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MIL-STD-188-164B
CHANGE NOTICE 1
20 July 2016

SUPERSEDING
MIL-STD-188-164B
23 March 2012

DEPARTMENT OF DEFENSE INTERFACE STANDARD

INTEROPERABILITY OF SHF SATELLITE COMMUNICATIONS TERMINALS

AMSC N/A AREA TCSS

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FOREWORD

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

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 Radio Communication 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. Comments, suggestions, and questions on this document should be addressed to DISA, 6910 Cooper Ave., ATTN: IE53, Fort Meade, MD 20755-5496 or emailed to henry.h.tran.civ@mail.mil. Since contact information can change, you may want to verify the currency of this address information by using the ASSIST Online database at https://assist.dla.mil

SUMMARY OF CHANGE 1 MODIFICATIONS

1. Changed 3.3 Antenna tracking to redefine open-loop and closed-loop Antenna Tracking.
2. Changed 3.12 Removed Maximum-linear EIRP and added IF Input definition.
3. Added 3.13 IF Output definition.
4. Changed 4.2.1. Transmit chain alignment to allow for greater design flexibility.
5. Changed 4.2.5. Carrier frequency accuracy and stability to clarify the range of deviation allowed and language to accommodate for arrays.
6. Changed 4.2.12 Transmit thermal noise EIRP to add new requirement applicable for both small and large terminals
7. Changed 4.2.13 Transmit function extraneous outputs to revise the requirement.
8. Changed 4.3.2 Maximum PFD to add new requirement across the entire X and Ka bands.
9. Changed 4.3.12 Antenna pointing loss to refine analysis methodology.
10. Removed APPENDIX C. Sea based system performance requirements will be considered with other on-the-move systems, and do not need a separate category.
11. Added new APPENDIX C. Array based system performance requirements to clarify interoperability requirements for non-reflector based systems.

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1 SCOPE

1.1 Scope. This standard establishes mandatory Radio Frequency/Intermediate Frequency (RF/IF) and associated interface requirements applicable to Satellite Communications (SATCOM) Earth Terminals (ET) operating over military X band and Ka band Super High Frequency (SHF) channels. Military unique requirements for ETs that may operate over commercial C-band, Ku-band, and Ka-band are included. 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. Existing certified SHF SATCOM terminals which predate this revision may not need to conform to this MIL-STD unless they undergo modernization or modifications which alter performance for requirements listed herein.

1.2 Implementation. In accordance with MIL-STD-962, section 4 (General Requirements) addresses requirements that apply to every terminal. Government sponsor program managers may, according to MIL-STD-962 and Department of Defense Manual (DoDM) 4120.24, Defense Standardization Program Procedures, exercise their discretion to tailor those items addressed in section 5 (Detailed Requirements). Government sponsor PMs may, with approval from the Terminal Certification Authority, deviate from the requirements in section 4, and tailor out what is not required from section 5. Special cases of general requirements are addressed in appendices for specific types of terminals. That way, the Terminal Certification Authority can issue a full terminal certification for any terminal that implements section 4 as modified by that specific appendix. In summary, the terminal certification community can authorize a deviation to section 4, while the program office can tailor any section 5 requirement without the need for any terminal certification authority approval. Thus, the program office may instruct the manufacturer to replace the section 4 or 5 paragraph with the appropriate appendix paragraph.

1.3 Document Structure. The main body of this document addresses requirements applicable to all terminals, including stationary and mobile On-The-Move (OTM) terminal types. Appendices are included, and address the unique terminal types, broken into the following categories:

a. Appendix A (Land-Based SATCOM OTM Terminals)

b. Appendix B (Air-Based SATCOM OTM Terminals)

c. Appendix C (Array-Based SATCOM OTM Terminals)

The requirements in these appendices replace specific requirements in the body of the document.

1.4 Request to tailor or deviate from the standard. Government sponsor program managers (PMs) may request tailoring and deviations from this standard in accordance with DoDM 4120.24. PMs shall send requests to the activity listed below:

U.S. Army Space and Missile Defense Command
Army Forces Strategic Command G6
Consolidated Wideband SATCOM System Expert (C-SSE)
350 Vandenberg Street
Peterson AFB, CO 80914-2749

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

To ensure that the terminal will be able to pass terminal certification, prior to approving any tailoring or deviations, the Government sponsor program manager should process a request to tailor or deviate through the terminal certification authorities. The terminal certification authority for the Wideband Global SATCOM (WGS) Communications System is United States Army Space and Missile Defense Command / Army Forces Strategic Command (USASMDC/ARSTRAT). The request should include the mission of the system, the rationale for tailoring or deviating, and both the technical and cost impact if the program is not allowed to tailor or deviate from the standard. USASMDC/ARSTRAT may levy additional certification requirements. Terminal designers/vendors shall coordinate with the certification authority for information related to the specific test requirements. Non-compliant terminals without proper tailoring coordination through the terminal certification authority are acquired at program risk.

1.5 Applicability. These interface and performance specifications are applicable for satellite terminals used to communicate through transponders on the DSCS and the WGS. The military unique requirements for SHF SATCOM terminals that operate over commercial C-band, Ku-band, and Ka-band are applicable when the terminal is used to provide access into the Global Information Grid.

2 APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 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 of documents cited in sections 3, 4, or 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
MIL-STD-188-165	-	Interoperability of SHF Satellite Communications PSK Modems (FDMA Operation)

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

GOVERNMENT SPECIFICATIONS INTERFACE STANDARD

GPS-ICD-060	-	NAVSTAR GPS Interface Control Document

(Copies of this document may be obtained online at http://www.navcen.uscg.gov)

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.

CODE OF FEDERAL REGULATIONS

47 CFR – Part 25	-	Code of Federal Regulations, Title 47, Part 25

(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 documents. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in solicitation or contract.

AMERICAN NATIONAL STANDARD (ANS)

T1.523.2001	-	Telecom Glossary

(Copies of ANS documents may be obtained from ITU online at http://www.itu.int.com)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) INTERNATIONAL

SAE AMS 3198	-	SPONGE, CHLOROPRENE RUBBER, MEDIUM

(Copies of this document may be obtained from SAE online at http://www.standards.ase.org)

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 documents may be obtained from INTELSAT online at http://www.intelsat.com)

INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS (IEEE)

IEEE 802.3	-	CSMA/CD (Ethernet) Access Method

(Copies are available from www.ieee.org or IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08854-4141).

NATO STANDARDS AGREEMENT (STANAG) DOCUMENTS

STANAG 4430	-	Precise Time and Frequency Interface and Its Management for Military Electronic Systems

(Copies of STANAG documents may be obtained from NATO Standardization Agency online at http://www.nato.int)

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 specific exemption has been obtained.

3 DEFINITIONS

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

3.2 Abbreviations and acronyms. The acronyms used in this military standard (MIL-STD) are defined below.

AC	alternating current
AM	amplitude modulation
ANSI	American National Standards Institute
bps	bits per second
CEVD	convolutional encoding and Viterbi decoding
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
DoDM	Department of Defense Manual
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
Gant	antenna gain
GHz	GigaHertz
GSO	Geo-Stationary Orbit
G/T	antenna receive gain to noise temperature
HPA	high-power amplifier
Hz	Hertz
IEEE	Institute of Electrical and Electronic Engineers
IESS	INTELSAT earth station standard
IF	intermediate frequency
INTELSAT	International Telecommunications Satellite Organization
ISO	International Organization for Standardization
ITU-R	International Telecommunications Union Radio Communication Sector
K	kelvin
kHz	kiloHertz

LHCP	left-hand circular polarization
LNA	low-noise amplifier
m2	square meter
Mbps	megabits per second
MHz	MegaHertz
MIL-STD	military standard
NATO	North Atlantic Treaty Organization
PM	phase modulation
Psat	saturated power
Plinear	maximum-linear power
QPSK	quadrature phase shift keying
RF	radio frequency
RHCP	right-hand circular polarization
RMS	root-mean-square
RSS	root-sum-square
Rs	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	SATCOM systems expert
STANAG	standardization agreement (NATO)
Tx	transmit
UAV	unmanned aerial vehicle
VSWR	voltage standing wave ratio
WGS	Wideband Global SATCOM

3.3 Antenna tracking. Earth terminal antenna tracking may be accomplished in either of two ways. In open-loop antenna tracking, the antenna is simply pointed in the direction of the satellite with the aid of positional, navigational and perhaps platform motion data but without the aid of received signal level (RSL) data. Closed-loop antenna tracking may be accomplished with any of the aids used in open-loop antenna tracking, and with the addition of RSL data.

3.4 Earth terminal (ET). The portion of a satellite system that receives and transmits RF signals to and from a satellite. The earth terminal is delimited by the IF interface to the modem and the RF interface including radome (if used). All earth terminal and antenna specifications must be met with radome performance included. For some requirements, modem functionality is included.

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

3.6 EIRP spectral density (ESD). ESD is calculated as EIRP/symbol rate.

3.7 Equivalent Diameter. For non-circular apertures, the equivalent diameter (D_e) may be computed by:

$$D_e = 2\sqrt{A/\pi}$$

Where A = Aperture Area

3.8 Extraneous emissions. Emissions that result from spurious tones, bands of noise, uplink RF harmonics, or other undesirable signals, but exclude intermodulation products.

3.9 G/T. G/T is the receive antenna gain-to-noise temperature (G/T) in dBi/K. Minimum G/T is measured while 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.

3.10 Harmonics. A harmonic is a component frequency of the signal that is an integer multiple of the fundamental frequency.

3.11 Instantaneous bandwidth. The range over which a system's passband amplitude and phase response vs. frequency remains compliant without any tuning, where compliance is governed by the transmit phase linearity, transmit amplitude response, receive phase linearity, and receive amplitude response sections in this standard.

3.12 IF Input. The first point of physical connection after the modulator output.

3.13 IF Output. The last point of physical connection before the demodulator input.

3.14 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 the subparagraphs below:

3.14.1 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.

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

3.15 Antenna Pointing. The action taken by the antenna control system to command the antenna's electrical boresight to a certain vector regardless of the antenna control system's method of determining the vector.

3.16 Antenna Pointing loss. The antenna gain decrease due to the angular difference between the antenna boresight gain vector and the intended satellite target vector.

3.17 Reception function. The reception function receives RF signals from a satellite, provides low-noise amplification, and downconverts the RF signal to an IF signal. The reception function includes all the equipment from the RF input (including radome if used) to the IF output.

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

3.19 Saturated power. The single-carrier output power level of an active device where the input power change to output power change ratio is 10:1.

3.20 Transmission function. The transmission function up-converts the IF signal to a RF signal, amplifies the RF signal, and transmits the RF signal to a satellite. The transmission function includes all the equipment from the IF input to the RF output, including radome (if used).

4 GENERAL REQUIREMENTS

4.1 General. Unless a specific band is identified in a paragraph, each paragraph in this section applies to all bands of operation.

4.2 Transmission function. The transmission function shall perform in accordance with 4.2.1 through 4.2.19.

4.2.1 Transmit chain alignment. Separate transmit alignment and power control functions shall be provided for the purpose of TX chain gain alignment and operational EIRP control, respectively. These functions shall be independently controlled, either in hardware (physically separate functions) or in software (independent user inputs). With a single 0 dBm signal applied to any IF input, the transmit chain gain shall be sufficient to achieve maximum linear power as referenced to the antenna feed.

4.2.2 RF frequency bands. The transmission function shall be tunable in one or more of the SHF frequency bands listed in TABLE I.

TABLE I. Transmit uplink allocated 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

4.2.3 Tuning. The upconversion function shall be tunable in 1 kHz increments, in conjunction with the modem, starting at the lowest frequency for each band, as listed in TABLE I. The instantaneous bandwidth shall be available at any tuned uplink frequency in 4.2.2, as long as the instantaneous bandwidth does not extend beyond the band edges.

4.2.4 EIRP stability. For any setting of the transmit gain (see 5.6.1) and a constant IF input level, the EIRP in the direction of the satellite shall not vary more than 2.5 dB peak to peak 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 due to pointing losses. See 6.6 through 6.8 for RSS theory and determination of power variations due to pointing losses.

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

where,

P_1 = transmit function output power level instability in dB

P_2 = uplink power variations, in dB, in the direction of the satellite caused by pointing losses as described in 4.3.12 and 6.8

This does not include adverse weather conditions or any other effects not controlled by the ET. For dual-band simultaneous operation, the variable P_2 shall be evaluated in the highest operational RF band.

4.2.5 Carrier frequency accuracy and stability. The radiated carrier frequency accuracy shall be within 1-kHz of the intended value for all RF carriers. The radiated carrier frequency accuracy shall be maintained for a 90-day period or more without recalibration.

4.2.6 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 be sufficient to attenuate the signal from maximum linear EIRP to 60 dBm as given by the following equation:

$$\text{Min Range (dB)} = \text{Maximum-linear EIRP (dBm)} - 60\ \text{(dBm)}$$

The power control range can be met using the combination of the terminal and modem power adjustment. 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).

4.2.7 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 the following:

a. ± 0.2 radians or less over any 2 MHz of instantaneous bandwidth.

b. ± 0.4 radians over any 36 MHz of instantaneous bandwidth

c. ± 0.5 radians over any 72 MHz of instantaneous bandwidth

d. ± 0.6 radians over any 90 MHz of instantaneous bandwidth

e. ± 0.7 radians over any 120 MHz of instantaneous bandwidth

4.2.8 Transmit amplitude response. Amplitude variations of the transmission (uplink) function when operating at the maximum-linear power, shall not exceed the following:

a. ±0.5 dB over any 10 MHz segment across the instantaneous bandwidth

b. ± 1.5 dB over any 120 MHz segment, or smaller segment across the instantaneous bandwidth (10 MHz < segment < 120 MHz)

c. ± 2.0 dB for each output frequency band listed in TABLE I

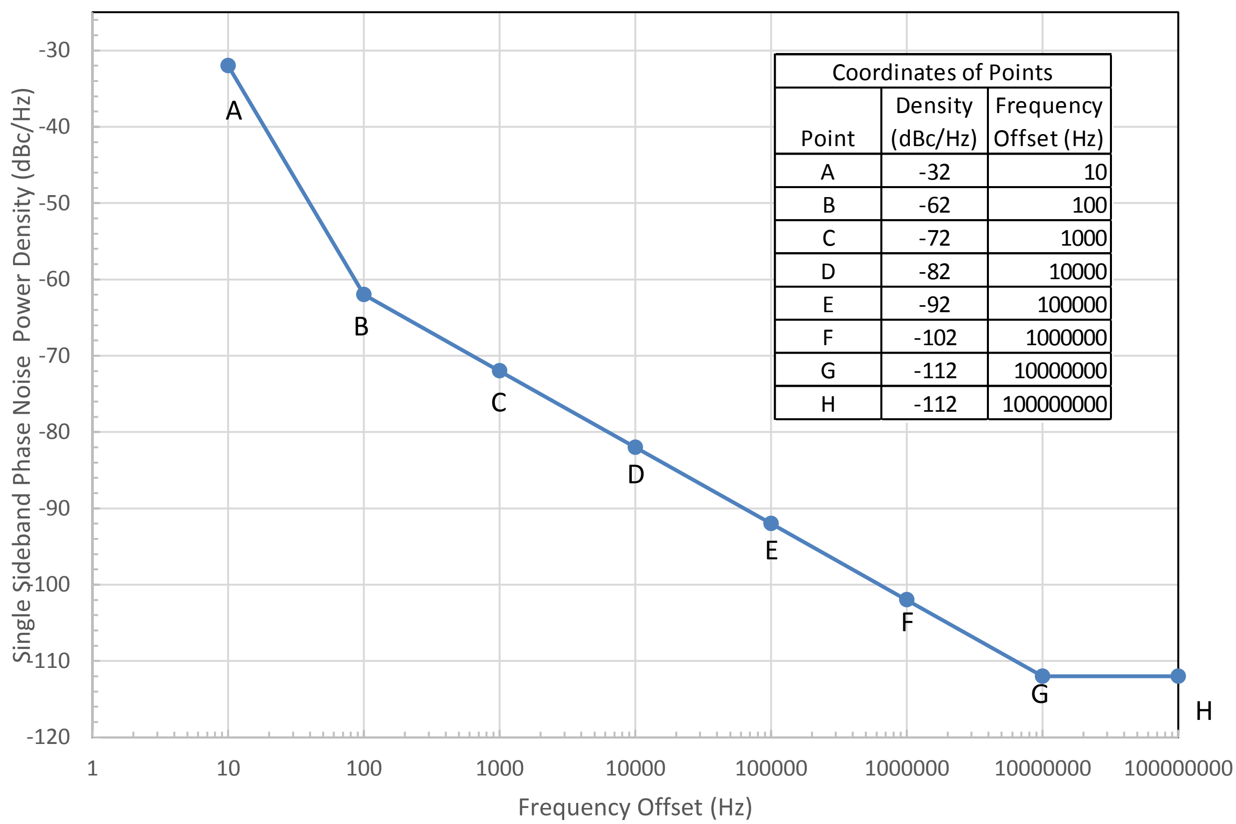
(NOTE: This may be exceeded if the terminal meets all implementation loss requirements mandated by the appropriate satellite communications systems expert (SSE).

4.2.9 AC power line. The sum of the fundamental and all harmonic components of the alternating current (AC) line frequency shall not exceed -30 dBc.

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

4.2.11 Phase noise. The single sideband power spectral density of the continuous phase noise component shall comply with the envelope defined in FIGURE 1. If specific points associated with the measured phase noise plot exceed the FIGURE 1 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).



Coordinates of Points		
Point	Density (dBc/Hz)	Frequency Offset (Hz)
A	-32	10
B	-62	100
C	-72	1000
D	-82	10000
E	-92	100000
F	-102	1000000
G	-112	10000000
H	-112	100000000

FIGURE 1. Terminal phase noise.

b. The single sideband phase noise due to the continuous component, when integrated over the bandwidth from 1% of the symbol rate (R_s) to R_s Hertz relative to carrier center frequency, shall be less than the value obtained when integrating the FIGURE 1 plot over the same limits. This requirement shall be verified at the lowest and highest symbol rates. This requirement applies to all operational R_s.

4.2.12 Transmit thermal noise EIRP. With the IF input terminated, the transmit function aligned according to 4.2.1, and power control set to achieve maximum linear power, the transmit thermal noise spectral density shall not exceed -75 dBm/Hz when measured at the antenna feed

4.2.13 Transmission function extraneous outputs. With the transmission equipment aligned and a CW signal applied to the IF input such that maximum linear power is achieved, or with the array configured to radiate maximum linear power and a CW signal applied to the IF input:

a. Transmit Band: Extraneous emissions as measured over any 10-kHz bandwidth shall not exceed -60 dBc, when measured at the feed. This requirement excludes a 2-MHz band centered on the carrier.

b. Non-Transmit Band: -60 dBc except for the band 31.0GHz $\leq f \leq$ 33.0GHz which shall not be greater than -45 dBc at 31.0GHz and decrease linearly to -60 dBc by 33.0GHz.

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

4.2.15 Transmit-to-receive isolation. Transmit-to-receive isolation shall be such that there is less than 0.1 dB increase 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.

TABLE II. Downlink frequency band.

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

4.2.16 Intermodulation products in the receive band. For all receive frequency bands of operation, the intermodulation products appearing at the low-noise amplifier (LNA) input or the arrays output 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 with the power in each carrier at 3 dB below maximum linear EIRP. This requirement applies to ETs supporting multiple communication carrier transmissions.

4.2.17 Transmit spectrum inversion. No spectral inversion shall exist between any IF input and the antenna output for ETs operating with non-embedded modems. Terminals with embedded modems shall be interoperable with terminals that do not have embedded modems.

4.2.18 Input Impedance. The input impedance shall be 50 ohms or 75 ohms, as needed, with a VSWR less than 1.5:1 over the specified bandwidth.

4.2.19 Transmit IF 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 in 4.2.7 and the amplitude response requirements in 4.2.8:

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

4.3 Reception function. The reception function shall be in accordance with 4.3.1 through 4.3.13.

4.3.1 RF frequency bands. The down-conversion function shall be tunable in one or more of the SHF frequency bands listed in TABLE II.

4.3.2 Maximum power flux densities. All reception functions shall be met with the maximum power-flux densities as follows:

4.3.2.1 <u>X-band.</u>

a. -142 dBW / m^2 in any 4 kHz band in any single carrier

b. -95 dBW / m^2 across the entire 500 MHz band

4.3.2.2 Military Ka-band.

a. -112 dBW / m^2 in any 1 MHz band in any single carrier

b. -90 dBW / m^2 across the entire 1 GHz band

4.3.3 Receive chain gain, linearity and IF interface characteristics. The receive chain (antenna feed output interface to terminal IF interface) shall exhibit the following characteristics:

a. The post LNA contribution to the system noise temperature shall not exceed 0.2 dB.

b. The receive chain absolute gain shall be sufficient to raise the IF output noise power spectral density, when pointing to a cold sky away from a geosynchronous satellite at an elevation angle of not less than 30 degrees, to a minimum of -103 dBm/Hz.

c. An IF output level adjustment of at least 20 dB in steps of 1 dB or less shall be provided.

d. With two equal-power modulated carriers, with a combined level equivalent to that from the antenna when receiving the maximum power flux density at the receive chain input, any third order intermodulation product power spectral density (PSD) at the IF output shall be at least 10 dB below the noise floor PSD.

e. 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.

4.3.4 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 II. The instantaneous bandwidth shall be available at any tuned downlink frequency in 4.3.1, as long as the instantaneous bandwidth does not extend beyond the band edges identified in 4.3.1.

4.3.5 Receive conversion frequency accuracy. The down-conversion frequency accuracy shall be within 1 kHz of the intended value for all received RF carriers. Down-conversion frequency accuracy shall be maintained for a 90 day period or more without recalibration.

4.3.6 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. ±0.2 radians over any 2 MHz segment across the instantaneous bandwidth

b. ±0.4 radians over any 36 MHz segment across the instantaneous bandwidth

c. ±0.5 radians over any 72 MHz segment across the instantaneous bandwidth

d. ±0.6 radians over any 90 MHz segment across the instantaneous bandwidth

e. ±0.7 radians over any 120 MHz segment across the instantaneous bandwidth

4.3.7 Receive amplitude response. Amplitude variations as measured at the terminal IF output (demodulator input) shall not exceed the following:

a. ±0.5 dB over any 10 MHz segment across the instantaneous bandwidth

b. ±1.5 dB over any 120 MHz segment or smaller segment across the instantaneous bandwidth (10 MHz $<$ segment $<$ 120 MHz)

c. ±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 SSE.)

4.3.8 Receive phase noise. The receive function shall meet phase noise requirements as defined in 4.3.9 through 4.2.11.

4.3.9 Receive spurious output. The sum total of spurious signal power (includes phase noise) measured at the IF output shall be at least 20 dB below the thermal noise power measured in the instantaneous bandwidth supported by the IF. No one spurious signal shall exceed -60 dBc. The requirements of this paragraph shall be met under the following simultaneous conditions:

a. Transmitting a single carrier at maximum-linear power

b. Receiving one carrier at the maximum input signal level to the LNA

(NOTE: The ET procurement documents will define the maximum input signal level and narrowest bandwidth of interest.)

4.3.10 Receive spectrum inversions. No spectral inversion shall exist between any RF input and the IF output of the terminal.

4.3.11 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.

4.3.12 Antenna pointing loss. The downlink loss due to antenna pointing error shall not exceed 0.8 dB 99.7% of the time. The loss shall be translated to the appropriate uplink loss in accordance with 6.8, and shall be used as the P_2 (power variations in the direction of the satellite caused by pointing losses) RSS contribution to the EIRP stability and accuracy specification in 4.2.4. This requirement shall be met in clear sky, calm wind conditions.

4.3.13 Receive IF frequency. An IF output interface centered at one or more of the following frequencies shall be provided, where the ± amounts represent the instantaneous bandwidths that are consistent with the phase linearity requirements in 4.3.6 and the amplitude response requirements in 4.3.7:

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

4.4 Military Ka-band Antenna Requirements.

4.4.1 Antenna sidelobe levels and transmit EIRP Spectral Density (ESD). The antenna sidelobe and ESD requirements are described in 4.4.1.1 and 4.4.1.2 (below):

4.4.1.1 $D_e/\lambda \geq 50$. The gain of the antenna in the Geo-Stationary Orbit (GSO) plane, including radome effects, shall be such that at least 90% of the sidelobe peaks do not exceed the mask given below. No individual peak shall exceed the mask by more than 3 dB.

a. $G(\theta)$ = 29-25 log10 θ (dBi) for 1° or 100 λ/D_e °
(whichever is larger, up to 2°) $\leq \theta <$ 20°

b. $G(\theta)$ = -3.5 (dBi) for 20° $\leq \theta \leq$ 26.3°

c. $G(\theta)$ = 32-25 log10 θ (dBi), for 26.3° $< \theta <$ 48°

d. $G(\theta)$ = -10 (dBi), for 48° $\leq \theta \leq$ 180°

where

G = gain relative to an isotropic antenna

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

D_e = equivalent antenna diameter, and

λ = wavelength (same units as De, computed from 31.0 GHz as reference frequency)

4.4.1.2 EIRP Spectral Density (ESD). For all terminals, ESD in the GSO plane shall not exceed the following:

a. $ESD(\theta)$ = -6.4 – 25 log10 θ (dBW/Hz) for 2.0° $\leq \theta <$ 20.0°

b. $ESD(\theta)$ = -38.9 (dBW/Hz) for 20.0° $\leq \theta \leq$ 26.3°

c. $ESD(\theta)$ = -3.4 – 25 log10 θ (dBW/Hz) for 26.3° $< \theta <$ 48.0°

d. $ESD(\theta)$ = -45.4 (dBW/Hz) for 48° $\leq \theta \leq$ 180°

where symbols are defined above.

The ESD requirement shall be met while incorporating transmit RMS pointing errors. FIGURE 2 below illustrates the ESD mask defined by the above parameters:

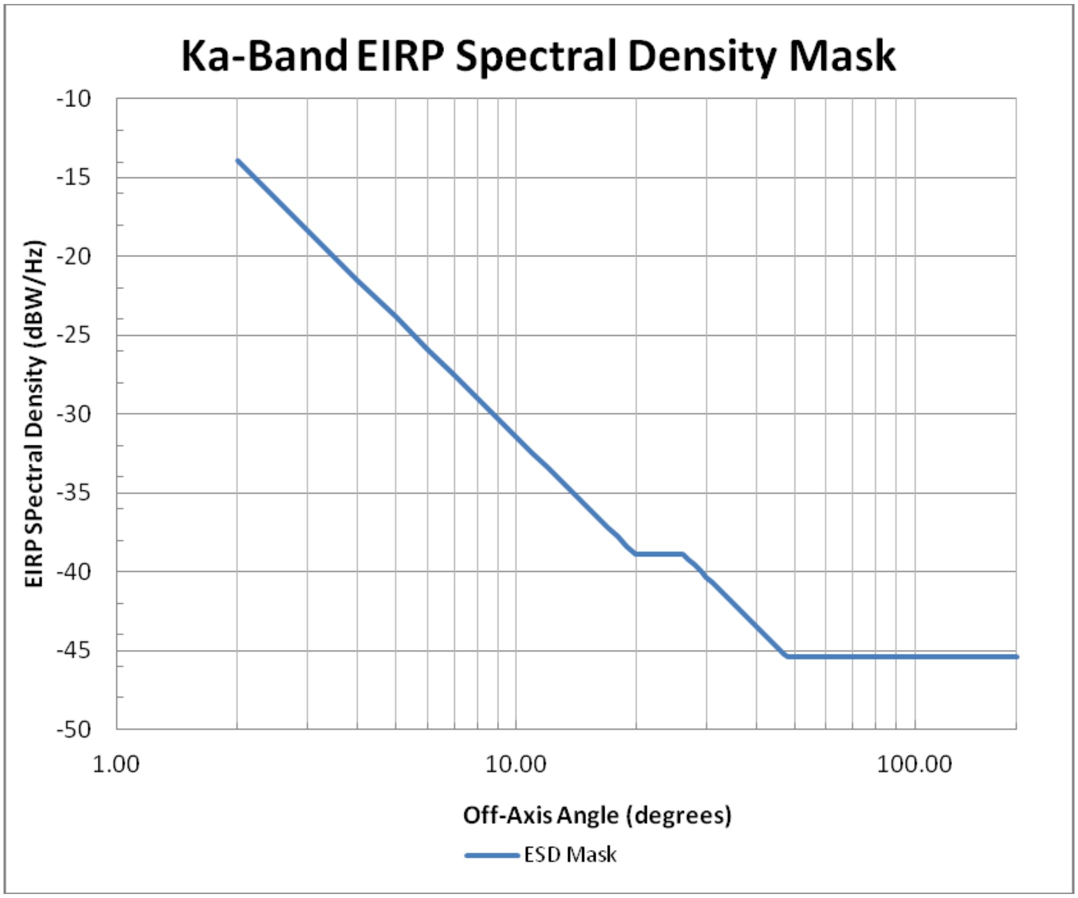


FIGURE 2. Ka-Band EIRP spectral density mask.

4.4.2 Antenna polarization, transmit. The antenna shall be capable of transmitting right-hand (clockwise) circular polarization (RHCP) and left-hand (counterclockwise) circular polarization (LHCP). However, military Ka-band terminals do not have to operate simultaneously with right-hand and left-hand circular polarizations.

4.4.3 Antenna axial ratio, transmit. The military Ka band transmit axial ratio shall be no greater than 1.0 dB.

4.4.4 Antenna polarization, downlink, receive. 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.

4.4.5 Antenna axial ratio, receive. The military Ka-band receive axial ratio shall be no greater than 1.5 dB.

4.5 Military X-band antenna requirements.

4.5.1 Antenna sidelobe levels and transmit EIRP Spectral Density (ESD). The antenna sidelobe and ESD requirements are described in 4.5.1.1 and 4.5.1.2 (below):

4.5.1.1 $D_e/\lambda \geq 50$. The gain of the antenna in the GSO plane, including radome effects, shall be such that at least 90% of the sidelobe peaks do not exceed the mask given below. No individual peak shall exceed the mask by more than 3 dB.

a. $G(\theta) = 29\text{-}25 \log10 \theta$ (dBi) for 1° or 100 λ/D_e ° (whichever is larger, up to 2°) $\leq \theta < 20°$

b. $G(\theta) = -3.5$ (dBi) for $20° \leq \theta \leq 26.3°$

c. $G(\theta) = 32\text{-}25 \log10 \theta$ (dBi), for $26.3° < \theta < 48°$

d. $G(\theta) = -10$ (dBi), for $48° \leq \theta \leq 180°$

where,

G = gain relative to an isotropic antenna

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

De = equivalent antenna diameter, and

λ = wavelength (same units as De, computed from 8400 MHz as reference frequency)

4.5.1.2 EIRP Spectral Density (ESD). For all terminals, ESD in the GSO plane shall not exceed the following:

a. $ESD(\theta) = 2.351 – 25 \log10 \theta$ (dBW/Hz) for $2.0° \leq \theta < 3.8°$

b. $ESD(\theta) = -13.0$ (dBW/Hz) for θ 3.8°

c. $ESD(\theta) = 1.49 – 25 \log10 \theta$ (dBW/Hz) for $3.8° < \theta < 5.0°$

d. $ESD(\theta) = -3.97 – 25 \log10 \theta$ (dBW/Hz) for $5.0° \leq \theta < 6.94°$

e. $ESD(\theta) = -25.0$ (dBW/Hz) for $6.94° \leq \theta \leq 12.42°$

f. $ESD(\theta) =2.35 – 25 \log10 \theta$ (dBW/Hz) for $12.42° < \theta < 48.0°$

g. $ESD(\theta) = -39.65$ (dBW/Hz) for $48° \leq \theta \leq 180°$

where symbols are defined above.

The ESD requirement shall be met while incorporating transmit RMS pointing errors. FIGURE 3 below illustrates the mask defined by the above parameters:

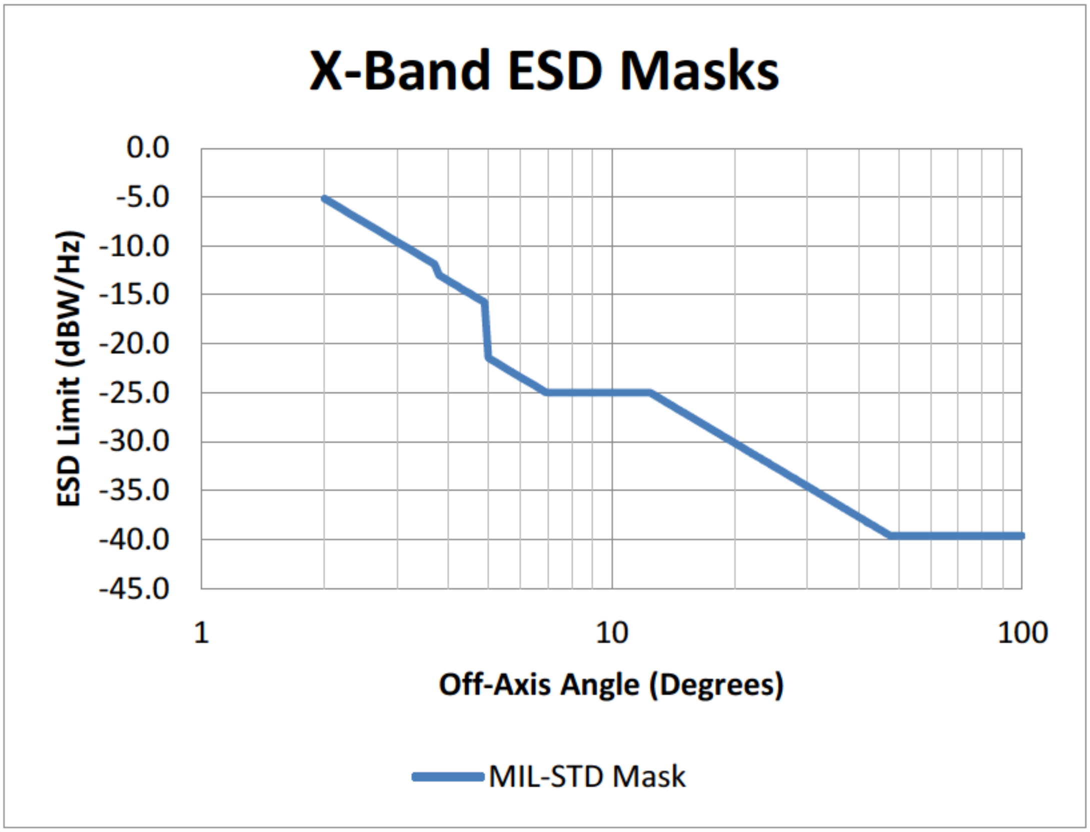


FIGURE 3. X-Band EIRP spectral density mask.

4.5.2 Antenna polarization, transmitting. The antenna shall be capable of transmitting right-hand (clockwise) circular polarization (RHCP).

4.5.3 Antenna axial ratio, transmit. The axial ratio for X-band circularly polarized beams shall be no greater than 2.0 dB over the transmit band.

4.5.4 Antenna polarization, downlink (receive). The antennas for all X-band terminal types shall be capable of receiving left-hand (counter-clockwise) circular polarization (LHCP).

4.5.5 Antenna axial ratio, receive. The X-band receive axial ratio shall be no greater than 2.0 dB.

4.6 Frequency references. If a terminal is capable of accepting an external frequency reference, the terminal shall accept at least one of the following: an external MIL-STD-188-115 5 MHz frequency reference or an external MIL-STD-188-115 10 MHz frequency reference.

4.6.1 Global Positioning System Disciplined Oscillator. For an external frequency reference that is global positioning system (GPS) dependent, such as a GPS Disciplined Oscillator (GPSDO), the following requirements shall apply.

4.6.1.1 External time code input. The GPSDO shall be an approved Selective Availability Anti- Spoofing Module SAASM receiver, or have the ability for an external time code input (i.e.

a Defense Advanced GPS Receiver (DAGR) in accordance with GPS-ICD-060 or STANAG 4430. The external input shall include 1PPS, 56 bit/sec Time of Day, and have Quick Time code.

4.6.1.2 Frequency stability. The Long Term final RF frequency stability drift (when using a GPSDO) shall not be greater than 1 kHz in a 90 day period without calibration and without GPS aided signal (GPS Antenna disconnected). The Long Term frequency stability drift shall not be greater than 1 kHz in a 90 day period when the GPS aided signal is active.

4.6.1.3 Allan deviation. The stability of the 10 MHz or 5 MHz reference source shall have the following Allan Deviation under the following conditions:

a. t=1 second <1.5E-11

b. t=10 second <1.5E-11

c. t=100 second <1.5E-11

d. t=1000 second <1.5E-11

These Allan Deviation values shall be met with and without GPS aided signal.

4.6.1.4 GPS receiver cold start. On initial GPS receiver turn on (cold start) with the GPS antenna disconnected; then connected antenna within 1 hour.

Connect the antenna and allow the GPS receiver to warm up for at least 1 hour, then re-measure the stability of the external frequency reference that is global positioning system dependent.

4.6.1.5 Vibration and shock. Under full vibration, temperature shock, and shock caused by hammer impact (see 5.5).

4.7 System implementation loss. Total implementation loss shall be less than 2.0 dB for all modem operational parameters measured when operating in satellite loopback. The reference used to determine implementation loss is the theoretical modem E_b/N_0 performance using a MIL-STD-188-165 certified modem with quadrature phase shift keying (QPSK) rate ½ convolutional encoding and Viterbi decoding (CEVD) with randomizer and differential encoding/decoding on. Implementation loss includes the effects of traversing the terminal uplink and downlink equipment as well as the satellite. This shall be tested at low, mid, and high operational data rates.

5 DETAILED REQUIREMENTS

5.1 General. The paragraphs in this section apply to the specific terminals referenced in the standard.

5.2 C-band antennas.

5.2.1 Antenna sidelobe levels, transmit. The terminal antenna and RF performance shall be in accordance with the mandatory requirements of IESS-601 or the performance standards established in 47 CFR – Part 25, as appropriate for the anticipated class of terminal operation.

5.2.2 Antenna polarization, transmit. The antennas 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. The ET linear feed shall be adjustable to match the satellite polarization angle to within 1 degree (clear sky).

5.2.3 Axial ratio, circular polarization, transmit. The axial ratio applies to all directions within the cone defined by the antenna pointing errors that correspond to the appropriate pointing loss requirement (see IESS-601, transmit and receive axial ratio section).

5.2.3.1 Circular polarized 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).

5.2.3.2 Circular polarized 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).

5.2.3.3 Linear polarized 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).

5.2.3.4 Linear polarized 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).

5.2.4 Maximum C-band receive PFD. The ET reception function shall conform to the following requirements when the maximum power flux density is as follows (see 47 CFR, Chapter 1, Subchapter B, Part 25, Subpart C, 25.208 Power flux density limits):

a. -152.0 dBW/m^2 in any 4-kHz band where $0° \leq \theta \leq 5°$

b. -149.5 dBW/m^2 in any 4-kHz band where $5° < \theta \leq 25°$

c. -142.0 dBW/m^2 in any 4-kHz band where $25° < \theta \leq 90°$

Theta (θ) is equal to elevation angle of the earth terminal.

5.2.5 Antenna polarization, receive. The downlink antennas shall be able to receive linear (horizontal and vertical) and circular (right-hand and left-hand) polarization simultaneously. The ET linear feed(s) shall be adjustable to match the satellite polarization angle to within 1 degree (clear sky).

5.2.5.1 Antenna axial ratio. Receive ET antennas shall comply with the axial ratio requirements in 5.2.3.

5.3 Commercial Ka-band antennas.

5.3.1 Antenna sidelobe levels. The terminal antenna and RF performance shall be in accordance with the mandatory requirements established in 47 CFR – Part 25, as appropriate for the anticipated class of terminal operation.

5.3.2 Antenna polarization, transmit. The antenna shall be able to transmit linear (horizontal and vertical) and circular (right-hand and left-hand) polarization; however, the antenna shall not be required to transmit linear and circular polarizations at the same time. The ET linear feed shall be adjustable to match the satellite polarization angle to within 1 degree (clear sky).

5.3.3 Antenna axial ratio. There are no military unique requirements for commercial Ka-band antennas.

5.3.4 Maximum Commercial Ka-band receive PFD. The ET reception function shall conform to the following requirements when the maximum power flux density is -115 dBW/m^2 in any 1 MHz band.

5.3.4.1 Antenna polarization. The downlink antenna shall be able to receive linear (vertical and horizontal) and circular (right-hand and left-hand) simultaneously. The earth terminal shall be capable of matching the satellite polarization angle to within 1 degree (clear sky).

5.3.4.2 Antenna axial ratio. There are no military unique requirements for commercial Ka-band antennas.

5.4 Commercial Ku-band antennas.

5.4.1 Antenna sidelobe levels, transmit. The terminal antenna and RF performance shall be in accordance with the mandatory requirements of IESS-601 or the performance standards established in 47 CFR – Part 25, as appropriate for the anticipated class of terminal operation.

5.4.2 Antenna polarization, transmit. The antenna shall be able to transmit horizontal linear and vertical linear polarizations; one polarization at a time. The ET feed(s) shall be adjustable to match the satellite polarization angle to within 1 degree (clear sky).

5.4.3 Antenna axial ratio, transmit. The axial ratio of transmission for linearly polarized beams shall be as described below:

5.4.3.1 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).

5.4.3.2 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).

5.4.4 Maximum Ku-band receive PFD. The ET reception function shall conform to the following paragraphs when the maximum power flux density is as follows (see 47 CFR, Chapter 1, Subchapter B, Part 25, Subpart C, 25.208 Power flux density limits):

a. -150.0 dBW/m^2 in any 4 kHz band where $0^\circ \leq \theta \leq 5^\circ$

b. -147.5 dBW/m^2 in any 4 kHz band where $5^\circ < \theta \leq 25^\circ$

c. -140.0 dBW/m^2 in any 4 kHz band where $25^\circ < \theta \leq 90^\circ$

5.4.4.1 Antenna polarization, downlink, receive. The antenna shall be able to receive horizontal linear and vertical linear polarizations; however, is not required to support simultaneous polarizations. The ET shall be adjustable to match the satellite polarization angle to within 1 degree (clear sky).

5.4.4.2 Antenna axial ratio. Receive ET antennas shall comply with the axial ratio requirements in 5.3.3.

5.5 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, and the receive function shall not change the linear phase of the input RF signal by more than 20 degrees in 0.2 seconds, for each of the following conditions:

a. Exposure to temperature shock from a nominal 23 ºC. The temperature range shall include the lowest and highest transmission function operating temperatures. Temperature rate of change between extremes shall be 22 ºC 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.

5.6 ET control and monitoring function. The ET shall meet the following requirements:

5.6.1 Control and monitoring parameters. As a minimum, remote and local Control, Monitor, and Alarm (CMA) shall be provided in accordance with TABLE III. 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.

5.6.1.1 Transmit gain. The transmit gain, as computed, shall be within ± 2 dB of actual gain, neglecting any frequency dependencies in accordance with 4.2.8. 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.

5.6.1.2 Receive gain. 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 down-conversion function and (2) the down-conversion function gain.

5.6.2 Control response times. The ET shall meet a response time of 0.5 second for all parameters in TABLE III.

5.6.3 ET remote control and monitoring interface. This interface shall be implemented as an IEEE 802.3 compliant Ethernet. The interface protocol shall be via the industry standard simple network management protocol (SNMP).

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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).

TABLE III. 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 upconversion function	Frequency setting of each down-conversion 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 down-conversion function output
	Receive gain setting of each down-conversion 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. This standard is intended to define the military SHF SATCOM earth terminal interfaces in terms of physical and functional performance criteria necessary to support program managers and buying activities in the acquisition 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 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) can specify which of the requirements in section 5 of this standard apply, and should state exclusion to any non-applicable requirements (for example, environmental requirements). Specific values are modified within the appendices to address specific terminal types. It is highly recommended that any exclusions are coordinated with the appropriate terminal certification authority to avoid any issues during terminal performance certification.

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

C-band
Defense Satellite Communications System (DSCS)
Ka-band, commercial
Ka-band, military
Ku-band
SATCOM
Wideband Global SATCOM (WGS)
X-band

6.5 International standardization agreement implementation. This standard implements STANAG 4484 (Edition 3), Overall SHF 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 https://assist.dla.mil.

6.6 RSS Theory. 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.

6.7 Antenna gain vs. pointing variations. Since the degrees off beam of the uplink beam will degrade the EIRP in the direction of the satellite, it is this change that is of concern for EIRP stability. The formula for attenuation as a function of the pointing error is as follows:

$$A(dB) = 12(\frac{\beta}{\varphi})^2$$

A is attenuation (dB).

β is uplink pointing error (degrees).

φ is 3 dB beamwidth (degrees).

6.7.1 Example. If the uplink beam is offset 0.01 degrees from alignment, then for a 38-foot (11.5824 meter) antenna at 8.4 GHz with φ at 0.219089023 degrees, the attenuation is 0.025 dB. If because of pointing errors, the uplink beam is now offset by 0.03 degrees, the attenuation is 0.225 dB. Thus, if the control system changes the pointing error from 0.01 degrees to 0.03 degrees, the EIRP will change by 0.2 dB. It is this change that must be accounted for in the RSS equation.

6.7.2 Satellite motion. It is important to note that satellite motion can also impact this loss. Terminal design must account for EIRP errors due to satellite motion regardless of whether the terminal has a pointing control system or not.

6.8 Accounting for pointing loss differences between uplink and downlink beams. Since the beamwidth is a function of the frequency used, and because pointing loss is determined by measuring variations in the downlink satellite beacon, the actual uplink loss will differ from the downlink loss. At X-band frequencies, the frequency separation is relatively small, and the difference between uplink and downlink pointing losses is negligible. However, at Ka-band frequencies, the 10 GHz separation between uplink and downlink can cause significant differences. For the purposes of EIRP stability, the uplink pointing loss will be greater than the downlink pointing loss, and will therefore be used in the RSS equation in 4.2.4. Unless otherwise specified, the equation for calculating the uplink pointing loss based on the measured downlink loss is as follows:

a. $L_{up} = L_{down}(\frac{F_{up}}{F_{down}})^2$

b. L_{up} = pointing loss on the uplink at the given frequency in dB

c. L_{down} = pointing loss on the downlink at the given frequency dB

d. F_{up} = highest operational uplink frequency

e. F_{down} = frequency of the downlink beacon

6.8.1 Exceptions. Should the uplink and downlink beams be significantly misaligned, or should they originate from different apertures, the above equation does not apply. In such a case, the individual beams will need to be compared to determine the uplink loss corresponding to a downlink loss due to mispointing. This shall be accomplished by converting the downlink pointing loss from 4.3.12 into a pointing error based on the receive (downlink) beam pattern. Assuming the transmit (uplink) and receive (downlink) beam pointing is coupled, this receive pointing error is then applied to the transmit (uplink) beam to determine the transmit pointing loss to be used in 4.2.4. For terminals with asymmetric beam shapes, these calculations shall be done at the worst case operational orientation of the beams.

6.8.2 Example. On WGS, the downlink Ka-band beacon is at 20.7 GHz while the uplink frequencies range between 30 and 31 GHz. Using these numbers along with a hypothetical circular center-fed terminal having a measured downlink loss of 1.0 dB gives an uplink loss of between 2.1 dB and 2.24 dB. In this case, the worst case uplink frequency loss of 2.24 dB would be utilized as the P_2 loss component for calculating total EIRP stability (see 4.2.4).

6.8.3 Multiband considerations. Also, it can be seen from the equation that the closer the downlink frequency is to the uplink frequency, the closer the uplink and downlink losses will be. Therefore, simultaneous multiband terminals must always use the highest operational beacon signal for tracking purposes.

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

APPENDIX A

LAND-BASED SATELLITE COMMUNICATIONS ON-THE-MOVE (SATCOM OTM)

A.1 Scope. This appendix applies to land-based SATCOM systems that operate while on-the-move. This Appendix is a mandatory part of the standard. The information contained herein is intended for compliance. The information contained herein may replace specific requirements in the body of the standard (see 1.1).

A.2 Uplink Inhibit. On-the-move terminals shall immediately inhibit transmission upon loss of downlink signal.

A.3 Antenna pointing loss. The entire text of 4.3.12 (Antenna pointing loss) shall be replaced with the following:

"**4.3.12 Antenna pointing loss.** The downlink loss due to antenna pointing error shall not exceed 0.8 dB 95.4% of the time. The loss shall be translated to the appropriate uplink loss in accordance with paragraph 6.9, and shall be used as the P_2 (power variations in the direction of the satellite caused by pointing losses) RSS contribution to the EIRP stability and accuracy specification in 4.2.4. The antenna pointing loss requirement is applicable to a blockage-free environment and does not include any timeframe when the antenna system supports a non-operating mode by design (for example, non-operating due to safety considerations)."

APPENDIX B

AIR-BASED SATCOM OTM

B.1 Scope. This appendix applies to air-based SATCOM systems that operate while on-the-move. This Appendix is a mandatory part of the standard. The information contained herein is intended for compliance. The information contained herein may replace specific requirements in the body of the standard (see 1.1).

B.2 EIRP stability and accuracy. The following replaces 4.2.4 (EIRP stability and accuracy) when a terminal's modulated signal occupies the entire bandwidth of the transponder.

"**4.2.4 EIRP stability.** 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 3.5 dB peak to peak in any 24-hour period. This tolerance, added on an RSS basis, includes all ET factors contributing to the EIRP variation, including output power level instability (including radome insertion loss variations with look angle) and power variations due to pointing losses. See 6.6 through 6.8 for RSS theory and determination of power variations due to pointing losses.

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

where,

P_1 = Transmit function output power level instability in dB

P_2 = Uplink power variations in the direction of the satellite caused by pointing losses

This does not include adverse weather conditions or any other effects not controlled by the ET. For dual-band simultaneous operation, the variable P_2 shall be evaluated in the highest operational RF band."

B.3 Carrier frequency accuracy. The following replaces 4.2.5 (Carrier frequency accuracy and stability).

"**4.2.5 Carrier frequency accuracy and stability.** The carrier frequency at the antenna feed shall be within 1 kHz of the intended value. The carrier frequency accuracy shall be maintained for the maximum mission duration without calibration."

B.4 Receive conversion frequency accuracy. The following replaces 4.3.5 (Receive conversion frequency accuracy).

"**4.3.5 Receive conversion frequency accuracy.** The down conversion frequency accuracy shall be within 1 kHz of the intended value for all received carriers. Down conversion frequency accuracy shall be maintained for the maximum mission duration without calibration.

B.5 Antenna pointing loss. 4.3.12 (Antenna pointing loss) shall be replaced with the following:

APPENDIX B

"**4.3.12 Antenna pointing loss.** The downlink loss due to antenna pointing error shall not exceed 0.8 dB 95.4% of the time. The loss shall be translated to the appropriate uplink loss in accordance with 6.9, and used as the P_2 (power variations in the direction of the satellite caused by pointing losses) RSS contribution to the EIRP stability and accuracy specification in 4.2.4. This requirement shall be met in clear sky, calm wind conditions, operational flight conditions, with no airframe blockage or keyhole events. A mechanism shall be provided to inhibit transmission in the event the antenna transmit pointing error causes the off axis ESD limit to be exceeded."

APPENDIX C

ARRAY-BASED SATCOM SYSTEMS

C.1 Scope. This appendix applies to array-based SATCOM systems that operate while on-the-move. This Appendix is a mandatory part of the standard. The information contained herein is intended for compliance. The information contained herein may replace specific requirements in the body of the standard (see 1.1).

C.2 EIRP Stability. The following replaces 4.2.4 (EIRP Stability).

"**4.2.4 EIRP stability.** For any fixed scan angle and any setting of the electronic transmit gain and a constant IF input level, the EIRP in the direction of the satellite shall not vary more than 2.5 dB peak to peak in any 24-hour period."

C.3 Receive chain gain and IF interface characteristics. The following replaces 4.3.3.a (Receive chain gain and IF interface characteristics).

"**4.3.3 Receive chain gain, linearity and IF interface characteristics.** a. The post-RF beam port contribution to the system noise temperature shall not exceed 0.2 dB."

C.4 Receive signal level stability. The following replaces 4.3.11 (Receive signal level stability).

"**4.3.11 Receive signal level stability.** For a fixed scan angle and 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."

C.5 Antenna sidelobe levels. The following replaces 4.4.1.1 and 4.5.1.1.

"**4.4.1.1 De/λ ≥ 50.** Where $De = 2\sqrt{A/\pi} * \cos(\theta)$. The gain of the antenna in the GSO plane, including radome effects, shall be such that at least 90% of the sidelobe peaks do not exceed the mask given below and no individual peak exceeds the mask by more than 3dB.

a. $G(\theta) = 29 - 25 \log_{10} \theta$ (dBi) for 1° or 100 λ/D_e ° (whichever is larger, up to 2°) ≤ θ < 20°

b. $G(\theta) = -3.5$ (dBi) for 20° ≤ θ ≤ 26.3°

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

d. $G(\theta) = -10$ (dBi), for 48° ≤ θ ≤ 180°

CONCLUDING MATERIAL

Custodians:

Army – CR

Navy - EC

Air Force - 02

NSA - NS

Preparing Activity:

DISA – DC1

TCSS-2015-004

Review Activities:

Army - AC, AV, MI, PT, TE, SPO

Navy - AS, CG, MC, OM

Air Force - 71, 11, 13, 44, 93, 99

DIA - DI

DISA - DC5

DoD M&S CO - DMS

NGA - MP

ODASD - 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 https://assist.dla.mil.