

**NOT MEASUREMENT
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**MIL-STD-188-164C
w/CHANGE 1
20 December 2023**

**SUPERSEDING
MIL-STD-188-164C
16 November 2018**

DEPARTMENT OF DEFENSE INTERFACE STANDARD

INTEROPERABILITY OF SUPER HIGH FREQUENCY (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 (DoD).

2. In accordance with DoD Instruction 8330.01, it is DoD policy that all information technology (IT) used by DOD components must interoperate with equipment of joint, combined, and coalition forces, other U.S. Government departments and agencies, and non-governmental organizations to the maximum extent possible.

3. Military standards (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 (STANAGs), and other standards, wherever applicable.

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

5. This revised standard was updated to improve the alignment with MIL-STD-188-165, to remove references to commercial frequency bands, to clarify numerous requirements, and to include requirements for variable performance terminals.

6. 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. Because contact information can change, verify the currency of this address information by using the ASSIST Online database at <https://assist.dla.mil>.

SUMMARY OF CHANGE 1 MODIFICATIONS

1. Updated Certification Authority information.
2. Updated definitions to improve clarity. Definitions in 3 were renumbered to facilitate readability.
3. TABLE I and TABLE II updated to clarify RF and IF bandwidth requirements.
4. ESD acronym replaced throughout with EIRP Spectral Density or EIRPSD.
5. Removed RSS discussion from 4.2.4, and removed requirement alterations in the appendices.
6. Updated transmit and receive frequency accuracy and stability requirement durations in 4.2.5 and 4.3.5.
7. Updated intermodulation products in the receive band requirements in 4.2.16.
8. Updated receive chain gain requirements in 4.3.3.1, 4.3.3.2 and 4.3.3.3.
9. Updated frequencies and added Recommendation ITU-R S.580-6 and Recommendation ITU-R S.732-1 details to 4.4.1.1 and 4.5.1.1.
10. Restructured 4.5.2-4.5.5.
11. Removed frequency reference requirements in 4.6.
12. Updated variable performance terminal guidance in 4.8.
13. Removed SNMP requirement from 5.3.3.
14. Typo corrected in TABLE IV.
15. Updated 6.2 and deleted 6.5 to remove STANAG references.
16. Added 6.9 and TABLE V to provide future guidance on the standard.
17. Merged APPENDIX B with APPENDIX A and deleted APPENDIX B.
18. The following modifications to MIL-STD-188-164 have been made:

Summary of Changes	Added
1.3	Changed
1.4	Changed
1.5	Changed
1.6	Changed
3.2	Changed
3.4	Added
3.5	Changed
3.7	Changed
3.10	Changed
3.13	Changed
3.14	Changed
3.15	Changed
3.18	Changed
3.19	Changed

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3.22	Added
3.27	Added
3.30 (previously 2.28)	Changed
4.1	Changed
Table I	Changed
4.2.5	Changed
4.2.8	Changed
4.2.13	Changed
Table II	Changed
4.2.16	Changed
4.2.18	Changed
4.3.3.1	Changed
4.3.3.2	Changed
4.3.3.3	Changed
4.3.4	Changed
4.3.5	Changed
4.3.7	Changed
4.3.9.3	Changed
4.3.12	Changed
4.3.13	Changed
4.4.1.1	Changed
4.4.1.2	Changed
4.4.2	Changed
4.4.3	Changed
4.4.4	Deleted
4.4.4	Deleted
4.4.5	Deleted
4.5.1	Changed
4.5.1.1	Changed
4.5.1.2	Changed
4.5.2	Changed
4.5.3	Changed
4.5.4	Deleted
4.5.5	Deleted
4.6	Deleted
Table III	Deleted
4.8	Changed
Table IV	Changed
6.6	Deleted
6.7	Deleted
6.8	Deleted
6.9	Added
Table V	Added
6.10 (previously 6.9)	Changed
A.1	Changed
A.3	Changed

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Appendix B
C.2

Deleted
Deleted

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1 SCOPE

1.1 Scope. This standard establishes mandatory radio frequency (RF)/intermediate frequency (IF) and associated interface requirements applicable to SATCOM ETs operating over military X-band and military K_a-band super high frequency (SHF) channels. 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 ETs that predate this revision may not need to conform to this MIL-STD unless they undergo modernization or modifications that alter performance for requirements listed herein.

1.2 Applicability. The interface and performance specifications contained herein apply to SATCOM ETs used to communicate through transponders on the Defense Satellite Communications System (DSCS) and the Wideband Global SATCOM (WGS) system.

1.3 Certification Authority. The U.S. Wideband Consolidated SATCOM System Expert (C-SSE) is the Certification Authority (CA) for the WGS communications system and the DSCS and may be contacted at the following address:

Space Force Delta 8
Wideband Consolidated SATCOM System Expert (C-SSE)
350 Vandenberg Street
Peterson Space Force Base, CO 80914-2749
widebandengineering@groups.af.mil

1.4 Additional requirements. The CA may levy certification requirements in addition to those listed herein. Terminal designers/vendors will coordinate with the CA to obtain certification requirements specific to their terminal. Note that this document is not intended to provide information regarding how to achieve the requirements contained herein; terminal designers/vendors should refer to applicable documents issued by the CA.

1.5 Deviation from the standard.

a. If an ET requires deviation from the specifications stated herein, the Government sponsor Program Manager (PM) should process a request to deviate from the standard through the CA, in accordance with DoD Manual (DoDM) 4120.24, Defense Standardization Program Procedures. The request should include the mission of the system, the rationale for deviating from the standard, and both the technical and cost impact if the program is not allowed to deviate from the standard. ETs that are accepted by the Government sponsor PM without first obtaining approval for deviation from the CA are acquired at program risk.

b. Throughout this document, requirements generally apply to every ET. Government sponsor PMs may, with approval from the CA as described in 1.5a, deviate from the requirements in section 4 or 5 of this document.

c. Special cases of general requirements are addressed in appendices for specific types of ETs, allowing the CA to issue a full ET certification for any ET that implements requirements as

modified by that specific appendix. The program office, without approval from the CA, may instruct a manufacturer to replace a section 4 or section 5 paragraph with the appropriate appendix paragraph.

1.6 Document structure. The main body of this document addresses requirements applicable to all ETs, including stationary and mobile on-the-move (OTM) ETs. Appendices addressing additional requirements, which replace specific requirements in the body of the document as described in 1.5c and are applicable to unique types of ETs, are categorized as follows:

- a. Appendix A, SATCOM OTM Earth Terminals.
- b. Appendix B, (Deleted).
- c. Appendix C, Array-Based SATCOM OTM Earth Terminals.

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 of documents cited in sections 3, 4, and 5 of this standard, whether or not they are listed in section 2.

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-188-165 - Interoperability of Super High Frequency (SHF)
Satellite Communications Phase-Shift Keying
(PSK) Modems

(Copies of these documents are available online at <https://assist.dla.mil>).

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.

GLOBAL POSITIONING SYSTEM (GPS) JOINT PROGRAM OFFICE

ICD-GPS-060 - GPS User Equipment (Phase III) Interface Control Document for the Precise Time and Time Interval (PTTI) Interface

(Copies of this document are available online at <https://www.navcen.uscg.gov/>.)

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 listed in solicitation or contract.

ALLIANCE FOR TELECOMMUNICATIONS INDUSTRY SOLUTIONS (ATIS)

ATIS-0100523 - ATIS Telecom Glossary (American National Standard T1.523)

(Copies of this document are available online at <https://www.atis.org/glossary/>.)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 802.3 - IEEE Standard for Ethernet

(Copies of this document are available online from <https://www.ieee.org> or from the IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08854-4141.)

INTERNATIONAL TELECOMMUNICATIONS UNION (ITU)

Recommendation ITU-R S.580-6 - Radiation diagrams for use as design objectives for antennas of earth stations operating with geostationary satellites

Recommendation ITU-R S.732-1 - Method for statistical processing of earth station antenna side-lobe peaks to determine excess over antenna reference patterns and conditions for acceptability of any excess

(Copies of these documents are available online from <https://www.itu.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 in this section are as defined in the ATIS Telecom Glossary.

3.2 Abbreviations. The abbreviations used in this MIL-STD are defined as follows.

AC	alternating current
ANSI	American National Standards Institute
ATIS	Alliance for Telecommunications Industry Solutions
CA	Certification Authority
C-SSE	Consolidated SATCOM Systems Expert
CEVD	convolutional encoding and Viterbi decoding
CMA	control, monitor, and alarm
CW	continuous wave
C3I	command, control, communications, and intelligence
DAGR	Defense Advanced GPS Receiver
D_e	equivalent antenna diameter
DISA	Defense Information Systems Agency
DoD	Department of Defense
DoDIN	Department of Defense Information Networks
DoDM	Department of Defense Manual
DSCS	Defense Satellite Communications System
EIRP	effective isotropic radiated power
EIRPSD	effective isotropic radiated power spectral density
ET	earth terminal
GPS	Global Positioning System
GPSDO	Global Positioning System disciplined oscillator
GSO	geostationary orbit
HPA	high-power amplifier
IEEE	Institute of Electrical and Electronics Engineers
IF	intermediate frequency
ISO	International Organization for Standardization
ITU	International Telecommunications Union
ITU-R	International Telecommunications Union Radiocommunication Sector
LHCP	left-hand circular polarization
LNA	low-noise amplifier
MIL-STD	military standard
MILSATCOM	military satellite communications
NATO	North Atlantic Treaty Organization
OTM	on the move
PFD	power flux density
PM	Program Manager
PSD	power spectral density
PSK	phase-shift keying
PTTI	Precise Time and Time Interval
QPSK	quadrature phase-shift keying

RF	radio frequency
RHCP	right-hand circular polarization
RMS	root mean square
R_s	symbol rate
RSL	received signal level
RSS	root sum square
SAASM	Selective Availability Anti-Spoofing Module
SAE	Society of Automotive Engineers
SATCOM	satellite communications
SHF	super high frequency
SNMP	Simple Network Management Protocol
SOW	statement of work
SSE	SATCOM Systems Expert
STANAG	standardization agreement
VSWR	voltage standing wave ratio
WGS	Wideband Global SATCOM
λ	wavelength

3.3 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.

3.4 Accuracy. The degree of conformity of a measured or calculated value to its actual or specified value.

3.5 Antenna pointing loss. The antenna gain decreases due to the angular difference between the antenna main beam gain vector and the intended satellite target vector.

3.6 Antenna tracking. Antenna tracking is the ability of an antenna to follow a signal source, such as a communications satellite.

3.7 dBc. Decibel (dB) relative to the carrier power.

3.8 dBi. In the expression of antenna gain, the number of decibels of gain of an antenna referenced to the zero dB gain of a free-space isotropic radiator.

3.9 dBm. Decibel relative to 1 mW.

3.10 dBW. Decibel relative to 1 W.

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

3.12 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.

3.13 EIRP spectral density. EIRP per Hz.

3.14 Equivalent diameter. The diameter that a circular antenna would require to exhibit identical gain performance as a non-circular antenna of a given aperture size. For non-circular apertures, the equivalent diameter (D_e), shown on FIGURE 1, may be computed by:

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

Where:

A = aperture area.

For electronically scanned antennas, the equivalent diameter (D_e) may be computed by:

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

Where:

A = aperture area.

ψ = the electronic scan angle

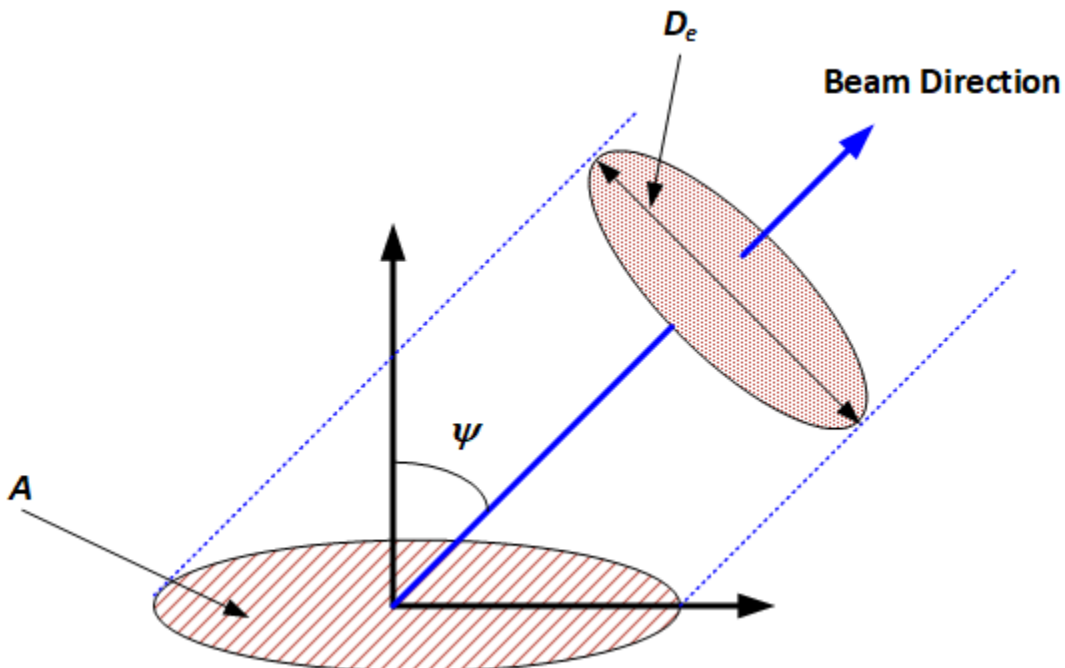


FIGURE 1. Equivalent diameter for electronically scanned antennas.

3.15 Extraneous emissions. Emissions that result from spurious tones, bands of noise, harmonics, or other undesirable signals; intermodulation products are excluded.

3.16 G/T. The receive antenna gain-to-noise temperature ratio (G/T) in dBi/K. Minimum G/T is measured while operating with the transmitter on at maximum linear power, at the lowest frequency in the band, at a 10° elevation angle, referenced to a clear-sky condition, 23 °C ambient temperature, and a water vapor density (absolute humidity) $\rho = 7\text{g/m}^3$. G/T includes the entire reception function contributions.

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

3.18 Instantaneous bandwidth. The range over which a system's passband amplitude and phase response vs. frequency remain compliant without any tuning; compliance is governed by 4.2.7, 4.2.8, 4.3.6, and 4.3.7.

3.19 IF input. The first analog connection after the modulation function.

3.20 IF output. The last analog connection before the demodulation function.

3.21 Maximum linear power. For ETs with a single carrier, the definition is as stated in 3.21.1. For an ET capable of supporting multiple carriers, maximum linear power is defined as in 3.21.1 or 3.21.2, whichever yields the lesser value.

3.21.1 Single carrier maximum linear power. The carrier power where the first spectral regrowth side lobe (measured at 1.0 symbol rate, expressed in Hz from the carrier center frequency) of the modulated carrier is -30 dBc.

3.21.2 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.

3.22 On-axis EIRP spectral density limit. The maximum on-axis EIRP spectral density for which all off-axis emissions do not exceed the established EIRP spectral density mask.

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

3.24 Symbol rate (R_s). The rate at which symbols are transferred across a satellite channel, measured in symbols per second (sym/s).

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

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

3.27 Spurious. Unintended signal components above the noise floor.

3.28 Stability. Accuracy over time.

3.29 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 of the equipment from the IF input to the RF output, including radome (if used).

3.30 Variable Performance Terminal. Any terminal that exhibits variations in EIRP, G/T, off-axis EIRP spectral density, or axial ratio as a function of its main beam pointing angle and are identified as terminals with non-symmetric radomes or electronically-steerable-beam antennas.

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. All performance requirements shall be met over the range of environmental conditions specified in the ET procurement documents over which the ET is required to operate, unless otherwise specified. It is the responsibility of individual programs to ensure deployed terminals are suitable for the operational requirements of individual mission sets.

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

4.2.1 Transmit chain alignment. Separate transmit alignment and power control functions shall be provided for the purpose of transmit 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).

4.2.1.1 IF input level. With a single 0-dBm signal applied to any IF input, the transmit chain gain shall be sufficient to achieve maximum linear EIRP.

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 allocated frequency ranges

Frequency Band	RF (MHz)	IF (MHz)
Military X-band	7900–8400	950-1450 or 1000-1500
Military K _a -band	30000–31000	1000-2000

4.2.3 Tuning. The up-conversion 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.

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 2.5 dB peak to peak in any 24 hours period.

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 without recalibration for the maximum mission duration or 90 days, whichever is less.

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 EIRP as given by the following equation:

$$\text{Minimum range (dB)} = \text{Maximum linear EIRP (dBm)} - 60 \text{ (dBm)}$$

The power control range can be met by using a combination of the ET and modem power adjustments. 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 (with the 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 radian or less over any 2 MHz of instantaneous bandwidth.
- b. ± 0.4 radian over any 36 MHz of instantaneous bandwidth.
- c. ± 0.5 radian over any 72 MHz of instantaneous bandwidth.
- d. ± 0.6 radian over any 90 MHz of instantaneous bandwidth.
- e. ± 0.7 radian over any 120 MHz of instantaneous bandwidth.

4.2.8 Transmit amplitude response. Amplitude variations of the transmit (uplink) function, when operating at any point up to the maximum linear power, shall not exceed the following:

- a. 1.0 dB peak to peak over any 10-MHz segment across the instantaneous bandwidth.
- b. 3.0 dB peak to peak over any 120-MHz segment, or any smaller segment, across the instantaneous bandwidth ($10 \text{ MHz} < \text{segment} < 120 \text{ MHz}$).
- c. 4.0 dB peak to peak for each output frequency band listed in TABLE I.

4.2.9 Alternating current 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 (PSD) of the continuous phase noise component shall comply with the envelope defined on FIGURE 2. If specific points associated with the measured phase noise plot exceed the FIGURE 2 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° root mean square (RMS) (with a two-sided value of 4.8° RMS).

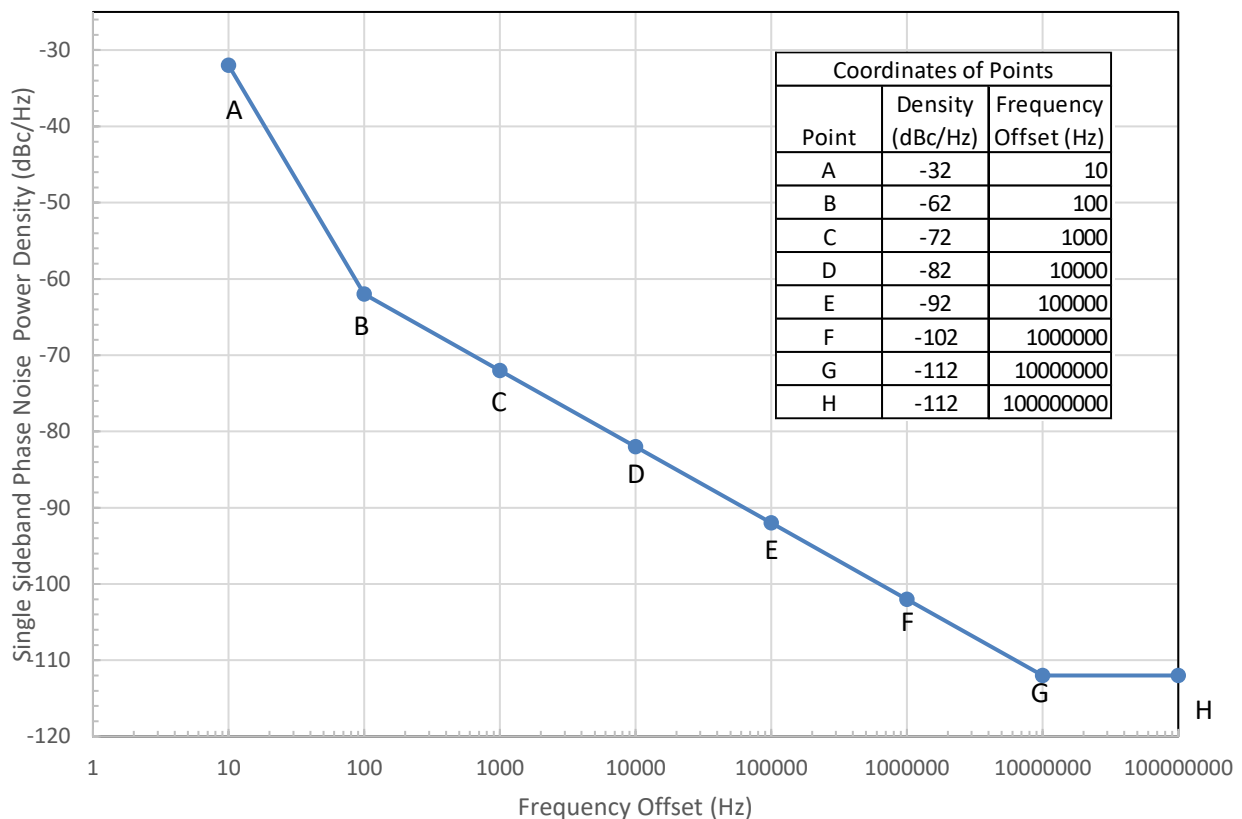


FIGURE 2. ET phase noise

b. The single sideband phase noise due to the continuous component, when integrated over the bandwidth from 1 percent of the symbol rate (R_s) to R_s Hz relative to the carrier center frequency, shall be less than the value obtained when integrating the FIGURE 2 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 values.

4.2.12 Transmit thermal noise EIRP. With the IF input terminated, the transmission 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 a CW signal applied to the IF input such that maximum linear power is achieved, extraneous emissions as measured over any 10-kHz bandwidth shall not exceed the following values:

a. Transmit band: -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 $31.0 \text{ GHz} \leq f \leq 33.0 \text{ GHz}$, which shall not be greater than -45 dBc at 31.0 GHz and shall decrease linearly to -60 dBc by 33.0 GHz.

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 a 0.1 dB increase, and no decrease, in receive noise density over the applicable frequency range shown in TABLE II with the transmitter operating at any EIRP level, compared to the receive performance with the transmitter turned off.

TABLE II. Receive allocated frequency ranges

Frequency Band	RF (MHz)	IF (MHz)
Military X-band	7250–7750	950-1450 or 1000-1500
Military K _a -band	20200–21200	1000-2000

4.2.16 Intermodulation products in the receive band. When transmitting two or more modulated carriers with the composite power at maximum linear power, any intermodulation product at the IF output shall be such that there is less than a 0.1 dB increase in receive noise density when compared to the receive performance with the transmitter turned off, measured at cold sky at an elevation angle of not less than 30° . Total carrier bandwidth shall be the greater of:

a. 128 kHz

b. The minimum bandwidth that complies with the EIRPSD mask at 4.5.1.2.

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. ETs with embedded modems shall be interoperable with ETs that do not have embedded modems.

4.2.18 Input impedance. The IF interfaces shall have a nominal impedance of 50Ω . The voltage standing-wave ratio (VSWR) over the IF band shall be less than 2.0:1.

4.2.19 Transmit IF frequency. The IF input interface shall support the required bandwidth as listed in TABLE I.

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

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 (PFDs). All reception functions shall be met with the maximum PFDs as follows:

4.3.2.1 Military X-band.

- a. -142 dBW/m² in any 4-kHz band in any single carrier.
- b. -95 dBW/m² across the entire 500-MHz band.

4.3.2.2 Military K_a-band.

- a. -112 dBW/m² in any 1-MHz band in any single carrier.
- b. -90 dBW/m² 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 ET IF interface) shall exhibit the following characteristics:

4.3.3.1 Receive Chain Gain. When pointing to a cold sky at an elevation angle of not less than 30°, the receive chain gain shall be sufficient to raise the IF output noise PSD to a minimum of -130 dBm/Hz.

4.3.3.2 Reception function intermodulation products. The PSD of any intermodulation product at the IF output shall be such that there is less than a 0.1 dB increase in receive noise density (when compared to the receive noise density measured at cold sky at an elevation angle of not less than 30°) at any power and bandwidth combination equivalent to the antenna receiving the maximum power flux density per carrier bandwidth, and up to the maximum aggregate power flux density, both as given in 4.3.2.

4.3.3.3 IF Output Level Adjustment. When ET is pointed to an operational satellite, the receive chain gain may be reduced to assist in complying with the linearity requirement described in 4.3.3.2, provided that the minimum IF output noise power spectral density does not decrease below -130 dBm/Hz. Any increase in system noise due to a reduction in receive chain gain shall be incorporated into the terminal's G/T.

4.3.3.4 Output Impedance. The IF interfaces shall have a nominal impedance of 50 Ω. The voltage standing-wave ratio (VSWR) over the IF band shall be less than 2.0:1.

4.3.4 Tuning. The down-conversion 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.

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 without recalibration for the maximum mission duration or 90 days, whichever is less.

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 radian over any 2-MHz segment across the instantaneous bandwidth.
- b. ± 0.4 radian over any 36-MHz segment across the instantaneous bandwidth.
- c. ± 0.5 radian over any 72-MHz segment across the instantaneous bandwidth.
- d. ± 0.6 radian over any 90-MHz segment across the instantaneous bandwidth.
- e. ± 0.7 radian over any 120-MHz segment across the instantaneous bandwidth.

4.3.7 Receive amplitude response. Amplitude variations as measured at the ET IF output (demodulation function) shall not exceed the following:

- a. 1.0 dB peak to peak over any 10-MHz segment across the instantaneous bandwidth.
- b. 3.0 dB peak to peak over any 120-MHz segment or smaller segment across the instantaneous bandwidth ($10 \text{ MHz} < \text{segment} < 120 \text{ MHz}$).
- c. 4.0 dB peak to peak for each output frequency band listed in TABLE II.

4.3.8 Receive phase noise. The reception function shall meet phase noise requirements as defined in 4.2.11.

4.3.9 Receive spurious output.

4.3.9.1 Continuous component. The sum of all spurious signal power within the narrowest bandwidth of interest shall be at least 10 dB below the thermal noise power within the narrowest bandwidth of interest, when measured across the terminal IF output interface.

4.3.9.2 Discrete component. No one spurious signal shall exceed the level of 20 dB below the thermal noise power within the narrowest bandwidth of interest, when measured across the terminal IF output interface.

4.3.9.3 Component conditions. Both 4.3.9.1 and 4.3.9.2 above shall be met under the following simultaneous conditions:

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

- b. Receiving one CW carrier at any frequency over the receive band, with a level equivalent to the antenna receiving the aggregate maximum power flux density given in 4.3.2.

The narrowest bandwidth of interest for this requirement shall be 64kHz, unless ET procurement documents specify a bandwidth less than 64kHz.

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

4.3.11 Receive signal level stability. For any setting of the receive gain and for a constant PSD level, the reception function output level shall not vary more than ± 2.0 dB in any 24 hour period.

4.3.12 Antenna pointing loss. The antenna downlink pointing loss shall not exceed 0.8 dB, 99.7 percent of the time. This requirement shall be met under operational conditions with no blockage or keyhole events.

4.3.13 Receive IF frequency. The IF output interface shall support the required bandwidth as listed in TABLE II.

4.4 Military Ka-band antenna requirements.

4.4.1 Antenna side-lobe levels and transmit EIRP spectral density. The antenna side-lobe and EIRP spectral density requirements are described in 4.4.1.1 and 4.4.1.2.

4.4.1.1 Antenna sidelobe levels. This requirement only applies where $D_e/\lambda \geq 50$. The radiation pattern of the antenna while both transmitting and receiving, including radome effects, in the geostationary orbit (GSO) plane, shall be in accordance with Recommendation ITU-R S.580-6. Recommendation ITU-R S.732-1 shall be used for statistical processing of earth station antenna side-lobe peaks to determine excess over the antenna reference pattern and conditions for acceptability of any excess. Computation of wavelength (λ) will use 30.0 GHz and 20.2 GHz as the reference transmit and receive frequencies, respectively. For reference, the mask from Recommendation ITU-R S.580-6 is outlined below:

- a. $G(\theta) = 29 - 25 \log_{10} \theta$ (dBi) for 1° or $100\lambda/D_e$ (whichever is larger, up to 2°) $\leq \theta < 20^\circ$.
- b. $G(\theta) = -3.5$ (dBi) for $20^\circ \leq \theta \leq 26.3^\circ$.
- c. $G(\theta) = 32 - 25 \log_{10} \theta$ (dBi), for $26.3^\circ < \theta < 48^\circ$.
- d. $G(\theta) = -10$ (dBi), for $48^\circ \leq \theta \leq 180^\circ$.

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

For reference, the angular regions and side-lobe peak allowed excess from Recommendation ITU-R S.732-1 are outlined below:

- a. 1 dB for $\theta_{\min} < \theta \leq 7^\circ$, where $\theta_{\min} = 1^\circ$ or $(100\lambda/D_e)$ degrees, whichever is greater
- b. 3 dB for $7^\circ < \theta \leq 9.2^\circ$
- c. 3 dB for $9.2^\circ < \theta \leq 48^\circ$
- d. 10 dB for $48^\circ < \theta \leq 180^\circ$

Note: Receive off-axis gain excursions may be considered allowable if it can be shown that relaxation of the off-axis gain results in improvement of the main beam gain.

4.4.1.2 EIRP spectral density. For all ETs, EIRP spectral density in the GSO plane shall not exceed the following:

- a. EIRP spectral density(θ) = $-6.4 - 25 \log_{10} \theta$ (dBW/Hz) for $2.0^\circ \leq \theta < 20.0^\circ$.
- b. EIRP spectral density (θ) = -38.9 (dBW/Hz) for $20.0^\circ \leq \theta \leq 26.3^\circ$.
- c. EIRP spectral density (θ) = $-3.4 - 25 \log_{10} \theta$ (dBW/Hz) for $26.3^\circ < \theta < 48.0^\circ$.
- d. EIRP spectral density (θ) = -45.4 (dBW/Hz) for $48^\circ \leq \theta \leq 180^\circ$.

Where:

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

The EIRP spectral density requirement shall be met while incorporating transmit RMS pointing errors. FIGURE 3 illustrates the EIRP spectral density mask defined by the above parameters.

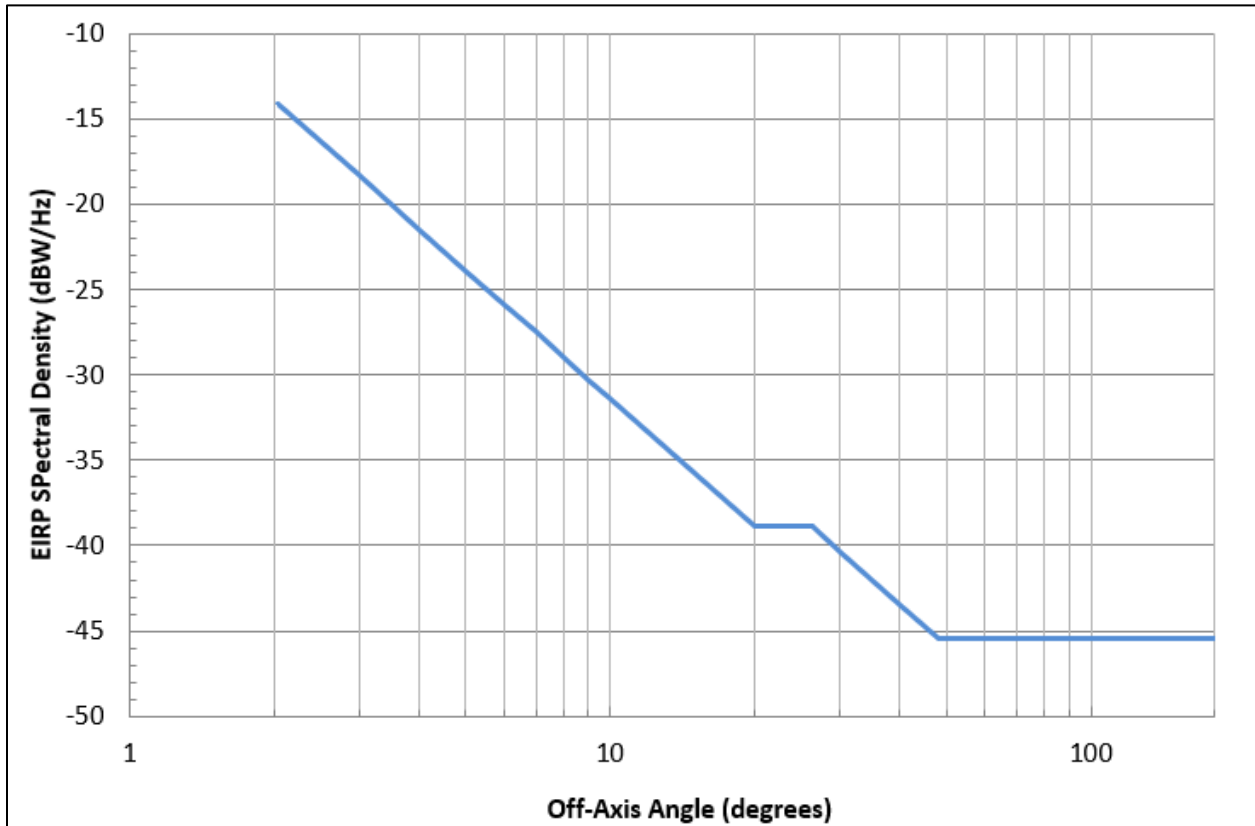


FIGURE 3. Military Ka-band EIRP spectral density mask

4.4.2 Transmit and receive antenna polarization. The antenna shall be capable of transmitting and receiving right-hand circular polarization (RHCP) (clockwise) and left-hand circular polarization (LHCP) (counterclockwise). However, military Ka-band ETs are not required to operate with simultaneous transmit of RHCP and LHCP or simultaneous receive of LHCP and RHCP.

4.4.3 Transmit and receive antenna axial ratio. The military Ka-band transmit axial ratio shall be no greater than 1.0 dB and the receive axial ratio shall be no greater than 1.5 dB.

4.4.4 Receive antenna polarization. Deleted. See 4.4.2.

4.4.5 Receive antenna axial ratio. Deleted. See 4.4.3.

4.5 Military X-band antenna requirements.

4.5.1 Antenna side-lobe levels and transmit EIRP spectral density. The antenna side-lobe and EIRP spectral density requirements are described in 4.5.1.1 and 4.5.1.2.

4.5.1.1 Antenna sidelobe levels. This requirement only applies where $D_e/\lambda \geq 50$. The radiation pattern of the antenna while both transmitting and receiving, including radome effects, in the GSO plane shall be in accordance with Recommendation ITU-R S.580-6. Recommendation ITU-R S.732-1 shall be used for statistical processing of earth station antenna

side-lobe peaks to determine excess over the antenna reference pattern and conditions for acceptability of any excess. Computation of λ will use 7900 MHz and 7250 MHz as the reference transmit and receive frequencies, respectively. The mask, angular regions, and side-lobe peak allowed excess are summarized for reference in 4.4.1.1.

Note: Receive off-axis gain excursions may be considered allowable if it can be shown that relaxation of the off-axis gain results in improvement of the main beam gain.

4.5.1.2 EIRP spectral density. For all ETs, EIRP spectral density in the GSO plane shall not exceed the following:

- a. EIRP spectral density (θ) = $2.351 - 25 \log_{10} \theta$ (dBW/Hz) for $2.0^\circ \leq \theta < 3.8^\circ$.
- b. EIRP spectral density (θ) = -13.0 (dBW/Hz) for $\theta = 3.8^\circ$.
- c. EIRP spectral density (θ) = $1.49 - 25 \log_{10} \theta$ (dBW/Hz) for $3.8^\circ < \theta < 5.0^\circ$.
- d. EIRP spectral density (θ) = $-3.97 - 25 \log_{10} \theta$ (dBW/Hz) for $5.0^\circ \leq \theta < 6.94^\circ$.
- e. EIRP spectral density (θ) = -25.0 (dBW/Hz) for $6.94^\circ \leq \theta \leq 12.42^\circ$.
- f. EIRP spectral density (θ) = $2.35 - 25 \log_{10} \theta$ (dBW/Hz) for $12.42^\circ < \theta < 48.0^\circ$.
- g. EIRP spectral density(θ) = -39.65 (dBW/Hz) for $48^\circ \leq \theta \leq 180^\circ$.

Where:

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

The EIRP spectral density requirement shall be met while incorporating transmit RMS pointing errors. FIGURE 4 illustrates the mask defined by the above parameters.

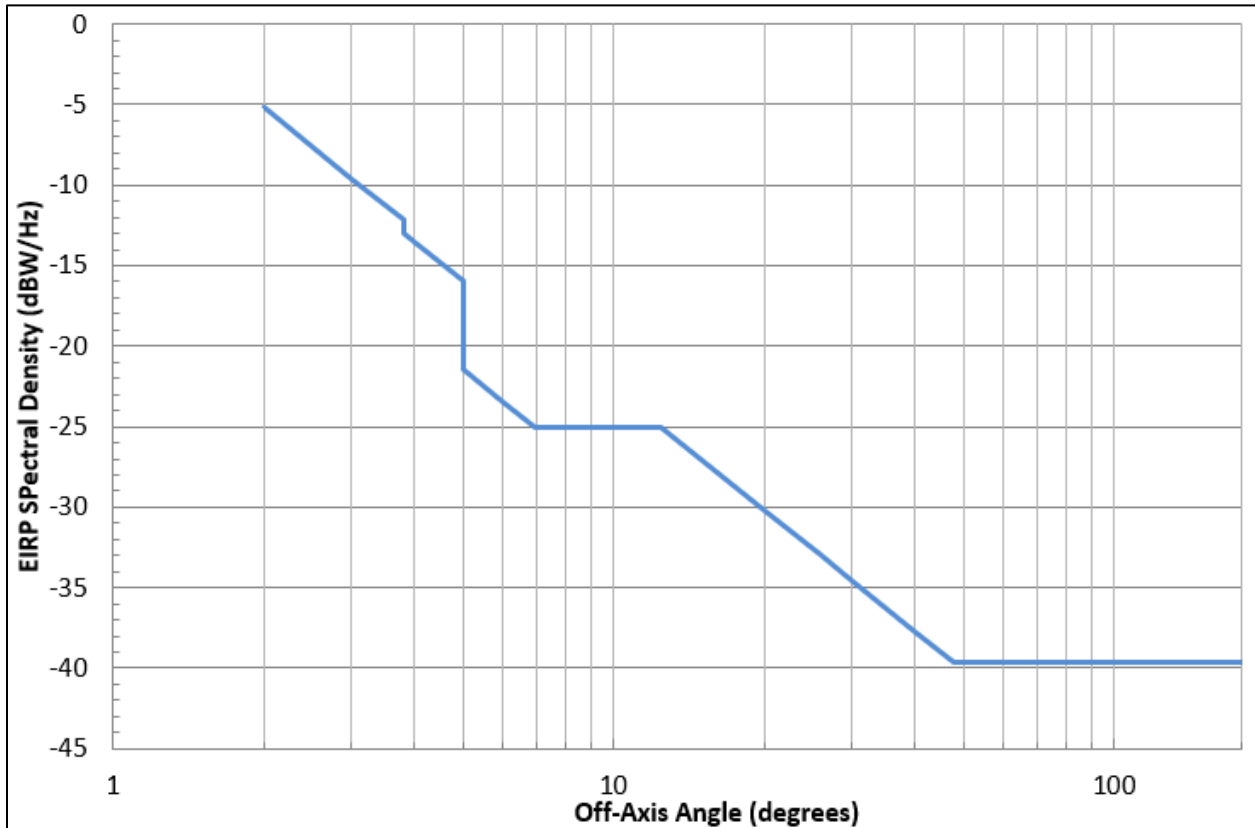


FIGURE 4. Military X-band EIRP spectral density mask

4.5.2 Transmit and receive antenna polarization. The antenna shall be capable of transmitting RHCP and receiving LHCP.

4.5.3 Transmit and receive antenna axial ratio. The military X-band transmit and receive axial ratios shall each be no greater than 2.0 dB.

4.5.4 Receive antenna polarization. Deleted. See 4.5.2.

4.5.5 Receive antenna axial ratio. Deleted. See 4.5.3

4.6 Frequency references. Deleted.

TABLE III. Deleted.

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 loop-back. 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) modulation, 1/2-rate convolutional encoding and Viterbi decoding (CEVD), randomizer on, and differential encoding/decoding on. Implementation loss includes the effects of traversing the ET uplink and downlink equipment, as well as the satellite. This shall be tested at low, middle, and high operational data rates.

4.8 Variable performance terminals. Terminals which fail to meet MIL-STD-188-164 requirements across the full range of the terminal's operational performance may be constrained to ensure compliance with MIL-STD-188-164. PMs are encouraged to contact the CA at the earliest opportunity to discuss the implications of variable terminal performance to their program.

5 DETAILED REQUIREMENTS

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

5.2 Phase perturbation. The transmission function shall not change the linear phase of the output RF signal by more than 20° in 0.2 s, and the reception function shall not change the linear phase of the input RF signal by more than 20° in 0.2 s, over the range of environmental conditions over which the ET is required to operate. This shall include as a minimum:

- a. Exposure to temperature deviation.
- b. Exposure to vibration.
- c. Exposure to shock on the outside surface of the ET, simulating maintenance, operator or other external action on the ET.

(NOTE: The ET procurement documents will provide guidance on the temperature range and rate of change, the vibration frequencies and accelerations, and any other expected environmental conditions over which the ET is required to operate.)

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

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 IV. For all ET 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 high-power amplifier (HPA) output power.

5.3.1.1 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 up-conversion function gain, (2) the gain/loss from the up-conversion function output to the power amplifier input, (3) the power amplifier gain, and (4) transmit loss to the antenna feed.

5.3.1.2 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.

5.3.2 Control response times. The ET shall meet a response time of 0.5 s for all parameters in TABLE IV.

5.3.3 ET remote control and monitoring interface. The ET remote control and monitoring interface shall be implemented as an IEEE 802.3-compliant Ethernet.

TABLE IV. ET control and monitoring parameters

Control	Monitoring
Transmit gain of each up-conversion function	Transmit gain setting of each up-conversion function
Frequency setting of each up-conversion function	Frequency setting of each up-conversion function
Frequency setting of each down-conversion function	Frequency setting of each down-conversion function
Auto-track source (frequency band)	Auto-track 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 up-conversion 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 ET interfaces in terms of physical and functional performance criteria necessary to support PMs and buying activities in the acquisition of interoperable and compatible ETs, 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.

6.3 Tailoring guidance. To ensure proper application of this standard, invitations for bids, requests for proposals, and contractual statements of work (SOWs) 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 in the appendices to this document to address specific ET types. It is highly recommended that any exclusions be coordinated with the appropriate CA to avoid any issues during ET performance certification.

6.4 Subject term (keyword) listing. The following keywords apply to this MIL-STD.

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

6.5 International standardization agreement implementation. Deleted.

6.6 RSS Theory. Deleted.

6.7 Antenna gain versus pointing variations. Deleted.

6.8 Accounting for pointing loss differences between uplink and downlink beams. Deleted.

6.9 Background and future guidance. This MIL-STD changes in response to changing DoD requirements and SATCOM technologies. TABLE V offers corresponding background on select requirements as well as projected changes. The table is predictive in nature, and highlights topics of discussion at working groups rather than formal guidance or direction.

TABLE V. Background and future guidance

Section or Requirement	Present Background	Future Guidance
3.16 G/T.	Measured G/T is a function of environmental conditions during testing. G/T values referenced to standardized environmental parameters will improve G/T comparability.	Discussion is ongoing.
4.2.1 Transmit chain alignment.	The current ‘transmit chain alignment’ requirement is not appropriate for terminals incorporating phased array antennas.	Discussion is ongoing regarding improving the language in the requirement to better capture phase array antennas. Intent of the requirement is unlikely change.
4.2.5 Carrier frequency accuracy and stability.	The current specification requires frequency accuracy to be within 1 kHz of the intended value, for the lesser of 90 days or mission duration without calibration.	Discussion is ongoing regarding how to make the requirement less prescriptive, and to reflect updates to frequency reference requirements. Discussion is ongoing as to how further relaxation may be incorporated into the requirement.
4.2.8 Transmit amplitude response.	The current requirement specifies allowable amplitude variations across set bandwidths.	The extant requirement may ultimately be supplemented by an Error Vector Magnitude specification. While studies are ongoing, a significant amount of work is required before any change is implemented.
4.2.11 Phase noise.	The current requirement details a phase noise mask applicable to all terminals.	Work continues on a new phase noise mask which varies depending on terminal size (diameter with respect to RF wavelength). Consultation with the MIL-STD-188-165 working group regarding this development is ongoing.
4.3.2 Maximum power flux densities (PFDs).	Terminals currently find it difficult to meet Rx intermodulation requirements, while simultaneously meeting the extant PFDs requirements, and the receive chain gain requirement.	Work is ongoing to provide relief in terms of the PFDs limits.

TABLE V. Background and future guidance - Continued

Section or Requirement	Present Background	Future Guidance
4.3.5 Receive conversion frequency accuracy.	The current specification requires frequency accuracy to be within 1 kHz of the intent value, for the lesser of 90 days or mission duration without calibration.	Discussion is ongoing regarding how to make the requirement less prescriptive, and to reflect updates to frequency reference requirements. Discussion is ongoing as to how further relaxation may be incorporated into the requirement.
4.3.7 Receive amplitude response.	The current requirement specifies allowable amplitude variations across set bandwidths.	The extant requirement may ultimately be supplemented by an Error Vector Magnitude specification. While studies are ongoing, a significant amount of work is required before any change is implemented.
4.3.8 Receive phase noise.	The current requirement details a phase noise mask applicable to all terminals.	Work continues in this area. Refer future guidance applicable to 4.2.11 Phase noise.
4.4 Military K _a -band antenna requirements.	The current requirement outlines specifications for EIRPSD and antenna radiation patterns.	Intent is to better align EIRPSD and antenna gain pattern requirements in military Ka Band. Studies to modify military Ka-band Rx gain mask requirements (4.4.1.1) to ESAs are ongoing.
4.4.3 and 4.5.3 Transmit and receive antenna axial ratio.	The MIL-STD currently sets transmit and receive axial ratio limits.	Discussion and study are ongoing as to how Axial Ratio limits might be altered to provide relief to the terminal community given operational and planning constraints, and regulatory obligations.
4.5 Military X-band antenna requirements.	The current requirement outlines specifications for EIRPSD and antenna radiation patterns.	Intent is to better align EIRPSD and antenna gain pattern requirements. Studies to modify military X-band Rx gain mask requirements (4.5.1.1) to ESAs are ongoing.
5.3 ET control and monitoring function.	Nil.	Discussion to specify web services implementation for management interface is ongoing.

TABLE V. Background and future guidance - Continued

Section or Requirement	Present Background	Future Guidance
Antenna Tracking	Nil.	Discussion and study are ongoing as to how an antenna tracking requirement might be incorporated to ensure that future WGS certified Earth Terminals are equipped to deal with satellite inclination.

6.10 Change notations. The margins of this standard are marked with vertical lines to indicate modifications generated by this change. 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.

APPENDIX A

SATCOM OTM EARTH TERMINALS

A.1 Scope. This appendix applies to SATCOM systems that operate while OTM. This appendix is a mandatory part of the standard. The information contained herein is intended for compliance and may replace specific requirements in the body of the standard (see 1.5c).

A.2 Uplink inhibit. OTM ETs shall immediately inhibit transmit upon loss of the downlink signal.

A.3 Antenna pointing loss. The following replaces the entire text of 4.3.12 Antenna pointing loss.

“4.3.12 Antenna pointing loss. The antenna pointing loss shall not exceed 0.8 dB 95.4 percent of the time. This requirement shall be met under operational conditions with no blockage or keyhole events and does not include any time frame during which the antenna system supports a non-operating mode by design (for example, when not operating due to safety considerations). A mechanism shall be provided to inhibit transmit in the event that the antenna transmit pointing error causes the off-axis EIRP spectral density limit to be exceeded.”

MIL-STD-188-164C
w/CHANGE 1

APPENDIX B

Deleted.

APPENDIX C

ARRAY-BASED SATCOM OTM EARTH TERMINALS

C.1 Scope. This appendix applies to array-based SATCOM systems that operate while OTM. This appendix is a mandatory part of the standard. The information contained herein is intended for compliance and may replace specific requirements in the body of the standard (see 1.5c).

C.2 EIRP stability. The following replaces 4.2.4 EIRP stability.

“4.2.4 EIRP stability. For any fixed scan angle, 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 hours period.”

C.3 Transmit-to-receive isolation. The following replaces 4.2.15 Transmit-to-receive isolation.

“4.2.15 Transmit-to-receive isolation. Transmit-to-receive isolation shall be such that there is less than a 0.5-dB increase, and no decrease, in receive noise density over the applicable frequency range shown in TABLE II with the transmitter operating at any EIRP level, compared to the receive performance with the transmitter turned off.**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, any setting of the receive gain, and a constant PSD level, the reception function output level shall not vary more than 2.0 dB in any 24 hour period.”

CONCLUDING MATERIAL

Custodians:

Army – CR
Navy – EC
Air Force – 02
NSA – NS

Preparing Activity:

DISA – DC1
(Project TCSS-2020-001)

Review Activities:

Army – AC, AV, CR2, MI, PT, TE, SPO
Navy – AS, CG, MC, OM
Air Force – 04, 11, 44, 49, 71, 93
DIA – DI
DISA – DC, DC5
NGA – MP
OUSD(R&E)SE&A – SE

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