part of this document to the extent specified herein. They are referenced solely to provide supplemental data and are only for informational purposes.

Department of Defense

DoDI 3222.03	The DoD Electromagnetic Environmental Effects (E3) Program
DoDI 6055.11	Protecting Personnel from Electromagnetic Fields
Joint Chiefs of Staff (JCS) Pub. No. 1-02	Department of Defense Dictionary of Military and Associated Terms

Department of the Navy

NAVSEA OP 3565/ NAVAIR 16-1-529	Volume 1 - Technical Manual, Electromagnetic Radiation Hazards (Hazards to Personnel, Fuel, and Other Flammable Material)
	Volume 2 - Technical Manual, Electromagnetic Radiation Hazards (Hazards to Ordnance)

(Copies of the directive, instruction, and Joint Pub are available from the Document Automation and Production Service, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094. If you have any questions, please contact the appropriate ASSIST-Help Desk team: Account/Password Issues: 215-697-6396 (DSN: 442-6396). Copies of OP 3565 Volume 1 are available as follows: for DoD agencies and contractors, contact the Director, Naval Surface Warfare Center, Attn: E421, Indian Head Division Detachment Earle, 201 Highway 34 South, Colts Neck, NJ 07722-5023; for all others contact the Commander, Naval Sea Systems Command, Attn: SEA 53H3, 1333 Isaac Hull Ave., SE, Washington, DC 20376-1080. Copies of OP 3565 Volume 2 are available from the Colts Neck address listed above.)

2.2 Non-Government Publications

The following document forms a part of this handbook to the extent specified herein.

American National Standards Institute (ANSI)

ANSI/IEEE C63.14	Dictionary of Electromagnetic Compatibility (EMC) including Electromagnetic Environmental Effects (E3)

(Copies of this document are available from Institute of Electrical and Electronics Engineers (IEEE) on www.ieee.org or IEEE Contact Center, 445 Hoes Lane, Piscataway, NJ 08854-1331 or 1-800-678-IEEE.)

3. DEFINITIONS

3.1 Acronyms and Abbreviations

Acronyms and abbreviations used in this handbook, including all of its parts, are defined below.

AM	Amplitude Modulation
ATCRBS	Air Traffic Control Radar Beacon System
AUR	All-Up Round
CIWS	Close-In Weapon System
CONOPS	Concept of Operations
CONREP	Connected Replenishment
COTS	Commercial Off-the-Shelf
CSG	Carrier Strike Group
CW	Continuous Wave
dB	Decibel
dBm	Decibel relative to 1 milliwatt
DISA	Defense Information Systems Agency
DoD	Department of Defense
E3	Electromagnetic Environmental Effects
EID	Electrically Initiated Device
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EME	Electromagnetic Environment
EMI	Electromagnetic Interference
EMP	Electromagnetic Pulse
EMV	Electromagnetic Vulnerability
ESD	Electrostatic Discharge
FID	Fast Ionization Device
FM	Frequency Modulation
GHz	Gigahertz
GW	Gigawatt
HERF	Hazards of Electromagnetic Radiation to Fuel
HERO	Hazards of Electromagnetic Radiation to Ordnance
HERP	Hazards of Electromagnetic Radiation to Personnel
HF	High Frequency
HIRF	High Intensity Radiated Fields
HPM	High-Power Microwave
IADS	Integrated Air Defense System
IED	Improvised Explosive Device
IEEE	Institute of Electrical and Electronics Engineers
JCIDS	Joint Capabilities Integration and Development System
JSC	Joint Spectrum Center

km	kilometer
MHz	Megahertz
MSC	Military Sealift Command
MW	Megawatt
NATO	North Atlantic Treaty Organization
nm	Nautical mile
PCM	Pulse Coded Modulation
PEL	Permissible Exposure Limit
PGM	Precision Guided Munitions
PRF	Pulse Repetition Frequency
P-Static	Precipitation Static
RF	Radio Frequency
RFW	RF Weapon
rms	Root mean square
S4	Stockpile-to-Safe-Separation Sequence
SAM	Surface-to-Air Missile
SATCOM	Satellite Communications
SOP	Standard Operating Procedure
SUA	Special Use Airspace
TACAN	Tactical Air Navigation
UAV	Unmanned Aerial Vehicle
UHF	Ultra High Frequency
USCG	United States Coast Guard
UWB	Ultra-Wideband
V/m	Volts per meter
VHF	Very High Frequency
VOR	VHF Omnidirectional Range
VSTOL	Vertical/Short Takeoff and Landing

3.2 Definitions

Many terms used in this handbook are defined in ANSI/IEEE C63.14, JCS Pub 1-02, DoDI 3222.03, MIL-STD-464, MIL-STD-461, or MIL-HDBK-237. The following definitions are repeated herein for ready reference.

3.2.1 Electromagnetic Environment (EME)

EME is the resulting product of the power and time distribution, in various frequency ranges, of the radiated and/or conducted EM emission levels that may be encountered by a military force, system, or platform when performing its assigned mission in its intended operational environment. It is dynamically comprised of EM energy from a multitude of natural sources (lightning, precipitation static (p-static), electrostatic discharge (ESD), galactic and stellar noise, etc.) and manmade sources (electrical and electronic systems, RF systems, EM devices, ultra-wideband (UWB) systems, high-power microwave (HPM) systems, etc.).

3.2.2 Electromagnetic Environmental Effects (E3)

E3 is the impact of the EME on the operational capability of military forces, equipment, systems, and platforms. It encompasses the EM effects addressed by the disciplines of electromagnetic compatibility (EMC); electromagnetic interference (EMI); electromagnetic vulnerability (EMV); electromagnetic pulse (EMP); electronic protection; ESD; and hazards of electromagnetic radiation to personnel, ordnance (HERO), and fuel (volatile materials), and includes the EM effects generated by all EME contributors, including RF systems, UWB systems, HPM systems, lightning, p-static, etc.

3.2.3 Electromagnetic Vulnerability (EMV)

EMV is the characteristic of an item that causes it to suffer degraded performance, or the inability to perform its specified task, as a result of the operational EME. An item is said to be vulnerable if its performance is degraded below a satisfactory level because of exposure to the stress of an operational EME or transient.

3.2.4 Susceptibility

Susceptibility is the inability of an item to perform its function without degradation while in the presence of an EM disturbance. EM disturbances can be in the form of either radiated or conducted emissions. An item is said to be susceptible if it malfunctions when exposed to a laboratory-generated radiated or conducted EME.

4. General Requirements

4.1 The Electromagnetic Environment

The term EME is defined in 3.2.1. It is the totality of EM energy, from manmade and natural sources, to which a platform, system, subsystem, or equipment will be exposed within any domain (that is, land, air, space, sea) while performing its intended mission throughout its operational life cycle. When defined, the EME will be for a particular time and place. Specific equipment characteristics (such as emitter power levels, operating frequencies, and receiver sensitivity), operational factors (such as distances between platforms, systems, and force structure), and frequency coordination all contribute to the EME. In addition, transient emissions such as those from EMP, lightning, and p-static, and their associated rise and fall times, also contribute to the EME.

General EME profiles for platforms/systems and subsystems/equipment can be found in MIL-STD-464 and MIL-STD-461, respectively. These EME levels can be very high and can degrade system performance if they are not addressed properly. Even relatively low-power personal communication system items such as cellular phones, when used in close proximity to sensitive electronic items, can create EM fields sufficient to degrade performance.

In all likelihood, each item will be exposed to several different EME levels during its life cycle. This handbook and MIL-STD-464 and MIL-STD-461 provide general information on the EME. Referring to these publications can be useful when defining the levels of the EME to which an item may be exposed. However, the EME tables should be tailored for specific applications.

Specifying an EME level that is too stringent may result in unnecessary additional costs. Each distinctive EME to which an item will be exposed during its life cycle should be defined before specifying its performance requirements. For example, a missile will be exposed to different EME levels during shipment, storage, checkout, launch, and approach to a target. The specified E3 control performance requirements should ensure that the item's performance will not be affected adversely by any of the EME levels that will be encountered.

4.1.1 EME Effects

The effects of undesired EM energy on an item that operates in a specific environment are dependent upon the item's susceptibility (or immunity) characteristics and the amplitude, frequency, and time-dependent characteristics of the EME. To prevent E3 problems from occurring, the possible effects of undesired EM energy should be considered for each item when operating in its intended EME.

Undesired EM energy may degrade the performance of an item temporarily, in which case the item may operate in a degraded mode when sufficient EM energy is present. Alternatively, the EM energy may cause permanent damage, in which case the item will not operate until it is either repaired or replaced and the E3 problem has been resolved. The following are examples of the effects that can be caused by undesired EM energy, depending on the victim.

a. Burnout or voltage breakdown of components, antennas, and so forth;

b. Performance degradation of receiver signal processing circuits;

c. Erroneous or inadvertent operation of electromechanical equipment, electronic circuits, components, ordnance, and so forth;

d. Unintentional detonation or ignition of ordnance and flammable materials; and

e. Personnel injuries.

4.1.2 Contributors to the EME

The EME in which military platforms, systems, subsystems, and equipment should operate is comprised of a multitude of natural and manmade sources. Natural sources consist of the following:

a. Galactic noise,
b. Atmospheric noise,
c. Solar noise,
d. P-static,
e. Lightning, and
f. ESD.

Manmade sources consist of friendly and hostile emitters, both intentional and unintentional, and spurious emissions such as motor noise and intermodulation products. Intentional emitters include, but are not limited to, the following types of subsystems/equipment:

a. Communications,
b. Navigation,
c. Meteorology,
d. Radar,
e. Weapon,
f. Electronic warfare, and
g. RF high-power threat emitters such as HPM systems.

Unintentional emitters encompass subsystems and equipment that use, transform, or generate undesired EM energy as a by-product of performing its mission. Therefore, any electrical, electronic, electromechanical, or electro-optic device can be an unintentional emitter. Examples of unintentional emitters include the following:

a. Intentional radiators emitting other than the intended emission;
b. Computers and associated peripherals;
c. Televisions, cameras, and video equipment;
d. Microwave ovens;
e. Radio and radar receivers;
f. Power supplies and frequency converters;
g. Motors and generators; and
h. Electrical hand tools.

Power levels and source locations relative to the item are the two main considerations used for determining which sources are the dominant contributors to the operational EME. For example, during normal, non-combat operations, the primary sources of EM energy would be primarily from intentional and spurious emissions from own, collocated equipment. In a combat scenario, transmissions from coalition forces could be another major contributor. Hence, the EME in which an item should operate and survive is both mission-dependent and scenario-dependent.

4.2 Defining the EME

The anticipated system or equipment EME is to be defined during the Concept Refinement Phase. The following procedure can be used when defining the environment:

a. Step 1--Determine the major geographic regions and countries in which the system or equipment is expected to operate.

b. Step 2--Define the theater and missions in which the system or equipment will participate and the associated platforms and systems supporting the missions.

c. Step 3--Determine present and future spectrum-dependent systems, military and civilian, that could interact with the proposed system or equipment during these missions. The identification should address both the military and commercial EME.

Although the EME is defined early in the program, continuous updates of the EME are necessary throughout the entire life cycle because the environment is not static. Other entities (friendly and hostile) will be developing or fielding items simultaneously that will operate within the same EME. Data concerning these “new” items should be sought out and added to the EME definitions. In addition, the original mission of the proposed item may be changed, forcing additional geographic regions, countries, host platforms, and nearby equipment to be considered.

The physical configuration of an item may vary depending on its intended location. An item's immunity or susceptibility to the EME also may vary depending on its physical configuration and location relative to the intended operational EME. Therefore, when developing E3 performance requirements, both the physical configuration and the location of the item within each of its intended operational EMEs should be considered.

4.2.1 External RF EME Levels for Systems and Platforms

When determining the appropriate external RF EME levels for systems and platforms, first consult the applicable MIL-STD-464 EME table(s) (ship, ground, aircraft, and so forth). This will give the general EME levels at specified distances that may range from less than 1 meter to several miles, depending on the table, and the corresponding frequency ranges for the system or platform. If EME levels at distances different from those used for the specific EME tables in the standard are desired, the EME levels may be tailored using the guidance in the MIL-STD-464 appendix and the applicable corresponding table(s) in the various parts of this handbook. This will provide the specific, platform-unique EME levels and corresponding frequency ranges. Additional information is provided on the individual emitters generating the EME levels, their specific operating frequency ranges, and the distances used for determining the EME levels. If an emitter no longer is in service, determine the replacement equipment and EME levels generated by the replacement equipment, and implement those EME levels. Other factors that could affect the EME levels are the probability of intercept, dwell times, specific type of emitter, and emitted power.

4.2.2 EME Levels for Subsystems and Equipment

The EME levels for subsystems and equipment are described in the RS103 requirement of MIL-STD-461. These EME levels are specified for different platforms or systems and are based simply on levels expected to be encountered during the service life of the equipment. They do not represent the worst-case environment to which the equipment may be exposed, necessarily. RF environments can be highly variable, particularly for emitters not located on the platform. The limits are placed at levels considered to be adequate to cover most situations, including design levels for "back door" effects (excluding direct coupling to platform antennas or externally mounted devices) resulting from RF high-power threat emitters such as radar, communication, and HPM systems.

Possible tailoring by the Procuring Activity in contractual documents may include modifying the specified EME levels and required frequency ranges based on the emitters on and near a particular installation or platform. Actual field levels can be calculated from the characteristics of the emitters, distances between the emitters and the equipment, and intervening shielding. The other parts of this handbook provide information on land-, air-, and sea-based RF emitters that contribute to the overall EME. Finally, the possible use of the equipment in other installations and the potential addition or relocation of RF emitters need to be considered.

4.2.3 Specifying the Intended EME

A significant difference usually exists between the levels of EM energy that will degrade or limit the effective performance of an item temporarily (operational) and those levels that will damage an item permanently (survivability). In addition, an item that is susceptible during a laboratory test should be evaluated to determine if it would be vulnerable in its intended operational environment. The requirement to control any effects from the EME under all circumstances should be, by necessity, more stringent than just to ensure that the item will not be damaged permanently. When specifying E3 control requirements, the item's function and criticalness to the intended mission should be taken into account. There also are precautions that can be taken to protect equipment not in use from being damaged permanently by EM energy that cannot be implemented when the equipment is in an operational mode.

The susceptibility characteristics of an item depend on its design characteristics. For example, the item may respond to a broad frequency range or be frequency-selective. In addition, some victims have response times in microseconds and are affected by the peak power levels of short-term signals, whereas other victims are affected by heating and respond more slowly to the average power levels of signals. The design characteristics of an item, as well as the shielding integrity, choice of components, and use of filtering, should be considered when evaluating EM effects on an item.

Possible changes in the intended operational EME and future applications of an item also should be considered when defining the EME that an item may encounter. An item designed to operate in a specific EME may be required to operate in another in the future, or the item may be used to perform functions and missions that were not planned for when the item was designed originally. Although the cost of an item may increase when designed for an EME more severe than the EME currently predicted to be encountered by the item, the increase in cost may be justified in terms of adaptability for future applications. This is true particularly for items designed by a Service that ultimately may be used in a Joint operation.

When defining the operational EME in which an item will be required to operate or survive during its life cycle, operational and installation conditions that can preclude or reduce exposure to the EME and any added information that may affect an item's exposure to the EME should be considered. For example, the complement of emitters on a platform or site will determine the frequency bands within which high levels of EM energy probably will be encountered. Dimensional restrictions and intervening structures may exist that cause an item to operate in the near or induction field region of an antenna. Other factors that should be considered are the platform on which an item is installed and its operational use.

5. Detailed Requirements

5.1 EME Levels

One of the basic objectives of the DoD is to provide equipment and systems whose performance will not be affected adversely by the EME during all phases of an equipment or system life cycle. To achieve this, EME levels have been developed and are specified in MIL-STD-464 and MIL-STD-461 to assist acquisition communities and equipment designers in defining the intended operational EME. The other parts of this handbook are listed in Table 1D-I. They were developed to support the EME tables found in MIL-STD-464. It is noted that there is no single EME table or part for unmanned systems. EME levels for unmanned systems can be determined by choosing the appropriate combination of parts based on the defined operational environment for the system.

5.2 Electromagnetic Data

Data in the EME tables are comprised of measured as well as calculated EME levels. Each EME table was created using the maximum measured EME values collected in each frequency band. Measured EME levels were obtained from survey reports, system certifications, and special tests. Measured EMEs were given priority over calculated EMEs. After the measured values were entered, the calculated EMEs were used to fill out the available spaces in the table. Finally, nearby EMEs were used when no onboard or on-site systems supported a particular frequency band. It is noted that the same transmitter does not necessarily drive the peak and average levels in a particular frequency range in any table. In addition to the EME levels, each part describes the methodology and rationale used to establish the levels, thereby providing the user with a means for tailoring the environments as needed.

5.3 Electromagnetic Characteristics

U.S. platforms and systems and their associated transmitters and antennas were evaluated and used to create the various EME tables found in Parts 2D through 10D that lead up to the worst-case tables of MIL-STD-464. Potential hostile HPM systems also were used to derive the EME levels in Part 8. The transmitter/antenna characteristics were collected from databases and models residing at the Defense Information Systems Agency (DISA)/Joint Spectrum Center (JSC) as well as manufacturers' data sheets, technical manuals, and EME survey reports. Since there are many transmitter/antenna configurations, the antenna with the maximum gain was selected for calculations. Transmitter characteristics include the frequency range, maximum output peak power, maximum output average power, pulse width, and pulse repetition frequency (PRF). Antenna specifications include the antenna nomenclature, gain, antenna type, horizontal dimension, vertical dimension, horizontal beam width, vertical beam width, antenna field regions, power density and field strength, antenna sidelobes, and rationales and assumptions for antenna distances.

5.4 Calculations

5.4.1 Average and Peak Power Calculations

The units used to define the EME levels in this handbook are in terms of root mean square (rms). All measurements or calculations of the field strength are derived in terms of the power density, either peak or average, and then converted to volts per meter-root mean square (V/m-rms).

Typically, communication systems are capable of modulation techniques such as amplitude modulation (AM), frequency modulation (FM), and pulse-code modulation (PCM), or continuous wave (CW). To determine the rms peak power for FM and PCM, a worst-case approach is used, where the average power is equal to the unmodulated carrier's peak power (or the CW equivalent). In this case, the duty cycle of a CW signal equals unity, which makes the average and peak powers equivalent. For AM signals, the worst-case scenario is where the peak envelope power of a 100-percent modulated AM signal is twice the carrier peak power and, therefore, is used for AM signals. The aforementioned rationale was used because of the randomly changing nature of true peak power over a specific interval.

Pulse modulated signals, typically from radars, have differences between peak and average power. The average power is determined by the ratio of time-on to time-off over an interval. This time-on/time-off ratio is the duty cycle and can be calculated using equation (1D-1). The average power can be calculated by the product of peak power and duty cycle as shown in equation (1D-2).

$$d.c. = \frac{pw}{pri} \quad \text{or} \quad d.c. = pw \times prf \qquad \text{(1D-1)}$$

$$p_a = p_p \times d.c. \qquad \text{(1D-2)}$$

where

$d.c.$ = the duty cycle
pw = the pulse width (seconds)
pri = the pulse repetition rate interval (seconds)
prf = the pulse repetition rate frequency (Hz)
P_a = the average power (watts)
P_p = the peak power (watts)

5.4.2 Near- and Far-Field Boundaries

The EM fields around an antenna are divided into three regions: the reactive near-field (equation (1D-3)), the radiating near-field or Fresnel (equation (1D-4)), and the far-field or Fraunhofer (equation (1D-5)).

$$NF_r \approx 0.62 \times \sqrt{\frac{L^3}{\lambda}} \qquad \text{(reactive near-field boundary)} \qquad \text{(1D-3)}$$

$$0.62 \times \sqrt{\frac{L^3}{\lambda}} \leq NF_{rad} \leq \frac{2 \times L^2}{\lambda} \qquad \text{(radiating near-field boundaries)} \qquad \text{(1D-4)}$$

$$FF \approx \frac{2 \times L^2}{\lambda} \qquad \text{(far-field boundary)} \qquad \text{(1D-5)}$$

where

NF_r = the reactive near-field region (meters)
NF_{rad} = the radiating near-field (Fresnel) region (meters)
FF = the far-field (Fraunhofer) region (meters)
λ = the wavelength (meters)
L = the largest dimension of antenna (meters)

Note: If the antenna is small compared to the wavelength ($\lambda > 10L$), the radiating near field does not exist.

5.4.3 Far-Field Power Density Calculation Method

In the far-field region, the power density for aperture and wire antennas can be calculated using equation (1D-6). All power density levels are calculated using the maximum output power of the transmitter and the antenna gain relative to the 3 dB beam width of the main-beam lobe.

$$PD = \frac{P_T \times G}{4 \times \pi \times d^2} \qquad \text{(1D-6)}$$

where

PD = the power density (watts/meter^2)
P_T = the average or peak transmitter output power (watts)
G = the numerical antenna gain
d = the distance or range from the antenna (meters)

The electric field strength is related to the power density by equation (1D-7):

$$E = \sqrt{P_d \times Z_0} \qquad \text{(1D-7)}$$

where

E = the maximum electric field (E-field) strength (V/m-rms)
Z_0 = the intrinsic impedance of free space (120π or approximately 377Ω)
P_d = the power density (watts/meter^2)

Depending on the source antenna's terminal voltage, impedance, and driver current, the E-field and magnetic field (H-field) at a given point will vary at different rates depending on which field becomes dominant. In the near-field region, the intrinsic impedance of free space is not a constant 120π (approximately 377Ω). As the far-field region is approached, the ratio of the E- and H-fields begins to approximate 377Ω. The variation between the fields becomes less, and any dominance of one field is reduced. Although these variations exist, equation (1D-7) was used as the convention to convert power density levels to E-field strength levels.

5.4.4 Near-Field Power Density Calculation Method

The method used to calculate the power density along the propagation axis of a large-aperture circular or rectangular antenna source in the "radiating" near-field region (Fresnel region) is provided in 5.4.4.1 and 5.4.4.2, respectively. Antenna gain and beam width both are degraded in the Fresnel region; therefore, the far-field power density equation (1D-6) is modified to account for the near-field antenna correction factor (N). (See equation (1D-8).)

$$PD = \frac{P_T \times G}{4 \times \pi \times d^2} \times N \qquad \text{(1D-8)}$$

where

PD = the average or peak power density (watts/meter^2)
P_T = the average or peak transmitter output power (watts)
G = the numerical antenna gain
N = the near-field gain correction factor
d = the distance or range from antenna (meters)

The near-field power density calculation method used in calculating the EME levels is based on a consistent approach for estimating the antenna illumination and calculating/verifying the antenna efficiency. It does not consider the following: mismatch (voltage standing wave ratio) loss derived from the reflection at the antenna feed port because of impedance mismatch, RF losses between the antenna and the antenna feed point, and spillover loss and phase error loss resulting from the fact that the antenna aperture is not a uniform phase surface. The method for calculating the power density for a circular aperture in the near field is provided in 5.4.4.1, and the method for calculating the power density for a rectangular aperture in the near field is provided in 5.4.4.2. The two methods are slightly different in that the rectangular aperture method computes a gain reduction value for the antenna, whereas the circular method computes a near-field correction factor that includes both a gain reduction value and the space loss value.

5.4.4.1 Near-Field Power Density Calculation Method for Circular-Aperture Antenna

The equation used to calculate the power density along the propagation axis of a large-aperture circular antenna source in the "radiating" near-field region is provided in equation (1D-9). The antenna gain and beam width both are degraded in the Fresnel region; therefore, the far-field power density equation (1D-6) is modified to account for the near-field antenna correction factor (NCF_{circ}).

$$PD = \frac{P_T \times G}{4 \times \pi \times d_{ff}^{\ 2}} \times NCF_{circ} \qquad \text{(1D-9)}$$

where

PD = the average or peak power density (watts/meter^2)
P_T = the average or peak transmitter output power (watts)
G = the numerical antenna gain (unitless)
NCF_{circ} = the near-field correction factor (unitless)
d_{ff} = the distance from antenna to the far-field using equation (1C-5) (meters)

Steps for computing the near-field power density:

a. Compute the power density at the far-field boundary using the Friis transmission formula.

b. Calculate the illumination constant (R) using equation (1D-10).

c. Estimate the antenna illumination and antenna factor using the illumination constant and table 1D-III.

d. Check to see if the antenna illumination is reasonable by computing the antenna efficiency (K) using equation (1D-11).

e. Calculate the normalized distance from the antenna and then determine the NCF using the appropriate antenna illumination in figure 1D-1.

f. Multiply the power density (at far-field boundary) computed in step a by the NCF determined in step e.

As stated above, the near-field correction factor depends on the type of antenna illumination and the distance from the antenna. If the antenna illumination is not known, it can be estimated by first calculating the illumination constant (R) using equation (1D-10).

$$R = 5.84 \times 10^{-5} \times (f) \times (BW) \times (L) \qquad \text{(1D-10)}$$

where

R = constant for estimating illumination
f = frequency in megahertz (MHz)
BW = beam width in degrees (horizontal or vertical) at 3 dB points
L = diameter of circular antenna (or largest horizontal or vertical dimension of rectangular antenna) in meters (m)

After calculating R, the antenna illumination can be estimated from table 1D-III. Illuminations above $(1-r^2)^4$ are omitted purposely since the gain reduction in the Fresnel region would be almost negligible.

TABLE 1D-III. Circular-aperture antenna illuminations $(1-r^2)^\rho$

Limits of R	Estimated Illumination	ρ	F
1.02 to 1.27	Uniform	0	1.00
1.27 to 1.47	$(1-r^2)$ Taper	1	0.75
1.47 to 1.65	$(1-r^2)^2$ Taper	2	0.56
1.65 to 1.81	$(1-r^2)^3$ Taper	3	0.44
> 1.81	$(1-r^2)^4$ Taper	4	0.36

When the illumination constant (R) is determined to be borderline between two orders of illumination, the higher order is selected because it will produce the maximum field strength. However, the antenna efficiency should be checked using equation (1D-11) to determine if it is reasonable for this antenna type and illumination. Should the higher-order illumination cause the antenna efficiency to be too high, then the next lower order should be selected. Antenna efficiency (K) between 0.3 and 0.9 is considered reasonable.

$$K = \frac{G(\lambda^2)}{4\pi(A)(F)} \qquad \text{(1D-11)}$$

where

K = antenna efficiency (unitless)

G = far-field antenna gain (unitless)
A = antenna aperture area (square meters)
λ = wave length (meters)
F = antenna illumination factor

Once the illumination factor (F) has been determined and the efficiency verified to be reasonable, then the appropriate gain correction factor can be applied to calculations in the near field for a circular antenna of a specific illumination type.

Now that the illumination type (ρ = 0,1,2,3,4) has been determined, the near-field correction factor can be selected by calculating the normalized distance from the antenna using equation (1D-12) and then selecting the appropriate correction factor (N) based on the illumination type from figure 1D-1.

$$x = \frac{d}{2 \times (L^2 / \lambda)} \qquad (1D\text{-}12)$$

where

x = normalized distance from antenna
λ = wave length (meters)
L = diameter of circular antenna (or largest horizontal or vertical dimension of rectangular antenna) in meters (m)
d = distance from antenna

The near-field power density level at given distance (r) from the antenna can be determined by computing the power density at the far-field distance and multiplying this value by the correction factor (N).

5.4.4.2 Near-Field Power Density Calculation Method for Rectangular-Aperture Antennas

Equation (1D-13) is used to calculate the power density along the propagation axis of a large-aperture rectangular antenna source in the "radiating" near-field region. The antenna gain and beam width both are degraded in the Fresnel region; therefore, the far-field power density equation (1D-6) is modified to account for the near-field antenna gain reduction factor (NGF_{rect}).

$$PD = \frac{P_T \times G}{4 \times \pi \times d^{\,2}} \times NGF_{rect} \qquad (1D\text{-}13)$$

where

PD = the average or peak power density (watts/meter^2)
P_T = the average or peak transmitter output power (watts)
G = the numerical antenna gain (unitless)
NGF_{rect} = the near-field gain reduction factor (unitless)
d = the distance from antenna (meters)

Steps for computing the near-field power density:

a. Compute the power density at the specific distance of concern using the Friis transmission formula.

b. Calculate the illumination constant (*R*) for both the horizontal and vertical plane using equation (1D-10).

c. Estimate the antenna illumination and antenna factor using the illumination constant and table 1D-IV.

d. Check to see if the antenna illumination is reasonable by computing the antenna efficiency (*K*) using equation (1D-11).

e. Determine the NGF_{rect} using the distance from the antenna (in wavelengths) and antenna length (in terms of wavelength) using the appropriate antenna illumination graph from figures 1D-2 through 1D-6.

f. Multiply the power density (at the distance of concern) computed in step a by the NGF_{rect} determined in step e.

The following provides details for calculating the near-field gain reduction factors (NGF_{rect}) for the Fresnel region of a rectangular-aperture antenna. As stated above, the near-field gain reduction factor depends on the type of antenna illumination and the distance from the antenna. A gain reduction factor for both the horizontal as well as the vertical axis/plane should be determined in order to compute the power density for a rectangular antenna. If the antenna illumination is not known for each axis/plane, it can be estimated by the method described in 5.4.4.1. First, calculate the illumination constant (*R*-value) using equation (1D-10) and determine the illumination type and factor (F_h and F_v) using equation (1D-14) and table 1D-IV for each axis/plane. Illuminations above $\cos^4$ are omitted purposely since the gain reduction in the Fresnel region would be almost negligible.

$$F = (F_h \times F_v) \qquad \text{(1D-14)}$$

where

F = the illumination factor
F_h = the horizontal illumination factor
F_v = the vertical illumination factor

TABLE 1D-IV. Rectangular-aperture antenna illuminations

Limits of *R*	Estimated Illumination	F (F_h x F_v)
0.88 to 1.2	Uniform	1.00
1.2 to 1.45	cos	0.810
1.45 to 1.66	$\cos^2$	0.667
1.66 to 1.93	$\cos^3$	0.575
1.93 to 2.03	$\cos^4$	0.515

When the illumination constant (*R*) is determined to be borderline between two orders of illumination, the higher order is selected because it will produce the maximum field strength. However, the antenna efficiency should be checked using equation (1D-11) to determine if it is reasonable for this antenna type and illumination.

Should the higher-order illumination cause the antenna efficiency to be too high, then the next lower order should be selected. Antenna efficiencies (*K*) between 0.3 and 0.9 are considered reasonable. Now that the illumination type (uniform, cos, $\cos^2$, $\cos^3$, $\cos^4$) has been determined, the near-field gain reduction factor can be selected by normalizing the distance from the antenna and the antenna dimension in terms of wavelength. (See equations (1D-15) and (1D-16).)

$$\lambda = \frac{300}{f} \qquad \text{(1D-15)}$$

where

f = the frequency in MHz

$$x_{rect} = \frac{d}{\lambda} \qquad \text{(1D-16)}$$

Figures 1D-2 through 1D-6 provide graphical curves of the gain reduction in decibels (dB) versus distance (x_{rect}) from the antenna (in terms of wavelength) relative to the antenna dimension (in terms of wavelength) for each of the illumination types (uniform, cos, $\cos^2$, $\cos^3$, $\cos^4$). Define the aperture dimensions (a_h and a_v) normalized to wavelength as shown in equation (1D-17):

$$a_h = \frac{L_h}{\lambda}, \qquad a_v = \frac{L_v}{\lambda} \qquad \text{(1D-17)}$$

Once the two appropriate gain reduction values have been selected for each plane, the combined near-field gain reduction factor can be computed. To do this, add the two gain reduction values and convert the units from dB to a numerical value. The near-field power density level at a given distance (*d*) from the antenna can be determined by computing the power density and multiplying this value by the near-field gain reduction factor (NGF_{rect}).

5.4.5 Sidelobes

Sidelobes for directional antenna systems were calculated using the method described in NAVSEA OP 3565/NAVAIR 16-1-529, Volume 1.

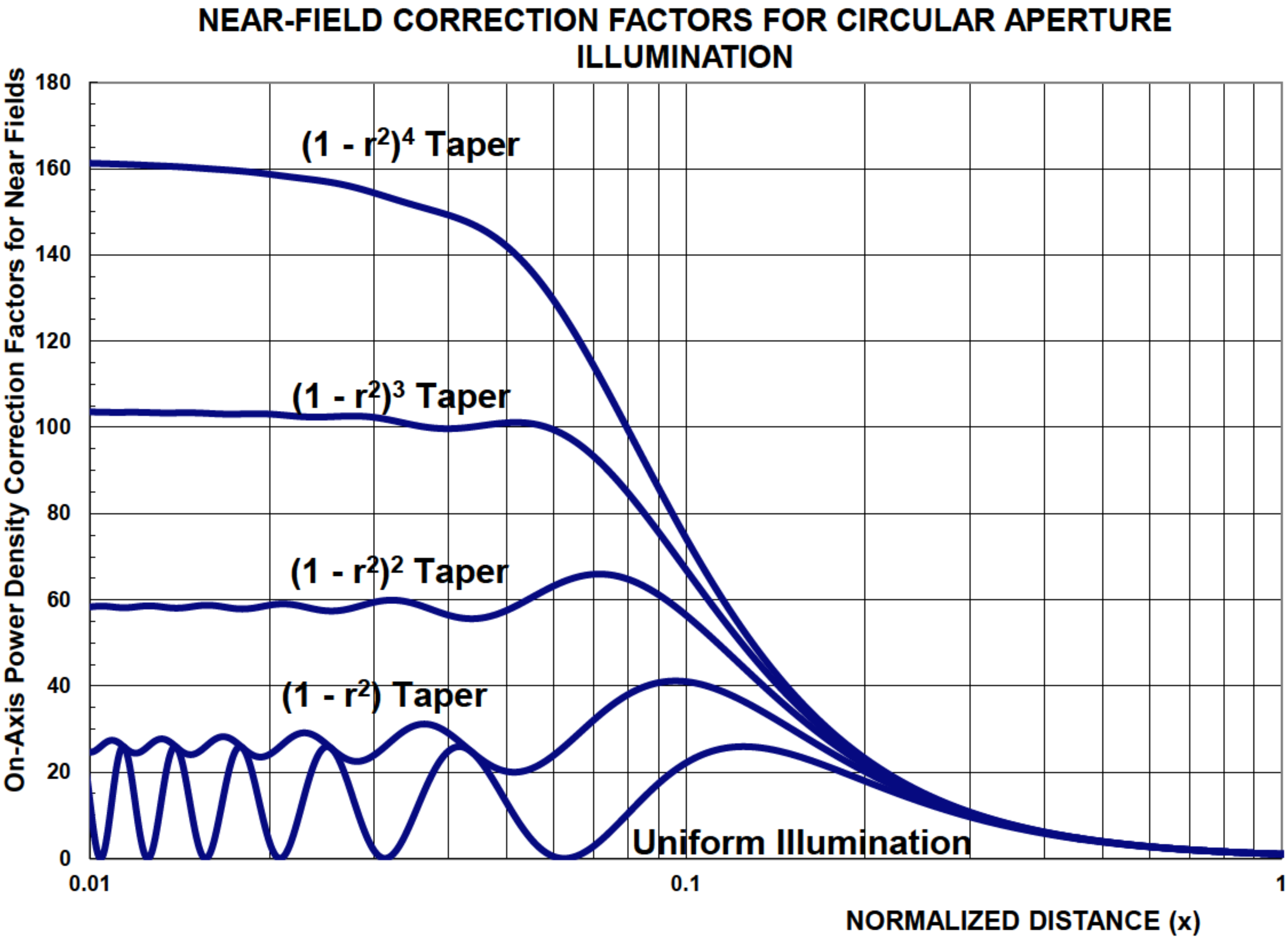

FIGURE 1D-1. Near-field correction factors for circular-aperture illumination

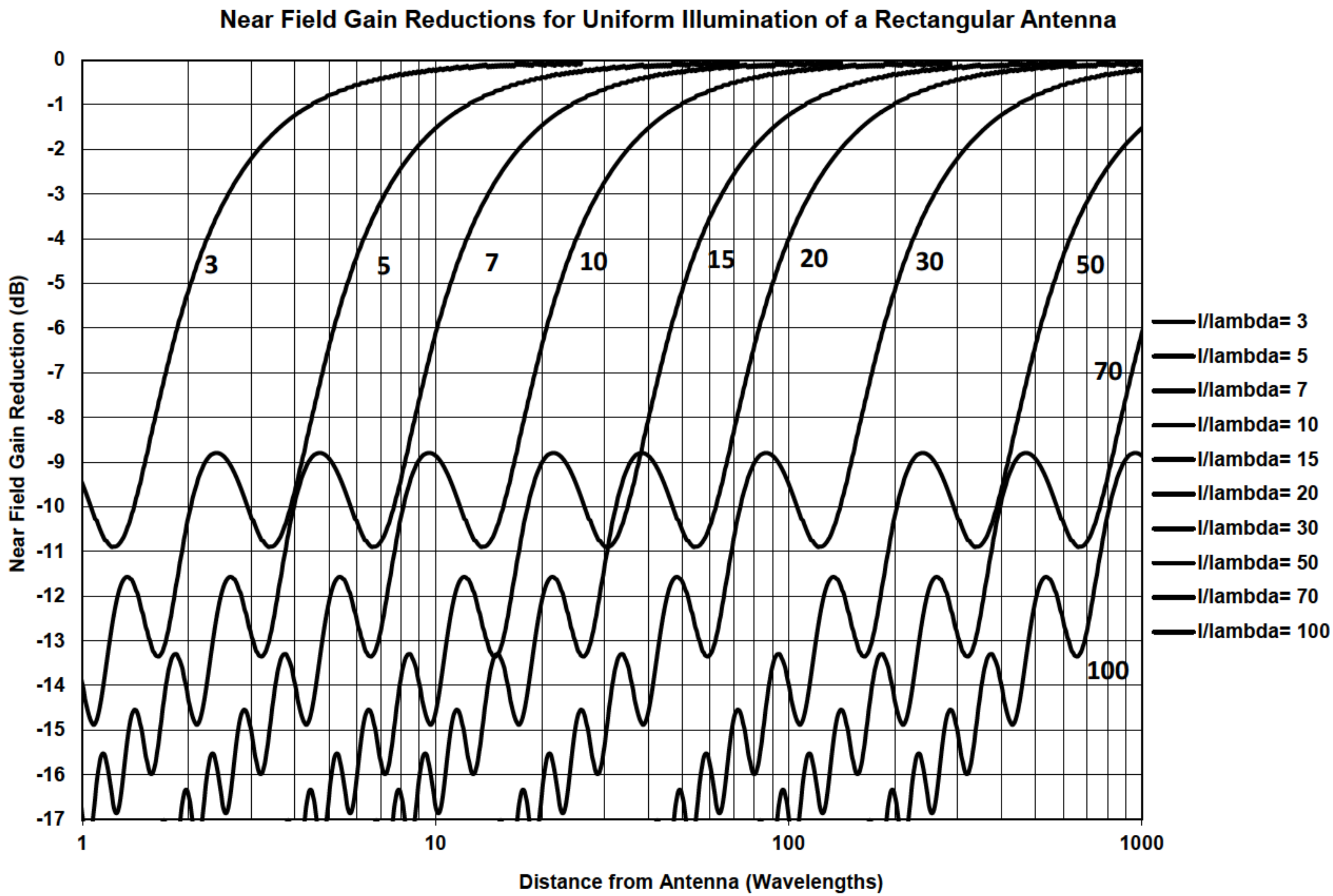

FIGURE 1D-2. Fresnel region gain correction for uniform illumination (rectangular aperture)

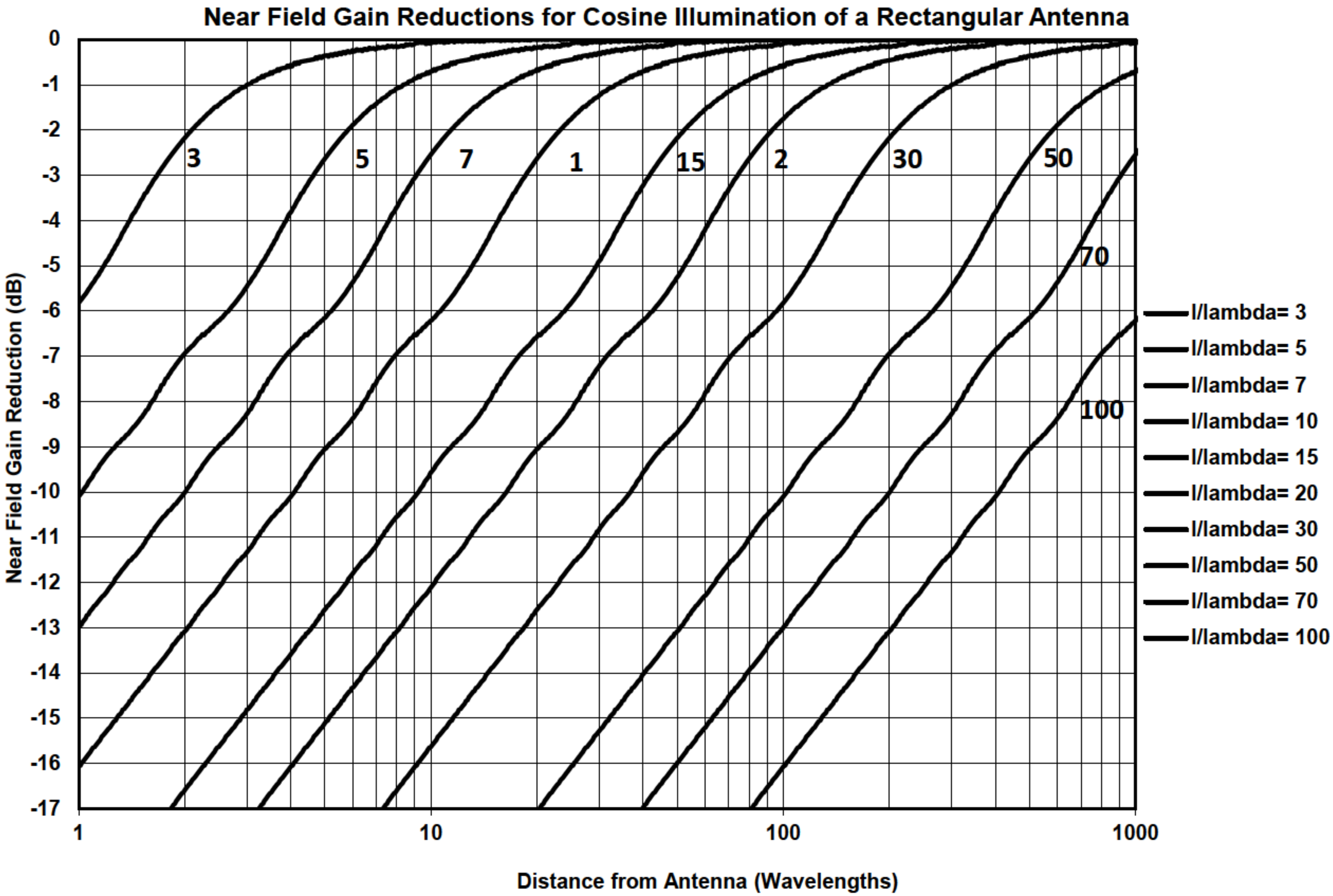

FIGURE 1D-3. Fresnel region gain correction for cosine illumination (rectangular aperture)

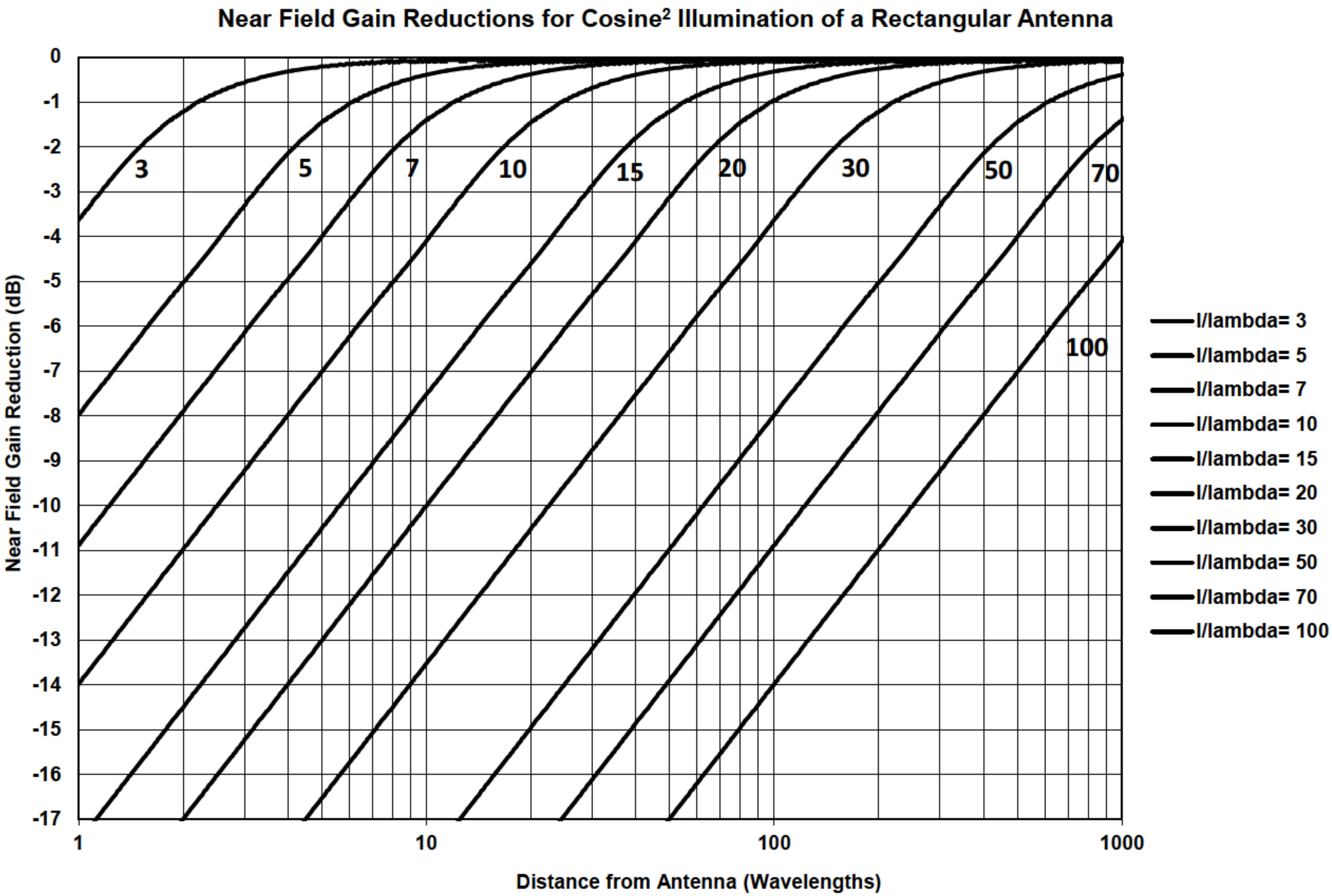

FIGURE 1D-4. Fresnel region gain correction for cosine square illumination (rectangular aperture)

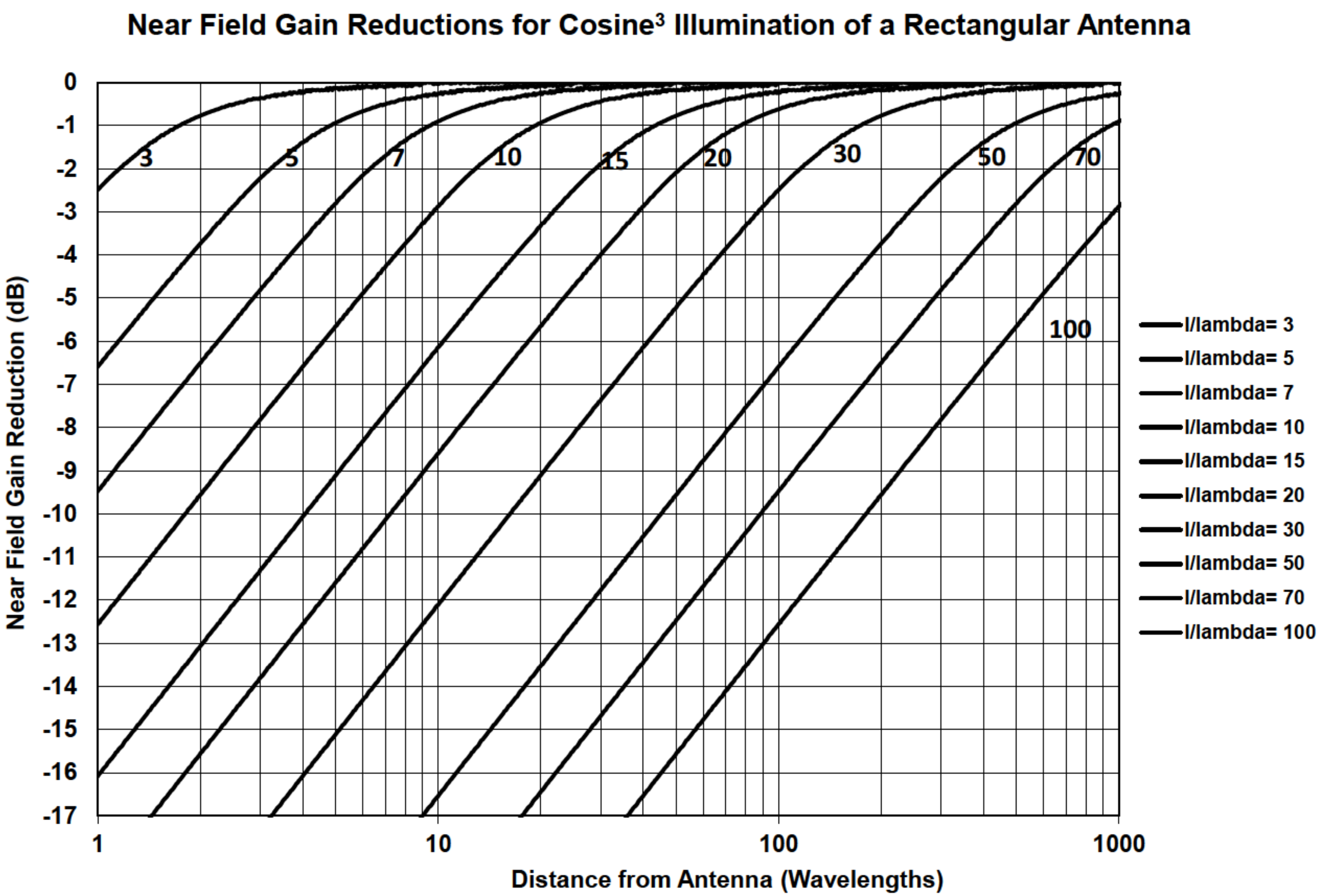

FIGURE 1D-5. Fresnel region gain correction for cosine cubed illumination (rectangular aperture)

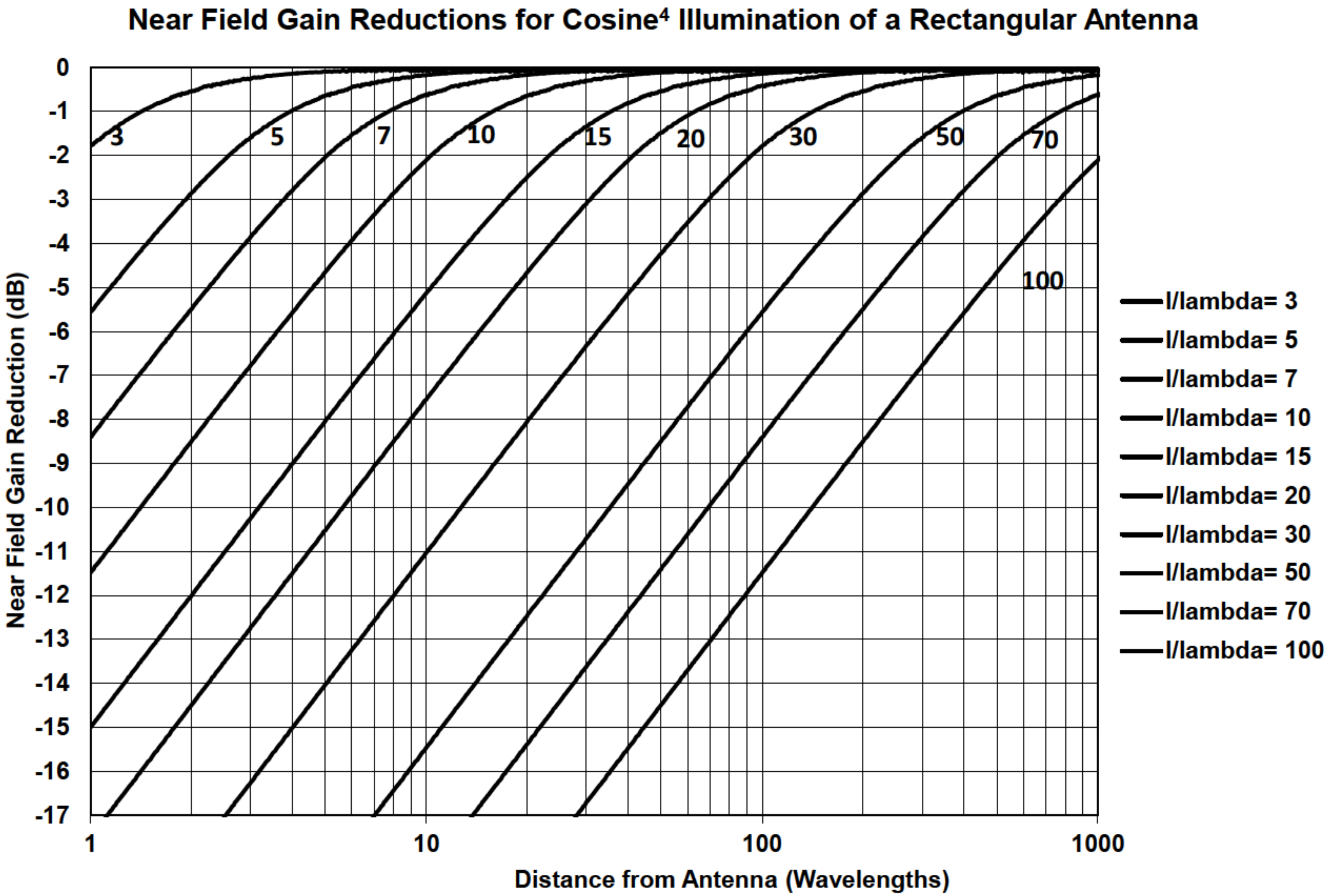

FIGURE 1D-6. Fresnel region gain correction for cosine fourth illumination (rectangular aperture)

6. NOTES

6.1 Intended Use

This handbook provides information for use in tailoring and supplementing the EME levels specified in MIL-STD-464 and the radiated susceptibility RS103 requirement of MIL-STD-461. Both standards may be imposed to ensure adequate consideration of the EME in the design, development, and procurement of DoD platforms, systems, subsystems, or equipment. This handbook is intended for use by DoD personnel responsible for requirements generation and acquisition life-cycle processes, including test and evaluation of these end items.

6.2 Supersession

This document supersedes MIL-HDBK-235-1C.

6.3 Changes from Previous Issues

Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

6.4 Subject Term (Key Word) Listing

E3
EM
EMC
EMI
EMV
HERO

6.5 Tailoring Guidance

The information contained herein will be valuable in implementing the DoD policies on the tailoring of requirements. This handbook may be used to tailor the EME levels in MIL-STD-464, MIL-STD-461, and other such military and commercial standards. Care should be taken to ensure that tailoring does not restrict the use of a platform, system, subsystem, or equipment.

For systems or platforms used in more than one environment or operational scenario, the EME levels in all applicable parts of the handbook should be compared, and tailored EME tables should be generated with the most severe levels in each frequency range applicable. These tailored EME levels should be incorporated into the JCIDS and other acquisition documentation, including the request-for-proposal, specification, contract, order, and so forth. While data from the EME tables found in the other parts of this handbook may be extracted and incorporated into the JCIDS and other acquisition documentation, it should be done with care. The EME tables may contain or are linked electronically with a combination of classified and unclassified data elements, and the extracted data should be marked properly according to their classification.

Tailoring of requirements should not violate International agreements. In the event that there are essential reasons for nonconformance with such an agreement, the Signatory Nations should be consulted, as required by the agreement.

6.6 Technical Points of Contact

Requests for additional information or assistance may be obtained from the following:

Air Force
AFLCMC/EZAC, Building 28
2145 Monahan Way
Wright Patterson AFB, OH 45433-7017
Mr. Joseph DeBoy
DSN 785-6995; Commercial (937) 255-6995
E-mail: joseph.deboy@us.af.mil

Army
USA AMRDEC
Aviation Engineering Directorate
Bldg. 4488
RDMR-AES-E3
Redstone Arsenal, AL 35898
DSN 897-8447, Commercial (256) 313-8447

Navy
Naval Sea Systems Command
Attn: SEA 05W
1333 Isaac Hull Ave. SE, Stop 5011
Washington Navy Yard, DC 20376-5011
(540) 653-3425
kurt.mikoleit@navy.mil

Defense Information Systems Agency (DISA)
Joint Spectrum Center (JSC)
Attn: JSC/J5 (M. Shellman, Jr.)
2004 Turbot Landing
Annapolis, MD 21402-5064
(410) 919-2749
marcus.shellman.civ@mail.mil

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

CONCLUDING MATERIAL

Custodians:
Army – AV
Navy – SH
Air Force – 11
DISA – DC5

Preparing Activity:
DISA (DC5)
Project No. EMCS-2018-001

Review Activities:
Air Force – 13, 19, 22
Army – AM, AR, AT, CR, GL, MD, MI, TE
Navy – AS, CG, EC, MC
DS
NRO
NS

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at https://assist.dla.mil/