NOT MEASUREMENT SENSITIVE

MIL-STD-188-165B
26 March 2018

SUPERSEDING
MIL-STD-188-165A
w/CHANGE 1
1 November 2005

DEPARTMENT OF DEFENSE INTERFACE STANDARD

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

AMSC N/A AREA TCSS

DISTRIBUTION STATEMENT A. Approved for public release. Distribution is unlimited.

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 Standardization Sector (ITU-T) recommendations, International Organization for Standardization (ISO) standards, 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) (6.4).

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.

CONTENTS

FIGURES

TABLES

1. SCOPE

1.1 Scope. This standard covers phase-shift keying (PSK) modems operating in frequency-division multiple access (FDMA) mode. 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 superhigh frequency (SHF) SATCOM modems that operate over commercial C-band, K_u-band, and K_a-band apply when the modem is used to provide access to the DoD Information Networks (DoDIN).

1.3 Certification authority. The U.S. Army Space and Missile Defense Command (USASMDC)/Army Forces Strategic Command (ARSTRAT) is the certification authority for the WGS communications system and the DSCS and may be contacted at the following address.

U.S. Army Space and Missile Defense Command
Army Forces Strategic Command G-6
Consolidated Wideband SATCOM System Expert (C-SSE)
350 Vandenberg Street
Peterson Air Force Base, CO 80914-2749
usarmy.peterson.smdc.list.wideband-engineering2@mail.mil

1.4 Additional requirements. USASMDC/ARSTRAT may levy certification requirements in addition to those listed herein. Modem designers/vendors shall 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 USASMDC/ARSTRAT.

1.5 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 if the program is not allowed to deviate from the standard. Modems that are accepted by the Government sponsor PM 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
NATO AComP-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 these documents 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.)

2.3 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 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 TS 102 606-1	-	Digital Video Broadcasting (DVB); Generic Stream Encapsulation (GSE); Part 1: Protocol

(Copies of this document 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 802.3i		IEEE Standard for Local and Metropolitan Area Networks - System Considerations for Multi-segment 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 this document 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 Global Service Corporation, 3400 International Drive NW, Washington, DC 20008 (202-944-6800) 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 https://tools.ietf.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 this document are available online at http://www.tiaonline.org.)

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

3. DEFINITIONS

3.1 Definitions of terms. Definitions of terms not listed in this section are as defined in the ATIS Telecom Glossary.

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

8-PSK	eight-phase-shift keying
AC	alternating current
ACI	adjacent channel interference
ACM	adaptive coding and modulation
AGC	automatic gain control
AH	antenna handover

ANSI	American National Standards Institute
APSK	amplitude-phase-shift keying
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
DAMA	demand-assignment multiple access
DEM	distant-end monitoring
DISA	Defense Information Systems Agency
DoD	Department of Defense
DoDIN	Department of Defense Information Networks
DSCS	Defense Satellite Communications System
DVB	digital video broadcasting
EBEM	Enhanced Bandwidth Efficient Modem
EIA	Electronic Industries Alliance
ETSI	European Telecommunications Standards Institute
EVM	error vector magnitude
FDMA	frequency-division multiple access
FEC	forward error correction
GSE	generic stream encapsulation
HDLC	high-level data link control
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
MIL-STD	military standard
NATO	North Atlantic Treaty Organization
OQPSK	offset quadrature phase-shift keying
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
RS	Reed–Solomon
Rx	reception
SATCOM	satellite communications
SHF	super high frequency
SOW	statement of work
SSB	single sideband
STANAG	standardization agreement
TDMA	time-division multiple access
TIA	Telecommunications Industry Association
Tx	transmission
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 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.

3.5 Bit error ratio (BER). The number of bit errors divided by the total number of transferred bits during a specified time interval.

3.6 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).

3.7 dBc. Ratio of a non-carrier power component to the total power in a carrier, expressed in decibels.

3.8 E_b/N_0. The ratio of energy per bit to noise power spectral density (PSD).

3.9 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.

$$EVM = \frac{\sqrt{\frac{1}{N_s}\sum_{k_s=0}^{N_s-1} EVM^2(k_s)}}{\sqrt{\frac{1}{N_c}\sum_{k_c=0}^{N_c-1} {I_{ref}}^2(k_c) + {Q_{ref}}^2(k_c)}}$$

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

$$EVM(k_s) = \sqrt{{I_{err}}^2(k_s) + {Q_{err}}^2(k_s)}$$

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.

3.10 E_s/N_0. The ratio of energy per symbol to noise PSD.

3.11 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.

3.12 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.

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

3.14 Quasi Error Free (QEF). A condition where the BER $\leq 10^{-10}$.

3.15 Reference E_b/N_0. The E_b/N_0 that corresponds to a referenced BER. Reference E_b/N_0 is used to define underlying conditions relevant to some specified performance.

3.16 Stability. The degree of conformity of a measured or calculated value to its original value at the beginning of some prescribed time interval, related to the offset from a prior state.

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

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

3.19 Threshold E_s/N_0. The E_s/N_0 at which the measured BER must not exceed the specified BER. Equal to Threshold E_b/N_0 × data rate (R_d)/symbol rate (R_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.

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 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 antenna handover effects, where applicable.

g. Descrambling for purposes of data de-randomization.

h. Decryption.

i. Service de-multiplexer.

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 suffer loss of bit or packet count integrity when the modem is subject to the following conditions at the E_b/N_0 required for 1×10^{-10} BER performance.

a. Exposure to temperature deviation. The temperature range shall include the lowest and highest operating temperatures. The rate of temperature change between extremes shall be 22 °C per hour.

b. Vibration with an input frequency varied between 50 and 2,000 Hz and with a constant input acceleration of 14.7 m/s^2 (peak).

c. A shock caused by the impact of a test hammer on the outside surface of the equipment housing the conversion circuitry, simulating a maintenance or operator action on the reception function subsystem. The test hammer shall be a 1-lb (453.59-g) weight attached to an 8-in (20.32-cm) arm pivoted from a rigid support and free to move through a vertical plane. The striking face shall be covered with a 0.5-in (1.27-cm) thickness of open-cell sponge rubber that has a density of 0.027 lb/in^3 (747.43 kg/m^3) and a compression deflection of 7–14 lbf/in^2 (4921–9843 kg/m^2) for 25-percent deflection. The shock shall be produced by releasing the hammer to swing freely through a 90° arc; the hammer shall impact the enclosure at the bottom of its swing.

5. DETAILED REQUIREMENTS

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

a. Frequency reference (5.2).

b. Baseband interfaces (5.3).

c. Modem emulations (5.4).

d. IF output interface (5.5).

e. IF input interface (5.6).

f. Demodulation performance (5.7).

g. Control and monitoring functions (5.8).

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. Modems that implement Ethernet data interfaces shall implement 10/100/1000Base-T in accordance with IEEE 802.3i (10Base-T), IEEE 802.3u (100Base-T) and IEEE 802.3ab (1000Base-T).

5.3.2.1 IP encapsulation. IP encapsulation for Ethernet data interfaces shall conform to at least one of the following methods.

a. Generic Stream Encapsulation (GSE) in accordance with TS 102 606-1 V1.2.1 "Generic Stream Encapsulation (GSE); Part 1: Protocol" dated 07/2014.

b. High-level data link control (HDLC) in accordance with NATO STANAG 4486, Annex on EBEM Systems, Appendix on EBEM Baseband Processing – General Requirements, sections on Ethernet frame encapsulation and Idle packet insertion.

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 5.4.1–5.4.10, 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 5.4.2–5.4.9, eight explicit modem emulations are generally defined by referencing external standards. In 5.4.10, 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 5.4.1–5.4.10, subject to the determination of the procuring authority.

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 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

(3)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) 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 5.4.2.e 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. When applicable, provisions for automated uplink power control shall be in accordance with NATO STANAG 4486 Annex on EBEM Systems, Appendix K on EBEM Automated Uplink Power Control (AUPC).

b. When applicable, provisions for information throughput adaptation (ITA) (adaptive coding and modulation) shall be in accordance with NATO STANAG 4486 Annex on EBEM Systems, Appendix on EBEM Information Throughput Adaptation (ITA).

c. When applicable, provisions for distant-end status monitoring shall be in accordance with NATO STANAG 4486 Annex on EBEM Systems, Appendix on EBEM Distant End Monitoring (DEM).

d. When applicable, embedded channel interfaces shall be in accordance with NATO AComP-4486 Annex on Turbo Code and 16-ary Modulation Air Interface, section on Embedded Channel, and Annex on Interface Control Document (ICD) for the EBEM, section on Embedded Channel Interfaces.

e. Service multiplexers shall be in accordance with NATO AComP-4486 Annex on Turbo Code and 16-ary Modulation Air Interface, sections on Frame Structures, Frame Format #1 (ITA) and Frame Format #2 (AH), as applicable.

f. Encryption shall be in accordance with NATO AComP-4486 Annex on Turbo Code and 16-ary Modulation Air Interface, section on Encryption.

g. Selectable scrambling shall be in accordance with NATO AComP-4486 Annex on Turbo Code and 16-ary Modulation Air Interface, section on Scrambler.

h. When applicable, encoding for mitigation of antenna handover effects shall be in accordance with NATO AComP-4486 Annex on Turbo Code and 16-ary Modulation Air Interface, section on Frame Format #2 (AH).

i. FEC encoding shall be in accordance with NATO AComP-4486 Annex on Turbo Code and 16-ary Modulation Air Interface, section on Turbo Code.

j. Symbol-level carrier modulation shall be in accordance with NATO AComP-4486 Annex on Turbo Code and 16-ary Modulation Air Interface, section on Symbol Mapping.

k. Modulation framing shall be in accordance with NATO AComP-4486 Annex on Turbo Code and 16-ary Modulation Air Interface, section on Framing through section on IF Spectral Polarity.

5.4.9 ETSI EN 302 307-1. Modems that implement ETSI EN 302 307-1 emulations shall do so in accordance with ETSI EN 302 307-1.

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

a. If the waveform is fully and explicitly specified in accordance with open commercial standards available to the DoD Government and vendor communities.

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

5.5 IF output interface. In 5.5.1–5.5.6, modem IF (transmission) output is specified in terms of the following.

a. Frequency bands (5.5.1) in terms of required L-band, as well as other optional bands.

b. Electrical impedance (5.5.2).

c. Output carrier (5.5.3) in terms of frequency, stability, accuracy, and phase noise.

d. Output power level (5.5.4) in terms of range and accuracy.

e. Spectral output (5.5.5) in terms of nominal confinement, thermal noise, spurious, and harmonics.

f. Modulation performance (5.5.6) in terms of spectral inversion and EVM.

5.5.1 IF output frequency bands. The modem shall support a 950 to 2000 MHz IF interface. Additional IF interfaces and minimum bandwidths may be chosen by the procuring authority from the following list.

a. 70 ± 18 MHz

b. 140 ± 36 MHz

c. 700 ± 62.5 MHz

Modem performance parameters detailed in this standard shall be met for all waveforms whose −25-dBc bandwidths are contained within the bandwidth limits of the corresponding IF interface.

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 centers below 1 GHz and 2.0:1 for IF band centers 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. When an external frequency reference is not present, the IF output carrier frequency shall be stable to within 1×10^{-8} per day without frequency source adjustments. When an external frequency reference is present, the IF output carrier frequency stability shall meet the frequency stability requirement of the external frequency standard.

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

5.5.3.4 Phase noise. The phase noise requirement is subdivided into continuous and discrete components. The applicable single sideband (SSB) RMS phase noise (in degrees) and the phase noise PSD shall be measured and recorded for the continuous and discrete components as defined in 5.5.3.4.1 and 5.5.3.4.2.

5.5.3.4.1 Continuous component. The continuous component consists of the Gaussian-based phase noise present within the modulator of interest and excludes the discrete component contributions.

a. The phase noise of the IF output carrier shall not exceed the mask shown on FIGURE 1.

b. If the mask is exceeded, then for all symbol rates supported by the modem, the following shall be true.

(1) The measured SSB RMS phase noise shall be integrated over the limits of 0.0005 R_s to 0.5R_s away from the carrier center frequency.

(2) The spectral mask shown on FIGURE 1 shall be integrated over the same limits.

(3) The integrated measured phase noise shall not exceed the integrated phase noise limit mask.

c. For all symbol rates supported by the modem, the calculated SSB continuous component RMS phase noise, integrated over the limits of 0.0005 R_s to 0.5 R_s, shall not exceed:

(1) 2.8° RMS for modems whose highest order modulation format is BPSK or QPSK;

(2) 2.25° for modems whose highest order modulation format is 8-PSK;

(3) 1.125° for modems whose highest order modulation format is 16-amplitude-phase-shift keying (APSK);

(4) 0.75° for modems whose highest order modulation format is 32-APSK.

5.5.3.4.2 Discrete component. The discrete component consists of emissions that result directly from known phenomena such as power line frequency and harmonics, switching frequencies and harmonics of switch-mode power supplies, or alternating current (AC) magnetic fields induced into the system of interest. The SSB phase noise at AC line fundamental and harmonic frequencies shall not exceed −36 dBc. The SSB sum (added on a power basis) of all other discrete component emissions shall not exceed −42 dBc.

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.

5.5.5 Spectral output.

5.5.5.1 Spectral confinement. For modulation symbol rates above 38.4 kilo symbols per second (ks/s), the IF output signal shall meet the PSD confinement mask shown on FIGURE 2. This requirement shall be met when terminating into a 50-Ω load with a VSWR as specified in 5.5.2 for any symbol rate greater than 38.4 ks/s. It shall be acceptable for transmission spectra to exhibit the following:

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

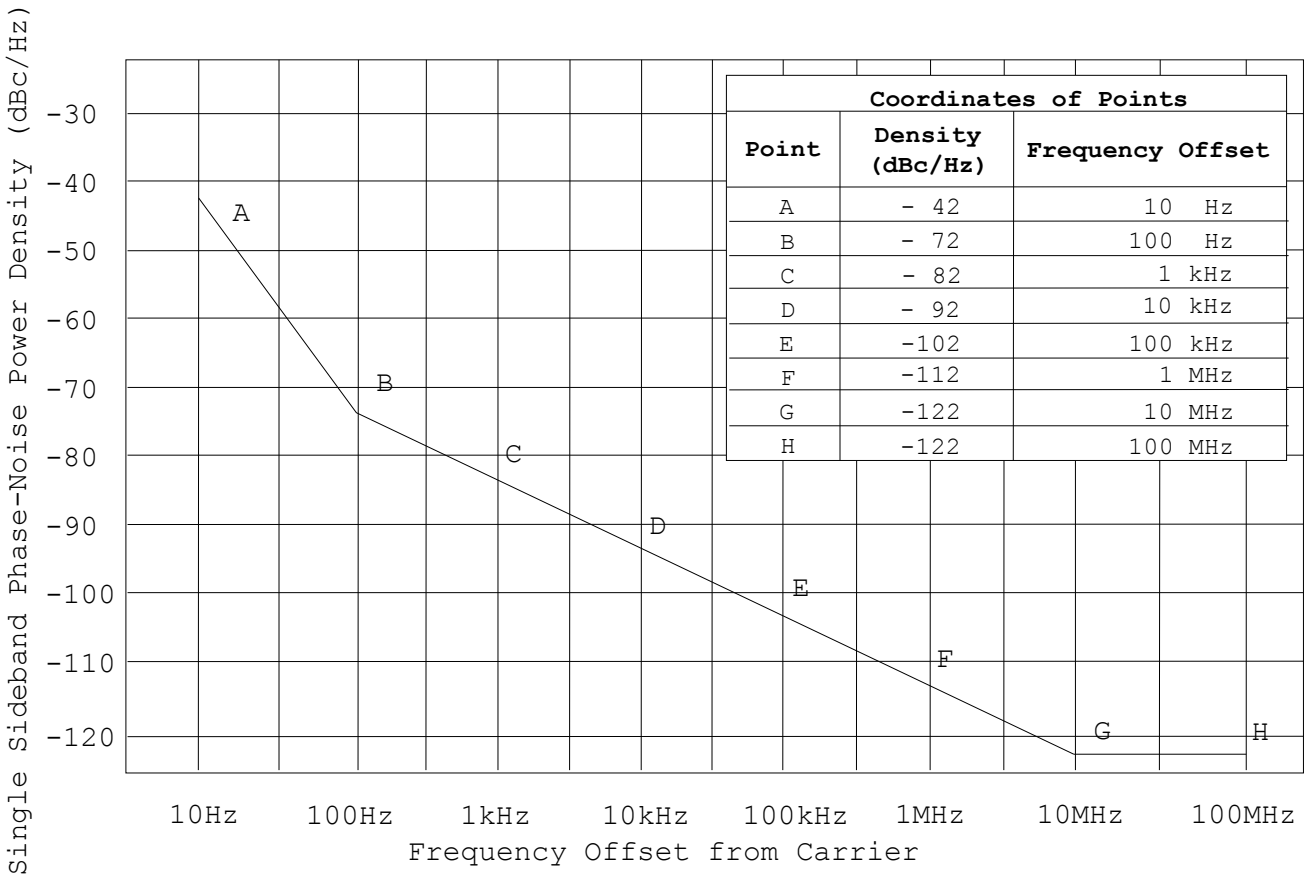
b. Clock nulls, offset by half the symbol rate from the carrier, for BPSK and OQPSK modulation only;

c. PSD not to exceed the Tx thermal noise floor threshold specified on FIGURE 2 when this threshold exceeds the PSD confinement mask shown on FIGURE 2;

d. Spurious emissions compliant with 5.5.5.3;

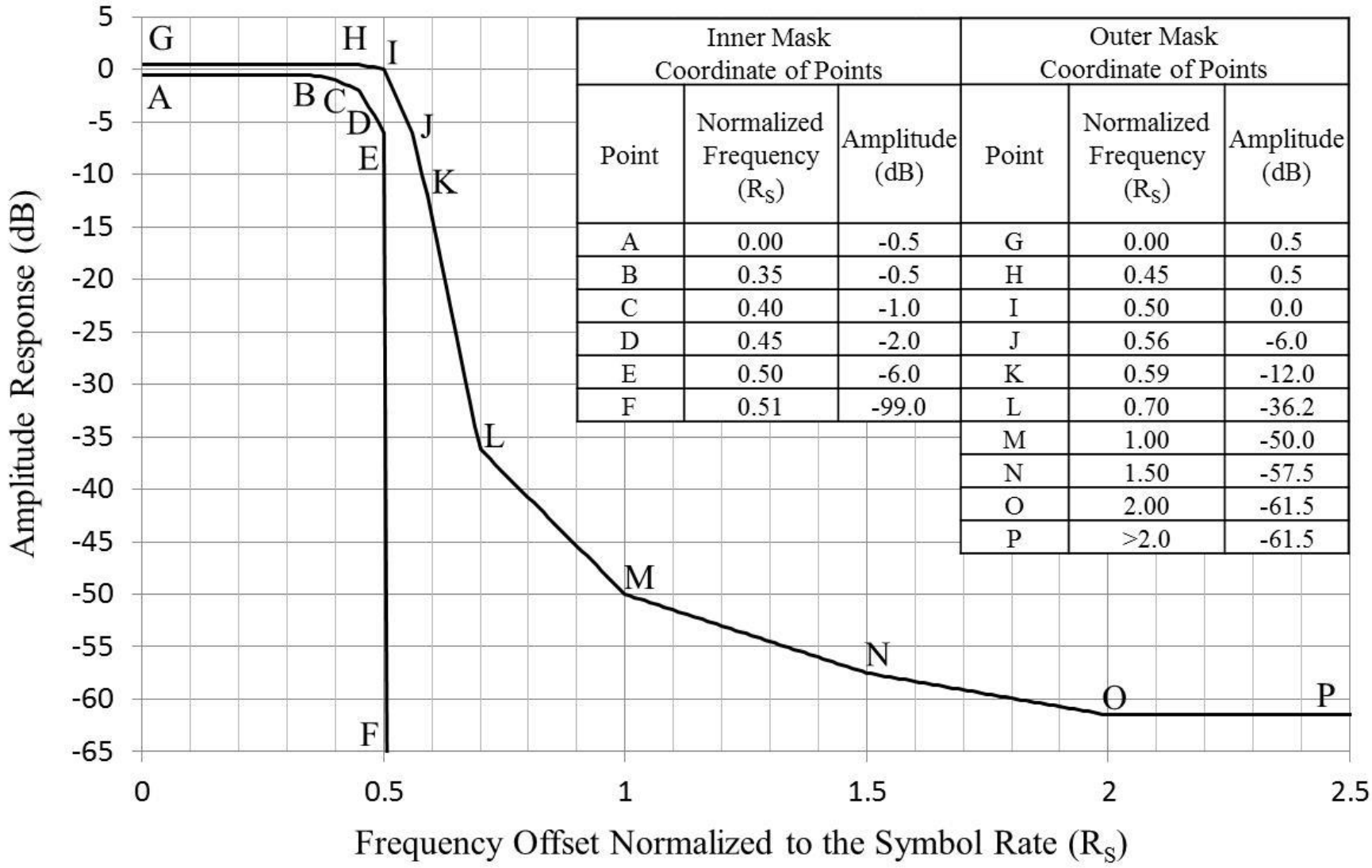
e. Output harmonics compliant with 5.5.5.4.

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.



Coordinates of Points		
Point	**Density (dBc/Hz)**	**Frequency Offset**
A	- 42	10 Hz
B	- 72	100 Hz
C	- 82	1 kHz
D	- 92	10 kHz
E	-102	100 kHz
F	-112	1 MHz
G	-122	10 MHz
H	-122	100 MHz

FIGURE 1. Transmitted IF phase noise mask.



Inner Mask Coordinate of Points		
Point	Normalized Frequency (R_S)	Amplitude (dB)
A	0.00	-0.5
B	0.35	-0.5
C	0.40	-1.0
D	0.45	-2.0
E	0.50	-6.0
F	0.51	-99.0

Outer Mask Coordinate of Points		
Point	Normalized Frequency (R_S)	Amplitude (dB)
G	0.00	0.5
H	0.45	0.5
I	0.50	0.0
J	0.56	-6.0
K	0.59	-12.0
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 2. Modulator output signal spectral density limit mask.

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.

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

Where:

$\left.\frac{E_s}{N_0}\right|_{QEF}$ is the threshold $\frac{E_s}{N_0}$ corresponding to a BER of 10^{-10} for the most spectrally efficient combination of modulation and coding 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}, 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 dBc.

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,

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

Where:

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

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

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. Additional IF interfaces and minimum bandwidths may be chosen by the procuring authority from the following list.

a. 70 ± 18 MHz.

b. 140 ± 36 MHz.

c. 700 ± 62.5 MHz.

Modem performance parameters detailed in this standard shall be met for all waveforms whose −25-dBc bandwidths are contained within the bandwidth limits of the corresponding IF interface.

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 centers below 1 GHz and 2.0:1 for IF band centers 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 5.6.4.1–5.6.4.3.

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 noise floor shall be less than -130 dBm/Hz. The demodulator shall operate with a minimum carrier level such that:

$$P_{min} = -113 \text{ dBm/Hz} + E_S/N_0 + 10 \log R_S$$

Where:

E_S/N_0 (in dB) is the specified performance value for a BER of 1×10^{-8};
R_S is symbol rate in symbols/s.

Where E_S/N_0 performance is not specified, then:

$E_S/N_0 = R_d/R_S \times E_b/N_0$
E_b/N_0 (in dB) is the specified performance value for a BER of 1×10^{-8};
R_d is data rate in b/s.

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

$$P_{max} = -3 \text{ dBm/MHz} + 10 \log R_s$$

Where:

R_s is the symbol rate in mega symbols per second (Ms/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 floor shall be less than -130 dBm/Hz.

5.7 Demodulation. In 5.7.1–5.7.3, demodulation performance is specified in terms of the following.

a. Applicability to all modem emulations (5.7.1).

b. Comprehensive acquisition and timing performance (5.7.2).

c. Comprehensive error performance (5.7.3), including baseline BER performance, as well as performance impaired by adjacent channels, high levels of composite power, or self-interference from other modem components.

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 be 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_b/N_0 is defined as the specified threshold E_b/N_0 that corresponds to a BER of 1×10^{-3}. If the threshold E_b/N_0 is not specified for a BER of 1×10^{-3}, then the reference E_b/N_0 is extrapolated from the threshold E_b/N_0 for the lowest specified BER point at a rate of 0.1 dB of E_b/N_0 per factor of 10 BER.

5.7.2.1 Initial acquisition. The modem shall achieve initial acquisition within the times shown in TABLE IV, with a probability of 99 percent and a confidence level of 95 percent over a frequency uncertainty of ±30 kHz at the reference E_b/N_0.

TABLE IV. Acquisition times for selected data rates.

Data Rate Range (kb/s)	Maximum Initial Acquisition Time (s)	Maximum Reacquisition Time (s)
$16 \leq R_d < 64$	500	25
$64 \leq R_d < 128$	250	25
$128 \leq R_d < 1544$	15	10
$1544 \leq R_d$	1	1

5.7.2.2 Reacquisition. This requirement applies after loss of the Rx carrier for up to 15 min and upon return of the carrier to within 500 Hz of its frequency at the time of loss. Reacquisition shall be achieved in accordance with TABLE IV, using the probability and confidence levels described in 5.7.2.1. Note that the initial modem acquisition requirement in 5.7.2.1 applies to carrier loss longer than 15 min and carrier return beyond 500 Hz of its 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 bit-count integrity (BCI) due to falsely adding or deleting bits shall be at least 7 days at the reference E_b/N_0. In addition, the BCI 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. Synchronization at all interfaces, and BCI at serial interfaces, shall be maintained at the reference E_b/N_0 for a signal loss of up to 200 modulation symbol periods with a probability of at least 90 percent.

5.7.2.5 Timing jitter. This requirement applies to serial baseband interfaces: At the reference E_b/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 V at the same reference E_b/N_0 defined in 5.7.2.

TABLE V. Doppler parameters.

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

[1] Doppler shift corresponds to satellite inclinations up to 7°.
[2] Doppler rate of change and acceleration correspond to Navy requirements based on shipboard motion.

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 5.7.3.1.1–5.7.3.1.10.

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 NATO STANAG 4486 Annex on EBEM Systems, Appendix on BER Performance.

5.7.3.1.9 ETSI EN 302 307-1. Error performance of ETSI EN 302 307-1-compliant emulations shall conform to ETSI EN 302 307-1.

5.7.3.1.10 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. Consider the following adjacent channel interference (ACI) conditions: R_d is the data rate of the carrier of interest; R_s is the symbol rate of the carrier of interest; ACI consists of two adjacent carriers, one higher in frequency and one lower in frequency, each with a spectral density 13 dB higher than that of the carrier of interest; symmetrical ACI is the case where each adjacent carrier is of symbol rate R_s; asymmetrical ACI is the case where each adjacent carrier is of symbol rate $2R_s$; and BER is any readily measurable BER.

When ACI is introduced, the threshold E_b/N_0 specified in 5.7.3.1 shall be allowed a degradation of

$$10 \log_{10} \left(\frac{\frac{1}{E_s/N_0}}{\frac{1}{E_s/N_0} - X} \right) \text{ dB}$$

Where:

X = 0.0059 in the symmetrical ACI case where center-to-center carrier spacing is $1.2R_s$;

X = 0.0043 in the symmetrical ACI case where center-to-center carrier spacing is $1.4R_s$;

X = 0.0156 in the asymmetrical ACI case 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 asymmetrical ACI case where center-to-center carrier spacing is $2.1R_s$ (1.4 times the average of the two symbol rates);

E_s/N_0 = the linear energy ratio computed using

$$\frac{R_d}{R_s}\frac{E_b}{N_0}$$

Where:

Eb/N0 = any relevant threshold Eb/N0 defined in 5.7.3.1 but expressed also as a linear energy ratio.

In cases where $\frac{1}{E_s/N_0} \leq X$, it is allowable for ACI, as defined above, to prevent reception at the BER corresponding to the relevant threshold E_b/N_0.

5.7.3.3 Composite power. Consider the case where reception carriers are present in the IF band, as defined in 5.6.1, with power levels that exceed that 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. Composite power does not exceed +20 dBm;

b. PSD does not exceed −3.0 dBm/MHz;

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. Consider the case where activation of any or all modulator or demodulator elements within a modem chassis degrade the performance of the demodulator element of interest. In this case, the threshold E_b/N_0 specified in 5.7.3.1 shall be allowed a degradation equal to the degradation that would result from introduction of an additive noise component whose PSD equals −133 dBm/Hz (5×10^{-14} mW/Hz). This requirement shall apply under the following conditions.

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 VI shall be controlled and monitored using the remote interface. Required response time is within 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, with a confidence level of 99.5, 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 VI. 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
--	Bit synchronization indicator (Tx/Rx)

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 FDMA 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.

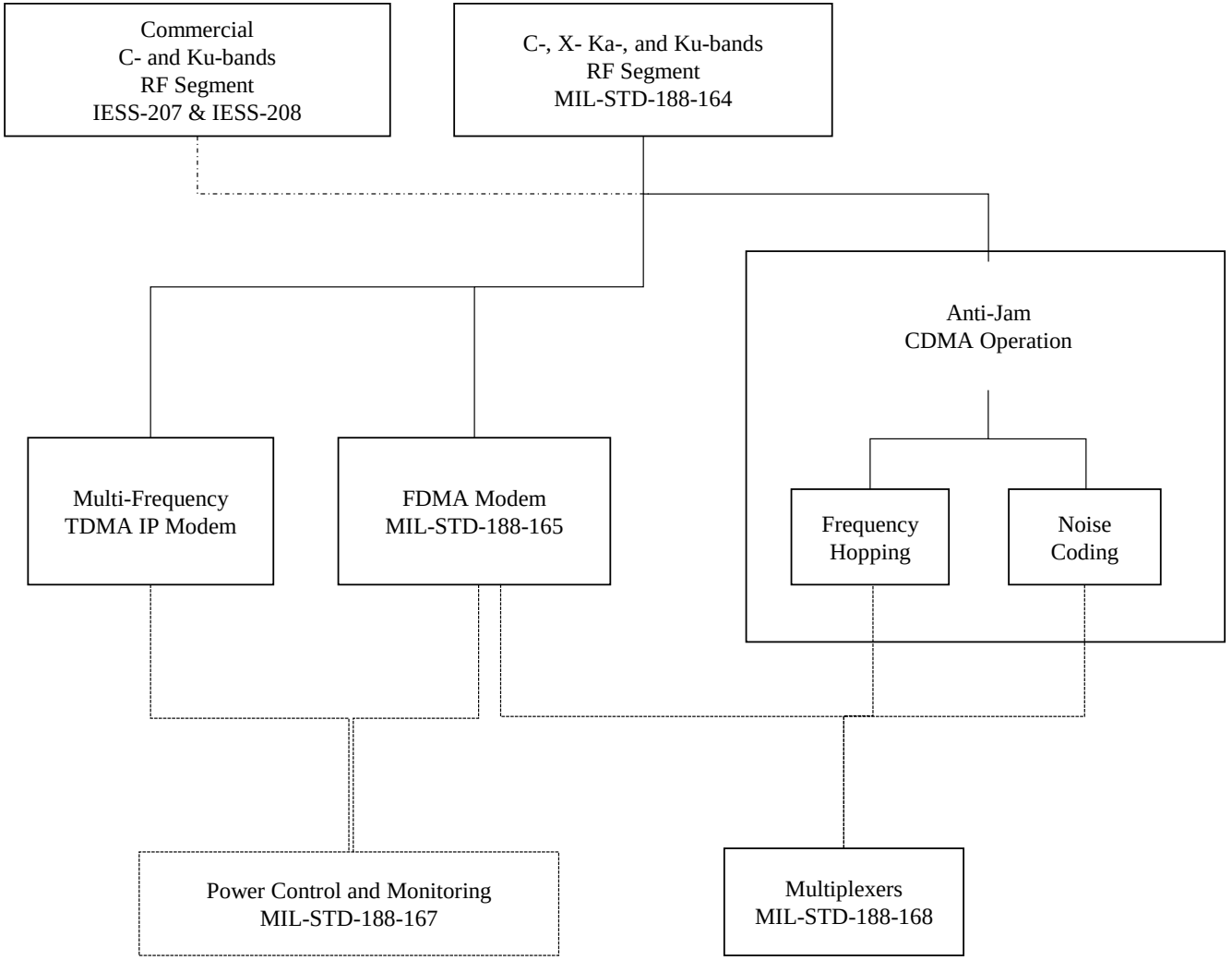
6.3 Tailoring guidance. To ensure proper application of this standard, invitations for bids, requests for proposals, and contractual statements of work (SOWs) should tailor the requirements in sections 4 and 5 of this standard to exclude any unnecessary requirements.

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

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

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 3.

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



CDMA – Code-Division Multiple Access
DAMA – Demand-Assignment Multiple Access
FDMA – Frequency-Division Multiple Access
TDMA – Time-Division Multiple Access
RF – Radio Frequency

FIGURE 3. SHF SATCOM standards profile.

6.7 Background and future guidance. This MIL-STD changes in response to changing DoD requirements and SATCOM technologies. The following table offers corresponding background on select requirements as well as projected changes.

TABLE VIIII. Background and Future Guidance.

MIL-STD-188-165B Background and Future Guidance		
Section or Requirement	Present Background	Future Guidance
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.
5.2 Frequency Reference	The intent is to meet section 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.	N/A
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.

MIL-STD-188-165B Background and Future Guidance		
Section or Requirement	Present Background	Future Guidance
5.4.10 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.
5.5.4 Output power control range, step size, and accuracy	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.	N/A
5.5.6.2 Error vector magnitude	A single EVM requirement replaces Tx degradation due to previously specified • modulation symbol jitter (±3%) • max peak modulation phase error (2 degrees peak) • group delay deviation from linear (±0.14 symbol intervals) Additionally, EVM accounts for the general effects of Tx phase noise on constellation integrity. Present EVM threshold scales with modulation index.	This requirement may be revised to scale reasonably with QEF E_S/N_0 $(\frac{E_S}{N_0}\Big\vert_{QEF})$

MIL-STD-188-165B Background and Future Guidance		
Section or Requirement	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.
5.6.3.2 Input frequency uncertainty	Sources of present ±30 kHz requirement are dominated by 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 input level	References power spectral density thresholds on account of symbol rate ranges anticipated	N/A
5.6.4.1.2 Maximum operating IF input level	References power spectral density thresholds on account of symbol rate ranges anticipated	N/A
5.7.2.1 Initial Acquisition	±30 kHz is based on LO frequency uncertainty and acceptable satellite inclination	Expect requirement to increase to ±100 kHz to accommodate airborne platform dynamics.
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.

MIL-STD-188-165B Background and Future Guidance		
Section or Requirement	Present Background	Future Guidance
5.7.2.6 Doppler environment	Present Doppler parameters are based on allowable satellite inclination combined with shipboard platform motion.	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 performance	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 was formerly a tabular degradation requirement against unimpaired performance. It is now an analytically expressed allowance for degradation against 5.7.3.1 performance thresholds.	N/A
5.7.3.3 Composite power	The intent is to • begin with section 5.7.3.2 ACI interference • add carrier power, within 10 MHz, for a total interfering carrier power, within 10 MHz, of +30 dBc • add carrier power, beyond 10 Mhz, for a total interfering carrier power of +40 dBc overall • meet the 5.7.3.2 ACI requirement	N/A

MIL-STD-188-165B Background and Future Guidance		
Section or Requirement	Present Background	Future Guidance
5.7.3.4 Isolation of additional integrated modulators and demodulators	Mod/demod isolation was formerly a fixed degradation requirement against unimpaired performance. It is now an analytically expressed allowance for degradation against 5.7.3.1 performance thresholds.	N/A
5.8.2 Control and monitoring parameters	Table VI "Modem Control and Monitoring Parameters" are presently relevant.	Table VI "Modem Control and Monitoring Parameters" are subject to change. For example, • abandoning legacy modem emulations may render "differential coding" irrelevant • abandoning serial data interfaces may render "bit synchronization indicator" irrelevant • new control and monitoring parameters, additional or otherwise, may become relevant in the future
6.1 Intended use	Intended use specifies FDMA function.	The FDMA caveat will be deleted in favor of incorporating new content specifying performance guidelines relevant to non-FDMA modems.
Not yet specified: MF-TDMA modems	MF-TDMA modems are presently certified as special cases of MIL-STD-188-165	MIL-STD-188-165B may be supplemented with content addressing the MF-TDMA modem case.
Not yet specified: frequency hop spread spectrum modems	Frequency hop spread spectrum modems are presently certified as special cases of MIL-STD-188-165	MIL-STD-188-165B may be supplemented with content addressing the frequency hop spread spectrum modem case.

MIL-STD-188-165B Background and Future Guidance		
Section or Requirement	Present Background	Future Guidance
Not yet specified: direct sequence and pseudo-noise spread spectrum modems	Direct sequence and pseudo-noise spread spectrum modems are presently certified as special cases of MIL-STD-188-165	MIL-STD-188-165B may be supplemented with content addressing the direct sequence / pseudo-noise spread spectrum modem case.
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.

CONCLUDING MATERIAL

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

Preparing Activity:
DISA – DC1
(TCSS-2016-002)

Review Activities:
- Army – AC, MI
- Navy – CG, MC, OM
- Air Force – 11, 13
- DIA – DI
- DISA – DC5
- DMSCO – DMS
- NGA (DepSO) – MP
- ODASD (SE) – 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.