METRIC

MIL-STD-188-164A
W/CHANGE 3
25 August 2009

SUPERSEDING
MIL-STD-188-164A
W/CHANGE 2
8 June 2004

DEPARTMENT OF DEFENSE
INTERFACE STANDARD

INTEROPERABILITY OF
SHF SATELLITE COMMUNICATIONS
TERMINALS

AMSC N/A AREA TCSS

FOREWORD

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

2. In accordance with DoD Instruction 4630.8, it is DoD policy that all joint and combined operations be supported by compatible, interoperable, and integrated command, control, communications, and intelligence (C3I) systems. All C3I systems developed for use by U.S. forces are considered for joint use. The Director, Defense Information Systems Agency (DISA), serves as the DoD single point of contact for developing information technology standards to achieve interoperability and compatibility. All C3I systems and equipment shall conform to technical and procedural standards for compatibility and interoperability.

3. MIL-STDs in the 188 series (MIL-STD-188-XXX) address telecommunications design parameters and are to be used in all new DoD systems and equipment, or major upgrades thereto. The MIL-STD-188 series is subdivided into a MIL-STD-188-100 series, covering common standards for tactical and long-haul communications; a MIL-STD-188-200 series, covering standards for tactical communications only; and a MIL-STD-188-300 series, covering standards for long-haul communications. Emphasis is being placed on the development of common standards for tactical and long-haul communications (the MIL-STD-188-100 series). The MIL-STD-188 series may be based on, or make reference to, American National Standards Institute (ANSI) standards, International Telecommunications Union Radiocommunication Sector (ITU-R) recommendations, International Organization for Standardization (ISO) standards, North Atlantic Treaty Organization (NATO) standardization agreements (STANAG), and other standards, wherever applicable.

4. This standard establishes interoperability and performance requirements for satellite communications (SATCOM) earth terminals (ET) operating with satellite transponders in the C-band, X-band, Ku-band, and commercial and military Ka-bands.

5. The activity designated as agent for all contacts relative to antenna design specifications in this standard is Dr. Roy A. Axford, Jr., Ph.D.; Senior Technologist, Wireless Communications; Space and Naval Warfare Systems Center Pacific (SSC Pacific); Code 55050, Technical Staff, Communications and Networks Dept.; 53560 Hull Street, San Diego, CA 92152-5001; niprnet e-mail 1: axfordra@ieee.org; niprnet e-mail 2: roy.axford@navy.mil; siprnet e-mail:

axfordra@spawar.navy.smil.mil; 619-553-3729 (office, STU-III); DSN: 553-3729.

6. The activity designated as agent for all contacts relative to satellite communications on-the-move (SOTM) design specifications in this standard is Mr. Darren P. LeBlanc, US Army AMC; email darren.leblanc@us.army.mil; 732-532-8662, Blackberry: 848-459-5480.

7. Comments, suggestions, and questions on this document should be addressed to DISA (ATTN: GE331), Building 283 (Squier Hall), Fort Monmouth, New Jersey 07703-5613, or emailed to ed.shirey@disa.mil. If the comment, suggestion, or question deals with antenna or communications-on-the-move specifications, the request should be addressed to the designated agent with a copy addressed to DISA. Since contact information may change, you may want to verify the currency of this address information using the ASSIST Online database at http://assist.daps.dla.mil.

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SUMMARY OF CHANGE 1 MODIFICATIONS

1. Changed 5.1.3.2.1. C-band earth terminal to clearly state what the distinction between terminal types A and B requirements and terminal types C through H requirements are, and to clearly note that the paragraph applies to the antenna, not to the terminal types themselves.

2. Changed 5.1.3.2.2 X-band and military Ka-band earth terminals to bring it into agreement with the receive paragraph 5.2.1.1.2. Note; however, that the paragraph does not prevent the terminal manufacturer from doing both simultaneously.

3. Changed 5.2.1.1.4 Ku-band earth terminal to address two areas. First, to make it clear that it is the antenna for terminal types I and II and that it is mandatory that both horizontal linear and vertical linear polarization reception be simultaneous. Secondly, to make it clear that simultaneous reception of the horizontal linear and vertical linear polarizations is optional for antennas supporting terminal types III through XIV (this is, not simultaneously.)

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SUMMARY OF CHANGE 2 MODIFICATIONS

1. Rewrote Section 2, Applicable Documents, to follow the guidance in MIL-STD-962D, removing any reference to the Department of Defense Index of Specifications and Standards (DoDISS).

2. Added definition of "maximum-linear EIRP" to Section 3, Definitions. This should assist in interpreting paragraphs 5.1.1.2 Input level and impedance; 5.1.2.6 Carrier power control accuracy, step size and range; and 5.1.2.14 Intermodulation products in the receive band.

3. Changed 5.2.1.1.2 to remove the requirement for all X-band terminal types to receive right-hand circular polarization. For X-band on DSCS and on WGS, the earth-to-space direction utilizes right hand circular polarization (RHCP) and the space-to-earth direction utilizes left hand circular polarization (LHCP). Neither DSCS or WGS X-band support the reversed polarization scheme. However, three of the ten Ka-band antennas (two of the narrow beam antennas and one of the wide beam antennas) on each WGS spacecraft can also be configured to support the reversed polarization scheme. To allow that reversal, paragraphs 5.1.3.2.2 and 5.2.1.1.2 require the capability to transmit and receive both polarizations, but not simultaneously.

4. Changed paragraph 6.2 Issue of DoDISS was replaced by paragraph 6.2 Acquisition requirements.

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SUMMARY OF CHANGE 3 MODIFICATIONS

1. Deleted the term “Earth” from the title on the cover page. The standard also addresses terminals in airborne platforms.

2. Changed the foreword to identify the preparing activity’s designated agents.

3. Changed the waiver guidance in 1.3 to clarify the process and to define the roles of the terminal certification authorities.

4. Deleted the last two sentences in 1.4 to comply with DSP policy on the use of binding and non-binding terms in sections 1, 2, and 3 of a standard.

5. Removed the DODSSP Uniform Resource Locator (URL) for obtaining copies of military standards from 2.2.1; changed the URL for obtaining a copy of DoD 4120.24-M and added a URL for obtaining CFR 47 in 2.2.2; and added a URL for obtaining a copy of EIA standard to 2.3.

6. Changed 2.4 to correct the wording in order to be in accordance with 962D.

7. Changed 3.1 to include the definition of SSE (satellite communications subject expert).

8. Added new sentence to definition of earth terminal, 3.3, noting that earth terminal is synonymous with user terminal

9. Renamed 3.14 Linear power to 3.9 Maximum-linear power and changed the definition to remove references to spectral density and to clarify that measurement was to be taken at the first sidelobe, not at 1.5 symbol rate displaced from the carrier. The wording was also changed to clarify the meaning of the definition.

10. Defined new class of terminal; Ultra Mobile, Tactical terminal (see 3.16); and changed Tables I, III, VI to add transmit type P and receive type XV.

11. Changed reference in 4.1 from 6.3 to 6.6 to correct an administrative error.

12. Changed binding requirement for an external frequency reference in 4.2.4 to a nonmandatory provision.

13. Changed 4.3 to correctly show the ET transmit and receive terminal types.

14. Changed Table I to remove references to narrowband and wideband. The definitions of the type A, B, and C terminals in section 3 are sufficient.

15. Paragraph 5.1.1.1 was changed to remove the inconsistency between 1 dB and amplitude response BWs.

16. Changed paragraph 5.1.1.2 to clarify the meaning of the paragraph.

17. Deleted last sentence in 5.1.2.2; deleting unnecessary binding requirement. The requirement was for a combiner even when it was not required. Paragraph 4.2a allows the combiner to be included as an optional capability with no additional interoperability or performance criteria specific to a combiner.

18. Changed Table III to make the typical data rate ranges applicable to both DSCS and WGS satellites by removing the term "DSCS" from the header row and added row for terminal type P.

19. Reworded and added note to paragraph 5.1.2.8 and 5.2.3.6 in order to make the transmit and receive flatness requirements identical. The wording of paragraph 5.1.2.8 was also changed.

20. Changed binding requirement in 5.1.2.9.1.1 to clarify that it was the sum of the fundamental and each spurious component at the alternating current (AC) line frequency, not the fundamental and each spurious component as individual entities had to meet the -30dBc specification.

21. Changed binding requirement in 5.1.2.9.2 to remove ambiguity on the test setup for terminal certification and to clarify that when an upconverter is placed on line that the expected value is a relative value (a measured value taken with no upconverters on line), not an absolute value. Changed last sentence in 5.1.2.9.2 to make it clear that the original binding requirement was not specific to a single modem/upconverter string--that the requirement actually applies to any one of the available modem/upconverter strings. Deleted the 3 dB binding requirement.

22. Although a revision to 5.1.2.9.2 was considered, a decision was made to keep the wording as currently written. Deviations from 5.1.2.9.2 can be considered on a case-by-case basic with sufficient analysis and justification (see 1.3)

23. Moved the exclusion band wording in 5.1.2.10 behind the term 10-kHz bandwidth to make it clear which 10-kHz bandwidths were excluded. Although a revision to 5.1.2.10 was considered, a decision was made to keep the current specifications. Deviations from 5.1.2.10 can be considered on a case-by-case basis with sufficient analysis and justification (see 1.3)

24. Added exception to binding intermodulation product requirement in 5.1.2.12 for those terminals that implemented overdrive protection.

25. Changed binding requirement in 5.1.2.17 to clarify that the Transmission operation is less than or equal to the maximum-linear power.

26. Changed Note in 5.1.3.1.2a to remove degree symbol from the factor D/λ, such that when the factor is greater than 150, the lower boundary of theta (θ) is always set to 1 degree.

27. Changed the applicability of the EIRP spectral density in electrically small antennas in 5.1.3.1.2c from X-band on DSCS satellites only to all X-band satellites (i.e., DSCS, WGS, and could even apply to XSTAR) and removed any reference to receive antennas.

28. Consideration was given to adding an exception for transmit terminal type P that allows the transmit antenna axial ratio at Ka-band in 5.1.3.3.1 and for receive terminal type XV in 5.2.1.2 to have an additional 0.5 dB or to completely rewrite the entire axial ratio requirements, and to changing the 1.21dB in 5.2.1.2 to 1.61dB. Given the potential to impact significant portions of the user community as well as the significant analysis required to evaluate any rewrite of these two requirements, no exception was added at this time. This issue will be addressed in the next revision to the standard.

29. Changed binding Ku-band receive antenna dual polarization requirement for terminal types I and II in 5.2.1.1.4 to a nonmandatory provision.

30. Changed Table VI to include minimum *G/T* requirements for type XV.

31. Deleted the post-LNA noise requirement in paragraph 5.2.3.2 in order to allow terminal designers to appropriately distribute gain to simultaneously meet and optimize *G/T*, IMs, spurious

response, and compression without impacting demod performance. Changed the receive chain absolute gain to its correct value of -103 dBm/Hz.

32. Changed 5.2.3.6 to make it clear that the amplitude response in the receive chain is measured at the input to the demodulator and that the terminal certification authorities (i.e., the satellite communications subject experts (SSEs) have the authority to allow a terminal to deviate from the standard.

33. Changed the receive spurious output (5.2.3.8) in order to agree with the transmission function extraneous outputs: receive spurs only impact the receiving terminal.

34. Deleted the binding requirement for an EIA-485 local interface (5.3.1) in order to enable program managers to have greater flexibility and deleted the reference to EIA-485 in paragraph 2.3.

35. Changed paragraph 5.3.3 in order to allow the use of more modern SNMP versions.

36. Changed the wording of 5.4 in order to clarify the paragraph's meaning and provide additional information.

37. Changed paragraph 6.3 to make it clear that requirements in sections 4 and 5 of this standard may be tailored by a program manager and added 6.3.1, 6.3.2, 6.3.3, and Table VIII to provide specifics.

38. Added 6.5 and Table IX to document the US MCEB ratification of STANAG 4484 Edition 2 (this makes this document the US implementation of STANAG 4484) and renumbered current 6.5 as 6.6. Because all of the terminal types in the standard are not covered by STANAG 4484 Edition 2, Table IX was added as a cross reference for renaming a US terminal type to a NATO terminal class. For example, terminal type A is not addressed in the STANAG therefore the program office would have no requirement to implement the STANAG, while terminal type F (when used in NATO) becomes STANAG 4484 Class B and the program office would implement the basic STANAG and requirements specific to class B.

39. Figure 5 updated to correct administrative errors.

40. Technical working group - international membership listing:

Country	Member	International Agreement
Australia	Keith Rosario	USSTRATCOM and Australia

41. Topic subject matter expert listing:

Topics	Last Name	First Name	Organization
Amplitude Response	Offner	Jim	Harris
	Daffron	William	Harris
Antenna Pointing Error	Gonzalez	Lino	LinQuest Corp
	McLain	Chris	LinQuest Corp.
	Bowers	Russ	L-3
Antenna Pointing Loss	Lyon	Scott	L-3
	Wexler	Rich	MITRE Corp.
	Bowers	Russ	L-3
	Demuri	Jerome	Harris
Antenna Sidelobes and ESD	Kumar	Anil	Boeing
	Martens	Paul	Boeing
	Watt	Gardner	L-3
	Wexler	Rich	MITRE Corp.
	Dillon	Dave	Femme Comp Inc
Axial Ratio	Howley	Robert	Harris
	Wexler	Rich	MITRE Corp.
Axial Ratio and Radomes	Bowers	Russ	L-3
Control and Monitoring Functions	Saam	Tom	Harris
Earth Terminal Definitions	Saam	Tom	Harris
Extraneous Outputs: 2nd Harmonic	Offner	Jim	Harris
IF Interface Bandwidth	Offner	Jim	Harris
IM Products in Receive band	Offner	Jim	Harris
Link Margins and pointing error	Weerackody	Vijitha	JHU/APL
Mobile ET Definition	Wexler	Rich	MITRE Corp.
Phase Noise	Wexler	Rich	MITRE Corp.
Phase Perturbation	Dittmer	Tim	Harris
Post-LNA Noise Contribution	Offner	Jim	Harris
Receive Chain Gain	Fisher	Evan	L-3
	Wexler	Rich	MITRE Corp.
Receive Spurious Output	Offner	Jim	Harris
Statistical approach to ESD	Ouyang	Feng	JHU/APL
	Weerackody	Vijitha	JHU/APL
Transmit Thermal Noise	Gonzalez	Lino	LinQuest Corp.
	Lecture	Ray	ViaSat
	McLain	Chris	LinQuest Corp.
	Offner	Jim	Harris
Transmit to Receive Isolation	Gammon	Keith	Datapath

42. Terminal certification authority listing:

Satellite	Government	Support Contractor
DSCS	John Rogers III DISA	
WGS	Max Delgado US Army SMDC/ARSTRAT	Dave Dillon FCI SETA Support
	Michael Rhoades US Army SMDC/ARSTRAT	

43. MIL-STD-188-164AwCN3 preparing activity designated agents listing:

Area	Agent	
Antenna specifications	Dr. Roy Axford	Space and Naval Warfare Systems Center Pacific (SSC Pacific)
SOTM - ground terminals	Darren P. LeBlanc	US Army

44. Subject matter expert contact data listing:

Last Name	First Name	Email address	Telephone Number
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Dittmer	Tim	Tim.dittmer@harris.com	321-729-7492
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Lyon	Scott		
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45. The following modifications to MIL-STD-188-164AwCN2 have been made:

PARAGRAPH	MODIFICATION
Cover page	Changed
Foreword	Added
1.3	Changed
1.4	Changed
2.2.1	Changed
2.2.2	Changed
2.3	Changed
2.4	Changed
3.1	Changed
3.2	Deleted
3.3	Changed
3.9	Changed
3.16	Added
4.1	Changed
4.2.4	Changed
4.3	Changed
5.1.1.1	Changed
5.1.1.2	Changed
5.1.2.2	Deleted
5.1.2.8	Changed
5.1.2.9.1.1	Changed
5.1.2.9.2	Changed
5.1.2.10	Changed
5.1.2.12	Changed
5.1.2.17	Changed
5.1.3.1.2a	Changed
5.1.3.1.2c	Changed
5.2.1.1.4	Changed
5.2.3.2	Changed
5.2.3.6	Changed
5.2.3.8	Changed
5.3.1	Changed
5.3.3	Changed
5.4	Changed
6.3	Changed
6.3.1	Added
6.3.2	Added
6.3.3	Added
6.5	Added
6.6	Changed

TABLE	MODIFICATION
Table I	Changed
Table III	Changed
Table IV	Changed
Table VI	Changed
Table VIII	Added
Table IX	Added

FIGURE	MODIFICATION
Figure 5	Changed

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TABLES

FIGURES

APPENDIX

1. SCOPE

1.1 Purpose. This military standard (MIL-STD) establishes mandatory radio frequency/intermediate frequency (RF/IF) design and associated interface requirements applicable to satellite communications (SATCOM) earth terminals (ET) operating over C-band, X-band, Ku-band, military Ka-band, and commercial Ka-band super high frequency (SHF) channels. The requirements specified herein represent the minimum set required for interoperability and performance for the ET. Equipment developers may exceed the requirements herein to satisfy specific program requirements, provided that interoperability is maintained. Thus, incorporating additional standard and nonstandard capabilities and interfaces is not precluded. This MIL-STD defines the minimum requirements for certification of new and modernized ETs.

1.2 Scope. This MIL-STD is mandatory within the Department of Defense (DoD) and will be invoked by equipment procurement documents for future terminals required to operate over SHF SATCOM channels. It includes requirements for operating on all allied military and commercial satellite systems. This MIL-STD defines typical types of terminals. Some of the performance parameters specified in this MIL-STD depend on the type of terminal. In these cases, the equipment procurement documents should adhere to only those paragraphs applicable to the specific type of terminal. Existing ETs need not conform to this MIL-STD unless they undergo a modernization program.

1.3 Request to tailor or deviate from the standard. Program managers may tailor and deviate from this standard, in accordance with DoD 4120.24-M. Copies will be sent to the activities listed below:

U.S. Army Space and Missile Defense
Army Strategic Command G6
Wideband Global SATCOM System
350 Vandenberg Street
Peterson AFB, CO 80914-2749

Joint Staff
J6S
Pentagon, Room 1C832
Washington, DC 20318-6000

Preparing Activity for this standard (see foreword, paragraph 7 for the current address)

To ensure that the terminal will be able to pass terminal certification, prior to approving any tailoring or deviations, the program manager needs to process a request to tailor or deviate through the terminal certification authorities. The request should include the rationale for the tailoring or deviating, the mission of the system, the technical impact, and the cost impact if the program is not allowed to tailor or deviate from the standard.

1.4 Application guidance. The terms *system standard* and *design objective* are defined in Federal Standard (FED-STD)-1037 and T1.523-2001.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, and 5 of this standard. This section does not include documents cited in other sections of this standard, or recommended for additional information, or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements within documents cited in sections 3, 4, and 5 of this standard, whether or not they are listed.

2.2 Government documents.

2.2.1 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 cited in the solicitation or contract.

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-188-115	*Interoperability and Performance Standards for Communications Timing and Synchronization Subsystems*

(Copies of these documents are available online at http://assist.daps.dla.mil/quicksearch/ or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.2.2 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 of these documents are those cited in the solicitation or contract.

DEFENSE STANDARDIZATION PROGRAM OFFICE

DoD 4120.24-M	*Defense Standardization Program Policies and Procedures*

(Copies of this document are available online at http://assist.daps.dla.mil/ or from the DoD Single Stock Point, Standardization Document Order Desk, 700 Robins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

CODE OF FEDERAL REGULATIONS

CFR47	*Code of Federal Regulations, Title 47*

(Copies of this document are available online at http://www.access.gpo.gov/cgi-bin/cfrassemble.cgi?title=199847 or from Mail Order Sales, Superintendent of Documents, ATTN: New Orders, P.O. Box 371954, Pittsburgh, PA 15250-7954. For charge orders, telephone the Government Printing Office order desk at 202-783-3238.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

INTERNATIONAL TELECOMMUNICATIONS SATELLITE ORGANIZATION (INTELSAT) EARTH STATION STANDARDS (IESS)

IESS-601	*Standard G, Performance Characteristics for Earth Stations Accessing the INTELSAT Space Segment for International and Domestic Services Not Covered by Other Earth Station Standards*

(Copies of IESS may be obtained from INTELSAT online at http://www.intelsat.com/)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specified exemption has been obtained.

3. DEFINITIONS

Definitions of terms not listed below are as defined in American National Standard T1.523-2001, *Telcom Glossary T1.523.2001*.

3.1 Abbreviations and acronyms. The abbreviations and acronyms used in this MIL-STD are defined as follows:

AC	alternating current
AM	amplitude modulation
ANSI	American National Standards Institute
bps	bits per second
CMA	control, monitor, and alarm
CW	continuous wave
C3I	command, control, communications, and intelligence
dB	decibel
dBc	ratio of a non-carrier power component to the total power in a carrier, expressed in dB
dBi	gain in dB relative to an isotropic antenna
dBm	dB relative to 1-milliwatt
dBW	dB relative to 1-watt
DISA	Defense Information Systems Agency
DoD	Department of Defense
DSCS	Defense Satellite Communications System
EIA	Electronic Industries Association
EIRP	effective isotropically radiated power
ESD	EIRP spectral density
ET	earth terminal
FED-STD	federal standard
G_{ant}	antenna gain
GHz	gigahertz
G/T	antenna gain-to-noise temperature
HPA	high-power amplifier
Hz	hertz
IESS	INTELSAT earth station standard
IF	intermediate frequency

INTELSAT	International Telecommunications Satellite Organization
ISO	International Organization for Standardization
ITU-R	International Telecommunications Union Radiocommunication Sector
K	kelvin
kHz	kilohertz
LHCP	left hand circular polarization
LNA	low-noise amplifier
m^2	square meter
Mbps	megabits per second
MHz	megahertz
MIL-STD	military standard
NATO	North Atlantic Treaty Organization
PM	phase modulation
P_{sat}	saturated power
P_{linear}	maximum-linear power
RF	radio frequency
RHCP	right hand circular polarization
RMS	root-mean-square
RSS	root-sum-square
R_S	symbol rate
Rx	receive
SATCOM	satellite communications
SHF	super high frequency
SNMP	simple network management protocol
SOTM	satellite communications on-the-move
SOW	statement of work
SSE	satellite communications subject expert
STANAG	standardization agreement (NATO)
Tx	transmit
USAT	Ultra Small Aperture Antenna
VSWR	voltage standing wave ratio

3.2 Closed network. Deleted.

3.3 Earth terminal (ET). The portion of a satellite system that receives and transmits RF signals between the earth and a satellite. Earth terminal is synonymous with user terminal.

3.4 Effective isotropically radiated power (EIRP). The product of the power supplied to an antenna and its gain relative to a hypothetical antenna that radiates or receives equally in all directions.

3.5 Extraneous emissions. Emissions that result from spurious tones, bands of noise, or other undesirable signals, but that exclude harmonics and multicarrier intermodulation products.

3.6 Heavy, large fixed ET. A typical ET in this class can be of unlimited weight and size, whose electronic functions, exclusive of the antenna, are usually housed in a building. The antenna may be installed either inside or outside a protective radome. Site preparation may be required. Set-up time is not limited. For purposes of this MIL-STD, the heavy, large fixed ET is denoted as transmit type A and receive type I ET.

3.7 Large transportable ET. A typical ET in this class weighs less than 4,536 kilograms (10,000 pounds) and has a volume less than 37 cubic meters (1,300 cubic feet). A small amount of site preparation may be required. Set-up time is less than 1-hour. This ET is not intended to be used while in motion. For purposes of this MIL-STD, the large transportable ET is denoted as a transmit type D and receive type IV.

3.8 Maximum-linear EIRP. The ET EIRP expressed in dBW at maximum-linear power as defined in 3.9a and b.

3.9 Maximum-linear power. For terminals with a single carrier, the definition is in subparagraph a below. For a terminal capable of supporting multiple carriers, this is defined as the lesser value of subparagraphs a or b below.

a. Single carrier maximum-linear power. For a single carrier the maximum-linear power will be defined as the carrier power where the first spectral regrowth sidelobe (measured at 1.0 symbol rate (expressed in Hz from the carrier center frequency)) of the modulated carrier is -30 dBc.

b. Two carrier maximum-linear power. The maximum combined transmit power of two equal amplitude continuous wave (CW) carriers, when the third order intermodulation product power is -25 dB relative to the combined power of the two CW carriers.

3.10 Medium, fixed ET. A typical ET in this class weighs less than 27,216 kilograms (60,000 pounds) and has a volume less than 142 cubic meters (5,000 cubic feet). The electronics may be housed within a building or in vans. A moderate amount of site preparation may be required. Set-up time is not limited. For purposes of this MIL-STD, the medium fixed ET is denoted as a transmit type B and receive type II.

3.11 Mobile ET. A typical ET in this class can be used while in motion and during halts at unspecified points. This includes operation in aircraft, ships, and ground vehicles. For purposes of this MIL-STD, the mobile ET is denoted as a transmit type F through L and receive type VI through XII.

3.12 Satellite system. A communications system that includes two or more ETs, a communications satellite or a space platform, and a control system.

3.13 Saturated power. The single-carrier output power level of an active device (typically a high-power amplifier (HPA)) where the input power change-to-output power change ratio is 10:1.

3.14 Small, fixed, covert operations ET. A typical ET in this class weighs less than 11,340 kilograms (25,000 pounds) and has a volume less than 57 cubic meters (2,000 cubic feet). A moderate amount of site preparation may be required. Set-up time is less than 6-hours. This ET is rarely moved. It is not used while in motion. For purposes of this MIL-STD, the small, fixed, covert operations ET is denoted as a transmit type C and receive type III.

3.15 Small transportable ET. A typical ET in this class weighs less than 2,268 kilograms (5,000 pounds) and has a volume less than 21 cubic meters (750 cubic feet). A small amount of site preparation may be required. Set-up time is less than 30-minutes. This ET is not intended to be used while in motion. For purposes of this MIL-STD, the small transportable ET is denoted as a transmit type E and receive type V.

3.16 Ultra mobile, tactical ET. A small aperture SATCOM terminal designed for SOTM.

4. GENERAL REQUIREMENTS

4.1 Basic satellite communications system. Figure 1 depicts the basic elements of a SATCOM system: the earth terminal (ET), the communications satellite, and the communications system control elements. The ET upconverts the modulated intermediate frequency (IF) to radio frequency (RF) and transmits the RF to the satellite. The ET also receives RF from the satellite and downconverts the RF to IF. This military standard (MIL-STD) addresses the RF/IF design and associated interfaces. Satellite access and network control, multiplexing, and modulation functions are addressed in other MIL-STDs, as identified in the super high frequency (SHF) SATCOM standards profile described in 6.6. The contribution of the satellite must be budgeted to provide required total system performance.

4.2 Earth terminal. Figure 2 shows the major ET functions:

a. Transmission function [includes IF combiner (if used), IF/RF upconversion, RF signal amplification, and RF radiation].

b. Reception function [includes RF signal reception, RF signal amplification, RF/IF downconversion, and IF divider (if used)].

c. Control and monitoring function (includes interfaces to an external controller and monitor).

d. Antenna.

4.2.1 Transmission function. The transmission function shall upconvert the IF signal to a RF signal, amplify the RF signal, and transmit the RF signal to a satellite. The transmission function includes all the equipment from the IF input to the antenna RF output (see 5.1).

4.2.2 Reception function. The reception function shall receive RF signals from a satellite, provide low-noise amplification, and downconvert the RF signal to an IF signal. The reception function includes all the equipment from the antenna RF input to the IF output (see 5.2).

4.2.3 Control and monitoring function. The ET shall interface with an external controller and monitor (see 5.3).

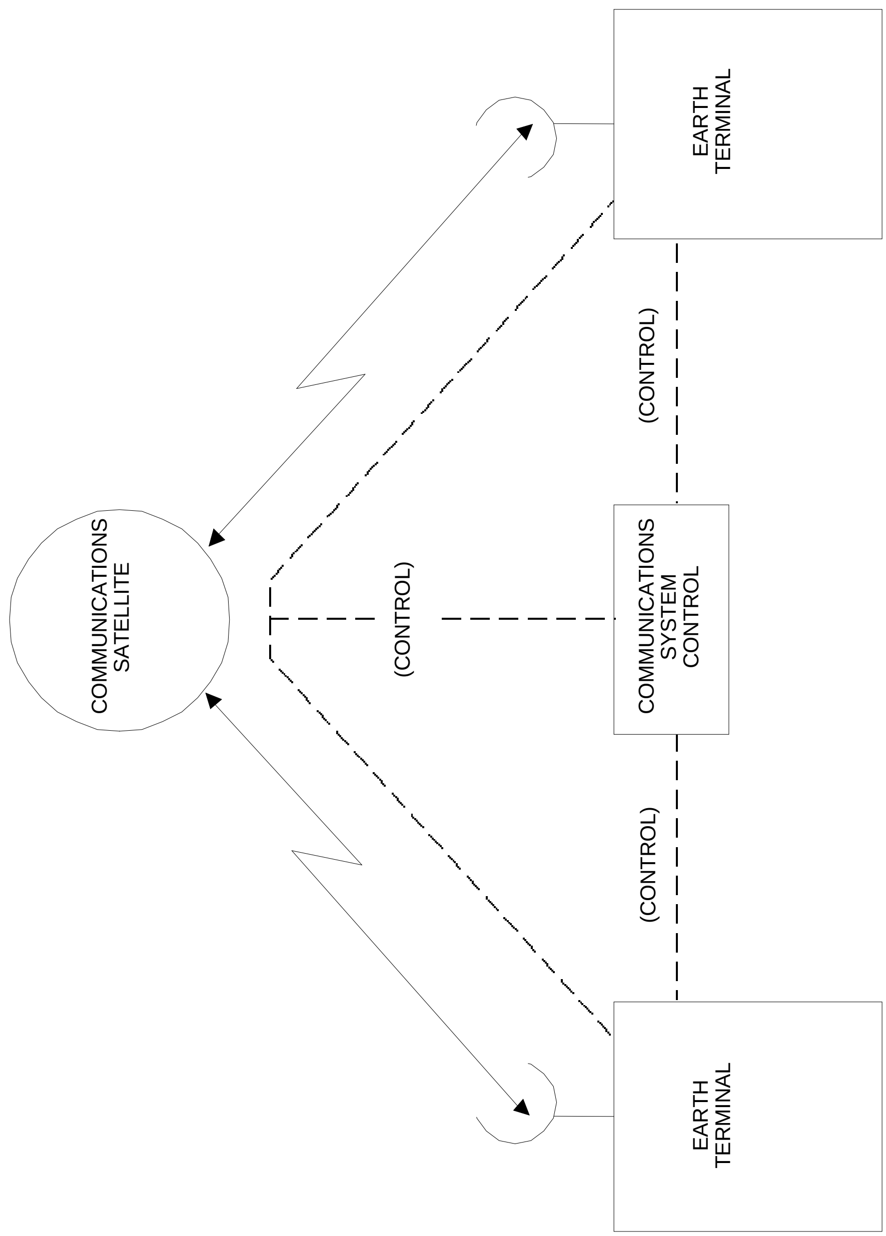
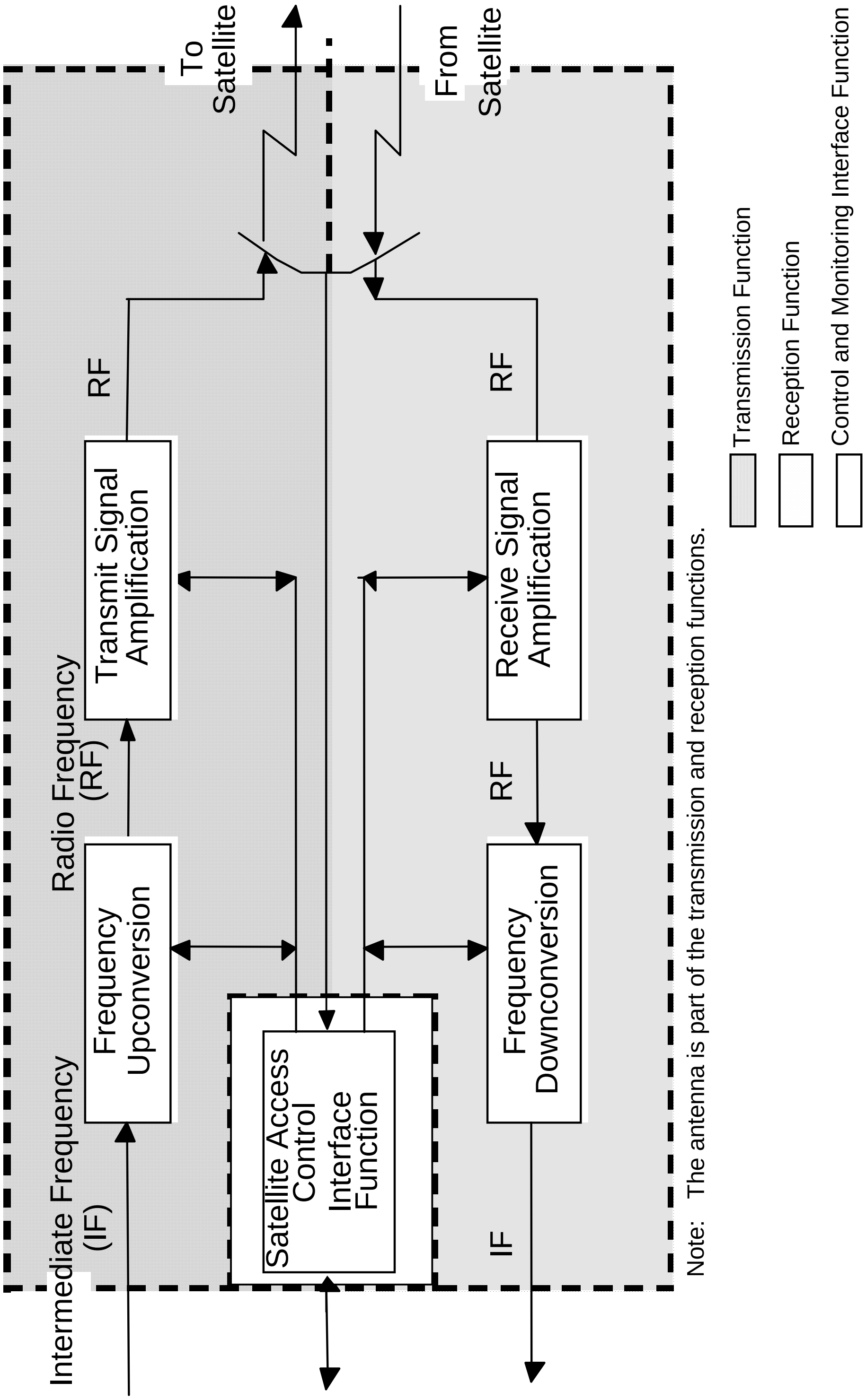


FIGURE 1. Basic satellite communications system



Note: The antenna is part of the transmission and reception functions.

FIGURE 2. Earth terminal functions (simplified)

4.2.4 Frequency references. The ET should provide for an external frequency reference, as specified in 5.4.

4.3 Types of earth terminals. ETs are classified into types based on their physical and operational requirements. The ET transmit (Tx) types (A to P) and receive (Rx) types (I to XV) are shown in Table I.

TABLE I. Types of earth terminals.

Tx Type	Rx Type	Physical Characteristics	Communications Topology
A	I	Heavy, large fixed	Tx and Rx multiple carriers
B	II	Medium, fixed	Tx and Rx multiple carriers
C	III	Small, fixed, covert operations	Tx and Rx multiple carriers
D	IV	Large transportable	Tx and Rx multiple carriers
E	V	Small transportable	Tx and Rx one carrier
F	VI	Mobile, frequent position changes	Tx and Rx one carrier
G	VII	Shipboard, single	Tx and Rx one carrier
H	VIII	Shipboard, double	Tx and Rx multiple carriers
J	IX	Mobile, amphibious	Tx and Rx one carrier
K	X	Very mobile	Tx and Rx one carrier
L	XI	Extremely mobile	Tx and Rx one carrier
M	XII	Shipboard, USAT	Tx and Rx one carrier
N	XIII	Mobile, underwater radome	Tx and Rx one carrier
	XIV	Shipboard, Receive only	Rx multiple carriers
P	XV	Ultra Mobile, Tactical	Tx and Rx one carrier

4.4 Operational conditions. The requirements specified in this document shall be met over the range of environmental conditions established in the ET procurement documents.

5. DETAILED REQUIREMENTS. The paragraphs in this section apply to all bands of operation in this standard unless a specific band is identified in a paragraph.

5.1 Transmission function. The transmission function shall be in accordance with 5.1.1 through 5.1.3.3.4.

5.1.1 IF requirements. Paragraphs 5.1.1.1 and 5.1.1.2 do not apply to terminals intended to operate only with embedded modem(s).

5.1.1.1 Input frequency. An IF input interface centered at one or more of the following frequencies shall be provided, where the ± amounts represent instantaneous bandwidths that are consistent with the phase linearity requirements of paragraph 5.1.2.7 for transmit (uplink) and paragraph 5.2.3.5 for receive (downlink), and the amplitude response requirements of paragraph 5.1.2.8 for transmit (uplink) and 5.2.3.6 for receive (downlink).

a. 70 MHz ± 18 MHz

b. 140 MHz ± 36 MHz

c. 700 MHz ± 62.5 MHz

d. 1,350 MHz ± 400 MHz

e. 1,500 MHz ± 500 MHz

f. 2,700 MHz ± 500 MHz

5.1.1.2 Input level and impedance. Maximum-linear EIRP shall be attainable over an input power range of at least —10 dBm to +10 dBm. For these input drive levels, maximum-linear EIRP shall be attained with devices in the transmit chain, prior to the final power amplifier(s), contributing less than 0.2 dB to the defining first spectral regrowth sidelobe (see 3.9a) or to the third order intermodulation product power (see 3.9b). The input impedance shall be nominally 50-ohms, with a VSWR not to exceed 1.5:1 over the specified bandwidth.

5.1.2 RF requirements. Budgeting of parameters among the equipment that constitute the transmission function, such as the upconverters and amplifier, will be determined by the system design activity.

5.1.2.1 RF frequency bands. The transmission function shall be tunable in one or more of the SHF frequency bands listed in Table II.

TABLE II. Transmit uplink frequency bands.

SHF FREQUENCY BAND	FREQUENCY (GHz)
C-band	5.850 to 6.650
X-band	7.900 to 8.400
Ku-band	13.750 to 14.500
Commercial Ka-band	27.500 to 30.000
Military Ka-band	30.000 to 31.000

5.1.2.2 Tuning. The upconversion function shall be tunable in 1.0-kHz increments, in conjunction with the modem, starting at the lowest frequency for each band, as listed in Table II. The nominal 1-dB bandwidth shall be available at any tuned uplink frequency in 5.1.2.1, as long as the 1-dB bandwidth does not extend beyond the band edges identified in 5.1.2.1.

5.1.2.3 EIRP. ETs that will operate in X- and Ka-bands shall have linear EIRP equal to or greater than the values, for the X- and Ka-bands, shown in Table III. These minimum numbers should be exceeded to provide greater EIRP margin, consistent with EIRP spectral density restrictions. ETs that will operate in C- and Ku-band shall conform to appropriate IESS requirements.

5.1.2.4 EIRP stability and accuracy. For any setting of the transmit gain and a constant IF input level, the EIRP in the direction of the satellite shall not vary more than +1.0 dB or -1.5 dB in any 24-hour period. This tolerance, added on a root-sum-square (RSS) basis, includes all ET factors contributing to the EIRP variation, including output power level instability and power variations in the direction of the satellite caused by tracking errors referenced to boresight. See appendix A for RSS theory and determination of power variations due to tracking errors.

The formula for RSS error is $\sqrt{P_1^2 + P_2^2}$

where

P_1 = Output power level instability in dB

P_2 = Power variations in the direction of the satellite caused by tracking errors referenced to boresight

This does not include adverse weather conditions or any other effects not controlled by the ET. For dual band simultaneous operation, tracking performance shall be determined while tracking using the highest operational band tracking beacon.

TABLE III. Linear EIRP levels.

TYPE	Typical Data Rate Range (Mbps)	EIRP (dBW)	
		X-BAND	Ka-BAND*
A	20 - 245	86	84**
B	8 - 100	83	80**
C	5 - 62	81	77**
D	2 - 50**	72	68
E	0.8 - 20**	67	68
F	0.064 - 0.768**	68	70
G	0.128 - 10**	68	68
H	0.128 - 5**	63	66
J	0.128 ** - 0.256 **		55
K	0.128 ** - 2.048 **		54
L	0.064 ** - 1.024 **		49
M	0.128 ** - 1.024 **		48
N	0.032 ** - 0.384 **	40	40
P	0.032 ** - 2.048 **		41

* Military Band.

** These data rates can be achieved only under restricted satellite coverage areas (spot beam coverage and high gain state), high elevation angle and ideal weather conditions. Terminal specifications should define the conditions under which the high-end data rates will be achieved.

5.1.2.5 Carrier frequency accuracy. The carrier frequency accuracy at the antenna feed shall be within 1-kHz of the intended value for all RF carriers. The carrier frequency accuracy shall be maintained for a period of 90-days or more without recalibration.

5.1.2.6 Carrier power control accuracy, step size and range. The absolute accuracy of the carrier power control attenuator(s) shall be within 1-dB of the selected attenuator value. The relative accuracy associated with the smallest step increment shall be within 0.1 dB. The minimum step size shall not exceed 0.25 dB. The minimum carrier power control range shall equal or exceed that given by the expression:

Min Range (dB) = Maximum-linear EIRP (dBm) – 55 (dBm)

When a carrier power change is initiated, the controlled carrier’s power shall transition monotonically and shall not induce burst errors into the controlled carrier’s bit stream or into the adjacent carrier’s bit stream (adjacent carrier spaced at 1.2 R_S).

5.1.2.7 Transmit phase linearity. Departure from phase linearity of the transmission function, when operating at any point up to the maximum-linear power, shall not exceed:

a. ± 0.4 radians over any 36-MHz for IF frequencies specified in 5.1.1.1 a, b, c, d, e, and f.

b. ± 0.5 radians over any 72-MHz for IF frequencies specified in 5.1.1.1 b, c, d, e, and f.

c. ± 0.6 radians over any 90-MHz for IF frequencies specified in 5.1.1.1 c, d, e, and f.

d. ± 0.7 radians over any 120-MHz for IF frequencies specified in 5.1.1.1 c, d, e, and f.

e. ± 0.2 radians or less over any 2-MHz for IF frequencies specified in 5.1.1.1 a, b, c, d, e, and f.

5.1.2.8 Transmit amplitude response. Amplitude variations of the transmission (uplink) function at the input to the antenna feed, when operating at the maximum-linear power, shall not exceed:

a. ± 2.0 dB for each output frequency band listed in Table II. (Note: This may be exceeded if the terminal meets all implementation loss requirements mandated by the appropriate satellite communications subject expert (SSE)).

b. ± 1.5 dB over any 120 MHz or smaller bandwidth.

c. ± 0.5 dB over any 10 MHz bandwidth.

5.1.2.9 Transmit spectral characteristics.

5.1.2.9.1 Transmit spectral purity.

5.1.2.9.1.1 AC power line. The sum of the fundamental and each harmonic component of the alternating current (AC) line frequency shall not exceed -30 dBc.

5.1.2.9.1.2 Single sideband. The single sideband sum (added on a power basis) of all other individual spurious components shall not exceed -36 dBc.

5.1.2.9.1.3 Phase noise. The single sideband power spectral density of the continuous phase noise component shall comply with the envelope defined on Figure 3. If specific points associated with the measured phase noise plot exceed the Figure 3 envelope, then the following two conditions shall be met:

a. The single sideband phase noise due to the continuous component, when integrated over the bandwidth from 10-Hz to 16-kHz relative to carrier center frequency, shall be less than 3.4 degrees-RMS (two-sided value of 4.8 degrees-RMS).

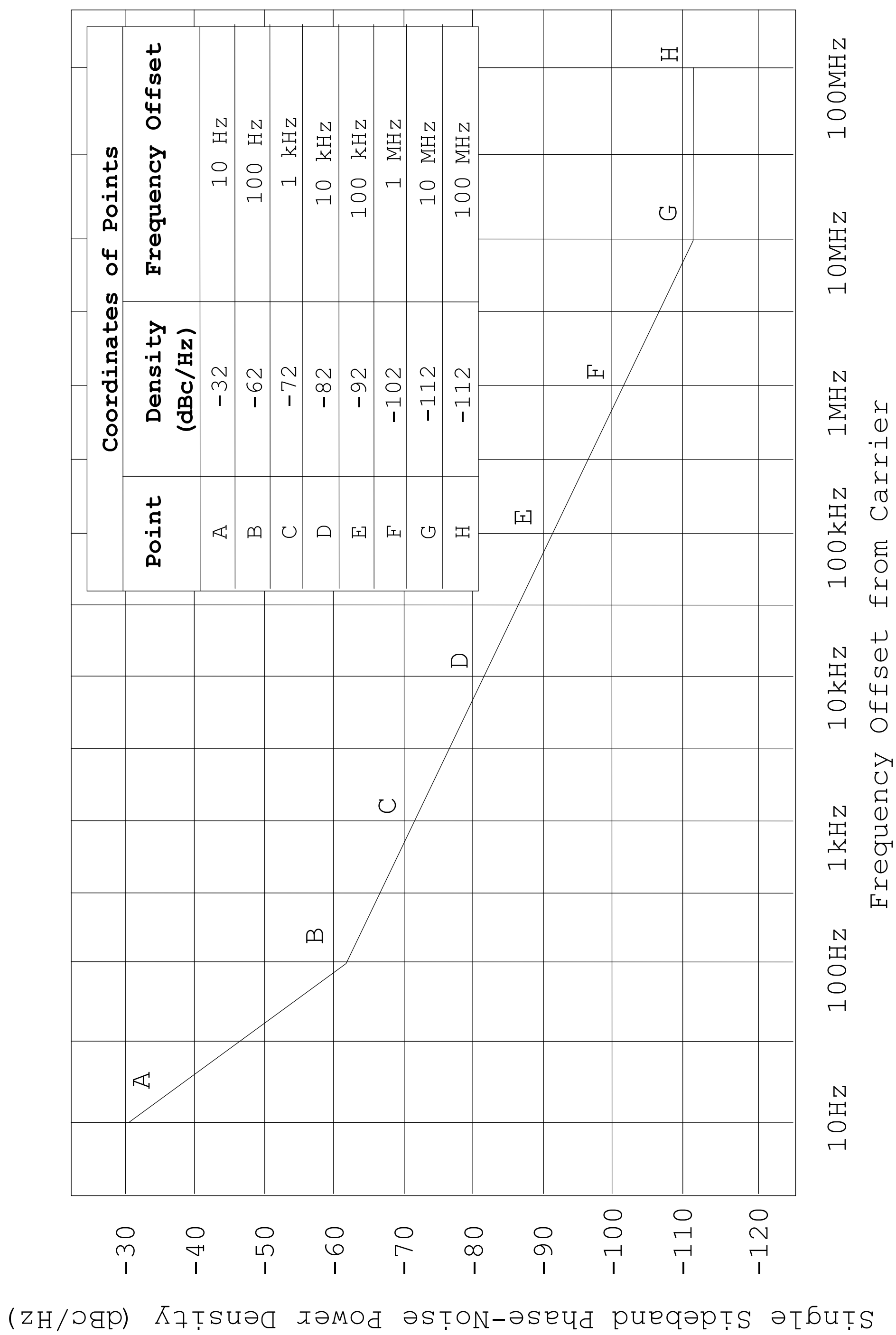
b. The single sideband phase noise due to the continuous component, when integrated over the bandwidth from 1%R_S to R_S hertz relative to carrier center frequency, shall be less than the value obtained when integrating the Figure 3 plot over the same limits.

Note: The R_S is the symbol rate of the lowest and highest operating mode of the terminal's associated modem.

5.1.2.9.2 Transmit thermal noise EIRP. For terminals with antenna gain less than or equal to 45 dBi, the thermal noise EIRP spectral density shall not exceed -10 dBm/Hz at X-band and -20 dBm/Hz at Ka-band. For terminals with antenna gain greater than 45 dBi, the thermal noise EIRP spectral density shall not exceed the value given by: -55 + G_{ant} (dBm/Hz) at X-band and the value given by: -65 + G_{ant} (dBm/Hz) at Ka-band. The above requirements are to be met with all upconverters off line (HPA noise alone). When one modem/upconverter string is connected to the HPA input, the noise increase shall not exceed 3-dB.

5.1.2.10 Transmission function extraneous outputs. With the transmission equipment aligned, the power control attenuator(s) set to provide maximum-linear power using a CW signal connected into the IF interface, the EIRP of extraneous emissions as measured over any 10-kHz bandwidth (excluding ± 1-MHz around the

CW carrier) shall be no greater than 37 dBm, or -60 dBc, whichever is larger.



Coordinates of Points

Point	**Density (dBc/Hz)**	**Frequency Offset**
A	-32	10 Hz
B	-62	100 Hz
C	-72	1 kHz
D	-82	10 kHz
E	-92	100 kHz
F	-102	1 MHz
G	-112	10 MHz
H	-112	100 MHz

Figure 3. ET spectral purity.

5.1.2.11 Harmonic emissions. The level of all harmonics of the transmit carriers shall not exceed -60 dBc when measured at maximum-linear power.

5.1.2.12 Intermodulation products. The intermodulation products relative to known power levels below saturated power that result from two carriers injected at the IF interface and simultaneously passing through the transmission function with equal output power shall not exceed the values in Table IV. The intermodulation products power is measured relative to the total output power level of the two carriers. The maximum allowable intermodulation product power includes the contribution of passive intermodulation products generated by the antenna and reflector structures. For systems incorporating overdrive protection, replace the term "saturated" with "maximum achievable" in Table IV.

TABLE IV. Maximum allowable intermodulation product levels.

dB Below Saturated POWER LEVEL (dB)	MAXIMUM 3rd order INTERMODULATION PRODUCTS (dBc)
-1.5	-14
-4.5	-19
-7.5	-25

5.1.2.13 Transmit-to-receive isolation. Transmit-to-receive isolation shall be such that there is less than 0.1-dB degradation in receive noise density over the Table II frequency band with the transmitter operating at any EIRP level, compared to the receive performance with the transmitter turned off.

5.1.2.14 Intermodulation products in the receive band. For all receive frequency bands of operation, the intermodulation products appearing at the low-noise amplifier (LNA) input due to two equal power transmit communications carriers shall be no greater than -135 dBm. The requirements of this paragraph shall be met with each transmit carrier at any frequency in the transmit band and the power in each carrier shall be 3-dB below maximum-linear EIRP. This requirement applies to ETs supporting multiple communication carrier transmission.

5.1.2.15 Transmit spectrum inversion. No inversion of spectrum shall exist between any IF input and the antenna output for ETs operating with a non-embedded modem(s). Terminals with embedded modems shall be interoperable with terminals that do not have embedded modems.

5.1.2.16 Transmit phase perturbation. The Transmission Function shall not change the linear phase of the output RF signal by more than 20-degrees in 0.2-seconds under the following conditions:

a. Exposure to temperature shock from a nominal 23°C. The temperature range shall include the lowest and highest Transmission Function operating temperatures. Temperature rate of change between extremes shall be 22°C per hour.

b. Vibration with an input frequency varied between 50 and 2000 Hz with a constant input acceleration of 1.5 gravitational force (peak).

c. A shock caused by the impact of a test hammer on the outside surface of the equipment housing the conversion circuitry simulating a maintenance or operator action on the Transmission Function subsystem. The test hammer shall be a 1-pound (453.59-grams) weight attached to an 8-inch (20.32-centimeter (cm)) arm pivoted from a rigid support and free to move through a vertical plane. The striking face shall be covered with a 0.5-inch (1.27-cm) thickness of SAE AMS 3198K[1] sponge, Chloroprene (CR) rubber, medium stiffness, or other open cell sponge rubber in accordance with the following:

(1) Density. 498.28 to 747.43 kg/cubic meter (0.018 to 0.027-lbs/cubic inch).

(2) Compression Deflection. 4218 to 9843 kg per square meter (6 to 14 pounds per square inch (psi)) for 25% deflection.

The shock shall be produced by releasing the hammer to swing freely through a 90-degree arc and to impact the enclosure at the bottom of its swing.

5.1.2.17 AM-PM conversion. The amplitude modulation (AM) to phase modulation (PM) conversion shall be no more than 2 degrees/dB for Transmission Function operation at any power less than or equal to the maximum-linear power.

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[1] SAE AMS 3198K sponge, chloroprene (CR) rubber, medium stiffness, in 1/2 inch thick sheets complies with the requirements of c(1) and c(2).

5.1.3 RF transmission radiation wave function (antenna). The RF radiation wave function shall conform to 5.1.3.1 through 5.1.3.3.4.

5.1.3.1 Antenna sidelobe levels.

5.1.3.1.1 C-band and Ku-band earth terminals. The sidelobe pattern of the antenna shall be in accordance with the transmit sidelobe mandatory requirements of IESS-601 or the antenna performance standards of CFR47, whichever is more stringent, for each off-axis angle in the direction of the satellite referred to the main-lobe axis. For antennas with a diameter less than 100 wavelengths (λ), only the requirements of IESS-601 apply.

5.1.3.1.2 X- and Ka-band earth terminals. The antenna sidelobe requirements are described in a and b, below:

a. $D/\lambda \geq 50$. The gain of the antenna shall be such that at least 90 percent of the sidelobe peaks do not exceed:

$$G(\theta) = 29\text{-}25 \log_{10} \theta \text{ (dBi), for } 1° \text{ or } 100\ \lambda/D\ ° \text{ (whichever is larger)} \leq \theta \leq 20°$$

Note: If $D/\lambda > 150$ then the lower boundary is always 1°.

$$G(\theta) = -3.5 \text{ (dBi), for } 20° < \theta \leq 26.3°$$

$$G(\theta) = 32\text{-}25 \log_{10} \theta \text{ (dBi), for } 26.3° < \theta \leq 48°$$

$$G(\theta) = -10 \text{ (dBi) for } 48° < \theta \leq 180°$$

where

G = gain relative to an isotropic antenna

θ = off-axis angle in the direction of the satellite referred to the main-lobe axis

D = antenna diameter

λ = wavelength (same units as D)

b. D/λ < 50. The gain of the antenna shall be such that at least 90 percent of the sidelobe peaks do not exceed:

$$G(\theta) = 32-25 \log_{10} \theta \text{ (dBi), for } 100\ \lambda/D\ ° \le \theta \le 48°$$

$$G(\theta) = -10 \text{ (dBi), for } 48° < \theta \le 180°$$

where symbols are defined in a, above.

c. EIRP spectral density requirements allowance for type F and J terminals only with electrically small antennas (D/λ less than 15) for X-band: The EIRP Spectral Density (ESD) shall not exceed the limits imposed by the following equations:

$$\text{ESD}(\theta) = 10.8 - 10.99(\theta)^2 \text{ (dBW/Hz), for } 0° < \theta \le 1.1°$$

$$\text{ESD}(\theta) = -2.7 \text{ (dBW/Hz), for } 1.1° < \theta \le 1.5°$$

$$\text{ESD}(\theta) = 1.78 - 25 \text{ Log}_{10}(\theta) \text{ (dBW/Hz), for } 1.5° < \theta \le 48°$$

$$\text{ESD}(\theta) = -40.2 \text{ (dBW/Hz), for } 48° < \theta \le 180°$$

The EIRP spectral density envelope resulting from the above equations is provided on Figure 4.

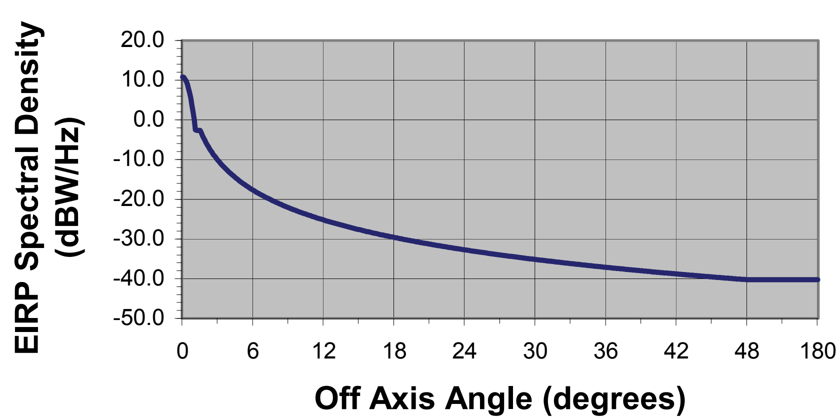

FIGURE 4. EIRP spectral density envelope

5.1.3.2 Antenna polarization, transmitting. Antenna polarization shall conform to one or more of the following subparagraphs, as applicable.

5.1.3.2.1 C-band earth terminal. The antennas for terminal types A and B shall be able to transmit horizontal linear and vertical linear polarizations simultaneously and right-hand circular and left-hand circular polarizations simultaneously. However, these terminals are not required to operate with both linear and circular polarizations at the same time. Antennas for terminal types C through H shall be able to transmit linear (horizontal and vertical) or circular (right-hand and left-hand) polarization. The antennas are not required to transmit simultaneously in any combination of polarization senses. The ET linear feed shall be adjustable to match the satellite polarization angle to within 1-degree (clear sky).

5.1.3.2.2 X-band and military Ka-band earth terminals. The antenna shall be capable of transmitting right-hand (clockwise) circular polarization (RHCP). The Ka-band terminal antenna shall also have the capability to transmit left-hand (counterclockwise) circular polarization (LHCP). However, Ka-band terminals do not have to operate simultaneously with right-hand and left-hand polarization.

5.1.3.2.3 Commercial Ka-band earth terminal. The antenna shall be able to transmit linear (horizontal and vertical) and circular (right-hand and left-hand) polarization; the antenna shall not be required to transmit both polarizations at the same time. The ET linear feed shall be adjustable to match the satellite polarization angle to within 1-degree (clear sky).

5.1.3.2.4 Ku-band earth terminal. The antenna shall be able to transmit linear (horizontal and vertical) polarization; one polarization at a time. The ET feed(s) shall be adjustable to match the satellite polarization angle to within 1-degree (clear sky).

5.1.3.3 Antenna axial ratio. The requirements for axial ratio of transmit ET antennas are described in 5.1.3.3.1 through 5.1.3.3.4. The axial ratio applies to all directions within the cone defined by the antenna tracking, pointing errors, or both.

5.1.3.3.1 Circular polarization, X-band and military Ka-band. The axial ratio for X-band circularly polarized beams shall be no greater than 2.0 dB over the transmit band. Military Ka-band transmit axial ratio shall be no greater than 1.0 dB.

5.1.3.3.2 Circular polarization, C-band. The axial ratio for C-band circularly polarized beams shall be as described below:

a. Antennas with diameter larger than 2.5 meters. The voltage axial ratio of transmission in the direction of the satellite shall not exceed 1.09 (27.3 dB polarization discrimination) within a cone defined by the antenna tracking and/or pointing errors.

b. Antennas with diameter 2.5 meters or smaller. The voltage axial ratio of transmission in the direction of the satellite shall not exceed 1.3 (17.7 dB polarization discrimination) within a cone defined by the antenna tracking and/or pointing errors.

5.1.3.3.3 Linear polarization, C-band. The axial ratio of transmission for linearly polarized beams shall be over the transmit bands described below:

a. Antennas with diameter larger than 4.5 meters. The voltage axial ratio of transmission in the direction of the satellite shall exceed 31.6 (30.0 dB polarization discrimination) within a cone defined by the antenna tracking/and or pointing errors.

b. Antennas with diameter 4.5 meters or smaller. The voltage axial ratio of transmission in the direction of the satellite shall exceed 22.4 (27.0 dB polarization discrimination) within a cone defined by the antenna tracking and/or pointing errors.

5.1.3.3.4 Linear polarization, Ku-band. The axial ratio of transmission for linearly polarized beams shall be as described below:

a. Antenna with diameter larger than 2.5 meters. The voltage axial ratio of transmission in the direction of the satellite shall exceed 31.6 (30.0 dB polarization discrimination) everywhere within a cone centered on the main beam axis. The antenna tracking and/or pointing errors define the cone angle.

b. Antenna with diameter 2.5 meters or smaller. The voltage axial ratio of transmission in the direction of the satellite shall exceed 20.0 (26.0 dB polarization isolation) everywhere within a cone defined by the antenna tracking and/or pointing errors.

5.2 Reception function. The ET reception function shall conform to 5.2.1 through 5.2.3.11 when the maximum power-flux density is as follows:

a. C-band:

-152.0 dBW/meter^2 in any 4-kHz band where $0° \leq \theta \leq 5°$;
-149.5 dBW/meter^2 in any 4-kHz band where $5° < \theta \leq 25°$;
-142.0 dBW/meter^2 in any 4-kHz band where $25° < \theta \leq 90°$.

b. X-band:

-152 dBW /meter^2 in any 4-kHz band.

c. Ku-band:

-150.0 dBW/meter^2 in any 1-MHz band where $0° \leq \theta \leq 5°$;
-147.5 dBW/meter^2 in any 4-kHz band where $5° < \theta \leq 25°$;
-140.0 dBW/meter^2 in any 4-kHz band where $25° < \theta \leq 90°$.

d. Ka-band:

-115 dBW/meter^2 in any 1-MHz band.

5.2.1 RF reception radiation wave function (antenna). The ET shall conform to 5.2.1.1 through 5.2.1.3, as they apply to receiving RF from a satellite.

5.2.1.1 Antenna polarization. Antenna polarization shall conform to one or more of the following subparagraphs, as applicable.

5.2.1.1.1 C-band earth terminal. Antennas for terminal types I and II shall be able to receive linear (horizontal and vertical) and circular (right-hand and left-hand) polarization simultaneously. Terminal types III through VII antennas shall be able to receive linear (horizontal and vertical) or circular (right-hand and left-hand) polarization. The ET linear feed(s) shall be adjustable to match the satellite polarization angle to within 1-degree (clear sky).

5.2.1.1.2 X-band and military Ka-band earth terminal. The antennas for all X-band terminal types shall be capable of receiving left-hand (counter-clockwise) circular polarization (LHCP). The antennas for military Ka-band terminal types shall be capable of receiving left-hand (counter-clockwise) and right-hand (clockwise) circular polarization (RHCP). However, military Ka-band terminals do not have to operate simultaneously with right-hand and left-hand circular polarizations.

5.2.1.1.3 Commercial Ka-band earth terminal. Terminal types I and II antennas shall be able to receive linear (vertical and horizontal) and circular (righthand and lefthand) simultaneously. Antennas for terminal types III through XII shall be able to receive linear (horizontal and vertical) or circular (righthand and lefthand) polarization. The earth terminal shall be capable of matching the satellite polarization angle to within 1-degree (clear sky).

5.2.1.1.4 Ku-band earth terminal. Antenna shall be able to receive horizontal linear and vertical linear polarizations; one polarization at a time. The ET shall be adjustable to match the satellite polarization angle to within 1-degree (clear sky).

5.2.1.2 Antenna axial ratio. Receive ET antennas shall comply with the axial requirements in 5.1.3.3.1 through 5.1.3.3.4 except that the X-band receive axial ratio shall be no greater than 1.21 dB and the military Ka-band receive axial ratio shall be no greater than 1.5 dB.

5.2.1.3 Antenna pointing loss. Antenna pointing loss shall not exceed 0.8 dB for systems employing tracking and 1.0 dB for systems without tracking. For maximum operational wind velocities, the pointing loss shall not exceed 2.0 dB for both tracking and non-tracking systems.

5.2.2 RF requirements. Budgeting of parameters among the equipment that constitute the reception function, such as the LNA and downconverters, will be determined by the system design activity.

5.2.2.1 RF frequency bands. The downconversion function shall be tunable in one or more of the SHF frequency bands listed in Table V.

TABLE V. Downlink frequency requirements.

SHF FREQUENCY BAND	FREQUENCY (GHz)
C-band	3.400 to 4.200
X-band	7.250 to 7.750
Ku-band	10.950 to 12.750
Commercial Ka-band	17.700 to 20.200
Military Ka-band	20.200 to 21.200

5.2.2.2 ***G/T.*** The minimum antenna gain-to-noise temperature (*G/T*) in dBi/K shall be in accordance with Table VI when operating with the transmitter 'on' in a clear-sky condition, at the lowest frequency in the band, at a 10-degree elevation angle, and at 23-degrees Celsius. Earth terminals that will operate in C- and Ku-band shall conform to an appropriate IESS.

TABLE VI. Minimum *G/T* requirements.

TYPE	Typical Data Rate Range (Mbps)	G/T per Band (dBi/K)	
		X	Ka
I	20 - 245	38.5	37.5*
II	8 - 100	35.0	34.5*
III	5 - 62	29.0	30.0*
IV	2 - 50*	26.0	27.0*
V	0.8 - 20*	20.0	26.0*
VI	0.064 - 0.768*	13.0	20.0
VII	0.128 - 10*	21.0	25.0
VIII	0.128 - 5*	16.0	21.0
IX	0.128 - 0.256*		11.0
X	0.128* - 2.048*		15.0
XI	0.064* - 1.024*		15.0
XII	0.128* - 1.024*		0.0
XIII	0.032* - 0.384*	2.0	6.0
XIV	1.544 - 23.58*		17.0
XV	0.032 * - 2.048 *		8.0

* These data rates can be achieved only under restricted satellite coverage areas (spot beam coverage), high elevation angle, ideal weather conditions when a very high percentage of the transponder power is allocated to the carrier. Terminal specifications should define the conditions under which the high-end data rates will be achieved.

5.2.3 IF requirements. The IF output shall comply with 5.2.3.1 through 5.2.3.11.

5.2.3.1 Output frequency. An IF output interface centered at one or more of the following frequencies (± represents the nominal 1-dB bandwidth) shall be provided.

a. 70 MHz ± 18 MHz

b. 140 MHz ± 36 MHz

c. 700 MHz ± 62.5 MHz

d. 1,350 MHz ± 400 MHz

e. 1,500 MHz ± 500 MHz

f. 2,700 MHz ± 500 MHz

5.2.3.2 Receive chain gain and IF interface characteristics. The receive chain (antenna interface to terminal IF interface) shall exhibit the following characteristics:

a. The receive chain absolute gain shall be sufficient to raise the IF interface noise power spectral density, when pointing to a cold sky away from a geosynchronous satellite at an angle of 30-degrees, to at least -103 dBm/Hz.

b. The RF-to-IF gain adjustment shall be at least 20-dB in steps of 1-dB or less.

c. The output impedance at the terminal IF interface shall be 50-ohms or 75 ohms as needed, with a VSWR less than 1.5:1 over the specified bandwidth.

5.2.3.3 Tuning. The downconversion function shall be tunable in 1.0 kHz increments, in conjunction with the modem starting at the lowest frequency for each band, as listed in Table V. The nominal 1-dB bandwidth shall be available at any tuned downlink frequency in 5.2.2.1, as long as the 1-dB bandwidth does not extend beyond the band edges identified in 5.2.2.1. The full IF bandwidth shall be available at any IF setting in 5.2.3.1.

5.2.3.4 Receive conversion frequency accuracy. The downconversion frequency accuracy shall be within 1-kHz of the intended value for all received RF carriers over all time. Downconversion frequency accuracy shall be maintained for a period of 90-days or more without recalibration.

5.2.3.5 Receive phase linearity. The RF-to-IF phase response of the reception function shall not deviate from linear by more than the following amounts:

a. ± 0.4 radians over any 36-MHz for IF frequencies specified in 5.2.3.1 a, b, c, d, e, and f.

b. ± 0.5 radians over any 72-MHz for IF frequencies specified in 5.2.3.1 b, c, d, e, and f.

c. ± 0.6 radians over any 90-MHz for IF frequencies specified in 5.2.3.1 c, d, e, and f.

d. ± 0.7 radians over any 120-MHz for IF frequencies specified in 5.2.3.1 c, d, e, and f.

e. ± 0.2 radians over any 2-MHz for IF frequencies specified in 5.2.3.1 a, b, c, d, e, and f.

5.2.3.6 Receive amplitude response. Amplitude variations as measured at the input to the demodulator shall not exceed the following amounts:

a. ± 2.0 dB for each output frequency band listed in Table V. (Note: This may be exceeded if the terminal meets all implementation loss requirements mandated by the appropriate satellite communications subject expert (SSE)).

b. ± 1.5 dB over any 120 MHz bandwidth.

c. ± 0.5 dB over any 10 MHz bandwidth.

5.2.3.7 Receive spectral purity. The spectral purity of any translated carrier shall be as defined in 5.1.2.9.

5.2.3.8 Receive spurious output. The sum total of spurious signal power, including phase noise measured at the IF output, shall be at least 20 dB below the thermal noise power measured in the bandwidth specified in 5.2.3.1, with a maximum signal into the LNA. No one spurious signal shall be greater than an equivalent signal 10 dB below the noise level in the narrowest bandwidth of interest or -60 dBc for spurious outputs which fall completely within the narrowest bandwidth of interest. The requirements of this paragraph shall be met under the following simultaneous conditions:

a. Transmitting a single carrier at maximum-linear power.

b. Receiving two carriers at the maximum input signal level to the LNA. The ET procurement documents will define the maximum input signal level and narrowest bandwidth of interest.

5.2.3.9 Receive spectrum inversions. No inversion of spectrum shall exist between any RF input and the downconversion function output.

5.2.3.10 Receive signal level stability. For any setting of the receive gain and for a constant RF flux density level, the receive function output level shall not vary more than ± 2.0 dB in any 24-hour period. This tolerance includes all ET factors contributing to the gain variations, including the antenna beam pointing and tracking errors referenced to boresight added on a root-sum-squared basis.

This does not include adverse weather conditions or any other effects not controlled by the ET.

5.2.3.11 Receive phase perturbation. The Receive Function shall not change the linear phase of the input RF signal by more than 20-degrees in 0.2 seconds under the following conditions:

a. Exposure to temperature shock from a nominal 23°C. The temperature range shall include the lowest and highest Transmission Function operating temperatures. Temperature rate of change between extremes shall be 22°C per hour.

b. Vibration with an input frequency varied between 50 and 2000 Hz with a constant input acceleration of 1.5 gravitational forces (peak).

c. A shock caused by the impact of a test hammer on the outside surface of the equipment housing the conversion circuitry simulating a maintenance or operator action on the Receive Function subsystem. The test hammer shall be a 1-pound (453.59 grams) weight attached to an 8-inch (20.32-centimeter (cm)) arm pivoted from a rigid support and free to move through a vertical plane. The striking face shall be covered with a 0.5-inch (1.27-cm) thickness of SAE AMS 3198K[2] sponge, Chloroprene (CR) rubber, medium stiffness, or other open cell sponge rubber in accordance with the following:

(1) Density. 498.28 to 747.43 kg/cubic meter (0.018 to 0.027 lbs/cubic inch).

(2) Compression Deflection. 4218 to 9843 kg per square meter (6 to 14 pounds per square inch (psi)) for 25% deflection.

The shock shall be produced by releasing the hammer to swing freely through a 90-degree arc and to impact the enclosure at the bottom of its swing.

5.3 Control and monitoring function. The ET shall meet the requirements of 5.3.1 through 5.3.3.

5.3.1 Control and monitoring parameters. As a minimum, remote and local control, monitor, and alarm (CMA) shall be provided in accordance with Table VII. For all earth terminal types, the composite and individual transmit carrier power shall be measured at the antenna feed for monitoring and reporting antenna feed power and EIRP. Antenna feed power may be computed from measured HPA output power.

The transmit gain, as computed, shall be within ± 2-dB of actual gain, neglecting any frequency dependencies in accordance with 5.1.2.8. Transmit gain is computed by adding (1) the upconversion function gain, (2) the gain/loss from the upconversion function output to the power amplifier input, (3) the power amplifier gain, and (4) transmission loss to antenna feed. The receive gain, as computed, shall be within ± 5-dB of actual gain. Receive gain is computed by adding (1) the gain from the LNA input to the downconversion function and (2) the downconversion function gain.

5.3.2 Control response times. The ET shall meet a response time of 0.5 seconds for all parameters in Table VII.

5.3.3 ET remote control and monitoring interface. This interface shall be implemented as an IEEE 802.3 compliant Ethernet (see http://en.wikipedia.org/wiki/IEEE_802.3 for a short tutorial on IEEE 802.3). The interface protocol shall be via the industry standard Simple Network Management Protocol (SNMP) (see http://en.wikipedia.org/wiki/Simple_Network_Management_Protocol).

5.4 Frequency references. If a terminal is capable of accepting an external frequency reference (see 4.2.4), the terminal shall accept either an external 5-MHz frequency reference in accordance with MIL-STD-188-115 or an external 10-MHz frequency reference.

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[2] SAE AMS 3198K sponge, chloroprene (CR) rubber, medium stiffness, in 1/2 inch thick sheets complies with the requirements of c(1) and c(2).

TABLE VII. ET control and monitoring parameters.

CONTROL	MONITORING
Transmit gain of each upconversion function	Transmit gain setting of each upconversion function
Frequency setting of each upconversion function	Frequency setting of each upconversion function
Frequency setting of each downconversion function	Frequency setting of each downconversion function
Autotrack source (frequency band)	Autotrack status
Total and individual carrier power level at antenna feed	Total and individual communications carrier power level at antenna feed
Antenna pointing angles (azimuth and elevation relative to true north)	Antenna pointing angles (azimuth and elevation relative to true north)
Signal path switches (redundant equipment and waveguide switches)	Equipment fault status
	Total transmit power level at the power amplifier output
	Transmit gain/loss setting from the output of each upconversion function to the input of the HPA
	Transmit gain setting of the power amplifier
	Receive gain setting from LNA input to each downconversion function output
	Receive gain setting of each downconversion function

6. NOTES

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

6.1 Intended use. Define the military SHF SATCOM earth terminals interface in terms of physical, functional, and acceptable performance criteria necessary to support program managers and buying activities in the strategy of interoperable and compatible earth terminals which are vital for effective joint and combined forces communication.

6.2 Acquisition requirements. Acquisition documents should specify the title, number, and date of this standard. Because the United States ratifying official for NATO STANAG 4484, *Overall Super High Frequency (SHF) Military Satellite Communications (MILSATCOM) Interoperability Standard*, did not designate MIL-STD-188-164 as the form for implementing the STANAG in the "ratification document", the title, edition, and date of ratification of the STANAG should be directly cited in solicitations and contracts when the terminals will be used to communicate with NATO participating nations.

6.3 Tailoring guidance. To ensure proper application of this standard, invitations for bids, requests for proposals, and contractual statements of work (SOW) should tailor the requirements in sections 4 and 5 of this standard to exclude any unnecessary requirements.

6.3.1 Military operational environment requirement. A program manager should tailor the transmit phase perturbation (5.1.2.16) and receive phase perturbation (5.2.3.11), as required.

6.3.2 Interface requirements. If the external frequency reference interface (see 4.2.4) is implemented, a program manager should tailor 5.4 to either require both a 5-MHz and a 10-MHz reference or to specify which of the two frequency references must be implemented.

6.3.3 Functional requirements. Requirements specific to particular frequency bands are provided in Table VIII.

TABLE VIII. Tailoring guidance for tables and paragraphs.

Table	C-band	Commercial Ka-band	Military Ka-band	Ku-band	X-band
II	x	x	x	x	x
III			x		x
V	x	x	x	x	x
VI		x	x		x
5.1.2.1	x	x	x	x	x
5.1.2.3	x	x	x	x	x
5.1.2.9.2		x	x		x
5.1.3.1.1	x			x	
5.1.3.1.2		x	x		x (and c)
5.1.3.2.1	x				
5.1.3.2.2			x		x
5.1.3.2.3		x			
5.1.3.2.4				x	
5.1.3.3.1			x		x
5.1.3.3.2	x				
5.1.3.3.3	x				
5.1.3.3.4				x	
5.2	a	d	d	c	b
5.2.1.1.1	x				
5.2.1.1.2			x		x
5.2.1.1.3		x			
5.2.1.1.4				x	
5.2.1.2			x		x
5.2.2.1	x	x	x	x	x
5.2.2.2	x			x	

6.4 Subject term (key-word) listing. The following key words, phrases, and acronyms apply to this MIL-STD:

- C-band
- Ku-band
- SATCOM
- X-band
- Military Ka-band
- Commercial Ka-band

6.5 International standardization agreement implementation. This standard implements STANAG 4484 (Edition 2), Overall Super High Frequency (SHF) Military Satellite Communications (MILSATCOM) Interoperability Standard. When changes to, revision, or cancellation of this standard are proposed, the preparing activity must coordinate the action with the U.S. National Point of Contact for the international standardization agreement, as identified in the ASSIST database at http://assist.daps.dla.mil.

The MIL-STD-188-164 Terminal Types that could operate in NATO are listed under the STANAG 4484 Class A, B, and C columns in Table IX.

Table IX. Types of earth terminal - NATO terminal classes.

MIL-STD-188-164A Type Terminal		Not in STANAG 4484	STANAG 4484 Class		
Transmit	Receive		A	B	C
A	I	X			
B	II	X			
C	III	X			
D	IV	X			
E	V				X
F	VI			X	
G	VII				X
H	VIII				X
J	IX	X			
K	X				X
L	XI			X	
M	XII	X			
N	XIII	X			
	XIV	X			
P	XV			X	X

6.6 SHF SATCOM standards profile. This MIL-STD is one of a series of MIL-STDs for SHF SATCOM. The SHF SATCOM standards profile is shown on Figure 5.

6.7 Changes from previous issue. The margins of this standard are marked with vertical lines to indicate where modifications from this change were made. This was done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content irrespective of the marginal notations.

The following list summarizes the changes to MIL-STD-188-164:

(1) Addition of Ka-band and associated parameter changes.

(2) Separation of terminal type classification based on uplink and downlink requirements.

(3) Expansion of selectable IF frequencies.

(4) Multiple carrier per frequency converter operation.

(5) Change to linear power definition.

(6) Changes to carrier power control range and accuracy.

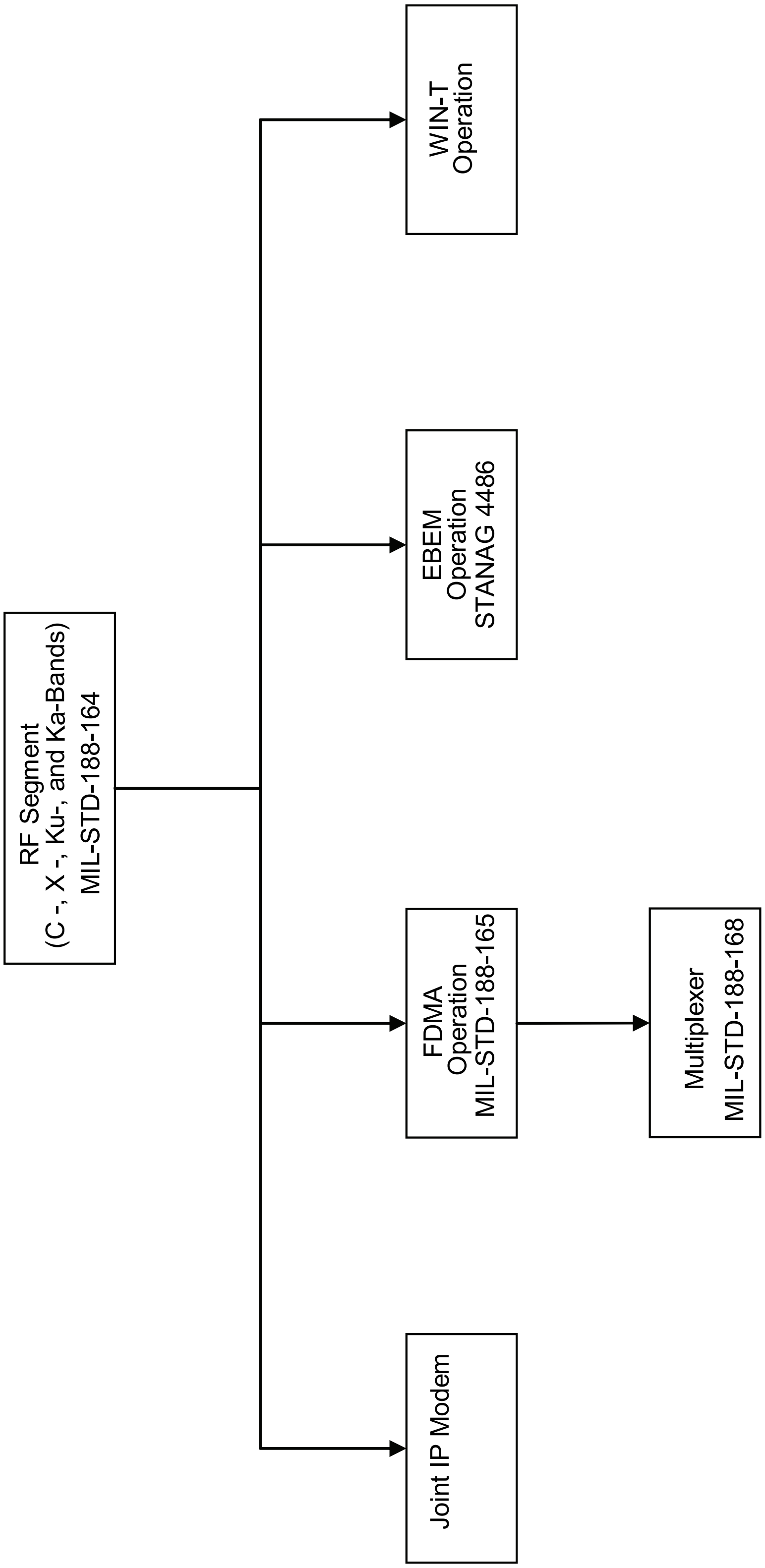
(7) Change to phase noise specification.

(8) Change to thermal noise specification.

(9) Change in extraneous emission specification.

(10) Change to IM product specification.

(11) Addition of control response time.



EBEM - Enhanced bandwidth efficient modem
FDMA - frequency-division multiple access
RF - radio frequency

FIGURE 5. SHF SATCOM standards profile

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TUTORIAL ON RSS THEORY

A.1 Scope. This appendix is not a mandatory part of this standard. The purpose is to impart information.

A.2 RSS theory. The following paragraph on RSS theory was prepared by Per Kullstam in May of 1996.

Root-sum-squares (RSS) is a method of determining the more likely overall variation of a sum $X = \sum x_k$ of components which each may vary. If each component x_k has a mean value m_k, then the mean $M = \sum m_k$ of the sum X and total deviation $X-M = \sum(x_k - m_k) = \sum \Delta x_k$, where $\Delta x_k = x_k - m_k$ denotes the deviation of the x_k component from its mean value. If the component deviations take the values $\pm\Delta x_k$ with equal probability and they are mutually uncorrelated, the sum-of-squares $\sum (\Delta x_k)^2$ is the variance and the root-sum-squares $RSS = \sqrt{[\sum ((\Delta x_k)^2]}$ is the standard deviation of the sum $X = \sum x_k$. Generally, since the various deviations seldom all add, or subtract, the RSS value represents a more likely, and appropriate measure, for the total variation of the sum even if the RSS value cannot be justified on strict probabilistic arguments.

A.3 Antenna gain vs. pointing variations. Since EIRP stability is concerned about the change in EIRP, not the accuracy, the relative difference in pointing accuracy between the receive beam and transmit beam is not considered. Thus, although the degrees off beam of the transmit beam will degrade the EIRP in the direction of the satellite, it is only the change that is of concern for EIRP stability. The formula for attenuation as a function of the pointing error is

$$A(dB) = 12 \ (\beta/\varphi_{3dB})^2$$

A is attenuation (dB)

β is pointing error (degrees)

φ is 3 dB beamwidth (degrees)

As an example: if the transmit beam is offset 0.01 degrees from alignment, then for a 38 foot antenna at 8.4 GHz, the attenuation is 0.025 dB. If because of tracking errors, the transmit beam is now offset by 0.03 degrees, the attenuation is 0.225 dB. Thus, if the tracking system changes the pointing error from 0.01 degrees to 0.03 degrees the EIRP will change by 0.2 dB. For fixed antennas that do not track, this parameter is not used in determining the EIRP stability. The terminal developer is not responsible for changes in gain in the direction of the satellite caused by satellite movement.

CONCLUDING MATERIAL

Custodians:
Army – CR
Navy - EC
Air Force - 02
NSA - NS

Preparing Activity:
DISA – DC1
(Project TCSS-2008-004)

Review Activities:
OASD - IR
Army - AC, MI, PT, TE
Navy - CG, MC, NC, OM
Air Force - 11, 13, 44, 93, 99
DCMA - CM
DIA - DI
DISA -DC5
DoD M&SCO - DMS
NGA - MP
NORAD/USSPACECOM - US
ODUSD (A&T) - SE

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 http://assist.daps.dla.mil.