NOT MEASUREMENT SENSITIVE

MIL-STD-188-165B
w/CHANGE 1
2 January 2024

SUPERSEDING
MIL-STD-188-165B
26 March 2018

DEPARTMENT OF DEFENSE
INTERFACE STANDARD

INTEROPERABILITY OF SUPER HIGH FREQUENCY (SHF) SATELLITE COMMUNICATIONS PHASE-SHIFT KEYING (PSK) MODEMS

AMSC N/A

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FOREWORD

1. This standard is approved for use by all Departments and Agencies of the Department of Defense (DoD) within the distribution limitations noted at the bottom of the cover.

2. 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 to be 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. 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 procurements, 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 only. 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 – Telecommunication (ITU-T) Standardization Sector recommendations, International Standards Organization (ISO), North Atlantic Treaty Organization (NATO) Standardization Agreements (STANAGs), and other standards, wherever applicable.

4. This MIL-STD is part of a profile of standards for Super High Frequency (SHF) Satellite Communications (SATCOM) (6.5).

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. 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. Allowances for special types of modems have bene added to 1.5.
3. Updated definitions to improve clarity. Definitions in 3 were renumbered to facilitate reading.
4. Updated 4.2 to include FIGURE 1 with modem functional overview.
5. Updated 4.4 to clarify requirement and remove procedure.
6. Added 10 Gigabit Ethernet as an option under 5.3.2, and removed IP Encapsulation requirements.
7. Added DVB RCS modem emulation under 5.4.9 and clarified requirements for modem emulation under NATO STANAG 4486 in 5.4.8 and 5.7.3.1.9.
8. Changed DVB-S2 modem emulation in 5.4.9 and 5.7.3.1.10.
9. Added DVB-S2X modem emulation to 5.4.11 and 5.7.3.1.11.
10. Rewrote Phase Noise requirements under 5.5.3.4.
11. Added PER equivalence to 5.5.5.3.
12. Reduced both minimum and maximum IF carrier input levels in 5.6.4.1.1 and 5.6.4.1.2 respectively.
13. Rewrote noise figure in 5.6.5.
14. Updated acquisition and timing requirements in 5.7.2 and following from Eb/N0 to ES/N0 and added mapping from BER to PER.
15. Rewrote data reacquisition requirements in 5.7.2.2.
16. Rewrote adjacent channel interference requirements in 5.7.3.2.
17. Updated 6.6 and TABLE VIII to provide future guidance on the standard.
18. Added several appendices to provide guidance for various waveform types.
19. The following modifications to MIL-STD-188-165 have been made:

Paragraph	Modification
Forward	Changed
Summary of Changes	Added
1.1	Changed
1.2	Changed
1.3	Changed
1.4	Changed
1.5	Added
1.6 (Old 1.5)	Changed
2.2.1	Changed
2.2.2	Added

2.3	Changed
2.4 (Old 2.3.1)	Added
3.1	Changed
3.2	Changed
3.4-3.19	Changed
3.20-3.24	Added
4.2	Changed
Figure 1	Added
4.2.1	Changed
4.2.2	Changed
4.4	Changed
5.1	Changed
5.2	Changed
5.3.2	Changed
5.3.2.1	Deleted
5.4	Changed
5.4.2	Changed
5.4.3	Changed
5.4.8	Changed
5.4.9	Changed
5.4.10	Changed
5.4.11	Added
5.4.12	Added
5.5	Changed
5.5.1	Changed
5.5.2	Changed
5.5.3.1	Changed
5.5.3.2	Changed
5.5.3.3	Changed
5.5.3.4	Changed
Table IV	Added
Figure 2	Updated
5.5.4	Changed
Figure 3	Added
5.5.5.1	Changed
Figure 4 (Old Figure 2)	Unchanged
5.5.5.3	Changed
5.5.5.4	Changed
5.6.1	Changed
5.6.2	Changed
5.6.4	Changed
5.6.4.1.1	Changed
5.6.4.1.2	Changed

5.6.4.2	Changed
5.6.4.3	Deleted
5.6.5	Changed
5.7.1	Changed
5.7.2	Changed
5.7.2.1	Changed
Table V (Old Table IV)	Changed
5.7.2.3	Changed
5.7.2.4	Changed
5.7.2.5	Changed
Table VI (Old Table V)	Changed
5.7.2.6	Changed
5.7.3.1.8	Changed
5.7.3.1.9	Changed
5.7.3.1.9.1	Added
5.7.3.1.9.2	Added
5.7.3.2	Changed
5.7.3.2.1	Added
Figure 5	Added
5.7.3.2.2	Added
Figure 6	Added
5.7.3.2.3	Added
Figure 7	Added
5.7.3.3	Changed
Figure 8	Added
5.7.3.4	Changed
5.8.2.1	Changed
Table VII	Changed
6.1	Changed
6.4	Changed
Figure 9 (Old Figure 3)	Updated
Table VIII (Old Table VIIII)	Changed
6.7	Changed
Appendix A	Added
Appendix B	Added
Appendix C	Added
Appendix D	Added
Appendix E	Added
Concluding Material	Changed

CONTENTS

FIGURES

TABLES

1 SCOPE

1.1 Scope. This standard covers Phase-Shift Keying (PSK) modems. The requirements specified herein represent the minimum performance specifications required for interoperability; the requirements may be exceeded by equipment developers to satisfy specific service requirements. Thus, incorporating additional standard and nonstandard capabilities and interfaces is not precluded.

1.2 Applicability. The interface and performance specifications contained herein apply to satellite modems used to communicate through transponders on the Defense Satellite Communications System (DSCS) and the Wideband Global SATCOM (WGS) system. The military-unique requirements for Super High Frequency (SHF) SATCOM modems that operate over military X-band and military Ka-band apply when the modem is used to provide access to the DoD Information Networks (DoDIN).

1.3 Certification authority. The U.S. Space Force (USSF) Delta 8 SATCOM is the certification authority for the WGS and DSCS communications system and may be contacted at the following address.

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

1.4 Additional requirements. Delta 8 SATCOM may levy certification requirements in addition to those listed herein. Modem designers/vendors coordinate with the certification authority to obtain test requirements specific to their modem. Note that this document is not intended to provide information regarding how to achieve the requirements contained herein; modem designers/vendors should refer to applicable requirements documents issued by Delta 8 SATCOM.

1.5 Special Types of Modems. Special cases of general requirements are addressed in the appendices for specific types of modems. The Program Office, without approval from the certification authority, may instruct a manufacturer to replace a Section 5 paragraph with the appropriate appendix paragraph, or to otherwise enforce an appropriate appendix.

1.6 Requests to deviate from the standard. If a modem requires deviation from the specifications stated herein, the Government sponsor Program Manager (PM) should process a request to deviate from the standard through the certification authority, 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 in the event that the program is not allowed to deviate from the standard. Modems accepted by the Government sponsor PM, which deviate from this standard without first obtaining approval for deviation from the certification authority, are acquired at program risk.

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.

INTERNATIONAL STANDARDIZATION AGREEMENTS

NATO STANAG 4486 - Super High Frequency (SHF) Military Satellite Communications (MILSATCOM) Frequency Division Multiple Access (FDMA) Non-EPM Modem for Services Conforming to Class-B of STANAG 4484

(Copies of this document may be obtained online at http://www.nato.int.)

DEPARTMENT OF DEFENSE SPECIFICATIONS

A3197423 - Specification for OM-73XX Modem Group

(Copies of this document are available from the U.S. Army Communications-Electronic Research, Development and Engineering Center, Space and Terrestrial Communications Directorate, SATCOM Systems Division, Independent Test and Certification Branch (RDER-STC-CT), 6690 Raritan Avenue, Aberdeen Proving Ground, MD 21005.)

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.

Navy Studies

Technical Report 1578 (AD-A267 884)	-	W. McDonald, "SHF SATCOM Terminal Ship-Motion Study." Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA, March 1993.

(Copies of this document are available online at https://apps.dtic.mil/sti/pdfs/ADA267884.pdf.)

2.3 Non-Government publications. The following non-Government 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.

EUROPEAN TELECOMMUNICATIONS STANDARDS INSTITUTE (ETSI)

ETSI EN 301 790	-	Digital Video Broadcasting (DVB); Interaction channel for satellite distribution systems
ETSI EN 302 307-1	-	Digital Video Broadcasting (DVB); Second Generation Framing Structure, Channel Coding and Modulation Systems for Broadcasting, Interactive Services, News Gathering and Other Broadband Satellite Applications; Part 1: DVB-S2
ETSI EN 302 307–2	-	Digital Video Broadcasting (DVB); Second Generation Framing Structure, Channel Coding and Modulation Systems for Broadcasting, Interactive Services, News Gathering and Other Broadband Satellite Applications; Part2: DVB-S2 Extensions (DVB-S2X)

(Copies of these documents are available online at http://www.etsi.org.)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 802.3ab	-	IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements. Supplement to Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications – Physical Layer Parameters and Specifications for 1000 Mb/s Operation over Four Pair of Category 5 Balanced Copper Cabling, Type 1000BASE-T
IEEE 802.3ae	-	IEEE Standard for Information technology – Local and metropolitan area networks – Part 3: CSMA/CD Access Method and Physical Layer Specifications – Media Access Control (MAC) Parameters, Physical Layer, and Management Parameters for 10 Gb/s Operation

IEEE 802.3i	-	IEEE Standard for Local and Metropolitan Area Networks - System Considerations for Multisegment 10 Mb/s Baseband Networks (Section 13) and Twisted-Pair Medium Attachment Unit (MAU) and Baseband Medium, Type 10BASE-T (Section 14)
IEEE 802.3u	-	IEEE Standards for Local and Metropolitan Area Networks: Supplement - Media Access Control (MAC) Parameters, Physical Layer, Medium Attachment Units, and Repeater for 100Mb/s Operation, Type 100BASE-T (Clauses 21-30)

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

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

IESS-308	-	Performance Characteristics for Intermediate Data Rate Digital Carriers Using Convolutional Encoding/Viterbi Encoding and QPSK Modulation (QPSK/IDR)
IESS-309	-	Performance Characteristics for INTELSAT Business Services (IBS)
IESS-310	-	Performance Characteristics for Intermediate Data Rate Digital Carriers Using Rate 2/3 TCM/8PSK and Reed–Solomon Outer Coding (TCM/IDR)
IESS-315	-	Performance Characteristics for VSAT Service Using Turbo Coding with QPSK/OQPSK Modulation

(Copies of these documents are available from INTELSAT General Communications LLC, 7900 Tysons One Place, Suite 12, McLean, VA 22102, telephone +01 703-270-4200, facsimile +01 703-270-4810, or online at http://www.intelsat.com.)

INTERNET ENGINEERING TASK FORCE (IETF)

RFC 5578	-	PPP over Ethernet (PPPoE) Extensions for Credit Flow and Link Metrics

(Copies of these documents are available online at http://www.rfc-editor.org.)

TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)

TIA-422	-	Electrical Characteristics of Balanced Voltage Digital Interface Circuits
TIA-423	-	Electrical Characteristics of Unbalanced Voltage Digital Interface Circuits

TIA-530	-	High Speed 25-Position Interface for Data Terminal Equipment and Data Circuit-Terminating Equipment, Including Alternative 26-Position Connector
TIA-612	-	Electrical Characteristics for an Interface at Data Signaling Rates up to 52 Mbit/s
TIA-613	-	High Speed Serial Interface for Data Terminal Equipment and Data Circuit-Terminating Equipment

(Copies of these documents are available online at http://www.tiaonline.org.)

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 Alliance for Telecommunications Industry Solutions (ATIS) Telecom Glossary.

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

8-PSK	Eight-Phase-Shift Keying
ACI	Adjacent Channel Interference
ACM	Adaptive Coding and Modulation
AGC	Automatic Gain Control
AH	Antenna Handover
ANSI	American National Standards Institute
ATIS	Alliance for Telecommunications Industry Solutions
AUPC	Automated Uplink Power Control
BCI	Bit-Count Integrity
BER	Bit Error Ratio
BPSK	Binary Phase-Shift Keying
C-SSE	Consolidated Wideband SATCOM System Expert
C3I	Command, Control, Communications, and Intelligence
CDMA	Code-Division Multiple Access
CE	Constellation Error
CSMA/CD	Carrier-Sense Multiple Access with Collision Detection
CW	Continuous Wave
DEM	Distant-End Monitoring
DISA	Defense Information Systems Agency
DLEP	Dynamic Link Exchange Protocol
DoD	Department of Defense
DoDIN	Department of Defense Information Networks
DoDM	Department of Defense Manual
DSCS	Defense Satellite Communications System
DSSS	Direct Sequence Spread Spectrum
DVB	Digital Video Broadcasting
EBEM	Enhanced Bandwidth Efficient Modem
E_b/N_0	Energy per Bit to Noise Ratio
EIRP Spectral Density	Energy Spectral Density
EIRP SD	Energy Spectral Density
E_S/N_0	Energy per Symbol to Noise Ratio
ETSI	European Telecommunications Standards Institute
EVM	Error Vector Magnitude
FDMA	Frequency-Division Multiple Access
FEC	Forward Error Correction
FHSS	Frequency-Hopping Spread Spectrum
HSSI	High Speed Serial Interface
GFP	Generic Framing Protocol
GSE	Generic Stream Encapsulation

G/T	Receive Antenna Gain / Noise Temperature
HSSI	High Speed Serial Interface
I	In-Phase Component
IBS	INTELSAT Business Services
IDR	Intermediate Data Rate
IEEE	Institute of Electrical and Electronics Engineers
IESS	INTELSAT earth station standard
IETF	Internet Engineering Task Force
IF	Intermediate Frequency
INTELSAT	International Telecommunications Satellite Organization
IP	Internet Protocol
ISO	International Organization for Standardization
ITA	Information Throughput Adaptation
ITU-T	International Telecommunications Union – Telecommunication Standardization Sector
LNA	Low Noise Amplifier
MAC	Media Access Control
MAI	Multiple Access Interface
MF-TDMA	Multiple Frequency Time Division Multiple Access
MILSATCOM	Military Satellite Communications
MIL-STD	Military Standard
modcod	combination of modulation and code rate
NATO	North Atlantic Treaty Organization
OQPSK	Offset Quadrature Phase-Shift Keying
PFSD	Power Flux Spectral Density
PM	Program Manager
PPP	Point-to-Point Protocol
PPPoE	Point-to-Point Protocol over Ethernet
PSD	Power Spectral Density
PSK	Phase-Shift Keying
Q	Quadrature-Phase Component
QEF	Quasi Error Free
QPSK	Quadrature Phase-Shift Keying
RF	Radio Frequency
RMS	Root Mean Square
R_D	Data Rate
RS	Reed–Solomon
R_S	Symbol Rate
Rx	Reception
SATCOM	Satellite Communications
SHF	Super High Frequency
SOW	Statement Of Work
STANAG	Standardization Agreement
TDMA	Time-Division Multiple Access
TIA	Telecommunications Industry Association
Tx	Transmission

USSF	United States Space Force
VLAN	Virtual Local Area Network
VSAT	Very Small Aperture Terminal
VSWR	Voltage Standing-Wave Ratio
WGS	Wideband Global SATCOM

3.3 Accuracy. The degree of conformity of a measured or calculated value to its definition, related to the offset from an ideal value.

3.4 Acquisition. Condition reflecting carrier and decoder lock.

3.5 Back to back. Refers to Intermediate Frequency (IF) testing of modems in which two identical modems are used with adequate physical separation to prevent any interaction beyond IF connectivity.

3.6 Baud. Elemental unit of transmission; e.g. "symbol" or "chip."

3.7 Bit Error Ratio (BER). The number of bit errors divided by the total number of transferred bits during a specified time interval.

3.8 Chip. A baud element in a Direct Sequence Spread Spectrum (DSSS) spreading sequence.

3.9 Chip rate (R_C). The baud rate of a DSSS spreading sequence.

3.10 Data rate (R_D). The rate at which data traffic, incident upon one or more data interfaces, is transferred across a satellite channel, measured in bits per second (bits/s).

3.11 Data synchronization. Condition reflecting demodulated data at the reception (Rx) data traffic interface subsequent to successful de-framing and decryption where relevant.

3.12 dBc. Ratio of a non-carrier power component to the total power in a carrier, expressed in decibels (dB).

3.13 E_b/N_0. The ratio of energy per bit to noise Power Spectral Density (PSD), typically expressed in dB. Converts from E_S/N_0 using

$$\frac{E_\mathrm{b}}{N_0} = \frac{E_\mathrm{S}}{N_0} - 10\ \log_{10}\frac{R_\mathrm{D}}{R_\mathrm{S}}$$

3.14 Error Vector Magnitude (EVM). Sometimes referred to as "constellation error" (CE), EVM is a measurement used to quantify the performance of a digital radio transmitter. EVM is expressed in percent Root Mean Square (RMS) and is computed as follows:

$$EVM = \frac{\sqrt{\frac{1}{N_S}\sum_{k_S=0}^{N_S-1} |\epsilon(k_S)|^2}}{\sqrt{\frac{1}{N_C}\sum_{k_C=0}^{N_C-1} I_{ref}{}^2(k_C) + Q_{ref}{}^2(k_C)}}$$

where:

N_S = the number of symbols over which the EVM measurement is taken;
k_S = the symbol index;
N_C = the number of constellation points in the modulation waveform = $2^{\text{mod index}}$;
k_C = the constellation point index;
$I_{ref}(k_C)$ = in-phase coordinate of k_c indexed ideal constellation point;
$Q_{ref}(k_C)$ = quadrature-phase coordinate of k_c indexed ideal constellation point.

and

$$\epsilon(k_S) = \sqrt{I_{err}{}^2(k_S) + Q_{err}{}^2(k_S)}$$

where:

$I_{err}(k_S) = I_{actual}(k_S) - I_{ref}(k_S)$;
$I_{actual}(k_S)$ = in-phase coordinate of k_S indexed actual constellation point;
$Q_{err}(k_S) = Q_{actual}(k_S) - Q_{ref}(k_S)$;
$Q_{actual}(k_S)$ = quadrature coordinate of k_S indexed actual constellation point.

3.15 E_S/N_0. The ratio of energy per symbol to noise PSD, typically expressed in dB. Converts from E_b/N_0 using

$$\frac{E_S}{N_0} = \frac{E_b}{N_0} + 10\ \log_{10}\frac{R_D}{R_S}$$

3.16 Frequency uncertainty. The difference between a received signal's expected frequency and its actual frequency. Frequency uncertainty results when 1) a difference in frequency between reference oscillators exists, 2) Doppler effects cause frequency shifts, or 3) frequency setting inaccuracies exist.

3.17 Modem emulation. A standardized or otherwise prescribed set of rules governing the signal processing and waveform construction required to produce a conforming modulation waveform. Conformance to specified modem emulations is the basis for waveform-level interoperability between modems.

3.18 Punctured code. A higher-rate code obtained by periodically deleting bits from a lower-rate code.

3.19 Quasi Error Free E_S/N_0 (QEF E_S/N_0). The threshold E_S/N_0 specified for BER = 10^{-10} (PER=10^{-7}). If the threshold E_S/N_0 is not specified for BER = 10^{-10} (PER=10^{-7}), then it will be extrapolated from the next higher specified threshold BER at a rate of 0.05 dB of E_S/N_0 per factor of 10 BER.

3.20 Reference E_S/N_0. A threshold relevant to some specified performance as an underlying condition. Reference E_S/N_0 often corresponds to a stated BER value.

3.21 Stability. The degree to which an oscillating signal produces the same frequency for a specified time interval.

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

3.23 Threshold E_b/N_0. The E_b/N_0 at which the measured BER must not exceed the specified BER.

$$\text{Threshold } \frac{E_\text{b}}{N_0} = \text{Threshold } \frac{E_\text{S}}{N_0} - 10 \log_{10} \frac{R_\text{D}}{R_\text{S}}$$

3.24 Threshold E_S/N_0. The E_S/N_0 at which the measured BER must not exceed the specified BER.

$$\text{Threshold } \frac{E_\text{S}}{N_0} = \text{Threshold } \frac{E_\text{b}}{N_0} + 10 \log_{10} \frac{R_\text{D}}{R_\text{S}}$$

4 GENERAL REQUIREMENTS

4.1 Overview. This section defines the subject modem and specifies the conditions under which it operates. A description of general modem transmission, reception, and control and monitor functions is provided in 4.2. The relevant operating environment is described in 4.3; 4.4 describes unique DoD environmental conditions under which the subject modem must operate.

4.2 Modem description. A modem shall implement one or more transmission functions and one or more reception functions, along with associated control and monitoring functions. Separate transmission and reception functions shall be implemented as applicable for different applications and asymmetric data rates. A modem functional overview is shown on FIGURE 1.

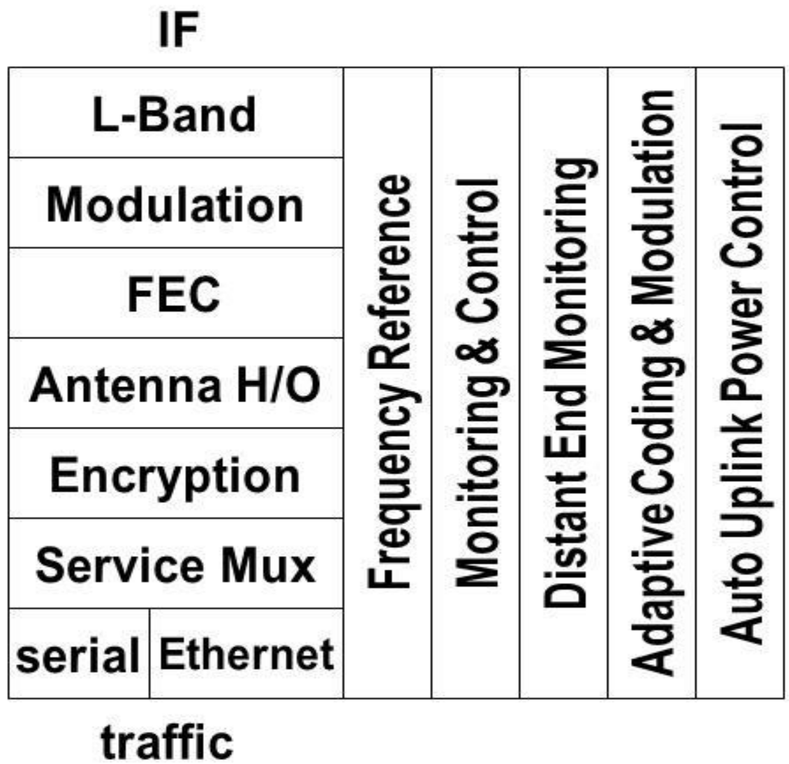


FIGURE 1. Modem functional overview.

4.2.1 Transmission function. The transmission function shall accept data signals from a digital data source and use these digital data signals to modulate an IF carrier in accordance with one or more prescribed modem standards. The transmission function shall then send this IF signal to an IF output interface. Prescribed modem standards define the following transmission functions and components:

a. Data input interface(s).

b. Provisions for automated power control, where applicable.

c. Provisions for adaptive coding and modulation, where applicable.

d. Provisions for supporting distant-end status monitoring, where applicable.

e. Internal service channel source.

f. Service multiplexer.

g. Encryption.

h. Scrambling for purposes of data randomization.

i. Encoding for mitigation of Antenna Handover (AH) effects, where applicable.

j. Differential encoding.

k. Forward Error Correction (FEC) encoding.

l. Symbol-level carrier modulation.

m. Modulation framing.

n. IF output interface.

4.2.2 Reception function. The reception function shall receive an IF signal from an IF input interface. The reception function shall then demodulate this IF signal in accordance with one or more prescribed modem standards. The reception function shall then send data and, if necessary, timing derived from the data, to a digital data sink. Prescribed modem standards define the following reception functions and components:

a. IF input interface.

b. Modulation de-framing.

c. Symbol-level carrier demodulation.

d. FEC decoding.

e. Differential decoding.

f. Decoding for mitigation of AH effects, where applicable.

g. Descrambling for purposes of data de-randomization.

h. Decryption.

i. Service demultiplexer.

j. Internal service channel sink.

k. Provisions for distant-end status monitoring, where applicable.

l. Provisions for supporting distant-end adaptive coding and modulation, where applicable.

m. Provisions for supporting distant-end automated power control, where applicable.

n. Data output interface(s).

4.2.3 Control and monitoring functions. The modem shall interface with external controlling and monitoring components.

4.3 Operational conditions. Unless otherwise specified, the requirements specified in this MIL-STD shall be met over the range of environmental conditions specified by the relevant procuring authority.

4.4 Environmental perturbation. Active links shall not lose acquisition, nor serial data traffic ports lose bit count integrity, at the E_S/N_0 required for BER = 10^{-10} (PER=10^{-7}), over the range of environmental conditions specified by the procuring authority. 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 modem, simulating maintenance, operator or other external action on the modem.

5 DETAILED REQUIREMENTS

5.1 Overview. This section provides detailed requirements that address every major modem interface, subsystem, and performance category.

5.2 Frequency reference. Modems shall accept an external frequency reference signal as follows:

a. Signal type: sinusoidal.

b. Frequency: either 5 MHz or 10 MHz, at least one or the other.

c. Input impedance: 50 Ω (nominal).

d. Input signal level: +6 to +16 dBm.

e. Maximum VSWR: 1.5:1.

Modems shall include an internal frequency reference for accuracy and stability when an external frequency reference signal is not present.

5.3 Baseband interfaces. In 5.3.1–5.3.3, modem baseband traffic interfaces are defined in terms of data rates and their granularity, mandatory Internet Protocol (IP)-centric Ethernet data interfaces, and optional legacy serial interfaces.

5.3.1 Data rates. The data rate resolution for all modems shall be in 1-bit-per-second increments. The minimum and maximum data rates shall be specified by the procuring authority.

5.3.2 Ethernet data interfaces. Ethernet data interfaces shall be implemented in accordance with

a. IEEE 802.3i (10Base-T), IEEE 802.3u (100Base-T) and IEEE 802.3ab (1000Base-T);

b. or IEEE 802.3ae (10 Gigabit Ethernet).

5.3.2.1 IP encapsulation. Deleted.

5.3.2.2 Ethernet flow control. When implementing radio aware routing, for the sake of adaptive coding and modulation (ACM) or otherwise, modems that implement Ethernet data interfaces shall support PPPoE with extensions introduced in RFC 5578 for credit-based session flow control and session-based link metric quality reports.

5.3.3 Serial data interfaces. When equipped with serial data interfaces, the modem shall operate with one or more baseband data interfaces that conform to one or more of the formats described in 5.3.3.1–5.3.3.3, as selected by the procuring authority.

5.3.3.1 High Speed Serial Interface. High Speed Serial Interface (HSSI) shall be in accordance with TIA-612 and TIA-613.

5.3.3.2 Balanced serial. Balanced serial with electrical characteristics shall be in accordance with TIA-422; mechanical characteristics shall be in accordance with TIA-530.

5.3.3.3 Unbalanced serial. Unbalanced serial with electrical characteristics shall be in accordance with TIA-423; mechanical characteristics shall be in accordance with TIA-530.

5.4 Modem emulations.

a. In 5.4.1–5.4.12, modem emulations are defined, where possible, by referencing military or commercial modem standards. The list of modem emulations begins with Continuous Wave (CW), a trivial case necessary for test and diagnostic purposes. In 5.4.7–5.4.11, four explicit modem emulations are generally defined by referencing external standards. In 5.4.12, provisions for introducing additional modem emulations beyond those indicated here are described.

b. The modem shall implement one or more of the following modem emulations in accordance with the prescribed standards as indicated in 5.4.1–5.4.11, subject to the determination of the procuring authority.

c. Each modem emulation implemented shall include provisions for uncoded operation of every modulation format employed.

5.4.1 Continuous wave. The modem shall be able to output an unmodulated signal. This emulation is mandatory.

5.4.2 OM-73. OM-73-compliant emulations shall be in accordance with the following paragraphs of A3197423, and as otherwise indicated:

a. Generally in accordance with Transmitter Module Characteristics.

b. Scrambling in accordance with Bit Randomizer.

c. Differential encoding in accordance with Differential Encoder and Interface.

d. FEC encoding in accordance with FEC Encoder, and with the punctured code patterns shown in TABLE I below.

TABLE I. FEC punctured code patterns

Code Rate	Symbol	Transmission Bit Sequence and Puncture Pattern						
		B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**
3/4	*P1*[1]	1	∅[2]	1	1	∅	1	1
	P2[3]	1	1	∅	1	1	∅	1
7/8	*P1*	1	∅	∅	∅	1	∅	1
	P2	1	1	1	1	∅	1	∅

[1] *P1* = 171_8 polynomial output.
[2] ∅ = Deleted bit.
[3] *P2* = 133_8 polynomial output.

e. Symbol-level carrier modulation in accordance with RF Modulator.

(1) For Binary Phase-Shift Keying (BPSK), transmitting *P2* followed by *P1*, according to the puncture pattern shown in TABLE I.

(2) For Quadrature Phase-Shift Keying (QPSK) and Offset Quadrature Phase-Shift Keying (OQPSK), with symbol mapping as presented in TABLE II below.

TABLE II. QPSK and OQPSK symbol mapping.

Code Rate	Channel	Number of Transmitted Symbols						
		S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
1/2	I[1]	*P1*[2] (B1)	*P1* (B2)	*P1* (B3)	*P1* (B4)	*P1* (B5)	*P1* (B6)	*P1* (B7)
	Q[3]	*P2*[4] (B1)	*P2* (B2)	*P2* (B3)	*P2* (B4)	*P2* (B5)	*P2* (B6)	*P2* (B7)
3/4	I	*P1* (B1)	*P1* (B3)	*P1* (B4)	*P1* (B6)	*P1* (B7)	--	--
	Q	*P2* (B1)	*P2* (B2)	*P2* (B4)	*P2* (B5)	*P2* (B7)	--	--
7/8	I	*P1* (B1)	*P2* (B3)	*P1* (B5)	*P1* (B7)	--	--	--
	Q	*P2* (B1)	*P2* (B2)	*P2* (B4)	*P2* (B6)	--	--	--

[1] I = In-phase component.
[2] *P1* = 171_8 polynomial output.
[3] Q = Quadrature-phase component.
[4] *P2* = 133_8 polynomial output.

5.4.3 Legacy MIL-STD-188-165. Legacy MIL-STD-188-165-compliant emulations shall be implemented as follows:

a. Scrambling selectable from:

(1) No scrambling.

(2) OM-73-compliant scrambling in accordance with A3197423, Bit Randomizer.

(3) Scrambling in accordance with the energy dispersal (scrambling) requirements of IESS-308, IESS-309, and IESS-310.

b. Differential encoding shall be either disabled or:

(1) For BPSK, bit-wise.
(2) For QPSK and OQPSK, separate for I and Q.
(3) For 8-PSK, in accordance with IESS-310.

c. FEC encoding.

(1) Reed-Solomon (RS) outer codes shall be selectable from the following options.

(a) No outer code.
(b) RS(126,112) for data rates below 512 kilobits-per-second (kb/s).
(c) RS(219,201) for data rates greater than or equal to 512 kb/s.
(d) RS(225,205) at any rate.

(2) Interleaver depth shall be selectable, either 4 or 8, for use when RS outer codes are selected.

(3) For BPSK, QPSK, and OQPSK, selectable convolutional encoding with 7-bit constraint-length convolutional encoding polynomials $P1 = 171_8$ and $P2 = 133_8$ and punctured code patterns shall be as presented in TABLE III.

TABLE III. BPSK, QPSK, and OQPSK punctured code patterns.

Code Rate	Symbol	Transmission Bit Sequence and Puncture Pattern						
		B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**
3/4	*P1*[1]	1	~~∅~~[2]	~~1~~	~~1~~	~~∅~~	1	1
	P2[3]	1	1	∅	1	1	∅	1
7/8	*P1*	1	∅	∅	~~∅~~	1	~~∅~~	~~1~~
	P2	1	1	1	1	∅	1	∅

[1] $P1 = 171_8$ polynomial output.
[2] ~~∅~~ = Deleted bit.
[3] $P2 = 133_8$ polynomial output.

(4) For 8-PSK, rate 2/3 pragmatic trellis FEC coding and signal mapping shall be in accordance with IESS-310.

d. Symbol-level carrier modulation.

(1) For BPSK, QPSK, and OQPSK, in accordance with 5.4.2e of this document.
(2) For 8-PSK, in accordance with IESS-310.

5.4.4 IESS-308. Modems that implement IESS-308 emulations shall do so in accordance with IESS-308.

5.4.5 IESS-309. Modems that implement IESS-309 emulations shall do so in accordance with IESS-309.

5.4.6 IESS-310. Modems that implement IESS-310 emulations shall do so in accordance with IESS-310.

5.4.7 IESS-315. Modems that implement IESS-315 emulations shall do so in accordance with IESS-315.

5.4.8 NATO STANAG 4486. Modems that implement NATO STANAG 4486 emulations shall do so as follows:

a. Apply requirements in general, in accordance with NATO STANAG 4486 annexes relevant to "EBEM."

b. IP encapsulation shall be in accordance with NATO STANAG 4486 section entitled "Packet Channel" and its subsections."

c. When applicable, provisions for Automated Uplink Power Control shall be in accordance with NATO STANAG 4486 section entitled "AUPC."

d. When applicable, provisions for Information Throughput Adaptation (ITA) (adaptive coding and modulation) shall be in accordance with NATO STANAG 4486 section entitled "ITA."

e. When applicable, provisions for Distant-End Monitoring shall be in accordance with NATO STANAG 4486 section entitled "DEM."

f. When applicable, embedded channel interfaces shall be in accordance with NATO STANAG 4486 sections entitled "Embedded Channel," "Embedded Channel Interfaces" and "Embedded Channel GFP Acquisition and Synchronization Procedures."

g. Service multiplexers shall be in accordance with NATO STANAG 4486 sections entitled Frame Format #1 (ITA)," "Multiplexor" and "Frame Format #2 (AH)."

h. Encryption shall be in accordance with NATO STANAG 4486 sections entitled "Encryption."

i. Selectable scrambling shall be in accordance with NATO STANAG 4486 sections entitled "Scrambler."

j. When applicable, encoding for mitigation of AH effects shall be in accordance with NATO STANAG 4486 sections entitled "Frame Format #2 (AH)," "Antenna Handover," "Antenna Handover Interface" and "Antenna Handover Cable."

k. FEC encoding shall be in accordance with NATO STANAG 4486 section entitled "Turbo Code and 16-ary Modulation Air Interface," specifically the subsection entitled "Turbo Code."

l. Symbol-level carrier modulation shall be in accordance with NATO STANAG 4486 sections entitled "Symbol Generation" and "Symbol Mapping."

m. Modulation framing shall be in accordance with NATO STANAG 4486 section entitled "Frame Structure," "Frame Structures" and "Frame Format #2 (AH)" as applicable.

5.4.9 ETSI EN 301 790 (DVB RCS). Modems that implement ETSI EN 301 790 emulations shall do so in accordance with ETSI EN 301 790.

5.4.10 ETSI EN 302 307-1 (DVB-S2). Modems that implement ETSI EN 302 307-1 emulations shall do so in accordance with ETSI EN 302 307-1.

5.4.11 ETSI EN 302 307–2 (DVB-S2X). Modems that implement ETSI EN 302 307–2 emulations shall do so in accordance with ETSI EN 302 307–2.

5.4.12 New modem emulations. New modem emulations may be considered for inclusion in this standard under the following conditions:

a. The waveform is specified

(1) in accordance with open commercial standards available to Government and vendor communities,
(2) or in accordance with other Government standards.

b. The waveform satisfies a need not met by existing waveforms cited in this standard.

c. The waveform is free of intellectual property restrictions.

5.5 IF output interface. In 5.5.1–5.5.6, modem IF (transmission) output is specified.

5.5.1 IF output frequency bands. The modem shall support a 950 to 2000 MHz IF interface. Modem performance parameters detailed in this standard shall be met for all waveforms whose -25 dB bandwidths are contained within the bandwidth limits.

5.5.2 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 1.5:1 for IF band center frequencies below 1 GHz and 2.0:1 for IF band center frequencies above 1 GHz.

5.5.3 IF output carrier.

5.5.3.1 IF output carrier frequency. The modem shall provide an IF output carrier configurable in 1 kHz steps, or sub-multiples thereof.

5.5.3.2 IF stability. The IF output carrier frequency shall be stable to within 10^{-8} per day without frequency source adjustments.

5.5.3.3 IF accuracy. When an external frequency reference is not present, the IF output carrier frequency shall be within 10^{-7} of the selected value after a 1 hour warm-up period. When an external frequency reference is present, the IF output carrier frequency shall be within 10^{-7} of the selected value without a warm-up period.

5.5.3.4 Phase noise. The single-sided phase noise PSD $S_\emptyset(f)$ shall not exceed the phase noise PSD threshold $S_{\emptyset\max}(f)$ over the interval $[f_1, f_2]$ where

$$S_{\emptyset\max}(f) = \frac{K_{\emptyset\max}}{f}$$

$$K_{\emptyset\max} = P_{\emptyset\max} - 11.4\text{ dB}$$

$$P_{\emptyset\max} = -20\text{ dB} - \left.\frac{E_S}{N_0}\right|_{\text{QEF max}} \quad \text{but not to exceed -40.6 dBc}$$

$\left.\frac{E_S}{N_0}\right|_{\text{QEF max}}$ is the maximum QEF $\frac{E_S}{N_0}$ presented by the modem

$$f_1 = 0.0005\ R_{\text{Smin}}$$

$$f_2 = 0.5\ R_{\text{Smax}}$$

R_{Smin} is the minimum symbol rate supported by the modem

R_{Smax} is the maximum symbol rate supported by the modem

If $S_{\emptyset}(f) > S_{\emptyset\max}(f)$ for any $f_1 \leq f \leq f_2$, then it shall be required that

$$2\int_{0.0005\,R_S}^{0.5\,R_S} S_{\emptyset}(f)\,df \leq P_{\emptyset\max}$$

for all symbol rates R_S supported by the modem.

Examples prepared in TABLE IV are illustrated on FIGURE 2.

TABLE IV. Transmitted IF phase noise threshold examples.

Example	$\boldsymbol{R_{\text{YMSmin}}}$	$\boldsymbol{R_{\text{Smax}}}$	$\boldsymbol{\left.\frac{E_S}{N_0}\right\vert_{\text{QEF max}}}$	$\boldsymbol{f_1}$	$\boldsymbol{f_2}$	$\boldsymbol{-20\text{ dB} - \left.\frac{E_S}{N_0}\right\vert_{\text{QEF max}}}$	$\boldsymbol{P_{\emptyset\max}}$	$\boldsymbol{K_{\emptyset\max}}$
1	32	64	16	16	32	-36	-40.6	-52
2	200	400	28	100	200	-48	-48	-59.4
units	ksym/s	Msym/s	dB	Hz	MHz	dBc	dBc	dBc

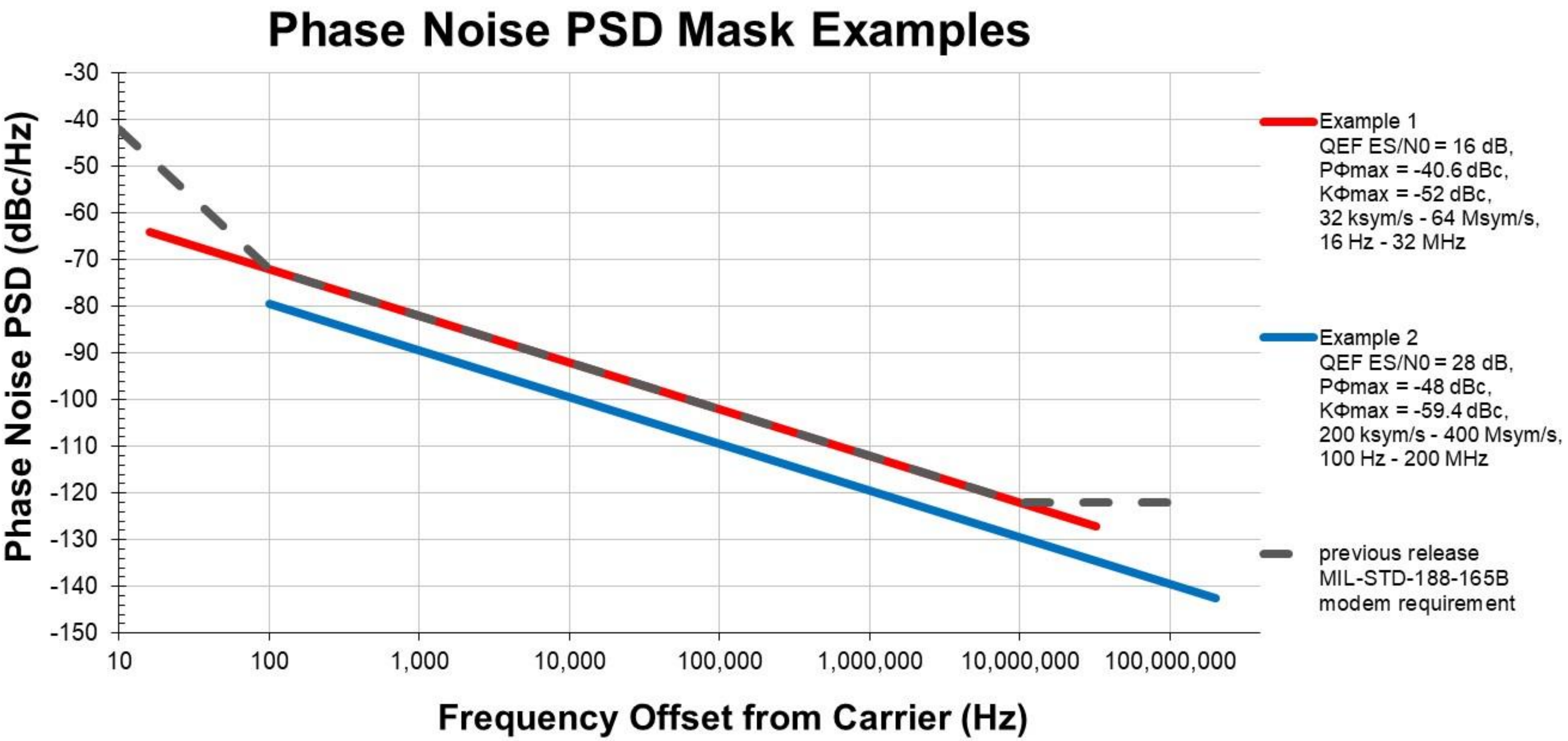


FIGURE 2. Transmitted IF phase noise mask examples.

5.5.4 Output power control range, step size, and accuracy. The absolute accuracy of the carrier power shall be within 1.0 dB of the selected 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 output power shall be adjustable over the range from 0 to −40 dBm. When a power change is initiated, the 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 1.2R_S). When the transmission carrier output is set to OFF, signal present at the output, from 0 to 4,000 MHz, shall be no greater than −70 dBm across any 3 MHz bandwidth and not greater than −80 dBm across any 30 kHz bandwidth. These transmission carrier output OFF thresholds are illustrated on FIGURE 3.

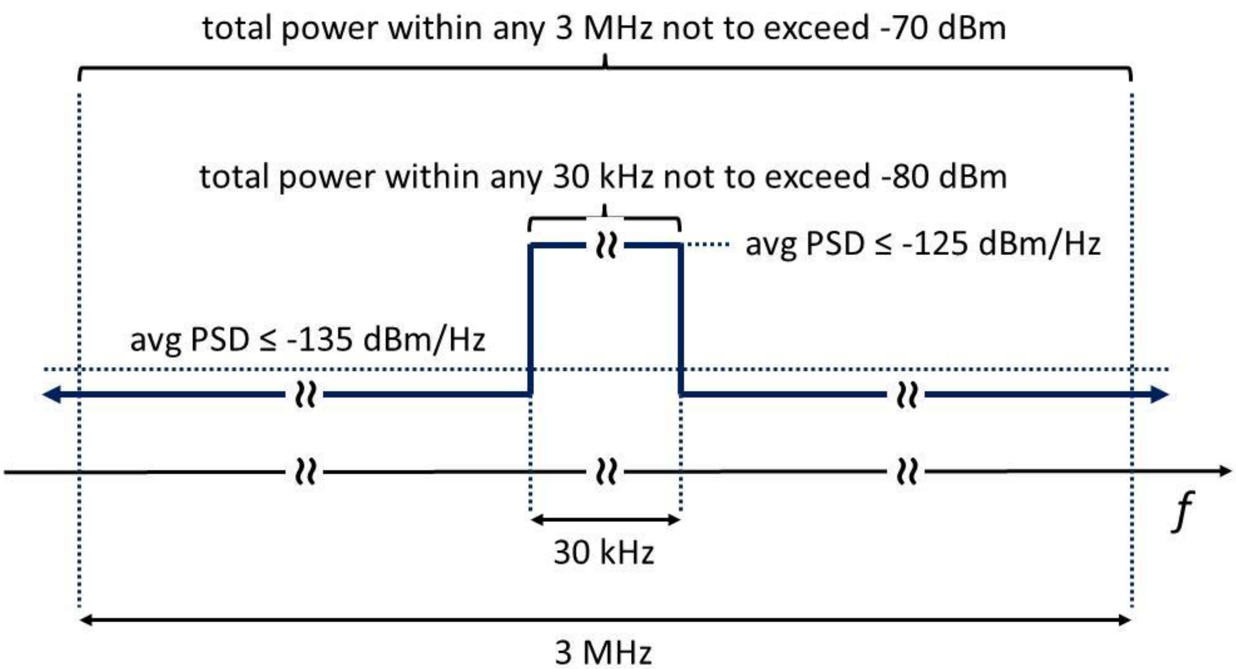


FIGURE 3. Transmission carrier output OFF thresholds.

5.5.5 Spectral output.

5.5.5.1 Spectral confinement. The IF output signal shall meet the modulator output signal spectral density mask shown on FIGURE 4. This requirement shall be met when terminating into a 50 Ω load with a VSWR as specified in 5.5.2. It shall be acceptable for transmission spectra to exhibit the following:

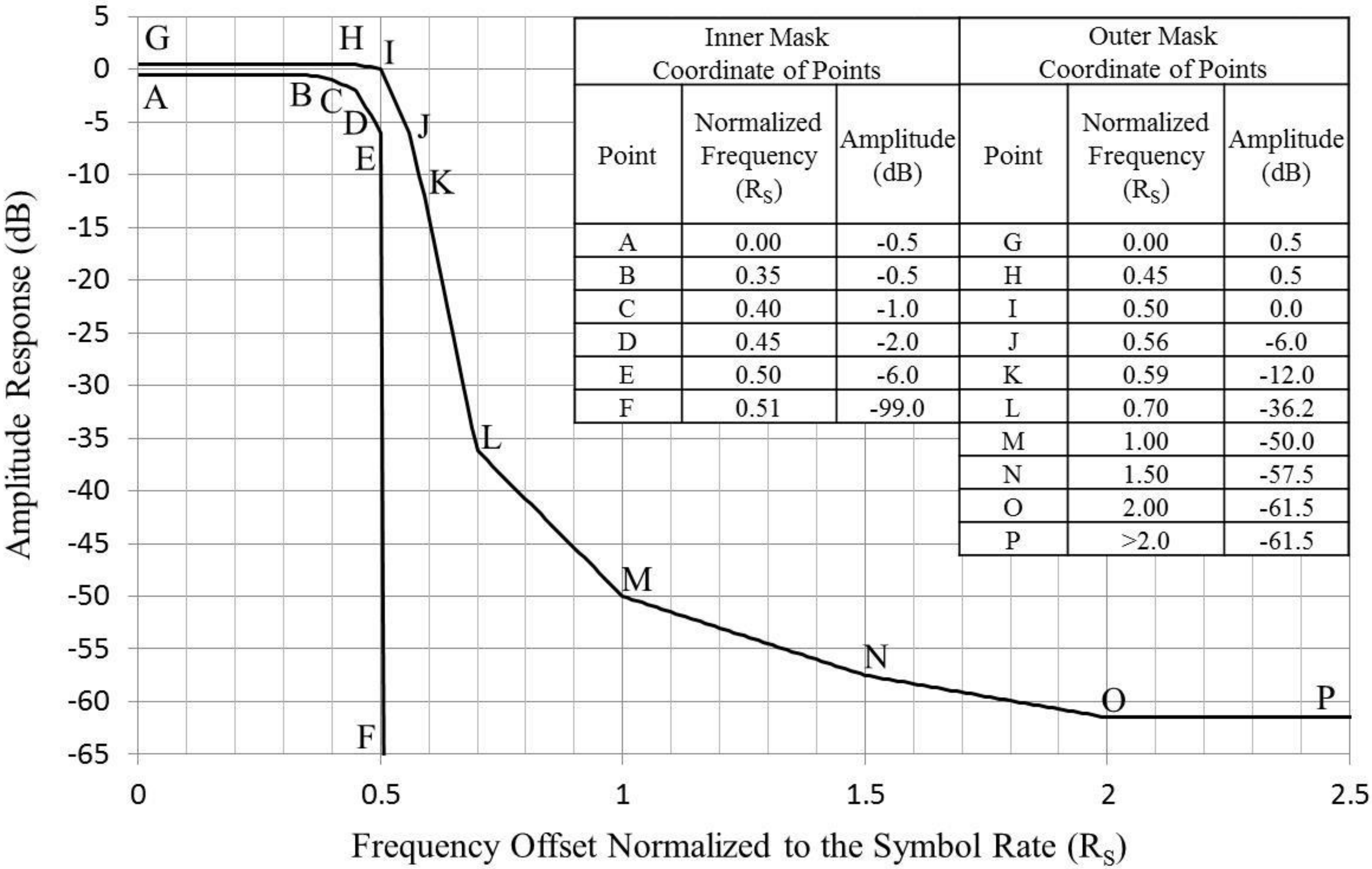
a. Carrier nulls at the carrier for BPSK modulation only.

b. Clock nulls, offset by half the symbol rate from the carrier, for BPSK and OQPSK modulation only.

c. PSD not to exceed the Transmit (Tx) thermal noise floor threshold specified in 5.5.5.2 when this threshold exceeds the PSD confinement mask shown on FIGURE 4.

d. Spurious emissions compliant with 5.5.5.3.

e. Output harmonics compliant with 5.5.5.4.



Inner Mask Coordinate of Points			Outer Mask Coordinate of Points		
Point	Normalized Frequency (R_S)	Amplitude (dB)	Point	Normalized Frequency (R_S)	Amplitude (dB)
A	0.00	-0.5	G	0.00	0.5
B	0.35	-0.5	H	0.45	0.5
C	0.40	-1.0	I	0.50	0.0
D	0.45	-2.0	J	0.56	-6.0
E	0.50	-6.0	K	0.59	-12.0
F	0.51	-99.0	L	0.70	-36.2
			M	1.00	-50.0
			N	1.50	-57.5
			O	2.00	-61.5
			P	>2.0	-61.5

FIGURE 4. Modulator output signal spectral density limit mask.

5.5.5.2 Transmission thermal noise. The IF output thermal noise density shall not exceed the greater of −135 dBm/Hz or −135 dBc/Hz over the full IF band.

5.5.5.3 Transmission output spurious emissions. Spurious emission power in any 10 kHz bandwidth, exceeding -70 dBm, shall be controlled relative to total modulated carrier power as follows:

$$P_{\text{spurious}} \leq -51\ \text{dBc} - \left.\frac{E_S}{N_0}\right|_{\text{QEF}}$$

where:

$\left.\frac{E_S}{N_0}\right|_{\text{QEF}}$ is the threshold $\frac{E_S}{N_0}$ corresponding to a BER of 10^{-10} (PER=10^{-7}) for the most spectrally efficient modulation and coding (modcod) supported by the modem;

If the threshold $\frac{E_S}{N_0}$ (or $\frac{E_b}{N_0}$) is not specified for a BER of 10^{-10} (PER=10^{-7}), then the threshold $\frac{E_S}{N_0}$ for the next higher specified BER may be used;

The expression bounding P_{spurious} is limited above by -51 dBc and below by -70 dBm.

This requirement excludes ±1.0R_S centered on the carrier.

5.5.5.4 Transmission output harmonics. The power of any transmission carrier harmonic exceeding -70 dBm shall be controlled, relative to total modulated carrier power, as follows:

a. Within the tunable band,

$$P_{\text{harmonic}} \leq -51\ \text{dBc} - \left.\frac{E_S}{N_0}\right|_{\text{QEF}}$$

where:

$\left.\frac{E_S}{N_0}\right|_{\text{QEF}}$ is as defined in 5.5.5.3;

The expression bounding P_{harmonic} is limited above by -51 dBc and below by -70 dBm.

b. Outside of the tunable band, the level of any transmission carrier harmonic shall not exceed −70 dBc.

5.5.6 Modulation performance.

5.5.6.1 Spectral inversion. Frequency conversion, if employed, shall not invert the modulator's output spectrum.

5.5.6.2 Error vector magnitude. Modulation EVM shall not exceed the following thresholds.

a. 6% for BPSK, QPSK and OQPSK.

b. 4% for 8-ary modulation.

c. 3% for 16-ary modulation.

d. 2% for 32-ary modulation or higher.

5.6 IF input interface. In 5.6.1–5.6.4, the modem IF (receive) input is specified in terms of the following.

a. Frequency bands (5.6.1) in terms of required L-band, as well as other optional bands.

b. Electrical impedance (5.6.2).

c. Input carrier (5.6.3) in terms of frequency resolution and uncertainty.

d. Input power level (5.6.4) in terms of maximum and minimum desired carrier levels, allowable composite power, and maximum non-damaging input power.

5.6.1 IF input frequency bands. The modem shall support a 950 to 2000 MHz IF interface. Modem performance parameters detailed in this standard shall be met for all waveforms whose -25 dB bandwidths are contained within the bandwidth limits.

5.6.2 Input impedance. The input shall have a nominal impedance of 50 Ω. The VSWR over the IF band shall be less than 1.5:1 for IF band center frequencies below 1 GHz and 2.0:1 for IF band center frequencies above 1 GHz.

5.6.3 IF input carrier.

5.6.3.1 IF input carrier frequency. The modem shall accept an IF input carrier configurable in 1 kHz steps, or submultiples thereof.

5.6.3.2 Input frequency uncertainty. The modem shall be able to acquire and demodulate carriers that are within 30 kHz of the nominal expected frequency (5.6.3.1). This includes the maximum offset due to doppler shift (5.7.2.6).

5.6.4 IF input power. The BER shall not be degraded from the requirements specified in 5.7.3 when the composite or desired IF input power levels are as described in 5.6.4.1–5.6.4.2.

5.6.4.1 Desired carrier. The demodulator shall operate with any IF input power level between the minimum and maximum levels specified in 5.6.4.1.1 and 5.6.4.1.2, respectively, for a given IF input carrier and required error performance.

5.6.4.1.1 Minimum operating IF carrier input level. The demodulator shall operate with a minimum carrier level such that:

$$P_{\min} = -130 \text{ dBm/Hz} + E_S/N_0 + 10 \log R_S \text{ [dBm]}$$

where:

E_S/N_0 (in dB) is the specified performance value for a BER of 10^{-8}
R_S is symbol rate in symbols per second (sym/s).

Where E_S/N_0 performance is not specified, then:

$$E_S/N_0 = E_b/N_0 + 10 \log R_D/R_S$$

where:

E_b/N_0 (in dB) is the specified performance value for a BER of 10^{-8}
R_D is data rate in Mbps.

5.6.4.1.2 Maximum operating IF carrier input level. The demodulator shall operate with a maximum carrier level such that:

$$P_{max} = -63 \text{ dBm/Hz} + 10 \log R_S \text{ [dBm]}$$

where:

R_S is the symbol rate in sym/s;
P_{max} is capped at +10 dBm.

5.6.4.2 Composite power. The modem shall be able to demodulate IF input carriers in the presence of total IF input power up to +20 dBm.

5.6.4.3 IF input overload. The modem shall not be damaged by a continuous IF input up to +25 dBm.

5.6.5 Noise Figure. The demodulator noise figure shall not exceed 27 dB, referenced to the IF input interface and to a physical temperature of 290K. This corresponds to an internal demodulator noise floor not to exceed -147 dBm/Hz.

5.7 Demodulation. In 5.7.1–5.7.3, demodulation performance is specified.

5.7.1 Demodulation requirements. All IF input carriers, incident on the IF input interface under conditions compliant with 5.6 through 5.6.4.3, that have been modulated in accordance with the specifications set forth in 5.4, shall meet performance indicated in 5.7.2 through 5.7.3.4 below.

5.7.2 Acquisition and timing performance requirements. In 5.7.2.1–5.7.2.6, the reference E_S/N_0 is defined as the specified threshold E_S/N_0 that corresponds to a BER of 10^{-4} or PER=10^{-2}. If the threshold E_S/N_0 is not specified for a BER of 10^{-4} or PER=10^{-2}, then the reference E_S/N_0 is extrapolated from the threshold E_S/N_0 for the highest specified BER point at a rate of 0.05 dB of E_S/N_0 per BER factor of 10.

5.7.2.1 Initial data acquisition. The modem shall achieve initial data acquisition within the times shown in TABLE V, over a frequency uncertainty of ±30 kHz at the reference E_S/N_0.

TABLE V. Acquisition times for selected symbol rates.

Symbol Rate Range (ksym/s)	Maximum Initial Data Acquisition Time (s)	Maximum Data Reacquisition Time (s)
$16 \le R_S < 64$	500	25
$64 \le R_S < 128$	250	25
$128 \le R_S < 1544$	15	10
$1544 \le R_S$	1	1

5.7.2.2 Data reacquisition. Data reacquisition shall be achieved in accordance with TABLE V, upon carrier return to within 500 Hz of the carrier frequency at the time of loss.

5.7.2.3 Bit count integrity. This requirement applies to serial baseband interfaces: In transmitting and receiving random data, the mean time to loss of data synchronization (Ethernet) or Bit-Count Integrity (BCI) (serial interfaces) due to falsely adding or deleting bits shall be at least 7 days at the reference E_S/N_0. In addition, data synchronization (Ethernet) and BCI (serial interfaces) shall be maintained over 50 consecutive bits in the case of all "ones" and the case of all "zeros," which shall occur no more than once in 10,000 bits without employing data scrambling.

5.7.2.4 Synchronization retention. Data synchronization (Ethernet) and BCI (serial interfaces) shall be maintained at the reference E_S/N_0 for a signal loss of up to 200 modulation symbol periods.

5.7.2.5 Timing jitter. This requirement applies to serial baseband interfaces: At the reference E_S/N_0, the peak output jitter of the reception output clock shall not exceed ±5 percent relative to an ideal reference output clock.

5.7.2.6 Doppler environment. The modem shall meet the requirements specified in 5.7.2.1–5.7.2.5, with a Doppler shift, rate of change, and acceleration as presented in TABLE VI at the same reference E_S/N_0 defined in 5.7.2.

TABLE VI. Doppler parameters.

Parameter	Military X-Band	Military Ka-Band
Doppler shift[1] (Hz)	±3,535	±11,810
Doppler rate of change[2] (Hz/s)	±270	±1,046
Doppler acceleration[2] (Hz/s^2)	±290	±1,124

[1] Doppler shift corresponds to geostationary satellite inclinations up to 7°.
[2] Doppler rate of change and acceleration correspond to Navy requirements based on shipboard motion at one side of the link (see Technical Report 1578 (AD-A267 884). Some waveforms cited in 5.4 may not be suitable for meeting these thresholds at lower symbol rates. Higher rate of change and acceleration thresholds may be appropriate when contemplating ship-to-ship operation, land mobile operation and airborne operation.

5.7.3 Error performance requirements.

5.7.3.1 Back-to-back error performance. Back-to-back error performance shall conform to standards and specifications relevant to the corresponding modem emulations as cited in 5.7.3.1.1–5.7.3.1.12.

5.7.3.1.1 CW modulation format. No requirement.

5.7.3.1.2 OM-73. Error performance of OM-73-compliant emulations shall conform to IESS-309 "QPSK Characteristics and Transmission Parameters for IBS Carriers Using Rate 1/2 FEC (Intelsat VI)" and "QPSK Characteristics and Transmission Parameters for IBS Carriers Using Rate 3/4 FEC (Intelsat VI)."

5.7.3.1.3 Legacy MIL-STD-188-165. Error performance of MIL-STD-188-165-compliant emulations shall conform to the following.

a. IESS-309 "QPSK Characteristics and Transmission Parameters for IBS Carriers Using Rate 1/2 FEC (Intelsat VI)" and "QPSK Characteristics and Transmission Parameters for IBS Carriers Using Rate 3/4 FEC (Intelsat VI)" for BPSK and QPSK.

b. IESS-310 Bit Error Rate Performance Characteristics for 8-PSK.

5.7.3.1.4 IESS-308. Error performance of IESS-308-compliant emulations shall conform to IESS-308, "Bit Error Rate Performance Characteristics."

5.7.3.1.5 IESS-309. Error performance of IESS-309-compliant emulations shall conform to IESS-309 "QPSK Characteristics and Transmission Parameters for IBS Carriers Using Rate 1/2 FEC (Intelsat VI)" and "QPSK Characteristics and Transmission Parameters for IBS Carriers Using Rate 3/4 FEC (Intelsat VI)."

5.7.3.1.6 IESS-310. Error performance of IESS-310-compliant emulations shall conform to IESS-310.

5.7.3.1.7 IESS-315. Error performance of IESS-315-compliant emulations shall conform to IESS-315.

5.7.3.1.8 NATO STANAG 4486. Error performance of NATO STANAG 4486 emulations shall conform to the thresholds specified in APPENDIX A.

5.7.3.1.9 ETSI EN 301 790 (DVB RCS). Error performance of ETSI EN 301 790 compliant emulations forward and return links shall conform to ideal E_S/N_0 performance cited in ETSI EN 302 307-1 with implementation loss allowances specified in 5.7.3.1.10.

5.7.3.1.10 ETSI EN 302 307-1 (DVB-S2). Error performance of ETSI EN 302 307-1-compliant emulations shall conform to ideal E_S/N_0 performance cited in ETSI EN 302 307-1 with implementation loss allowances as follows.

a. 0.8 dB for QPSK

b. 0.9 dB for 8-PSK

c. 1.0 dB for 16-ary

d. 1.1 dB for 32-ary

5.7.3.1.11 ETSI EN 302 307–2 (DVB-S2X). Error performance of ETSI EN 302 307–2-compliant emulations shall conform to ideal E_S/N_0 performance cited in ETSI EN 302 307–2 with implementation loss allowances as follows.

a. 0.8 dB for QPSK

b. 0.9 dB for 8-PSK

c. 1.0 dB for 16-ary

d. 1.1 dB for 32-ary

e. 1.2 dB for 64-ary

f. 1.3 dB for 128-ary

g. 1.4 dB for 256-ary

5.7.3.1.12 New modem emulations. New modem waveforms shall be considered on the basis of competitive performance relevant to significant new and needed capabilities or applications. Any new modem waveform proposed shall be accompanied by draft error performance requirements.

5.7.3.2 Error performance with Adjacent Channel Interference (ACI). Consider a carrier of interest of symbol rate R_S. ACI is defined in terms of equal symbol-rate interferer scenarios and double symbol-rate interferer scenarios. The demodulator shall meet all defined ACI scenarios as follows.

5.7.3.2.1 Equal symbol-rate ACI scenarios. In the equal symbol-rate scenarios, interfering carriers are located at center frequencies above and below the carrier of interest. Interfering carriers are of symbol rate R_S equal to that of the carrier of interest. ACI requirements shall be enforced at center-to-center carrier spacing of both 1.2 R_S and 1.4 R_S. The PSD of each interfering carrier is 13 dB higher than that of the carrier of interest. The equal symbol-rate ACI scenario is illustrated on FIGURE 5.

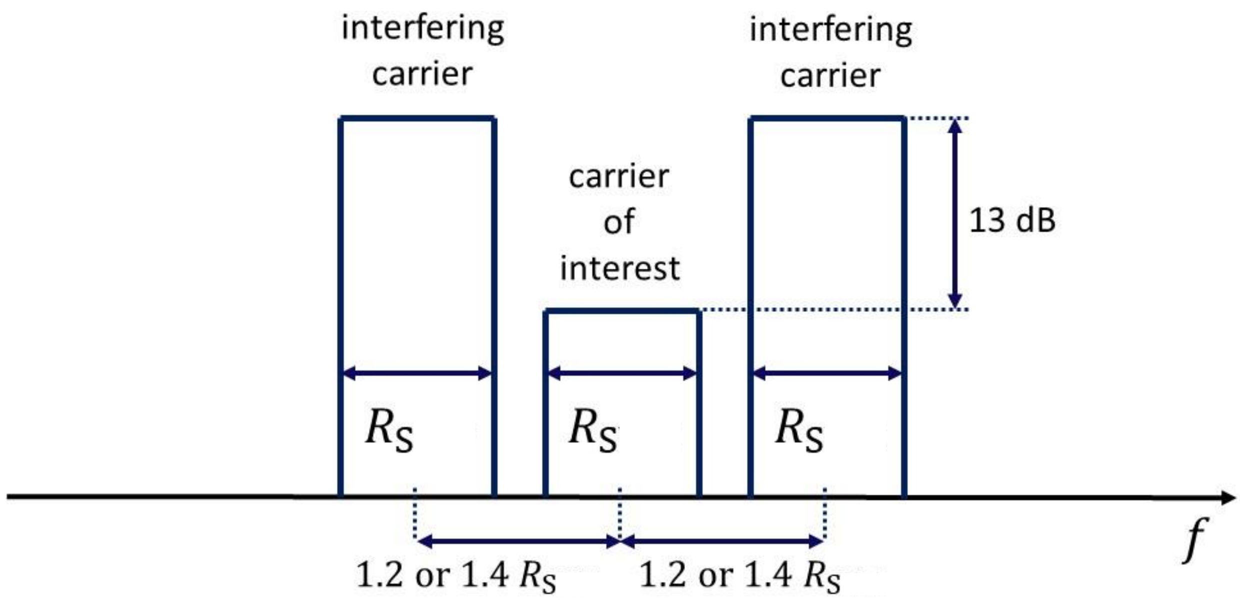


FIGURE 5. Equal symbol rate ACI.

5.7.3.2.2 Double symbol rate ACI scenario. In the double symbol-rate scenario, interfering carriers are located at center frequencies above and below the carrier of interest. Interfering carriers are of symbol rate 2 R_S, double that of the carrier of interest. ACI requirements shall be enforced at center-to-center carrier spacing of both 1.8 R_S (1.2 times the average of the two symbol rates) and 2.1R_S (1.4 times the average of the two symbol rates). The PSD of each interfering carrier is 13 dB higher than that of the carrier of interest. The double symbol-rate ACI scenario is illustrated on FIGURE 6.

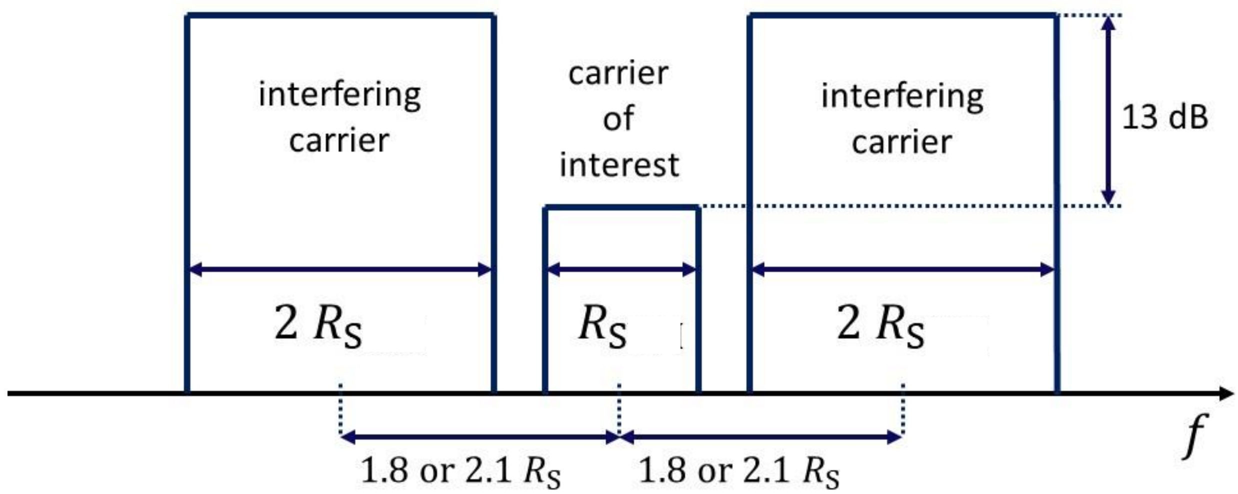


FIGURE 6. Double symbol rate ACI.

5.7.3.2.3 Threshold E_S/N_0 allowance for ACI. When ACI is introduced, the threshold E_S/N_0 performance specified in 5.7.3.1 and its subsections shall be granted an associated impairment allowance of

$$10\ \log_{10}\left(\frac{10^{-\frac{E_S/N_0}{10}}}{10^{-\frac{E_S/N_0}{10}} - X}\right)\ \text{dB}$$

where:

X = 0.0059 in the equal symbol-rate ACI scenario where center-to-center carrier spacing is 1.2R_S.

X = 0.0043 in the equal symbol-rate ACI scenario where center-to-center carrier spacing is 1.4R_S.

X = 0.0156 in the double symbol-rate ACI scenario where center-to-center carrier spacing is 1.8R_S (1.2 times the average of the two symbol rates).

X = 0.0115 in the double symbol-rate ACI scenario where center-to-center carrier spacing is 2.1R_S (1.4 times the average of the two symbol rates).

E_s/N_0 is defined in 3.15.

In cases where $10^{-\frac{E_S/N_0}{10}} \leq X$, it is allowable for ACI, as defined above, to prevent reception at the BER corresponding to the relevant threshold E_S/N_0.

ACI implementation loss allowances are illustrated on FIGURE 7.

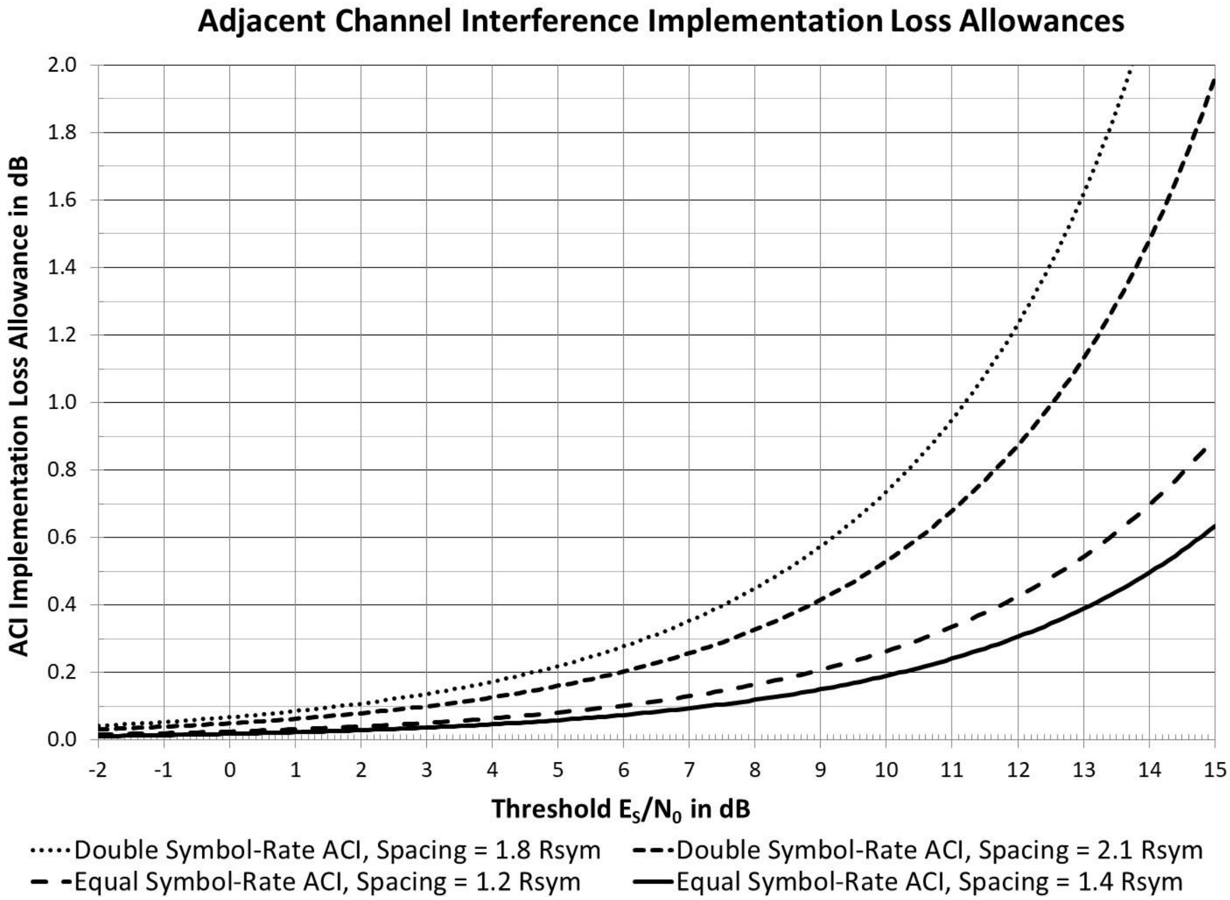


FIGURE 7. ACI implementation loss allowances.

5.7.3.3 Composite power. The purpose of this requirement is to specify maximum signal power ranges, both absolute (a. and b.) and relative (c. and d.). Relative power thresholds are expressed in "dBc" which indicates dB relative to "C," the power of the carrier of interest. The demodulator shall maintain the performance specified in 5.7.3.1 and 5.7.3.2, under the following conditions.

a. Total IF input power does not exceed +20 dBm.

b. The PSD of any carrier does not exceed -63 dBm/Hz.

c. The sum of all carriers within 10 MHz of the desired carrier does not exceed +30 dBc.

d. The sum of all carriers does not exceed +40 dBc.

5.7.3.4 Isolation of integrated modulators and demodulators. When one or more modulators or demodulators, co-located in the same chassis, are enabled, the error performance requirements of sections 5.7.3 through 5.7.3.3 shall be met, to within a 0.2 dB implementation allowance, provided that

a. The PSD of the carrier received by the demodulation function of interest shall be within 60 dB of the PSD of any transmitted output of any co-located modulation function.

b. No restrictions on co-located demodulation functions.

5.8 Modem control and monitoring functions.

5.8.1 Modem remote control interface. The modem shall provide external interfaces for controlling and monitoring modem functions.

5.8.2 Control and monitoring parameters.

5.8.2.1 Control response times. As a minimum, all modem functions shown in TABLE VII shall be controlled and monitored using the remote interface. Response time, from configuration to implementation, shall not exceed 0.25 s.

5.8.2.2 E_b/N_0 reporting requirements. The modem shall be capable of reporting the mean E_b/N_0 at a minimum interval of 0.25 s. For each reporting cycle, the reported mean E_b/N_0 shall be within 0.3 dB of the true mean, over the range from –3 to 20 dB.

5.8.3 Positive modem control. The modem shall be capable of management by an external element utilizing existing interfaces.

TABLE VII. Modem control and monitoring parameters.

Control	Monitoring
Data rate (Tx/Rx)	Data rate (Tx/Rx)
Modulation type (Tx/Rx)	Modulation type (Tx/Rx)
Differential coding (Tx/Rx)	Differential coding (Tx/Rx)
Scrambling (Tx/Rx)	Scrambling (Tx/Rx)
FEC coding(Tx/Rx)	FEC coding(Tx/Rx)
IF carrier frequency (Tx/Rx)	IF carrier frequency (Tx/Rx)
Transmission IF power ON/OFF	Transmission IF power ON/OFF
Transmission IF power level	Transmission IF power level
Frequency reference source	Fault status
--	Store faults
--	Received E_b/N_0
--	Acquisition indicator
--	Received signal power level, Automatic Gain Control (AGC), or both
--	Data synchronization indicator

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 defines the military SHF SATCOM PSK modem interface in terms of physical, functional, and acceptable performance criteria necessary to support PMs and buying activities in ensuring interoperability with modems used in 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) should tailor the requirements in sections 4 and 5 of this standard to exclude any unnecessary requirements.

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

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

6.5 SHF SATCOM standards profile. This MIL-STD is one in a series of MIL-STDs addressing SHF SATCOM. The SHF SATCOM standards profile is shown on FIGURE 8.

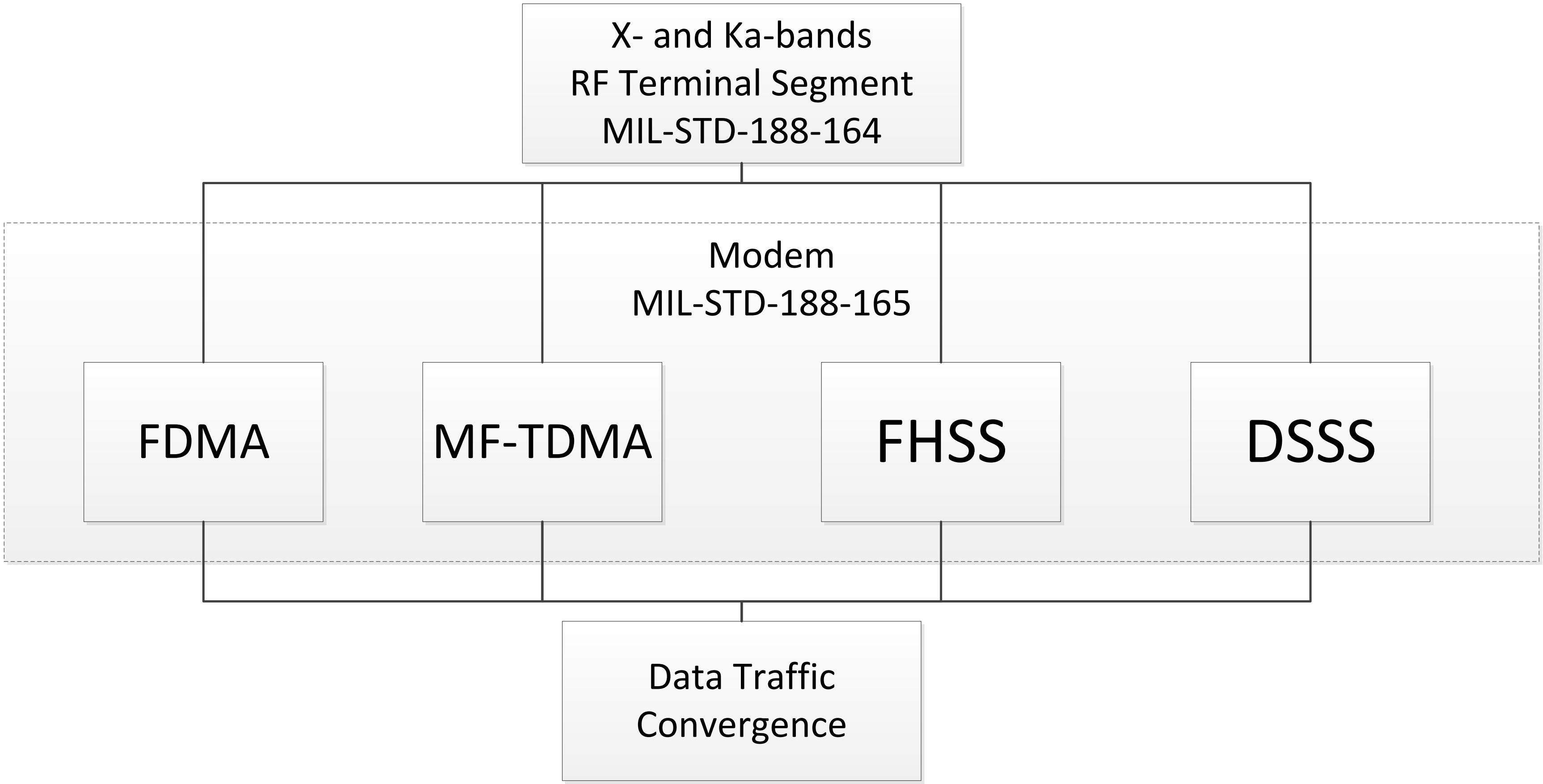


FIGURE 8. SHF SATCOM standards profile.

6.6 Background and future guidance. This MIL-STD changes in response to changing DoD requirements and SATCOM technologies. TABLE VIII 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 VIII. Background and future guidance

Section	Present Background	Future Guidance
3.19 Quasi Error Free E_S/N_0 (QEF E_S/N_0).	Threshold E_S/N_0 is indicated in terms of both BER and PER. The implied factor of 1000 falls between limiting assumptions of uncorrelated bit errors and 50% BER packets. Strictly speaking, this factor is not necessarily valid. However, its accuracy is adequate, for the purpose indicated, and in view of steep waterfall BER vs E_S/N_0 behavior of modern FEC systems.	None at this time.
3.21 Stability.	Updated definition for more clarity	None at this time
4.2 Modem description.	Lists all anticipated signal processing steps for Tx and for Rx.	Some steps may change. Deletions are possible upon completion of migration to IP. Additions are possible in response to new requirements, features or implementation approaches.
4.4 Environmental perturbation.	Reference E_S/N_0 is indicated in terms of both BER and PER. The implied factor of 1000 falls between limiting assumptions of uncorrelated bit errors and 50% BER packets. Strictly speaking, this factor is not necessarily valid. However, its accuracy is adequate, for the purpose indicated, and in view of steep waterfall BER vs E_S/N_0 behavior of modern FEC systems.	None at this time.
5.2 Frequency reference.	The intent is to meet 5.5.3.2 & 5.5.3.3 requirements for Tx carrier stability and accuracy when the external frequency reference is disconnected due to loss or compromise.	None at this time.

TABLE VIII. Background and future guidance – Continued.

Section	Present Background	Future Guidance
5.3.2 Ethernet data interfaces.	Ethernet data interfaces are introduced and prioritized due to the DoD migration in progress, from serial communications traffic to IP traffic.	Ethernet will gradually become the only modem data-traffic interface.
5.3.3 Serial data interfaces.	Serial data interfaces are reduced to secondary importance due to the DoD migration in progress, from serial communications traffic to IP traffic.	Serial data interfaces will gradually be eliminated.
5.4 Modem emulations.	Waveform descriptions have been deliberately abandoned, to every extent possible, in favor of references to modem waveform standards.	Legacy modem waveforms (OM-73, MIL-165, IESS-308, -309 & -310) will gradually be abandoned in favor of better performing Turbo and LDPC coded waveforms.
5.4 Modem emulations. Item c. Uncoded Operation	Uncoded operation is required, for diagnostic purposes, of every modulation format for all modem emulations implemented.	None at this time.
5.4.12 New modem emulations.	Provisions are offered for accommodating new modem waveforms where a new capability becomes necessary.	Where appropriate, new modem waveforms may be added to the modem emulation list in future revisions.
5.5 IF output interface.	L-Band is presently the terminal IF interface in primary use.	A Digital IF output interface format will be added in the near future. This will require performance requirements allocated to elements of the SATCOM signal chain be repartitioned across new Digital IF functional elements.

TABLE VIII. Background and future guidance – Continued.

Section	Present Background	Future Guidance
5.5.1 IF output frequency bands.	Removed text specifying additional interfaces authorized. Additional interfaces identified by specific programs.	None at this time
5.5.3.4 Phase noise.	Intent is a. To limit degradation of operational C/N threshold (equivalently QEF ES/N0 degradation) due to phase noise to less than 0.05 dB; b. For analysis to be adequate in the small signal; c. For phase noise thresholds to scale with modem performance demand in terms of operational C/N threshold (QEF ES/N0) and symbol rate range [RSmin, RSmax].	Thresholds inherently scale with modem performance demand in terms of operational C/N threshold (QEF E_S/N_0) and symbol rate range [R_{Smin}, R_{Smax}].
5.5.4 Output power control range, step size, and accuracy., output power	0 dBm at the modem Tx is intended to drive the terminal to max linear Tx power. The modem-to-terminal demarcation point is at the modem IF output. Cable losses are mitigated by the terminal.	None at this time.
5.5.4 Output power control range, step size, and accuracy., carrier "off" PSD	Hybrid threshold was developed with vendor consensus to balance the following considerations. a. -70 dBm across any 3 Mhz corresponds to -135 dBm/Hz average PSD which is adequately low; b. -80 dBm across any 30 kHz corresponds to a higher -125 dBm/Hz, which aids the ability to implement by allowing for excursions above the baseline -135 dBm/Hz threshold.	None at this time.
5.5.5.1 Spectral confinement.	Well designed modems implementing root raised cosine (RRC) spectral shape factors (SSFs) up to 21% are expected to meet this mask.	None at this time.

TABLE VIII. Background and future guidance – Continued.

Section	Present Background	Future Guidance
5.5.5.3 Transmission output spurious emissions.	Hybrid threshold was developed with vendor consensus to balance the following considerations. a. relative threshold of $$-51\text{ dBc} - \left.\frac{E_S}{N_0}\right\|_{\mathrm{QEF}}$$ relevant to higher level carriers; b. absolute threshold of -70 dBm relevant to lower level carriers; c. hybrid approach being both adequate and implementable. Threshold E_S/N_0 is indicated in terms of both BER and PER. The implied factor of 1000 falls between limiting assumptions of uncorrelated bit errors and 50% BER packets. Strictly speaking, this factor is not necessarily valid. However, its accuracy is adequate, for the purpose indicated, and in view of steep waterfall BER vs E_S/N_0 behavior of modern FEC systems.	None at this time.
5.5.5.4 Transmission output harmonics	Hybrid threshold was developed with vendor consensus to balance the following considerations. a. relative threshold of $$-51\text{ dBc} - \left.\frac{E_S}{N_0}\right\|_{\mathrm{QEF}}$$ relevant to higher level carriers; b. absolute threshold of -70 dBm relevant to lower level carriers; c. hybrid approach being both adequate and implementable.	None at this time.

TABLE VIII. Background and future guidance – Continued.

Section	Present Background	Future Guidance
5.5.6.2 Error vector magnitude	History: A single EVM requirement replaces Tx degradation due to previously specified a. modulation symbol jitter (±3%) b. max peak modulation phase error (2 degrees peak) c. group delay deviation (±0.14 symbol intervals) Additionally, EVM accounts for the general effects of Tx phase noise on constellation integrity. Derivation: $$\text{EVM} \leq \sqrt{\frac{0.01}{\left.\frac{E_S}{N_0}\right\|_{\text{QEF}}}}$$ The objective is for modulation distortion to contribute no more than 1% of incident noise power at QEF E_S/N_0 conditions. As such, a. EVM is computed as a ratio with respect to unit signal amplitude b. Hence unit energy per symbol, $$E_S = 1$$ c. At the QEF ES/N0,incident noise energy equals $$\frac{1}{\left.\frac{E_S}{N_0}\right\|_{\text{QEF}}}$$ d. Dividing numerator and denominator by equal time intervals yields identical ratio of incident noise power to unit signal power. e. 1% of incident noise power is then $$\frac{0.01}{\left.\frac{E_S}{N_0}\right\|_{\text{QEF}}}$$ Corresponding amplitude is the square root, $$\sqrt{\frac{0.01}{\left.\frac{E_S}{N_0}\right\|_{\text{QEF}}}},$$ the EVM threshold.	

TABLE VIII. Background and future guidance – Continued.

Section	Present Background	Future Guidance
5.6 IF input interface.	L-Band is presently the terminal IF interface in primary use.	A Digital IF input interface format will be added in the near future. This will require that subsystem requirements be repartitioned across new Digital IF functional elements.
5.6.1 IF input frequency bands.	Removed text specifying additional interfaces authorized. Additional interfaces identified by specific programs.	None at this time
5.6.3.2 Input frequency uncertainty	Sources of present ±30 kHz requirement are dominated by Local Oscillator (LO) tolerances at the various conversion processes in the SATCOM signal chain.	Requirement may increase to ±100 kHz for the sake of accommodating airborne platforms.
5.6.4.1.1 Minimum operating IF carrier input level	Rx IF noise floor is the basis for all IF Receive level thresholds. Corresponds to antenna system (antenna + LNA) noise amplified through the terminal receive chain.	May be lowered to better balance noise figure at the low end with nonlinearities at the high end.
5.6.4.1.2 Maximum operating IF carrier input level	PSD based on max anticipated Power Flux Spectral Density (PFSD) and terminal Gain/Temperature (G/T). Power cap based on max anticipated carrier PFD and terminal G/T. Both respective of terminal noise floor at the modem interface. Decreased the P_{max} from 0dBm to -7dBm.	None at this time
5.6.4.2 Composite power.	5 dB margin with respect to maximum total power.	May increase proportionally with maximum operating IF carrier input level as it is raised to accommodate higher satellite power levels or higher maximum terminal G/T values.

TABLE VIII. Background and future guidance – Continued.

Section	Present Background	Future Guidance
5.6.5 Noise Figure.	Establishes an internal modem demodulation noise floor intended to be 17 dB below the terminal Receive IF noise floor corresponding to minimum operating IF carrier input level. Reduced the Rx IF noise floor to better balance noise figure at the low end with nonlinearities at the high end.	None at this time
5.7.2 Acquisition and timing performance requirements.	Threshold E_S/N_0 is indicated in terms of both BER and PER. The implied factor of 1000 falls between limiting assumptions of uncorrelated bit errors and 50% BER packets. Strictly speaking, this factor is not necessarily valid. However, its accuracy is adequate, for the purpose indicated, and in view of steep waterfall BER vs E_S/N_0 behavior of modern FEC systems.	None at this time.
5.7.2.1 Initial data acquisition.	±30 kHz is based on LO frequency uncertainty and acceptable satellite inclination.	None at this time.
5.7.2.3 Bit count integrity.	Applies to serial data interfaces.	Serial data interfaces will gradually be eliminated. At the conclusion of which, this requirement will no longer be relevant.
5.7.2.4 Synchronization retention.	BCI caveat applies to serial data.	Serial data interfaces will gradually be eliminated. At the conclusion of which, the BCI caveat will no longer be relevant.
5.7.2.5 Timing jitter.	Applies to serial data interfaces.	Serial data interfaces will gradually be eliminated. At the conclusion of which, this requirement will no longer be relevant.

TABLE VIII. Background and future guidance – Continued.

Section	Present Background	Future Guidance
5.7.2.6 Doppler environment.	Present Doppler parameters are based on allowable satellite inclination combined with shipboard platform motion in accordance with TR 1578 “SHF SATCOM Terminal Ship-Motion Study.”	The Government is investigating the impact of airborne and land mobile platform motion on Doppler. This requirement is subject to revision accordingly.
5.7.3.1 Back-to-back error	Explicit BER vs E_b/N_0 tables have been deliberately abandoned, to every extent possible, in favor of references to modem waveform standards. Subsections correspond to those of 5.4 Modem emulations.	Any new waveforms incorporated in the future will require associated error performance thresholds.
5.7.3.2 Error performance with Adjacent Channel Interference (ACI).	History: ACI was formerly a tabular degradation requirement against unimpaired performance. It is now an analytically expressed allowance for degradation against 5.7.3.1 subsection performance thresholds.	None at this time.

5.7.3.2.3 Threshold E_S/N_0 allowance for ACI.	General Approach: The presence of interfering carriers degrades the performance of a carrier of interest successively more as 1) carrier spacing is reduced, and 2) interfering carrier BW is increased. This requirement constitutes four sample points in this continuum of interfering carrier spacing and bandwidth. Derivation: Analytical impairment allowance is derived by considering a. A carrier of interest of power C and symbol rate RS; b. Subject to underlying noise power N = N0 RS [all in linear power]; c. Subject also to interfering carriers delivering additive interfering power NX, which is uncorrelated to the carrier of interest, but which scales with the carrier of interest. There is a value ΔC which, when used to scale the carrier, results in a C/N subject to interference equal to the C/N without interference. Consider [all in linear power] $\frac{\mathrm{C}}{\mathrm{N}} = \frac{\mathrm{C} + \Delta\mathrm{C}}{\mathrm{N} + \mathrm{N}_X\left(1 + \frac{\Delta\mathrm{C}}{\mathrm{C}}\right)}$ This equates baseline C/N with the corresponding ratio, where a. C scales by adding ΔC; b. C is subject to additive interfering power N_X; c. interfering power N_X scales with C. This can be rearranged [all in linear power] $1 + \frac{\Delta\mathrm{C}}{\mathrm{C}} = \frac{\frac{\mathrm{N}}{\mathrm{C}}}{\frac{\mathrm{N}}{\mathrm{C}} - \frac{\mathrm{N}_X}{\mathrm{C}}}$ Substituting [all in linear power] $\frac{\mathrm{C}}{\mathrm{N}} = \frac{E_S\, R_S}{N_0\, R_S} = \frac{E_S}{N_0}$ and denoting interfering power relative to the carrier of interest $X = \frac{\mathrm{N}_X}{\mathrm{C}}$ yields [all still in linear power]	Not at this time.

TABLE VIII. Background and future guidance – Continued.

Section	Present Background	Future Guidance
	$$1+\frac{\Delta C}{C}=\frac{\frac{1}{E_s/N_0}}{\frac{1}{E_s/N_0}-X}$$ Converting back to dB yields $$\Delta\frac{E_S}{N_0}=10\ \log_{10}\left(\frac{10^{-\frac{E_s/N_0}{10}}}{10^{-\frac{E_s/N_0}{10}}-X}\right)$$	
5.7.3.3 Composite power.	The intent is to a. begin with 5.7.3.2 ACI interference scenarios; b. add carrier power, within ±10 MHz of the carrier center frequency, for a total interfering carrier power, within 10 MHz, of +30 dBc; c. add carrier power, beyond ±10 MHz of center frequency, for a total interfering carrier power of +40 dBc over the entire band, up to +20 dBm; d. meet the 5.7.3.2 ACI requirement with the additional interferers present.	N/A
5.7.3.3 Composite power. Item a. Total Input Power.	Based on max anticipated total flux density and terminal G/T with respect to terminal noise floor at the modem interface	May increase to accommodate higher satellite power levels
5.7.3.3 Composite power. Item b. Max Carrier PSD.	Consistent with 5.6.4.1.2 Maximum operating IF carrier input level.	May change to remain consistent with 5.6.4.1.2 Maximum operating IF carrier input level.
5.7.3.3 Composite power. Item c. Relative Power within 10 MHz.	Serves to quantify dynamic range, in terms of relative carrier power, with respect to carrier spacing.	None at this time.

TABLE VIII. Background and future guidance – Continued.

Section	Present Background	Future Guidance
5.7.3.3 Composite power. Item d. Relative Total Power.	Serves to quantify dynamic range in terms of carrier power relative to total power.	None at this time.
5.7.3.4 Isolation of integrated modulators and demodulators.	Corresponding electromagnetic isolation appears to be about 74 dB due to a. -14 dB incremental noise corresponding to 0.2 dB implementation allowance b. -60 dB max carrier disadvantage	
5.8.2 Control and monitoring parameters.	TABLE VIII is presently relevant.	TABLE VIII is subject to change. For example, a. abandoning legacy modem emulations may render "differential coding" irrelevant b. abandoning serial data interfaces may render "bit synchronization indicator" irrelevant c. new control and monitoring parameters, additional or otherwise, may become relevant in the future
Not yet specified: Digital IF	The predominant IF interface is presently L-Band.	Digital IF will first be added as a selectable IF interface, then later it may become the predominant IF interface.

6.7 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

NATO STANAG 4486 BACK-TO-BACK ERROR PERFORMANCE

A.1 Scope. This appendix applies to the NATO STANAG 4486 waveform. This appendix is a mandatory part of the standard. The information contained herein is intended for compliance.

A.2 Turbo code mode. The Enhanced Bandwidth Efficient Modem (EBEM) operating in the turbo code mode, with an information block size of 16,384 bits for multiplexed data rates ≥ 4096 kbps, shall provide back-to-back BER vs. Eb/N0 performance better than or equal to the values shown in TABLE A-I, TABLE A-II, and TABLE A-III when using the modulation formats indicated. When using an information block size of 4096 bits for multiplexed data rates ≥ 1024 kbps but < 4096 kbps, the EBEM shall provide BER vs. E_b/N_0 performance better than or equal to a 0.8 dB degradation over the values shown in TABLE A-I, TABLE A-II, and TABLE A-III. When using an information block size of 1024 bits for multiplexed data rates < 1024 kbps, the EBEM shall provide BER vs. E_b/N_0 performance better than or equal to a 1.6 dB degradation over the values shown in TABLE A-I, TABLE A-II, and TABLE A-III.

TABLE A-I. NATO STANAG 4486 BPSK, QPSK, and OQPSK performance.

E_b/N_0 (dB)	Rate=1/2	Rate=2/3	Rate=3/4	Rate=7/8	Rate=19/20
2.55	1E-6				
2.60	1E-8				
2.70	1E-10				
3.40		1E-6			
3.45		1E-8			
3.55		1E-10			
3.90			1E-6		
4.00			1E-8		
4.10			1E-10		
4.60				1E-6	
4.70				1E-8	
4.80				1E-10	
6.20					1E-6
6.40					1E-8
6.60					1E-10

TABLE A-II. NATO STANAG 4486 8-PSK performance.

E_b/N_0 (dB)	Rate=1/2	Rate=2/3	Rate=3/4	Rate=7/8	Rate=19/20
4.00	1E-6				
4.05	1E-8				
4.10	1E-10				
5.60		1E-6			
5.65		1E-8			
5.70		1E-10			
6.50			1E-6		
6.55			1E-8		
6.60			1E-10		
7.80				1E-6	
7.90				1E-8	
8.00				1E-10	
10.20					1E-6
10.25					1E-8
10.30					1E-10

TABLE A-III. NATO STANAG 4486 16-ary performance.

E_b/N_0 (dB)	Rate=1/2	Rate=2/3	Rate=3/4	Rate=7/8	Rate=19/20
4.90	1E-6				
5.00	1E-8				
5.05	1E-9				
6.65		1E-6			
6.75		1E-8			
6.80		1E-9			
7.60			1E-6		
7.95			1E-8		
8.00			1E-9		
9.05				1E-6	
9.15				1E-8	
9.40				1E-9	
11.70					1E-6
11.80					1E-8
11.85					1E-9

APPENDIX B

MULTIPLE CARRIER MODEMS

B.1 Scope. This Appendix applies to multiple carrier (multi-carrier) modems. 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.

B.2 Multi-carrier modem requirements application. This section identifies various section 5 requirements whose application to multi-carrier modem performance may differ with respect to baseline application to single carrier modems. In the context of multi-carrier modems, the following guidance shall be used to interpret the indicated requirements and their performance thresholds.

a. 5.5.1 "IF output frequency bands." Excursion of any carrier(s) outside the band as specified shall not relieve performance requirements for any carrier(s) within the band as specified.

b. 5.5.4 "Output power control range, step size, and accuracy." Total output power of all carriers together shall be capped at 0 dBm.

c. 5.5.5.1 "Spectral confinement." It will be acceptable to relieve lower carrier PSD mask requirements to the minimum sidelobe level required of the highest PSD carrier (-61.5 dBc_{max} floor on sidelobe PSD thresholds for all carriers).

d. 5.5.5.3 "Transmission output spurious emissions." Spurious emission thresholds shall apply to all of the following scenarios.

(1) No carriers for baseline spurious performance
(2) One carrier at 0 dBm
(3) Two carriers at -3 dBm each
(4) N carriers at $-10 \log_{10} N$ dBm each for N = 1 to the maximum carrier count supported by the multi-carrier modem

e. 5.6.1 "IF input frequency bands." Excursion of any carrier(s) outside the band as specified shall not relieve performance requirements for any carrier(s) within the band as specified.

f. Where not otherwise indicated, specified performance shall apply to each carrier.

B.3 Multi-carrier modem test guidance. Multi-carrier modems carry a significantly higher computational burden than single-carrier modems. As such, it is recommended, to every extent possible, that testing be exercised on carriers of interest while the modem is maximally loaded with additional incidental active carriers. Maximum practical modem loading throughout test, certification or otherwise, has the purpose of revealing weaknesses with respect to function and performance during high load multi-carrier operation. Such revelations are of value and significance to the certifying authority, to the acquisition authority and to the end-user.

APPENDIX C

MULTIPLE FREQUENCY – TIME DIVISION MULTIPLE ACCESS (MF-TDMA)

C.1 Scope. This Appendix applies to modems employing MF-TDMA. This appendix is a mandatory part of the standard. The information contained herein is intended for guidance.

C.2 Spectral confinement. In 5.5.5.1, requirements shall be met under the following conditions:

a. At a single fixed center frequency under continuous modulation.

b. At a single fixed center frequency under burst modulation.

c. For each carrier frequency at alternating fixed carrier frequencies spaced sufficiently far from each other to allow discrimination of the two spectra.

APPENDIX D

FREQUENCY HOPPING SPREAD SPECTRUM (FHSS)

D.1 Scope. This Appendix applies to modems employing FHSS. 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.

D.2 Spectral confinement. In 5.5.5.1, requirements shall be met under the following conditions.

a. Hopping in place.

b. For each carrier frequency when hopping between two fixed frequencies spaced sufficiently far from each other to discriminate spectra.

APPENDIX E

DIRECT SEQUENCE SPREAD SPECTRUM (DSSS)

E.1 Scope. This Appendix applies to modems employing DSSS. 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.

E.2 DSSS requirements application. This section identifies various section 5 requirements whose application to DSSS systems may differ from baseline application to FDMA modems. In the context of DSSS, the following guidance shall be used to interpret the indicated requirements and their performance thresholds.

a. 5.5.1 “IF output frequency bands. Modem performance parameters detailed in this standard shall be met for all waveforms whose -3 dBc bandwidths, with respect to chip rate R_C, are contained within the bandwidth limits of applicable IF interfaces.

b. 5.5.3.4 “Phase noise.” The symbol rate R_S shall be retained when considering DSSS phase noise requirements IAW 5.5.3.4.

c. 5.5.5.1 “Spectral confinement.” The chip rate R_C shall be used in place of the symbol rate R_S when considering DSSS spectral confinement requirements IAW 5.5.5.1.

d. 5.6.1 “IF input frequency bands.” Modem performance parameters detailed in this standard shall be met for all waveforms whose -3 dBc bandwidths, with respect to chip rate R_C, are contained within the bandwidth limits of applicable IF interfaces.

e. 5.7.2.1 “Initial data acquisition.” The symbol rate R_S shall be retained when considering DSSS initial acquisition requirements IAW 5.7.2.1. It may be appropriate to allow for additional initial acquisition time for demodulators of some DSSS waveforms.

f. 5.7.2.2 “Data reacquisition.” The symbol rate R_S shall be retained when considering DSSS reacquisition requirements IAW 5.7.2.2. It may be appropriate to allow for additional reacquisition time for demodulators of some DSSS waveforms.

g. 5.7.3.2 “Error performance with Adjacent Channel Interference (ACI).” Whereas DSSS systems employ spreading gain, performance allowances for ACI IAW 5.7.3.2 and its subsections are not applicable to spread spectrum systems.

h. 5.7.3.3 “Composite power.” Whereas DSSS systems employ spreading gain, the composite power requirements of 5.7.3.3 applied to DSSS systems are more stringent to the extent that performance allowances for ACI IAW 5.7.3.2 and its subsections are not applicable to DSSS systems.

E.3 EIRP spectral density masks and terminal certification. The military K_a-band and military X-band EIRP Spectral Density masks that apply to earth terminals accessing the wideband constellations are given in both "EIRP spectral density" sections (4.4.1.2 and 4.5.1.2), respectively, of MIL-STD-188-164. The purpose of these EIRP spectral density masks is to avoid causing harmful Adjacent Satellite Interference (ASI). If an antenna gain pattern-waveform-transmit power combination causes any excursions above the EIRP spectral density mask, then the earth terminal EIRP spectral density must be reduced. This appendix presents options for reducing the EIRP spectral density, both with and without DSSS.

E.4 EIRP spectral density definition for standard waveforms. For standard digital communications waveforms, i.e., ones that do not use DSSS, the EIRP spectral density is given by

$$EIRPSD_{Unspread} = 10\,log_{10}\left(\frac{EIRP}{R_S}\right) \text{ [dBW/Hz]} \tag{E.1}$$

where

EIRP: effective isotropic radiated power (watts), and

R_S: symbol rate (symbols/sec).

The EIRP spectral density definition in eqn. (E.1) complies with that given in MIL-STD-188-164 "EIRP spectral density" definition section. The correct value of R_S to use in eqn. (E.1) must consider all overhead in the transmitted waveform as follows:

$$R_S = (1+\delta)\frac{R_D}{r\cdot k} R_S = (1+\delta)\frac{R_D}{r\cdot k} \text{ [sym/sec]} \tag{E.2}$$

where

R_D: data rate (bits/sec),

r: forward error correction (FEC) code rate ($r < 1$),

k: number of bits/symbol (1 for BPSK, 2 for QPSK, 3 for 8-PSK, etc.), and

δ: factor accounting for the overhead in the transmitted waveform.

The value of δ varies not only from modem to modem, but also within the same modem as a function of the features enabled by the end user (e.g., Adaptive Coding and Modulation (ACM), AUPC, etc.). Typical values of δ range from 0.02 to 0.08, but values outside this range are also possible.

To accomplish EIRP spectral density reduction with a standard waveform, the available options include the following.

a. Reduce the modulation order, i.e., reduce k.

b. Reduce the FEC code rate, i.e., reduce r.

Each of these options increases R_S and thereby decreases the EIRP spectral density for a fixed EIRP (at the expense of increasing the occupied bandwidth). However, each of these options also reduces the C/N required at the demodulator for any particular BER requirement. Therefore, these options can also be expected to reduce the required EIRP, thereby further reducing the EIRP spectral density.

Changing the data rate, R_D, typically has no effect on the EIRP spectral density for the following reasons. Changing R_D by ±X dB reduces R_S by ±X dB as is clear from eqn. (E.2). But this also typically changes the required EIRP by ±X dB if everything else is held constant. These two changes cancel out in eqn. (E.1) and the net result is no change in the EIRP spectral density.

E.5 DSSS spread factor. The central concept of DSSS is embodied in the *spread factor*, *SF*. In commercially available modems, the supported spread factors are typically strictly integers, although a small number of modems may support non-integer spread factors. The appropriate spread factor for addressing EIRP spectral density and ASI operates on the symbol rate as follows.

$$R_{\mathrm{C}} = SF \times R_{\mathrm{S}} \text{ (chips/sec)} \tag{E.3}$$

where

R_{C}: chip rate (chips/sec).

A *chip* is a symbol in the spreading sequence and, clearly, the chip rate is higher than the symbol rate by the factor *SF*. Whereas the occupied bandwidth of the unspread signal is determined by R_S, that of the DSSS signal is determined by R_C.

E.6 EIRP spectral density reduction using DSSS. When spreading is not used, the EIRP spectral density is given by eqn. (E.1). When spreading is used, the EIRP spectral density is given by

$$EIRPSD_{\mathrm{Unspread}} = 10\, log_{10}\left(\frac{EIRP}{SF}\right) \text{ (dBW/Hz).} \tag{E.4}$$

When spreading is used, the EIRP spectral density reduction is given by

$$\Delta_{\mathrm{EIRPSD}} = 10\, log_{10}\left(\frac{R_{\mathrm{S}}}{R_{\mathrm{C}}}\right) = -10\, log_{10}(SF) \text{ (dB)} \tag{E.5}$$

if all else is held constant. The quantity $10\, log_{10}(SF)$ is sometimes referred to as the *processing gain*.

E.7 Numerical example. Consider a waveform that causes a maximum 6 dB excursion above the applicable EIRP spectral density mask. Thus, a Δ_{EIRPSD} of -6 dB is needed and the required spread factor is given by

$$SF = \left\lceil 10^{\frac{-\Delta_{\mathrm{EIRPSD}}}{10}} \right\rceil = \lceil 10^{0.6} \rceil = \lceil 3.9811 \rceil = 4 \tag{E.6}$$

where

$\lceil \cdot \rceil$: denotes the "ceiling function" defined as the smallest integer greater than or equal to the argument.

Because the required spread factor is 4, the bandwidth needed to accommodate the DSSS waveform increases by a factor of 4 over that required to support the standard waveform.

E.8 DSSS procurement considerations. This section presents additional topics that should be considered when an acquisition authority contemplates procuring a DSSS modem.

E.8.1 Code Division Multiple Access (CDMA). Code division multiple access (CDMA) is frequently used in combination with DSSS. In a DSSS CDMA network, *K* users persistently share the assigned bandwidth. This bandwidth sharing results in some degree of Multiple Access Interference (MAI) that is most often the limiting factor in determining the capacity of the DSSS CDMA network in practical implementations. (Idealized implementations are possible in which the complete mutual orthogonality of the spreading sequences eliminates MAI altogether. However, these setups do not reflect standard MILSATCOM practice for various reasons that are beyond the scope of this appendix.)

The dominant factor in determining the capacity of a DSSS CDMA network is the spread factor, *SF*. To a close approximation, the following condition on *SF* must be met to keep the MAI at an acceptably small level for *K* links in a homogeneous CDMA network to close.

$$SF \geq \left\lceil (K-1) \times \left(\frac{E_S}{N_0}\right)_R \right\rceil \quad \text{(E.7)}$$

where

$\left(\frac{E_S}{N_0}\right)_R$: SNR (linear) required for the specified BER, BLER, or PER on each link.

The modem must be capable of a sufficiently large spread factor in order to support the intended network capacity, *K*. As a numerical example, consider a modcod that requires an E_S/N_0 of 0.5789 linear (-2.4 dB) to provide the specified BER. TABLE E-I presents the minimum *SF* values required to support several network sizes (*K*) calculated using eqn. (E.7).

TABLE E-I. Minimum spread factor values required to support various network sizes.

Desired Network Size, *K* number of users	10	15	20	50	75	100
Minimum Required *SF*	6	9	11	29	43	58

E.8.2 Derivation of minimum required spread factor SF. In a homogeneous CDMA network consisting of *K* users, the SNR of any one of the users at the base is given by

$$\left(\frac{C}{N+I_{MAI}}\right)^{-1} = \left(\frac{C}{N}\right)^{-1} + \left(\frac{SF}{(K-1)}\right)^{-1} \text{ (unitless)} \quad \text{(E.8)}$$

where the second term on the right-hand side (RHS) of (E.8) results from (a) treating the *multiple access interference* (MAI) as band-limited additive white Gaussian noise (AWGN) and (b) ignoring any MAI reduction that may result from the cross-correlation properties of the spreading sequences. (It has been shown that using these two approximations yields experimental results that are 0.5 dB within predictions when the spreading sequences are derived from Gold codes and $K \leq 48$.)

(E.8) is the familiar sum-of-inverses form. It is the same form as the equation for the equivalent resistance of the parallel combination of two resistors wherein $C/(N + I_{MAI})$ is the value of the parallel combination of C/N and $SF/(K - 1)$. Therefore, we know that

$$\frac{C}{N+I_{MAI}} < min\left(\frac{C}{N}, \frac{SF}{(K-1)}\right) \text{ (unitless).} \tag{E.9}$$

Each term on the RHS of (E.9) must be greater than the SNR required for the specified BER, BlER, or PER on each link. Denote this required SNR as $(E_S/N_0)_R$, which is the same for each link in the CDMA network under the homogeneity assumption. We can therefore write the following condition.

$$\frac{SF}{(K-1)} \geq \left(\frac{E_S}{N_0}\right)_R \tag{E.10}$$

Solving (E.10) for SF and recognizing that SF must be an integer yields (E.7),

$$SF \geq \left\lceil (K-1) \times \left(\frac{E_S}{N_0}\right)_R \right\rceil \tag{E.7}$$

Alternatively, solving equation (3) for K yields

$$K \leq \left\lfloor SF \cdot \left(\frac{E_S}{N_0}\right)_R^{-1} + 1 \right\rfloor \tag{E.11}$$

where K must also be an integer.

CONCLUDING MATERIAL

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

Preparing Activity:
DISA – DC1
(TCSS-2019-006)

Review Activities:
Army – AC, MI
Navy – CG, MC, OM
Air Force – 11, 13
DIA – DI
DISA – DC5
DMSCO – SE
NGA – MP
OUSD(R&E)SE&A – SE

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