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MIL-STD-188-181A  
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SUPERSEDING  
MIL-STD-188-181  
18 September 1992

# DEPARTMENT OF DEFENSE INTERFACE STANDARD

INTEROPERABILITY STANDARD  
FOR  
SINGLE-ACCESS 5-kHz and 25-kHz UHF  
SATELLITE COMMUNICATIONS CHANNELS



## MIL-STD-188-181A

### FOREWORD

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

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

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

4. This standard complies with Joint Staff direction requiring that a standard be developed to define all technical characteristics essential for interoperability and performance of satellite communications (SATCOM) terminals that use single-access 5-kHz and 25-kHz ultra high frequency (UHF) SATCOM channels. This standard defines mandatory system parameters for planning, engineering, procuring, and using UHF SATCOM terminals.

5. Beneficial comments and any pertinent data which may be of use in improving this standard should be addressed to:

Defense Information Systems Agency  
Joint Interoperability and Engineering Organization  
ATTN: JEBBC  
Fort Monmouth, NJ 07703-5613

by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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**MIL-STD-188-181A****1. SCOPE**

**1.1 Purpose.** This standard establishes mandatory requirements applicable to satellite communications (SATCOM) terminals that are required to operate over single-access 5-kHz and 25-kHz ultra high frequency (UHF) SATCOM channels. Minimum interoperability requires a terminal to meet the mandatory requirements within this document. A terminal may exceed these requirements if it maintains interoperability and adjacent channel emission (ACE)(5.1.1.4 and 5.2.1.4) requirements. For example, the incorporation of additional standard and nonstandard interfaces is not precluded.

**1.2 Scope.** This standard is mandatory for all applicable terminals. An applicable terminal is a 5- or 25-kHz UHF SATCOM terminal that (1) is undergoing major modification after the date of this standard, or (2) is under development.

**1.3 Application guidance.** In this standard the word *shall* identifies mandatory terminal requirements. The word *should* identifies design objectives that are desirable but not mandatory. FED-STD-1037 defines *system standard* and *design objective*. With the exception of ACE requirements in 5.1.1.4 and 5.2.1.4, all requirements in this standard apply to terminal operation only at the mandatory data rates and associated modulation types. If the optional capabilities are implemented, the requirements of this standard apply. Requirements in 5.1.1.4 and 5.2.1.4 apply whenever operating over single access 5- or 25-kHz channels including the use of unspecified data rates and modulation types.

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**MIL-STD-188-181A****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 documents cited in sections 3, 4, and 5 of this standard, whether or not they are listed.

**2.2 Government documents**

**2.2.1 Specifications, standards, and handbooks.** The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplements thereto, cited in the solicitation.

**SPECIFICATIONS**

## Department of Defense

MIL-C-28883	<i>Military Specification for the Advanced Narrowband Digital Voice Terminal (ANDVT) Set, AN/USC-43 (V)</i>
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(Unless otherwise indicated, copies of the above specifications are available from Commander, Space and Naval Warfare Systems Command, Washington, D.C., 20363-5100.)

**STANDARDS**

## FEDERAL

FED-STD-1037	<i>Glossary of Telecommunication Terms</i>
FED-STD-1016	<i>Telecommunications: Analog to Digital Conversion of Radio Voice by 4,800 Bit/Second Code Excited Linear Prediction (CELP)</i>

(Unless otherwise indicated, copies of the above specifications and standards are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

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**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 are those cited in the solicitation.

FSCS-200-83-1	<i>Navy UHF Satellite Communications Description</i>
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(Copies of FSCS-200-83-1 may be obtained through its sponsor, NAVELEX PDE 106-11, NCI, Washington, D.C. 20363 or through the Naval Ocean Systems Center, Code 761, 271 Catalina Boulevard, San Diego, CA 92152.)

National Security Agency (NSA)

NSA NO. 82-2	<i>NSA Performance and Interface Specification for TSEC/KG-84A, General Purpose Encryption Equipment (GPEE)</i>
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NSA NO. CSESD-14	<i>Communications Security Equipment System Document for TSEC/KY-57/58</i>
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(Copies of NSA documents are available from the Director, National Security Agency, ATTN: V31, 9800 Savage Road, Fort George G. Meade, MD 20755-6000.)

**2.3 Non-Government publications.** The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DoDISS cited in the solicitation.

North Atlantic Treaty Organization (NATO)  
Standardization Agreements (STANAG)

4198	<i>Parameters and Coding Characteristics That Must Be Common to Assure Interoperability of 2400 bps Linear Predictive Encoded Digital Speech</i>
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**2.4 Order of precedence.** 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.

**MIL-STD-188-181A****3. DEFINITIONS**

**3.1 Terms.** Terms not listed below are defined in FED-STD-1037.

**3.1.1 Acquisition.** A necessary preliminary condition of a receiver, by which frequency and phase ambiguities of an incoming rf carrier are sufficiently resolved to allow information modulated onto the carrier to be properly demodulated.

**3.1.2 Binary phase-shift keying (BPSK).** A form of phase-shift keying (PSK). In PSK modulation, the phase angle of the carrier is discretely controlled by the information bits being transmitted. In BPSK, the instantaneous phase of the carrier can be either unchanged or shifted 180 degrees.

**3.1.3 Bit synchronization (clock lock).** The condition achieved when significant transitions of the recovered data rate clock are phase-stable to within 25 percent of the bit period.

**3.1.4  $C/kT$ .** The ratio of the rf carrier power ( $C$ ) relative to noise power density. Carrier power is measured into the receiving system.  $k$  = Boltzman's constant and  $T$  = the effective noise temperature at the terminal antenna in kelvins.

**3.1.5 Coherent demodulation.** A demodulation process characterized by a synchronized, phase-matched condition between a receiver's reference and the received signal.

**3.1.6 Differential encoding.** A process by which baseband digital data before modulation is used to resolve the phase ambiguity of digital data recovered from demodulation. It is not used for error detection or correction. A process such that if the prior code bit and the message bit are the same, the encoder output is zero. If they are different, the encoder output is a one.

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

**3.1.8 Energy per bit ( $E_b$ ).** The average signal energy contained in a binary digit.

**3.1.9 Frequency uncertainty.** The difference between a receive signal's expected frequency and its actual frequency. Frequency uncertainty results when (1) there is a difference in frequency between reference oscillators, (2) Doppler effects

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cause frequency shifts, or (3) there are frequency-setting inaccuracies.

**3.1.10 Frequency-shift keying (FSK).** A form of frequency modulation. In FSK modulation, the frequency of the carrier is discretely controlled by the transmitted information bits. In binary FSK, the instantaneous frequency of a signal is shifted between two discrete values called the *mark* and *space* frequencies.

**3.1.11 Narrowband operation.** A communications mode whose essential spectral content is limited to a channel of nominal 5-kHz bandwidth.

**3.1.12 Noise power spectral density ( $N_0 = kT$ ).** The noise power per Hz of bandwidth.

**3.1.13 Noncoherent demodulation.** A demodulation process in which there is no synchronized phase-matched condition between a receiver's reference and the desired signal.

**3.1.14 Nonprocessed satellite channel.** A channel capable only of receiving, amplifying, frequency translating, and retransmitting a received signal. (There is no signal processing.)

**3.1.15 Offset quadrature phase-shift keying (OQPSK).** A form of QPSK in which the in-phase (I) and quadrature (Q) bit streams are offset in time by one-half a symbol period, equal to the reciprocal of the data rate.

**3.1.16 Preamble.** Consists of an unmodulated carrier segment followed immediately by a carrier segment modulated by a predetermined signal used for acquisition. The unmodulated carrier segment is used by the receiver during carrier acquisition. The carrier segment modulated by a predetermined bit pattern is used by the demodulator for bit synchronization. The preamble bit pattern immediately precedes, and is phase-locked to, transmitted baseband data.

**3.1.17 Quadrature phase-shift keying (QPSK).** A form of PSK in which the instantaneous phase of the carrier can be either unchanged, shifted  $\pm 90$  degrees, or shifted 180 degrees. QPSK may be represented as two independent binary bit streams modulated onto the I and Q components of the carrier.

**3.1.18 Shaped binary phase-shift keying (SBPSK).** A form of BPSK modified to produce the phase-shift over a period of time. For example, in 50-percent SBPSK, the phase-shift occurs over a period of time equal to one-half a bit period.

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**3.1.19 Shaped offset quadrature phase-shift keying (SOQPSK).** A form of OQPSK modified to produce phase-shift over a period of time. For example, in 50-percent SOQPSK, the phase-shift occurs over a period of time equal to one-half a bit period.

**3.1.20 Terminal.** Equipment designed to receive and transmit voice or data information using the frequencies, modulations, data rates, access protocols, eirp, and sensitivity needed to establish and sustain voice or data communications over a satellite channel. A terminal may include internal or external voice or data encryption devices, or both.

**3.1.21 Total received carrier power.** The amount of signal power captured by the receiving antenna.

**3.1.22 Transmitter turn-on time.** The time interval between baseband equipment key down and the time at which the transmitter has stabilized to within 90 percent of steady-state transmit power and  $\pm 20$  Hz of the steady-state transmit center frequency.

**3.1.23 Wideband operation.** A communications mode whose essential spectral content is limited to a nominal 25-kHz channel bandwidth.

**3.2 Abbreviations and acronyms.** The abbreviations and acronyms used in this standard are defined as follows:

ACI	adjacent channel interference
AM	amplitude modulation
ANDVT	Advanced Narrowband Digital Voice Terminal
BER	bit error ratio
bps	bits per second
BPSK	binary phase-shift keying
$C$	total received carrier power
CELP	code-excited linear prediction
$C/kT$	carrier-to-noise power density
COMSEC	communications security
CVSD	continuously variable slope delta
dB	decibel
dBW	decibels relative to 1 watt
DCS	Defense Communications System
DISA	Defense Information Systems Agency
DoD	Department of Defense
DoDD	DoD Directive
DoDISS	DoD Index of Specifications and Standards
$E_b$	energy per bit
$E_b/N_o$	energy-per-bit to noise-power-spectral-density ratio
eirp	effective isotropically radiated power

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<i>f</i>	frequency
FDMA	frequency-division multiple access
FEC	forward error correction
FED-STD	federal standard
FLTSATCOM	Fleet Satellite Communications
FM	frequency modulation
FSK	frequency-shift keying
GHz	gigahertz
GPPE	general-purpose encryption equipment
<i>G/T</i>	antenna gain-to-noise temperature in dB/K
Hz	hertz
I	in-phase
I/O	input/output
JCS	Joint Chiefs of Staff
JIEO	Joint Interoperability and Engineering Organization
<i>k</i>	Boltzman's constant
K	kelvin
kbps	kilobits per second
kHz	kilohertz
LEASAT	leased satellite
LSB	least significant bit
<i>M</i>	power margin
MARISAT	maritime satellite
MELP	Mixed Excitation Linear Prediction
MHz	megahertz
MIL-STD	military standard
MJCS	JCS memorandum
ms	millisecond
MSB	most significant bit
NATO	North Atlantic Treaty Organization
NSA	National Security Agency
<i>N<sub>o</sub></i>	noise power spectral density
NMCS	National Military Command System
OTAR	over-the-air rekeying
OQPSK	offset quadrature phase-shift keying
ppm	part per million
PSK	phase-shift keying
<i>Q</i>	quadrature
<i>R</i>	link data rate
rf	radio frequency
SATCOM	satellite communications
SBPSK	shaped binary phase-shift keying
SHF	super high frequency
SOM	start-of-message
SOQPSK	shaped offset quadrature phase-shift keying
STANAG	standardization agreement (NATO)
<i>T</i>	bit period
UFO	UHF Follow-On
UHF	ultra high frequency
W	watt
$\Delta f$	change in frequency ( $f_2 - f_1$ )

**MIL-STD-188-181A****4. GENERAL REQUIREMENTS**

**4.1 Communications system characteristics.** The parameters defined in this document provide for the interoperability and performance of land-based, surface ship, aircraft, and submarine terminals that use nonprocessed 5- and 25-kHz ultra high frequency (UHF) SATCOM channels. The 5-kHz nominal bandwidth channels are referred to as narrowband; the 25-kHz nominal bandwidth channels are referred to as wideband. The parameters defined herein provide efficient use of the satellite channels, minimize interference among satellite users, and ensure an interoperable mode exists for all users. Optional capabilities that are implemented shall be as specified in this standard. Interoperable access modes shall be single access on a satellite channel. The interoperable modes and data rates are shown in Table I.

**TABLE I. Interoperability I/O data rates.**

<b>OPERATING MODES</b>	<b>NARROWBAND MODE RATES (bps)</b>	<b>WIDEBAND MODE RATES (kbps)</b>
Voice (Mandatory)	2400	16
Voice (Optional)	4800	
Data (Mandatory)	1200/2400	16
Data (Optional)	75/300/600/ 4800/6400	9.6/16/19.2/ 32/38.4

**4.2 General waveform structure**

**4.2.1 Operating modes.** There are two operating modes, as indicated below:

**a. Narrowband mode.** Operation will be limited to a 5-kHz bandwidth (a single 5-kHz channel, or a 5-kHz bandwidth of a 25-kHz or 500-kHz channel, as they are defined in Appendix A), as specified in 5.1 through 5.1.9.2.

**b. Wideband mode.** Operation will be limited to a 25-kHz bandwidth (a single 25-kHz channel, or a 25-kHz bandwidth of a 500-kHz channel, as they are defined in Appendix A), as specified in 5.2 through 5.2.9.

**4.2.2 Synchronization.** For coherent demodulation (PSK), the terminal shall transmit a preamble to allow demodulator synchronization before the communications security (COMSEC) synchronization preamble is transmitted. A preamble shall not be

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used for FSK modulation in the wideband mode. Note that *mode* is not synonymous with *channel*.

**4.2.3 Communications security waveform.** Communications security is provided as specified in 5.1.7 and 5.2.7. Hardware implementation of the terminals with embedded COMSEC shall include provisions for future implementation of over-the-air rekeying (OTAR).

**4.2.4 Satellite interface.** The waveform shall interface with maritime satellite (MARISAT) (also known as Gapfiller), Fleet Satellite Communications (FLTSATCOM), Leased Satellite (LEASAT), and UHF Follow-On (UFO) satellites, which are described in FSCS-200-83-1. Frequency plans for LEASAT, FLTSATCOM, MARISAT, and UFO are shown in Appendix A, in Tables A-I, A-II, A-III, and A-IV, respectively.

**4.2.5 Forward error correction (optional).** Convolutional forward error correction (FEC) coding at rates 1/2, and 3/4 is provided as an optional capability. If the terminal implements FEC, it shall be compliant with the FEC requirements of this standard. Code rate 1 refers to no FEC coding.



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## 5. DETAILED REQUIREMENTS

## 5.1 Narrowband mode

**5.1.1 Transmit.** The effective isotropically radiated power (eirp) requirements specified in 5.1.1.1 through 5.1.1.4.2 include all gains and losses from the transmitter to the antenna, inclusive.

**5.1.1.1 Effective isotropically radiated power.** The terminal shall be capable of providing eirp of at least 16 dBW with respect to right-hand circular polarization. The terminal eirp shall be incrementally or continuously adjustable between a minimum setting no greater than 10 dBW and the maximum eirp, with a power setting resolution of 2 dB or better.

**5.1.1.2 Effective isotropically radiated power accuracy.** The terminal shall maintain an eirp accuracy of  $\pm 1.5$  dB, assuming antenna gain and passive losses are fixed.

**5.1.1.3 Transmitter turn-on time.** The transmitter turn-on time shall not exceed 50 ms.

**5.1.1.4 Adjacent channel emissions.** In a nominal 5-kHz bandwidth whose center frequency is displaced by  $\Delta f$  from a terminal transmitter's carrier frequency, the eirp shall be as specified in 5.1.1.4.1 and 5.1.1.4.2.

**5.1.1.4.1 Carrier level less than +18 dBW.** The eirp, relative to the terminal's total output eirp, shall not exceed the values specified in Table II. These values shall apply when the transmitter carrier frequency is either unmodulated or modulated.

**5.1.1.4.2 Carrier level greater than or equal to +18 dBW.** For carrier eirp levels equal to or greater than +18 dBW, the maximum eirp values shall not exceed the values specified in Table II.

Table II. Allowable adjacent channel emissions, narrowband.

$\Delta f$ (kHz)	RELATIVE EIRP (dB) (CARRIER LEVEL < +18 dBW)	MAXIMUM EIRP (dBW) (CARRIER LEVEL $\geq$ +18 dBW)
5	-14	+4
10	-34	-16
15	-38	-20
$\geq 20$	-40	-22

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**5.1.1.5 Tuning.** The transmit frequency shall be tunable in 5-kHz increments over the frequency range of 291.000 to 318.000 MHz.

**5.1.2 Receive****5.1.2.1 Susceptibility to adjacent channel interference.**

The terminal shall achieve a bit error ratio (BER) of  $1 \times 10^{-5}$  or better at the  $C/kT$  specified in Table III, when operating in the presence of adjacent channel interference (ACI), at 5-kHz offset. For test conditions, ACI power in the desired channel shall be 15 dB below the average power of the desired signal, where the ACI signal is a 2400-bps random bit pattern that is 50-percent SBPSK-modulated.

**TABLE III. Susceptibility to adjacent channel interference, narrowband mode.**

<b>BIT RATE (bps)</b>	<b><math>C/kT</math> FOR BER EQUAL TO <math>1 \times 10^{-5}</math> (dB-Hz)</b>
75	32.3
300	38.3
600	41.3
1200	44.3
2400	47.3
4800	51.8
6400	52.8

**5.1.2.2 Tuning.** The receive frequency shall be tunable in 5-kHz increments over a frequency range of 243.000 to 270.000 MHz.

**5.1.2.3 Bit error ratio.** The BER measured at the output of the demodulator, for FEC code rate 1, shall not exceed  $1 \times 10^{-5}$  for a data rate of 2400 bps and a  $(G/T)/(E_b/N_o)$  of -34.7 dB/K (or -42.4 dB/K for aircraft and submarine installations), assuming a sky noise temperature of 200 K and a 0-dB gain antenna for airborne platforms. The required  $(G/T)/(E_b/N_o)$  for rate 3/4 and 1/2 codes shall be reduced by 3.0 dB and 4.25 dB, respectively. The  $G/T$  and  $E_b/N_o$  of terminals may be independently evaluated for test purposes. However, when performance of the independent components is combined analytically, the calculated value of system performance shall comply with the requirements of this paragraph.

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**5.1.3 Modulation.** For code rate 1, the modulation shall be interoperable with BPSK and 50-percent SBPSK (see Figure B-1 in Appendix B) for data rates of 1200 and 2400 bps and, if implemented, for data rates of 75, 300, and 600 bps. If a 4800- or 6400-bps rate is implemented, the modulation shall be interoperable with OQPSK and 50-percent SOQPSK. The phase vector rotation caused by modulation shall not cause a frequency shift in the transmitted data. A brief overview of SBPSK is presented in Appendix B. If FEC coding is implemented, the modulation shall be as defined in Table IV.

**TABLE IV. 5-kHz channel FEC coding versus modulation options.**

<b>OPTION #</b>	<b>I/O DATA RATE (bps)</b>	<b>CODING RATE</b>	<b>MODULATION TYPE</b>	<b>MODULATION RATE (sps)</b>
1	75	1/2	BPSK or SBPSK	150
	75	1	BPSK or SBPSK	75
2	300	1/2	BPSK or SBPSK	600
	300	1	BPSK or SBPSK	300
3	600	1/2	BPSK or SBPSK	1200
	600	1	BPSK or SBPSK	600
4	1200	1/2	BPSK or SBPSK	2400
	1200*	1	BPSK or SBPSK	1200
5	2400*	1	BPSK or SBPSK	2400
	2400	1/2	OQPSK or SOQPSK	2400
6	4800	1	OQPSK or SOQPSK	2400
	4800	3/4	OQPSK or SOQPSK	3200
7	6400	1	OQPSK or SOQPSK	3200

\* Mandatory

#### **5.1.4 Acquisition**

**5.1.4.1 Preamble generation.** The transmitting radio shall generate a preamble as specified on Figure 1A for BPSK/SBPSK and Figure 1B for OQPSK/SOQPSK, if implemented. Baseband data shall

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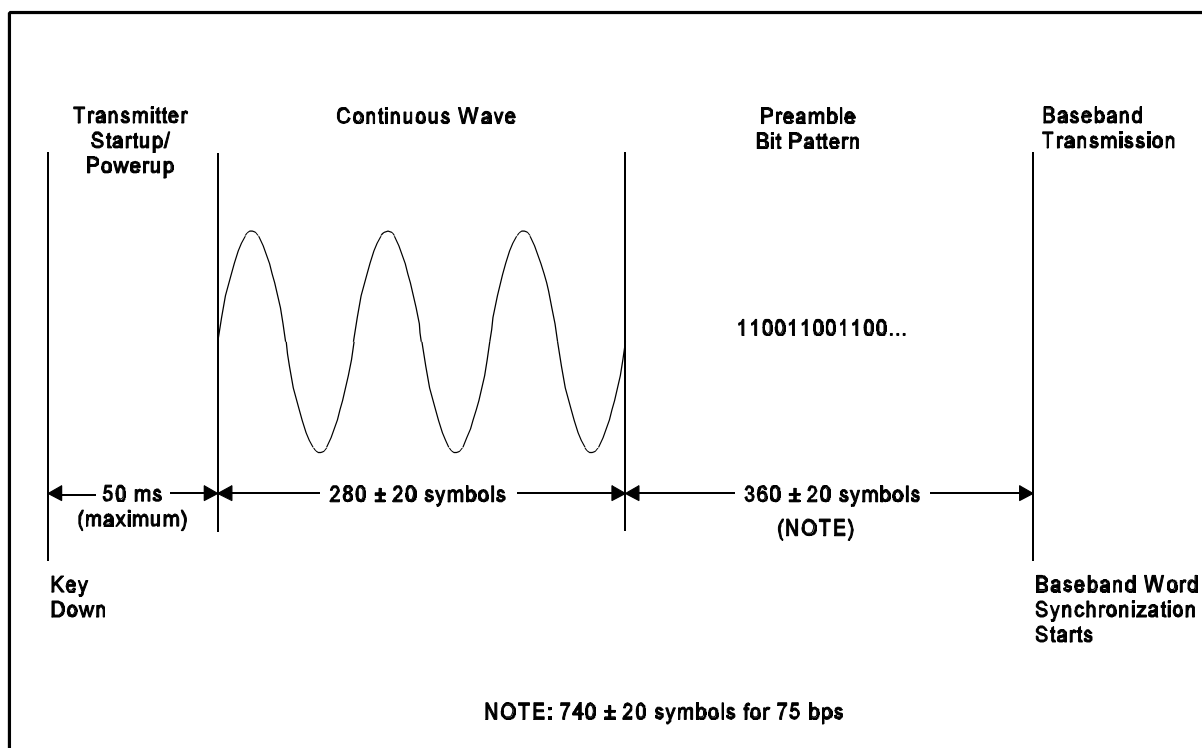


FIGURE 1A. Synchronization method for BPSK/SBPSK.

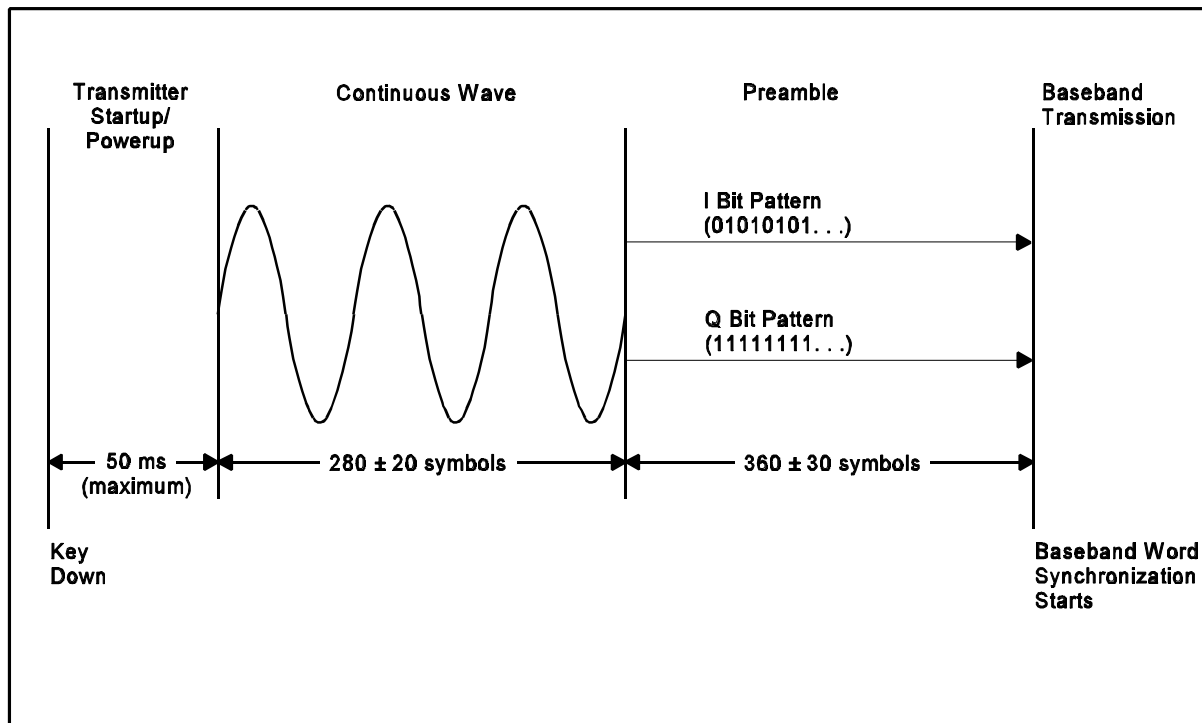


FIGURE 1B. Synchronization method for OQPSK/SOQPSK.

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follow the preamble bit pattern without a shift in data bit timing greater than 25 percent of a bit interval. Figure 1A shows the preamble bit pattern for BPSK and SBPSK for all data rates.

**5.1.4.2 Receiver synchronization.** Upon successful acquisition the terminal shall output, as a minimum, all baseband data that immediately follows the preamble bit pattern.

**5.1.4.3 Frequency uncertainty.** The terminal shall achieve acquisition and demodulate the signal for carrier frequency uncertainties up to  $\pm 1.2$  kHz at the receive antenna.

**5.1.4.4 Probability of acquisition.** The probability of achieving acquisition on the first attempt under the conditions described in 5.1.4.3 and  $E_b/N_o$  equal to or higher than the reference  $E_b/N_o$  shall exceed 95 percent with a confidence level of 90 percent. Reference  $E_b/N_o$  is defined as the  $E_b/N_o$  needed by the terminal to achieve a BER of  $10^{-3}$ .

**5.1.4.5 Maintaining bit synchronization.** The probability of maintaining bit synchronization for at least 10 seconds, when the  $(G/T)/(E_b/N_o)$  is degraded by up to 3 dB from that which is specified in 5.1.2.3, shall be 95 percent with a confidence level of 90 percent. The terminal shall maintain bit synchronization if the carrier is interrupted (lost and returns within 230 milliseconds). If, after a 250-millisecond interruption another carrier is received, the terminal shall synchronize to and process the new carrier.

**5.1.4.6 Receive timing stability.** The terminal shall maintain the frequency of its receive clock output to data terminal equipment within  $\pm 1$  percent of the clock frequency for the selected operating data rate under all conditions in which bit synchronization can be maintained.

**5.1.5 Frequency generation.** The frequency generation system shall provide long-term plus short-term frequency accuracy within  $\pm 1$  part per million (ppm) across the full range of environmental conditions outlined in the terminal specification. The root-mean-square value of the phase noise shall not exceed 10 degrees over the specified frequency range in a bandwidth of 10 Hz to 15 kHz.

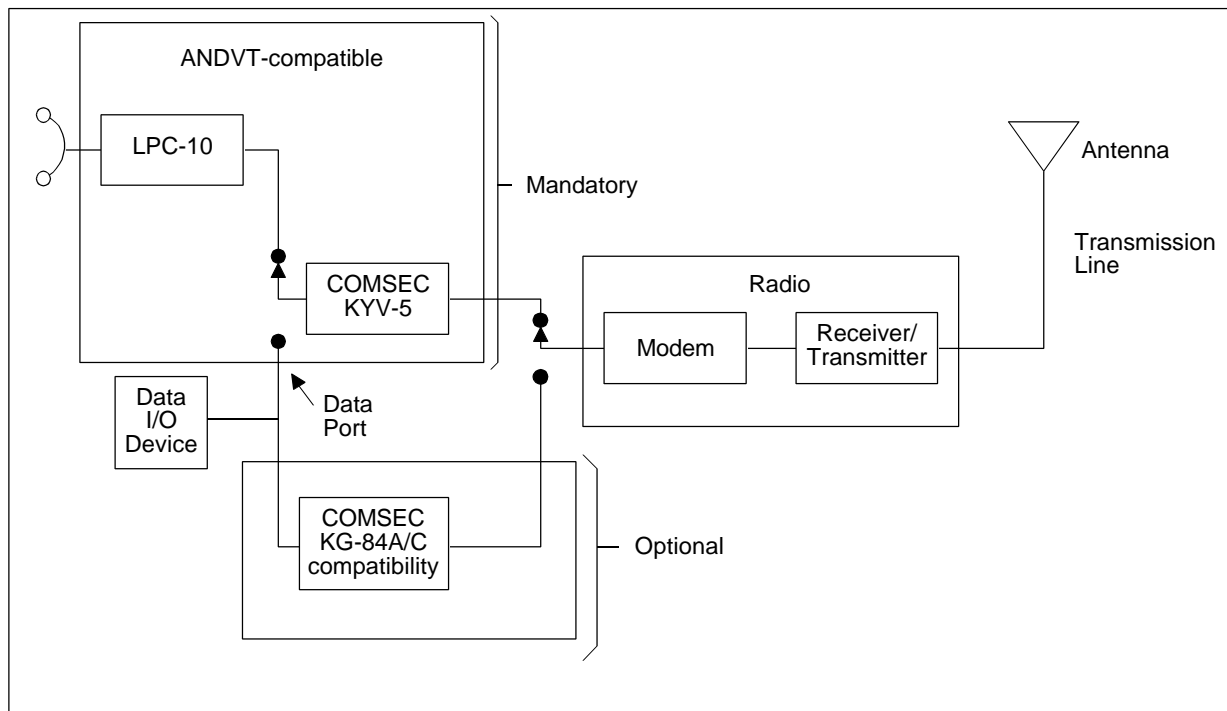
**5.1.6 Voice digitization.** For 2400-bps voice, the voice digitization shall be interoperable with equipment that meets the requirements of Standardization Agreement (STANAG) 4198. It shall be interoperable with the CV-3591. If 4800-bps voice is implemented, the voice digitizer for 4800-bps voice shall comply with requirements of FED-STD-1016.

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**5.1.7 Communications security.** Figure 2 shows two methods of achieving communications security (COMSEC).

**5.1.7.1 Voice.** Voice digitization and security requirements are as follows:

**a. Mandatory.** The COMSEC waveform shall be interoperable with the AN/USC-43 (ANDVT) waveform, used in application 3, as specified in MIL-C-28883, when transmitting and receiving. The version current at the time of writing of this standard is discussed in 6.3.1.



**FIGURE 2. UHF SATCOM terminal, narrowband mode.**

**b. Optional.** Secure voice at 4800 bps shall be interoperable with the digitization techniques specified in FED-STD-1016, and the encryption techniques used by the TSEC/KG-84A/C, as specified in NSA No. 82-2. See 6.3.2 for discussion of other possible secure voice digitization techniques.

**5.1.7.2 Data.** Data security is as follows:

**a. Mandatory.** The COMSEC waveforms shall be interoperable with the AN/USC-43 (ANDVT) waveform used in application 3, as specified in MIL-C-28883, when transmitting and receiving.

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**b. Optional.** The COMSEC waveforms shall be interoperable with the TSEC/KG-84A/C waveform when transmitting and receiving, as specified in NSA NO.82-2.

**5.1.8 Differential encoding.** All baseband data following the preamble bit pattern shall be differentially encoded. For BPSK/SBPSK the differential encoding shall be as follows:

$$C(k) = \{C(k-1) \oplus m(k)\}$$

where

$C(k)$  = present code bit  
 $C(k-1)$  = prior code bit  
 $\oplus$  = exclusive OR operation  
 $m(k)$  = message bit

For QPSK/SOQPSK the differential coding shall be as follows:

$$C(2k) = \{C(2k-2) \oplus m(2k)\}$$

$$C(2k+1) = \{C(2k-1) \oplus m(2k+1)\}$$

where

$C(2k)$  = present I code bit  
 $C(2k-2)$  = previous I code bit  
 $C(2k+1)$  = present Q code bit  
 $C(2k-1)$  = previous Q code bit  
 $\oplus$  = exclusive or operation  
 $m(2k)$  = I message bit  
 $m(2k+1)$  = Q message bit

**5.1.9 Error control (optional).** If FEC coding is implemented, the terminal shall add a Start-of-Message (SOM) data field to the preamble shown in Figures 1A or 1B preceding the baseband transmission. For BPSK/SBPSK, the SOM shall be the 37-bit sequence, 1110001000010001111010011011101100101. For OQPSK/SOQPSK, the 42-bit SOM shall be a 21-bit sequence in each I and Q channel, where the I channel sequence is 000000101110100111001 and the Q channel sequence, offset one-half symbol later, is 001101100001000010101. The SOM shall be transmitted in the order shown with the left-most bit transmitted first. For OQPSK/SOQPSK modulation with FEC coding, the first FEC-encoded user data bit shall be sent on the I channel. The output of the FEC encoder shall be identical to the output of the rate 1/2 constraint length 7 convolutional encoder shown on

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Figure 3. For rate 3/4 the output of the encoder shall be identical with the output described in 5.1.9.2.

**5.1.9.1 FEC characteristics.** The code tap positions are as follows:

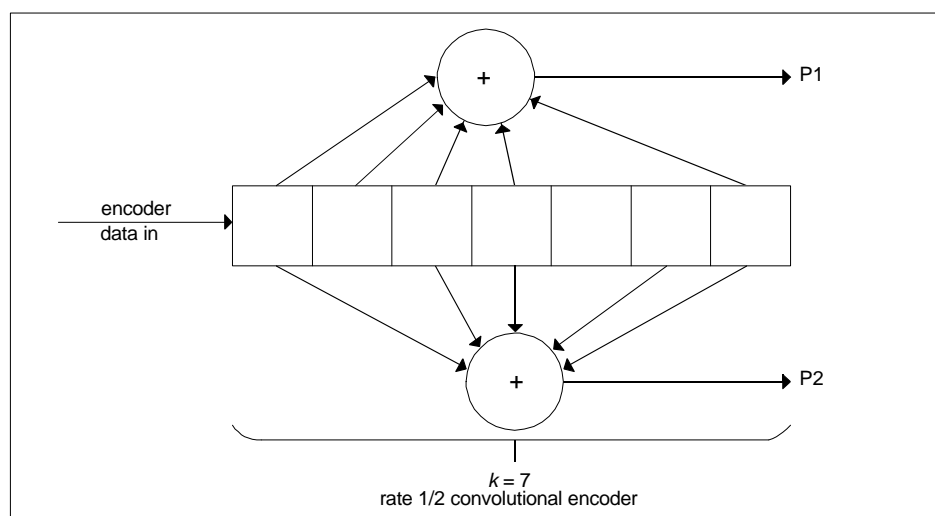
Rate = 1/2

$k = 7$

P1 1111001

P2 1011011

NOTE: The most significant bit (MSB) is farthest left, and the least significant bit (LSB) is farthest right. The encoder tap connections shall be as shown in Figure 3. The new data bit is shifted into the left-most position of Figure 3.



**FIGURE 3. Convolutional encoder tap positions.**

**5.1.9.2 Punctured forward-error-correction codes, narrowband.** From the rate 1/2 code, higher rate 3/4 code could be constructed by a technique known as *puncturing*. The puncture pattern is given in Table V. Only those bits identified with a 1 in Table V are transmitted. They are transmitted in pairs and are transmitted from left to right.

**TABLE V. Puncture code patterns.**

CODE RATE	SYMBOL	PUNCTURE PATTERN (0 = DELETED BIT)
3/4	P1:	101
	P2:	110



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**5.2.1 Transmit.** The eirp requirements specified in 5.2.1.1 through 5.2.1.4 include the gains and losses from the transmitter to the antenna, inclusive.

**5.2.1.1 Effective isotropically radiated power.** The terminal shall be capable of providing eirp of at least 16 dBW with respect to right-hand circular polarization. The terminal eirp shall be incrementally or continuously adjustable between a minimum setting no greater than 10 dBW and the maximum eirp, with a power setting resolution of 2 dB or better.

**5.2.1.2 Effective isotropically radiated power accuracy.** The terminal shall maintain an eirp accuracy of  $\pm 1.5$  dB, assuming antenna gain and passive losses are fixed.

**5.2.1.3 Transmitter turn-on time.** The transmitter turn-on time shall not exceed 50 ms.

**5.2.1.4 Adjacent channel emissions.** For FSK modulation, the total of all emissions outside the 25-kHz channel shall be less than 1 percent of the total transmitted power. For PSK modulation in a nominal 25-kHz bandwidth whose center frequency is displaced by  $\Delta f$  from the terminal transmitter's carrier frequency, the eirp shall not exceed the values specified in Table VIa for a carrier level less than + 18 dBW and Table VIb for a carrier level greater than or equal to + 18 dBW.

**TABLE VIa. Allowable adjacent channel emissions, wideband (moderate power).**

$\Delta f$ (kHz)	RELATIVE EIRP (dB) (CARRIER LEVEL < +18 dBW)				
	9.6 kbps BPSK/SBPSK INTEROPERABLE	19.2 kbps BPSK/SBPSK INTEROPERABLE	32 kbps OQPSK/SOQPSK INTEROPERABLE	38.4 kbps OQPSK/SOQPSK INTEROPERABLE	ALL OTHER RATES AND MODULATION
25	-17	-11	-16	-13	-11
50	-37	-26	-23	-21	-21
75	-40	-34	-37	-35	-34
100	-40	-40	-39	-40	-39
$\geq 125$	-40	-40	-40	-40	-40

**5.2.1.5 Tuning.** The transmit frequency shall be tunable in 25-kHz increments over a frequency range of 291.000 to 318.000 MHz.

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TABLE VIb. Allowable adjacent channel emissions, wideband (high power).

$\Delta f$ (kHz)	MAXIMUM EIRP (dBW) (CARRIER LEVEL $\geq$ +18 dBW)				
	9.6 kbps BPSK/SBPSK INTEROPERABLE	19.2 kbps BPSK/SBPSK INTEROPERABLE	32 kbps OQPSK/SOQPSK INTEROPERABLE	38.4 kbps OQPSK/SOQPSK INTEROPERABLE	ALL OTHER RATES AND MODULATION
25	+1	+7	+2	+5	+7
50	-19	-8	-5	-3	-3
75	-22	-16	-19	-17	-16
100	-22	-22	-21	-22	-21
$\geq 125$	-22	-22	-22	-22	-22

## 5.2.2 Receive

## 5.2.2.1 Susceptibility to adjacent channel interference.

The terminal shall achieve a BER of  $1 \times 10^{-5}$  or better, at the  $C/kT$  specified in Table VII, when operating in the presence of ACI at a 50-kHz offset. For test conditions, ACI power in the desired channel shall be 20 dB below the average power of the desired signal, where the ACI signal is a 19.2-kbps bit pattern that is 50-percent SBPSK-modulated.

TABLE VII. Modulation types and susceptibility to adjacent channel interference, wideband mode.

SYMBOL RATE (sps)	MODULATION	$C/kT$ FOR BER SPECIFIED IN 5.2.2.1 (dB-Hz)
9600 (Optional)	BPSK/SBPSK	53.3
16000 (Optional)	BPSK/SBPSK	55.5
16000 (Mandatory)	FSK	58.5
19200 (Optional)	BPSK/SBPSK	56.3
32000 (Optional)	OQPSK/SOQPSK	58.5
38400 (Optional)	OQPSK/SOQPSK	59.3

**5.2.2.2 Tuning.** The receive frequency shall be tunable in 25-kHz increments over a frequency range of 243.000 to 270.000 MHz.

## 5.2.2.3 Bit error ratio

**a. FSK BER.** The BER measured at the output of the demodulator shall not exceed  $1 \times 10^{-5}$  for a data rate of 16 kbps and a  $(G/T)/(E_b/N_o)$  of -37.7 dB/K (or -45 dB/K for aircraft and submarine installations), assuming a sky noise temperature of

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200 K and assuming a 0 dB gain antenna for airborne platforms. The  $G/T$  and  $E_b/N_o$  of terminals may be independently evaluated for test purposes. However, when the performance of the independent components is combined analytically, the calculated value of system performance shall meet the requirements of this paragraph. A method for improving the  $G/T$  of UHF terminals or aircraft and submarine platforms is given in Appendix C.

**b. PSK BER.** The BER measured at the output of the demodulator, for FEC code rate 1, shall not exceed  $1 \times 10^{-5}$  for a data rate of 19.2 kbps and a  $(G/T)/(E_b/N_o)$  of -34.7 dB/K (or -42.4 dB/K for aircraft and submarine installations), assuming a sky noise temperature of 200 K and a 0-dB gain antenna for airborne platforms. The required  $(G/T)/(E_b/N_o)$  for rate 3/4, and 1/2 codes shall be reduced by 3.0 dB and 4.25 dB, respectively. The  $G/T$  and  $E_b/N_o$  of terminals may be independently evaluated for test purposes. However, when performance of independent components is combined analytically, the calculated value of system performance shall comply with the requirements of this paragraph. An overview of link calculations used in determining required eirp and  $(G/T)/(E_b/N_o)$  is shown in Appendix D.

**5.2.3 Modulation.** Modulation shall be as shown in Table VII. The FSK modulation characteristics shall be as specified in 5.2.3.1 and 5.2.3.2. If FEC coding is implemented, the modulation shall be as defined in Table VIII.

**5.2.3.1 Deviation.** The deviation of the modulated signal shall be 5.6 kHz  $\pm$  1 kHz for a binary 0 and -5.6 kHz  $\pm$  1 kHz for a binary 1. The demodulator shall be interoperable with modulated signals that have deviations of 5.6 kHz  $\pm$  1.2 kHz for a binary 0 and -5.6 kHz  $\pm$  1.2 kHz for a binary 1.

**5.2.3.2 Input data signal sense.** A binary 1 shall be indicated by a voltage that is negative with respect to the reference point, and a binary 0 by a voltage that is positive with respect to the reference point.

**5.2.3.3 Phase vector rotation.** The phase vector rotation caused by modulation shall not cause a frequency shift in the transmitted data. A brief overview of SBPSK is presented in Appendix B.

**5.2.4 Acquisition.** Paragraphs 5.2.4.1, 5.2.4.2, and 5.2.4.4 apply to PSK interoperable rates only.

**5.2.4.1 Preamble generation.** The transmitting radio shall generate a preamble as specified on Figure 1A for BPSK/SBPSK or Figure 1B for OQPSK/SOQPSK, if implemented. Baseband data shall

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TABLE VIII. 25-kHz channel FEC coding versus modulation options.

OPTION #	I/O DATA RATE (bps)	CODING RATE	MODULATION TYPE	MODULATION RATE (sps)
1	9600	1	BPSK/SBPSK	9600
	9600	1/2	BPSK/SBPSK	19200
2	16000	1	BPSK/SBPSK	16000
	16000	1/2	OQPSK/SOQPSK	16000
3*	16000	1	FSK	16000
4	19200	1	BPSK/SBPSK	19200
	19200	1/2	OQPSK/SOQPSK	19200
5	32000	1	OQPSK/SOQPSK	16000
	32000	3/4	OQPSK/SOQPSK	21333.3
6	38400	1	OQPSK/SOQPSK	19200

\* Mandatory

follow the preamble pattern without a shift in data bit timing greater than 25 percent of a bit interval.

**5.2.4.2 Receiver synchronization.** Upon successful acquisition, the terminal shall output as a minimum all baseband data that immediately follows the preamble bit pattern.

**5.2.4.3 Frequency uncertainty.** The terminal shall achieve acquisition and demodulate the signal for carrier frequency uncertainties up to  $\pm 1.2$  kHz from the desired channel center frequency.

**5.2.4.4 Probability of acquisition.** The probability of achieving acquisition on the first attempt under the conditions of 5.2.4.3 and  $E_b/N_o$  equal to or higher than the reference  $E_b/N_o$  shall exceed 95 percent, with a confidence level of 90 percent. Reference  $E_b/N_o$  is defined as the  $E_b/N_o$  needed by the terminal to achieve a BER of  $10^{-3}$ .

**5.2.4.5 Maintaining bit synchronization.** The probability of maintaining bit synchronization for at least 10 seconds when the  $(G/T)/(E_b/N_o)$  is degraded by up to 3 dB from that which is specified in 5.2.2.3, shall be 95 percent with a confidence level of 90 percent. For PSK signals the terminal shall maintain bit synchronization if the carrier is interrupted (lost and returns within 230 milliseconds). For any signal (PSK or FSK), if, after

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a 250-millisecond interruption another carrier is received, the terminal shall synchronize to and process the new carrier.

**5.2.4.6 Receive timing stability.** The terminal shall maintain the frequency of its receive clock output to data terminal equipment within  $\pm 1$  percent of the clock frequency for the selected operating data rate, under all conditions in which bit synchronization can be maintained.

**5.2.5 Frequency generation.** The frequency generation system shall provide long-term plus short-term frequency accuracy within  $\pm 1$  ppm across the full range of environmental conditions outlined in the terminal specification.

**5.2.6 Voice digitization.** Secure voice at 16000 bps shall be interoperable with continuously variable slope delta (CVSD) digitization techniques used by the VINSON encryption device, as specified in NSA NO. CSESD-14.

**5.2.7 Communications security.** The COMSEC device shall be interoperable with the TSEC/KY-57 and TSEC/KY-58. See Figure 4.

**5.2.7.1 Voice.** Secure voice at 16000 bps shall be interoperable with techniques used by the VINSON, as specified in NSA NO. CSESD-14.

**5.2.7.2 Data**

**a. Mandatory.** The COMSEC waveforms shall be interoperable with the TSEC/KY-57/58 VINSON waveform when transmitting and receiving, as specified in NSA NO. CSESD-14.

**b. Optional.** The COMSEC waveforms shall be interoperable with the TSEC/KG-84A/C waveform when transmitting and receiving, as specified in NSA NO. 82-2.

**5.2.8 Differential encoding.** For PSK modulation at all bit rates, all baseband data following the preamble bit pattern shall be differentially encoded as specified in 5.1.8.

**5.2.9 Error control (optional).** FEC coding, if implemented, shall be as defined in 5.1.9.

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**MIL-STD-188-181A****6. NOTES**

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

**6.1 Tailoring guidance.** To ensure proper application of this standard, invitations for bids, requests for proposals, and contractual statements of work should tailor the requirements in sections 4 or 5 of this standard to exclude any unnecessary requirements. For example, if the statement of work requires a revision to a standard, then all the paragraphs related to handbooks, bulletins, and notices should be excluded.

**6.2 Key-word listing.** The following key words, phrases, and acronyms apply to MIL-STD-188-181A:

Fleet Satellite Communications (FLTSATCOM)  
nonprocessed satellite communications  
single-access SATCOM channels  
UHF Follow-On SATCOM communications

**6.3 Voice capability.**

**6.3.1 MIL-C-28883 baseline.** At the time of publication of this standard the version of MIL-C-28883 available was MIL-C-28883A with change 2 and engineering change proposal (ECP) up through 060. Future use of this standard for system development should refer to latest version of this specification.

**6.3.2 Mixed Excitation Linear Prediction (MELP).** There are efforts underway to improve the quality of voice communications employing MELP techniques. MELP was developed by Texas Instruments under contract to NSA. Interim test results show that performance on a 2400 bps channel employing MELP is equivalent to or better than that on a 4800 bps channel employing CELP techniques. A federal standard is in the process of being developed. Pending completion of the federal standard, information on MELP is documented in NSA Report R22-03-96, "Analog to Digital Conversion of Voice by 2400 bps Mixed Excitation Linear Prediction", with NSA library number S243,638. The NSA report contains the draft version of the federal standard. A DoD Digital Voice Processing Consortium is looking the implementing MELP into communications equipment. Assuming success in completing the federal standard, this voice digitization technique will have application for those terminals operating over UHF SATCOM channels.

**6.4 Major changes.** Table IX shows the major differences between MIL-STD-188-181A and the September 1992 edition of MIL-STD-188-181.

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Table IX. Major changes from the September 1992 edition of this standard.

CHANGE	PARAGRAPHS/FIGURES/TABLES AFFECTED
Format/editorial changes to comply with MIL-STD-962C.	Multiple
Convolutional error correction coding at rates 1/2 and 3/4, added as an optional capability.	4.2.5, 5.1.9, 5.1.9.1, 5.1.9.2, 5.2.9, Figure 3, and Table V.
The transmitter turn-on time was changed from 875 microseconds to 50 milliseconds.	5.1.1.3, 5.2.1.3, and Figures 1A and 1B.
The ACE for narrowband and wideband modes was changed.	Tables II, Va and Vb.
Clarified optional data rates versus coding and modulation type.	5.1.3, Table IV, 5.2.3, and Table VII.
The preamble was changed to conform to MIL-STD-188-182.	Figure 1B and 5.2.4.1.
The requirement that spectral containment for the narrowband mode be 95 percent in a 5-kHz bandwidth at 2400 bps was deleted.	5.1.5
Added differential encoding requirement for QPSK/SOQPSK modulation.	5.1.8 and 5.2.8
The $(G/T)/(E_b/N_o)$ used for PSK BER measurement was changed from -27 to -34.7 and from -33.4 to -42.4 for aircraft and submarine installations.	5.2.2.3
The narrowband mode level of ACI level in the desired channel was changed to 15 dB below the desired signal. The $C/kT$ for 4.8 and 6.0 ksps was increased by 1.5 dB.	5.1.2.1 and Table III



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### **APPENDIX A**

#### **FREQUENCY PLANS**

##### **A.1 SCOPE**

This appendix is a mandatory part of this standard. The information contained herein is intended for compliance. All frequencies used to communicate in the narrowband and wideband modes are required to conform to the frequency plans defined in this appendix. The frequency plans for use on 5- and 25-kHz channels are defined. Table A-1 provides the frequency plans for the LEASAT, FLTSATCOM, MARISAT (Gapfiller), and UHF Follow-On systems.

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**TABLE A-I. Current and UHF Follow-On frequency plans.**  
 (This table will be used for the Channel Frequency fields.  
 See key at end of table.)

CHANNEL NUMBER		UPLINK FREQUENCY (MHz)	DOWNLINK FREQUENCY (MHz)	PRESENT CHANNEL	UFO CHANNEL	NOTES
DECIMAL	HEX					
0	0	NONE	NONE	NONE	N/A	
1	1	SHF	250.350	W1	N1	Fleet broadcast
2	2	SHF	250.400		N'1	"
3	3	SHF	250.450	A1	O1	"
4	4	SHF	250.500		O'1	"
5	5	SHF	250.550	B1	P1	"
6	6	SHF	250.600		P'1	"
7	7	SHF	250.650	C1	Q1	"
8	8	SHF	250.700		Q'1	"
9	9	292.850	251.850	W3	N2	NAVY 25kHz CHANNELS, 41 MHz OFFSET
10	0A	292.950	251.950	A2	O2	"
11	0B	293.050	252.050	B2	P2	"
12	0C	293.150	252.150	C2	Q2	"
13	0D	294.550	253.550	W4	N3	"
14	0E	294.650	253.650	A3	O3	"
15	0F	294.750	253.750	B3	P3	"
16	10	294.850	253.850	C3	Q3	"
17	11	296.250	255.250	W5	N4	"
18	12	296.350	255.350	A4	O4	"
19	13	296.450	255.450	B4	P4	"
20	14	296.550	255.550	C4	Q4	NAVY 25kHz CHANNELS, 41 MHz OFFSET
21	15	297.850	256.850	W6	N5	"

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TABLE A-I. Current and UHF Follow-On frequency plans (Continued).

CHANNEL NUMBER		UPLINK FREQUENCY (MHz)	DOWNLINK FREQUENCY (MHz)	PRESENT CHANNEL	UFO CHANNEL	NOTES
DECIMAL	HEX					
22	16	297.950	256.950	A5	O5	"
23	17	298.050	257.050	B5	P5	"
24	18	298.150	257.150	C5	Q5	"
25	19	299.350	258.350	W7	N6	"
26	1A	299.450	258.450	A6	O6	"
27	1B	299.550	258.550	B6	P6	"
28	1C	299.650	258.650	C6	Q6	"
29	1D	306.250	265.250	W8	N7	"
30	1E	306.350	265.350	A7	O7	"
31	1F	306.450	265.450	B7	P7	"
32	20	306.550	265.550	C7	Q7	"
33	21	307.750	266.750	*	N8	"
34	22	307.850	266.850	A8	O8	"
35	23	307.950	266.950	B8	P8	"
36	24	308.050	267.050	C8	Q8	"
37	25	309.150	268.150		N9	"
38	26	309.250	268.250	A9	O9	"
39	27	309.350	268.350	B9	P9	"
40	28	309.450	268.450	C9	Q9	"
41	29	310.650	269.650		N10	"
42	2A	310.750	269.750	A10	O10	"
43	2B	310.850	269.850	B10	P10	"
44	2C	310.950	269.950	C10	Q10	NAVY 25kHz CHANNELS, 41 MHz OFFSET

\* 307.750 was used as the Gapfiller channel A uplink frequency. 266.750 is not in correct use as a downlink frequency.

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TABLE A-I. Current and UHF Follow-On frequency plans (Continued).

CHANNEL NUMBER		UPLINK FREQUENCY (MHz)	DOWNLINK FREQUENCY (MHz)	PRESENT CHANNEL	UFO CHANNEL	NOTES
DECIMAL	HEX					
45	2D	293.950	260.350	A23-1		DoD 500 kHz CHANNELS/ UFO 25kHz CHANNELS
46	2E	293.975	260.375	A23-2	N11	"
47	2F	294.000	260.400	A23-3		"
48	30	294.025	260.425	A23-4	P11	"
49	31	294.050	260.450	A23-5		"
50	32	294.075	260.475	A23-6	N12	"
51	33	294.100	260.500	A23-7		"
52	34	294.125	260.525	A23-8	P12	"
53	35	294.150	260.550	A23-9		"
54	36	294.175	260.575	A23-10	O11	"
55	37	294.200	260.600	A23-11		"
56	38	294.225	260.625	A23-12	Q11	"
57	39	294.250	260.650	A23-13		"
58	3A	294.275	260.675	A23-14	O12	"
59	3B	294.300	260.700	A23-15		"
60	3C	294.325	260.725	A23-16	Q12	"
61	3D	294.350	260.750	A23-17		"
62	3E	294.375	260.775	A23-18		"
63	3F	294.400	260.800	A23-19		"
64	40	294.425	260.825	A23-20		"
65	41	294.450	260.850	A23-21		"
66	42	295.050	261.450	B23-1		"

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## APPENDIX A

TABLE A-I. Current and UHF Follow-On frequency plans (Continued).

CHANNEL NUMBER		UPLINK FREQUENCY (MHz)	DOWNLINK FREQUENCY (MHz)	PRESENT CHANNEL	UFO CHANNEL	NOTES
DECIMAL	HEX					
67	43	295.075	261.475	B23-2		DoD 500 kHz CHANNELS/ UFO 25kHz CHANNELS
68	44	295.100	261.500	B23-3		"
69	45	295.125	261.525	B23-4		"
70	46	295.150	261.550	B23-5		"
71	47	295.175	261.575	B23-6	N13	"
72	48	295.200	261.600	B23-7		"
73	49	295.225	261.625	B23-8	P13	"
74	4A	295.250	261.650	B23-9		"
75	4B	295.275	261.675	B23-10	N14	"
76	4C	295.300	261.700	B23-11		"
77	4D	295.325	261.725	B23-12	P14	"
78	4E	295.350	261.750	B23-13		"
79	4F	295.375	261.775	B23-14	N15	"
80	50	295.400	261.800	B23-15		"
81	51	295.425	261.825	B23-16	P15	"
82	52	295.450	261.850	B23-17		"
83	53	295.475	261.875	B23-18	N16	"
84	54	295.500	261.900	B23-19		"
85	55	295.525	261.925	B23-20	P16	"
86	56	295.550	261.950	B23-21		"
87	57	295.650	262.050	C23-1		"
88	58	295.675	262.075	C23-2	O13	"
89	59	295.700	262.100	C23-3		"
90	5A	295.725	262.125	C23-4	Q13	"

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## APPENDIX A

TABLE A-I. Current and UHF Follow-On frequency plans (Continued).

CHANNEL NUMBER		UPLINK FREQUENCY (MHz)	DOWNLINK FREQUENCY (MHz)	PRESENT CHANNEL	UFO CHANNEL	NOTES
DECIMAL	HEX					
91	5B	295.750	262.150	C23-5		"
92	5C	295.775	262.175	C23-6	O14	DoD 500 kHz CHANNELS/ UFO 25kHz CHANNELS
93	5D	295.800	262.200	C23-7		"
94	5E	295.825	262.225	C23-8	Q14	"
95	5F	295.850	262.250	C23-9		"
96	60	295.875	262.275	C23-10	O15	"
97	61	295.900	262.300	C23-11		"
98	62	295.925	262.325	C23-12	Q15	"
99	63	295.950	262.350	C23-13		"
100	64	295.975	262.375	C23-14	O16	"
101	65	296.000	262.400	C23-15		"
102	66	296.025	262.425	C23-16	Q16	"
103	67	296.050	262.450	C23-17		"
104	68	296.075	262.475	C23-18		"
105	69	296.100	262.500	C23-19		"
106	6A	296.125	262.525	C23-20		"
107	6B	296.150	262.550	C23-21		"
108	6C	297.150	263.550	W2-1		"
109	6D	297.175	263.575	W2-2	N17	"
110	6E	297.200	263.600	W2-3		"
111	6F	297.225	263.625	W2-4	P17	"
112	70	297.250	263.650	W2-5		"
113	71	297.275	263.675	W2-6	N18	"
114	72	297.300	263.700	W2-7		"

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TABLE A-I. Current and UHF Follow-On frequency plans (Continued).

CHANNEL NUMBER		UPLINK FREQUENCY (MHz)	DOWNLINK FREQUENCY (MHz)	PRESENT CHANNEL	UFO CHANNEL	NOTES
DECIMAL	HEX					
115	73	297.325	263.725	W2-8	P18	"
116	74	297.350	263.750	W2-9		"
117	75	297.375	263.775	W2-10	O17	DoD 500 kHz CHANNELS/ UFO 25kHz CHANNELS
118	76	297.400	263.800	W2-11		
119	77	297.425	263.825	W2-12	Q17	"
120	78	297.450	263.850	W2-13		"
121	79	297.475	263.875	W2-14	O18	"
122	7A	297.500	263.900	W2-15		"
123	7B	297.525	263.925	W2-16	Q18	"
124	7C	297.550	263.950	W2-17		"
125	7D	297.575	263.975	W2-18		"
126	7E	297.600	264.000	W2-19		"
127	7F	297.625	264.025	W2-20		"
128	80	297.650	264.050	W2-21		"
129	81	302.445	248.845		N27	GAPFILLER 500 kHz CHANNELS/ UFO 5 kHz CHANNELS
130	82	302.450	248.850	G1		"
131	83	302.455	248.855		N28	"
132	84	302.465	248.865		N29	"
133	85	302.475	248.875	G2	N30	"
134	86	302.485	248.885		N31	"
135	87	302.495	248.895		N32	"
136	88	302.500	248.900	G3		"

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TABLE A-I. Current and UHF Follow-On frequency plans (Continued).

CHANNEL NUMBER		UPLINK FREQUENCY (MHz)	DOWNLINK FREQUENCY (MHz)	PRESENT CHANNEL	UFO CHANNEL	NOTES
DECIMAL	HEX					
137	89	302.505	248.905		N33	"
138	8A	302.515	248.915		N34	"
139	8B	302.525	248.925	G4	N35	"
140	8C	302.535	248.935		N36	GAPFILLER 500 kHz CHANNELS/ UFO 5 kHz CHANNELS
141	8D	302.545	248.945		N37	"
142	8E	302.550	248.950	G5		"
143	8F	302.555	248.955		N38	"
144	90	302.565	248.965		N39	"
145	91	302.575	248.975	G6	O27	"
146	92	302.585	248.985		O28	"
147	93	302.595	248.995		O29	"
148	94	302.600	249.000	G7		"
149	95	302.605	249.005		O30	"
150	96	302.615	249.015		O31	"
151	97	302.625	249.025	G8	O32	"
152	98	302.635	249.035		O33	"
153	99	302.645	249.045		O34	"
154	9A	302.650	249.050	G9		"
155	9B	302.655	249.055		O35	"
156	9C	302.665	249.065		O36	"
157	9D	302.675	249.075	G10	O37	"
158	9E	302.685	249.085		O38	"
159	9F	302.695	249.095		O39	"
160	A0	302.700	249.100	G11		"



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TABLE A-I. Current and UHF Follow-On frequency plans (Continued).

CHANNEL NUMBER		UPLINK FREQUENCY (MHz)	DOWNLINK FREQUENCY (MHz)	PRESENT CHANNEL	UFO CHANNEL	NOTES
DECIMAL	HEX					
161	A1	302.705	249.105		P27	"
162	A2	302.715	249.115		P28	"
163	A3	302.725	249.125	G12	P29	"
164	A4	302.735	249.135		P30	"
165	A5	302.745	249.145		P31	GAPFILLER 500 kHz CHANNELS/ UFO 5 kHz CHANNELS
166	A6	302.750	249.150	G13		"
167	A7	302.755	249.155		P32	"
168	A8	302.765	249.165		P33	"
169	A9	302.775	249.175	G14	P34	"
170	AA	302.785	249.185		P35	"
171	AB	302.795	249.195		P36	"
172	AC	302.800	249.200	G15		"
173	AD	302.805	249.205		P37	"
174	AE	302.815	249.215		P38	"
175	AF	302.825	249.225	G16	P39	"
176	BO	302.835	249.235		Q27	"
177	B1	302.845	249.245		Q28	"
178	B2	302.850	249.250	G17		"
179	B3	302.855	249.255		Q29	"
180	B4	302.865	249.265		Q30	"
181	B5	302.875	249.275	G18	Q31	"
182	B6	302.885	249.285		Q32	"
183	B7	302.895	249.295		Q33	"
184	B8	302.900	249.300	G19		"

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TABLE A-I. Current and UHF Follow-On frequency plans (Continued).

CHANNEL NUMBER		UPLINK FREQUENCY (MHz)	DOWNLINK FREQUENCY (MHz)	PRESENT CHANNEL	UFO CHANNEL	NOTES
DECIMAL	HEX					
185	B9	302.905	249.305		Q34	"
186	BA	302.915	249.315		Q35	"
187	BB	302.925	249.325	G20	Q36	"
188	BC	302.935	249.335		Q37	"
189	BD	302.945	249.345		Q38	"
190	BE	302.950	249.350			GAPFILLER 500 kHz CHANNELS/ UFO 5 kHz CHANNELS
191	BF	302.955	249.355		Q39	"
192	CO	307.750	254.150	GA		GAPFILLER 25 kHz (UFO CHAN N8 UPLINK)
193	C1	311.150	257.550	GB		GAPFILLER 25 kHz
194	C2	316.955	243.855	W9		AFSAT/ LEASAT NON-PROC. 5 kHz REPLACE- MENT CHANNELS
195	C3	316.960	243.860	W10		"
196	C4	316.975	243.875	W11		"
197	C5	317.000	243.900	W12		"
198	C6	317.010	243.910	W13		"
199	C7	317.015	243.915		N19	"
200	C8	317.025	243.925		N20	"
201	C9	317.035	243.935		N21	"
202	CA	317.045	243.945	A11	N22	"

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TABLE A-I. Current and UHF Follow-On frequency plans (Continued).

CHANNEL NUMBER		UPLINK FREQUENCY (MHz)	DOWNLINK FREQUENCY (MHz)	PRESENT CHANNEL	UFO CHANNEL	NOTES
DECIMAL	HEX					
203	CB	317.055	243.955	A12	N23	"
204	CC	317.065	243.965	A14	N24	"
205	CD	317.075	243.975	A16	N25	"
206	CE	317.085	243.985	A18	N26	"
207	CF	317.090	243.990	A19		"
208	DO	317.095	243.995	A20	O19	"
209	D1	317.100	244.000	A21		AFSAT/ LEASAT NON-PROC. 5 kHz REPLACE- MENT CHANNELS
210	D2	317.105	244.005		O20	"
211	D3	317.110	244.010	A22		"
212	D4	317.115	244.015		O21	"
213	D5	317.125	244.025		O22	"
214	D6	317.135	244.035		O23	"
215	D7	317.145	244.045	B11	O24	"
216	D8	317.155	244.055	B12	O25	"
217	D9	317.165	244.065	B14	O26	"
218	DA	317.175	244.075	B16	P19	"
219	DB	317.185	244.085	B18	P20	"
220	DC	317.190	244.090	B19		"
221	DD	317.195	244.095	B20	P21	"
222	DE	317.200	244.100	B21		"
223	DF	317.205	244.105		P22	"
224	EO	317.210	244.110	B22		"
225	E1	317.215	244.115		P23	"

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TABLE A-I. Current and UHF Follow-On frequency plans (Continued).

CHANNEL NUMBER		UPLINK FREQUENCY (MHz)	DOWNLINK FREQUENCY (MHz)	PRESENT CHANNEL	UFO CHANNEL	NOTES
DECIMAL	HEX					
226	E2	317.225	244.125		P24	"
227	E3	317.235	244.135		P25	"
228	E4	317.245	244.145	C11	P26	"
229	E5	317.255	244.155	C12	Q19	"
230	E6	317.265	244.165	C14	Q20	"
231	E7	317.275	244.175	C16	Q21	"
232	E8	317.285	244.185	C18	Q22	"
233	E9	317.290	244.190	C19		AFSAT/ LEASAT NON-PROC. 5 kHz REPLACE- MENT CHANNELS
234	EA	317.295	244.195	C20	Q23	"
235	EB	317.300	244.200	C21		"
236	EC	317.305	244.205		Q24	"
237	ED	317.310	244.210	C22		"
238	EE	317.315	244.215		Q25	"
239	EF	317.325	244.225		Q26	"
240	FO					
241	F1					
242	F2					
243	F3					
244	F4					
245	F5					
246	F6					
247	F7					
248	F8					

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TABLE A-I. Current and UHF Follow-On frequency plans (Concluded).

CHANNEL NUMBER		UPLINK FREQUENCY (MHz)	DOWNLINK FREQUENCY (MHz)	PRESENT CHANNEL	UFO CHANNEL	NOTES
DECIMAL	HEX					
249	F9					
250	FA					
251	FB					
252	FC					
253	FD					
254	FE					
255	FF					

Key to channel numbers: There are several frequency plans used on UHF satellites for the DoD. The FLTSATCOM satellites use frequency plans A, B, and C. The Leased Satellites (LEASATs) use frequency plans X, Y, and Z, which are abbreviated versions of plans A, B, and C (LEASATs have fewer channels). In addition, LEASAT has plan W, which shares frequencies with AFSATCOM polar frequency plan E. Gapfiller has been labeled for this table as G. UHF Follow-On (UFO) uses four frequency plans, N, O, P, and Q. In addition, there are alternate Fleet Broadcast downlink frequencies labeled N', O', P', and Q'.

Table A-I lists *present Channel* and *UFO Channel* as follows: Frequency plan, transponder number, and an optional transponder subdivision. As an example, Channel Number 46 (Hex 2E) is A23-2. This corresponds to FLTSATCOM frequency plan A, a DoD 500 kHz wideband channel (used as a 25 kHz sub-channel) which is being replaced by UFO 25 kHz channel N11 (frequency plan N, transponder 11).

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**MIL-STD-188-181A****APPENDIX B****OVERVIEW OF SHAPED BINARY PHASE-SHIFT KEYING MODULATION****B.1 SCOPE**

This Appendix is not a mandatory part of this standard. The information contained herein is intended for guidance only. The purpose of this appendix is to provide a brief tutorial on shaped binary phase-shift keying modulation.

**B.2 APPLICABLE DOCUMENTS**

**B.2.1 General.** This section does not include documents cited in other sections of this standard. The documents below are recommended for additional information or as examples.

**B.2.2 Non-Government publications.** The following documents form a part of this appendix to the extent specified herein.

Mark J. Dapper, Terrance J Hill, MILCOM 1984	"SBPSK: A Robust Bandwidth-Efficient Modulation for Hard-Limited Channels"
--	---

R. Cofer, E. Franke, O. Johnson, T Erman, MILCOM 1990	"Shaped BPSK in a Digital Modem with Direct Digital Synthesis"
---	---

Carl Andren, <i>Microwave Journal</i> , January 1978	"PSK Sidebands reduced by pre-modulation filtering"
--	--

(Applications for copies should be addressed to the publisher.)

**B.3 INTRODUCTION**

The ultra high frequency (UHF) satellites used for military communications have hard-limiting transponders. This hard-limiting feature precludes the use of any amplitude modulation (AM) scheme by forcing the modulated signal to have a constant envelope. Therefore, the modulation must be either frequency or phase modulation.

**B.3.1 Binary phase-shift keying.** Binary phase-shift keying (BPSK) is well suited for the modulation of a carrier with a two-level digital baseband signal. A carrier phase of 90 degrees represents one level (1), and a carrier phase of

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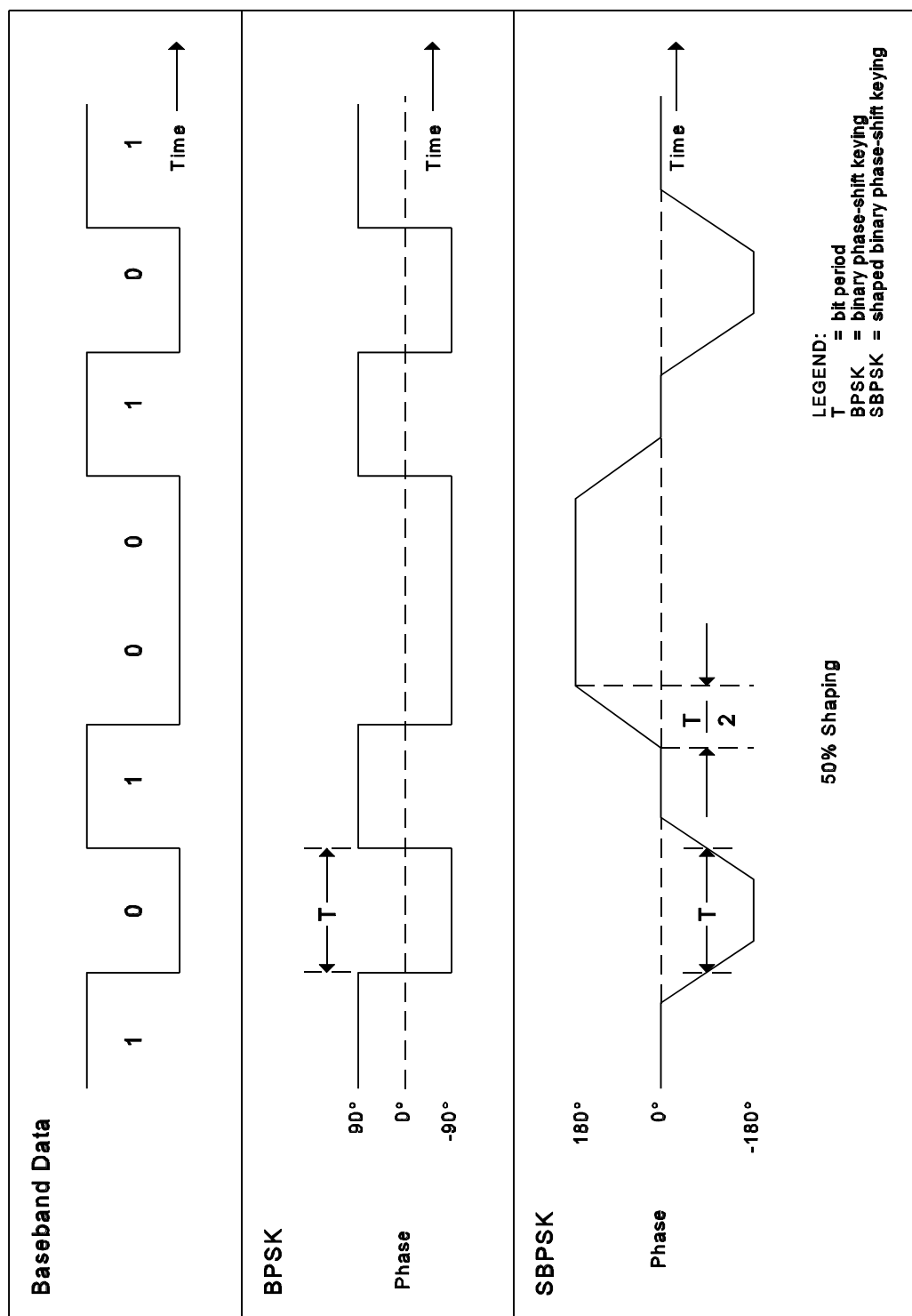


FIGURE B-1. A comparison of BPSK and SBPSK waveforms.



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-90 degrees represents the other level (0). The waveform is depicted in Figure B-1. Mathematically, BPSK can be expressed as

$$S(t) = A(t) \sin [\omega_o t + \phi_i(t)] \quad (B-1)$$

where

$$\begin{aligned} S(t) &= \text{transmitted signal} \\ A(t) &= \text{amplitude} \\ \omega_o &= 2\pi f_c \text{ (} f_c \text{ is the carrier frequency)} \\ \phi_i(t) &= \pm \pi/2 \text{ radians (90 degrees)} \end{aligned}$$

**B.3.2 Disadvantage of binary phase-shift keying.**

The disadvantage of BPSK is that it is not spectrally efficient. The abrupt change in phase causes energy to spill over into adjacent channels. This adjacent channel interference (ACI) degrades the communications of other satellite users. Spectral containment cannot be improved by filtering because post-modulation filtering will create a non-constant envelope.

**B.4 SHAPED BINARY PHASE-SHIFT KEYING**

At MILCOM 1984, Mark J. Dapper presented a paper written by him and Terrance J. Hill, Cincinnati Electronics Corporation. This paper, titled "SBPSK: A Robust Bandwidth-Efficient Modulation for Hard-Limited Channels," described shaped BPSK (SBPSK) as a variation of BPSK modulation that has good spectral containment and is compatible with BPSK. (See also a MILCOM 1990 paper, "Shaped PSK in a Digital Modem with Direct Digital Synthesis," Cofer R., Franke, E., Johnson, O., and Erman, T., 30 September 1990, Vol. 1, pp. 86-92, as well as PSK Sidebands Reduced by Pre-modulation Filtering, Carl Andren, *Microwave Journal*, January 1978, pp. 69-73.) The modulation scheme gradually changes the phase of the carrier by 180 degrees over a time equal to 50 percent of the bit period. The waveform is depicted in Figure B-1. Mathematically, SBPSK can be expressed the same way as BPSK, except that  $\phi_i(t)$  is not a two-valued variable. Instead, it is a function of the convolution of a unit pulse with three values ( $\pi$ , 0,  $-\pi$ ).

**B.4.1 Advantage of shaped binary phase-shift keying.** The main advantage of SBPSK is that the rate of falloff of the side lobes, as compared to the main lobe, is much greater than for BPSK. Thus, the spectral containment is enhanced. In contrast to postmodulation-filtered BPSK, SBPSK is created by premodulation filtering that preserves a constant envelope.

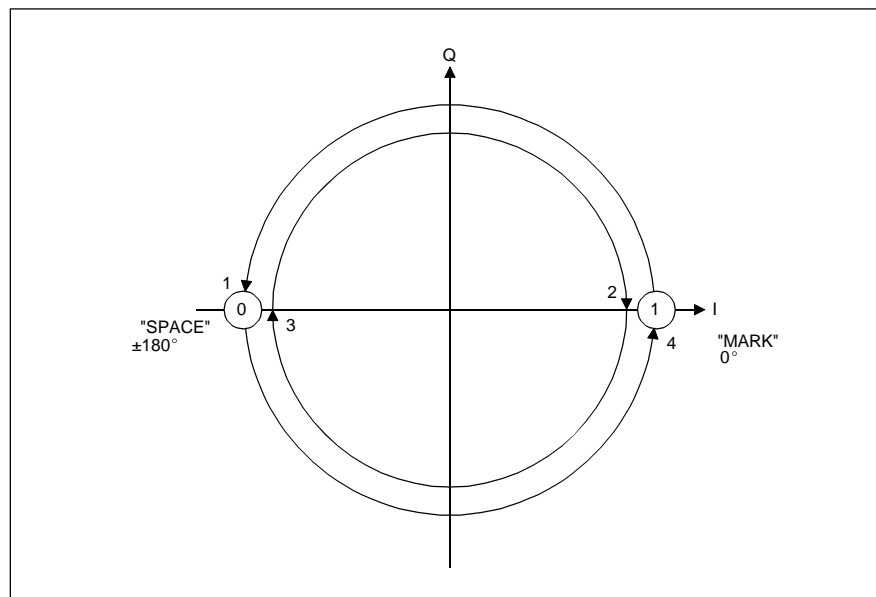
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SBPSK is compatible with BPSK if the shaping does not exceed approximately 50 percent.

**B.4.2 Disadvantage of shaped binary phase-shift keying.**

The disadvantage of SBPSK is that the shaping degrades detection efficiency. The loss of detection efficiency for an integrate and dump detector is approximately 1 dB with 50-percent shaping.

**B.4.3 Phase vector rotation.** The Dapper/Hill paper recommends that the direction of the phase vector rotation during a phase transition be implemented so that transitions to the  $180^\circ$  state occur by alternately rotating the phase in the clockwise and counter-clockwise directions from the  $0^\circ$  position. Rotation back to  $0^\circ$  is in the opposite direction from that most recently taken. In other words, the direction of rotation reverses upon reaching the  $180^\circ$  state, resulting in a change of the direction of phase vector rotation every other phase transition (see Figure B-2). According to the paper, there is an offset of the carrier frequency equal to one-fourth the data rate if the phase is rotated in the same direction for each data bit transition. This means there is a 600-Hz offset when the data rate is 2.4 kbps. The article further states that reversal of phase rotation allows interoperability of SBPSK with conventional BPSK demodulators not specifically designed for interoperability with SBPSK. The reason given is that a nonzero average value disturbs the phase-error measurement of conventional demodulation techniques, which are unable to separate transitional information from phase-error measurement.



**FIGURE B-2. SBPSK phase vector rotation.**

**MIL-STD-188-181A****APPENDIX C****METHOD OF IMPROVING THE G/T OF EXISTING UHF TERMINALS****C.1 SCOPE**

This appendix is not a mandatory part of this standard. The information contained herein is intended for guidance only. The purpose of this appendix is to provide a brief tutorial on a method to improve the G/T of an ultra high frequency (UHF) satellite communications (SATCOM) terminal.

**C.2 APPLICABLE DOCUMENTS**

**C.2.1 General.** This section does not include documents cited in other sections of this standard. The documents below are recommended for additional information or as examples.

**C.2.2 Government documents.** The following documents form a part of this appendix to the extent specified herein.

**C.2.2.1 Other Government documents, drawings, and publications.** The following other Government documents, drawings, and publications form a part of this appendix to the extent specified herein.

JTC3A Unnumbered	<i>Technical Assessment of UHF SATCOM Radio for KC-10 Aircraft, 19 December 1986</i>
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(Copies of this technical assessment may be obtained from the Defense Information Systems Agency, Joint Interoperability and Engineering Organization, ATTN: JEBBC, Fort Monmouth, NJ 07703-5613.)

**C.3 SYSTEM NOISE TEMPERATURE EQUATION**

The equation for effective noise temperature of a receiving system with two stages of amplification is

$$T_s = T_a + (L_c - 1)T_o + L_c (Fr_1 - 1)T_o + \frac{L_c (Fr_2 - 1)T_o}{Gr_1} \quad (C-1)$$

where

$T_s$	=	system noise temperature in kelvins (K)
$T_a$	=	antenna noise temperature in K
$L_c$	=	cable loss factor, dimensionless
$T_o$	=	ambient thermal temperature of 290 K

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$Fr_1$  = first receiver amplifier noise factor, dimensionless  
 $Fr_2$  = second receiver amplifier noise factor, dimensionless  
 $Gr_1$  = first receiver amplifier gain, dimensionless

**C.3.1 Typical noise temperature values.** The antenna noise temperature, as stated in MJCS-33-87, is typically 200 K. The cable loss, as stated in the JTC3A Report *Technical Assessment of UHF SATCOM Radio for KC-10 Aircraft*, dated 19 December 1986, is typically 3 dB (noise factor 2). Many current specifications require the noise figure of the receiver to be 4 dB maximum (noise factor is 2.5),

hence

$$T_s = 200 + (2-1)290 + 2(2.5-1)290 \quad (C-2)$$

$$= 1360 \text{ K (equivalent to 31.3 dB-K)}$$

where

$T_s$  = system noise temperature in kelvins (K)

The last term in the equation is ignored because the noise figure of the first receiver includes the contributions of the post-first-receiver stage.

**C.3.2 Preamplifier use.** As an example, if a preamplifier that has a noise figure of 2.5 dB (1.78 noise factor) and a gain of 14 dB (that is, 25 times) is installed close to the antenna (see Figure C-1), the noise temperature is greatly improved. The improvement occurs because the noise temperature corresponding to transmission line loss is reduced by the gain of the preamplifier, and the preamplifier itself has a lower noise figure than the ultra high frequency (UHF) terminal receiver. The equation for effective noise temperature that uses a preamplifier is

$$T_s = T_a + (F_p - 1)T_o + \frac{(L_c - 1)T_o}{G_p} + \frac{L_c (Fr_1 - 1)T_o}{G_p} \quad (C-3)$$

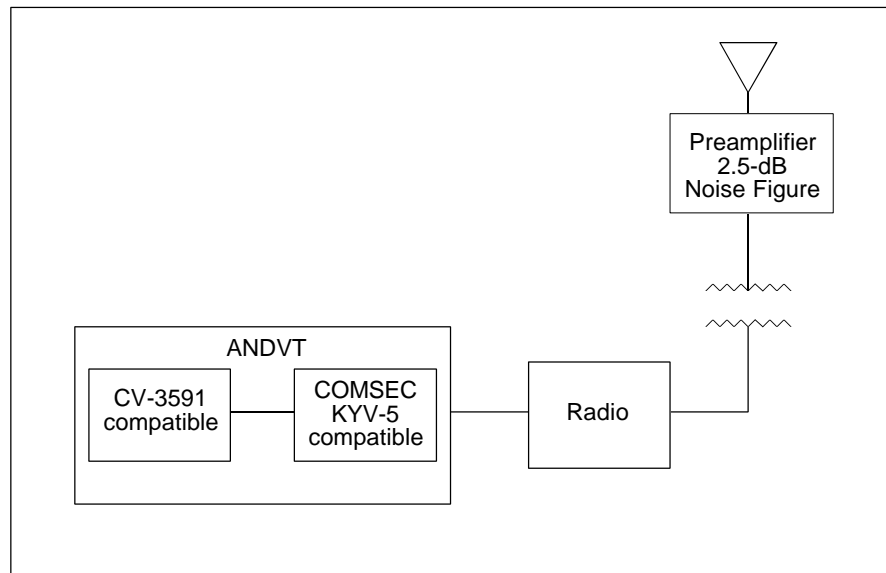
$$= 200 + (1.78 - 1)290 + \frac{(2-1)290}{25} + \frac{2(2.5-1)290}{25}$$

$$= 200 + 226.2 + 11.6 + 34.8$$

$$= 472 \text{ K (equivalent to 26.7 dB-K)}$$

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**FIGURE C-1. Improvement of existing terminals.**

where

$T_s$	=	system noise temperature in kelvins (K)
$T_a$	=	antenna noise temperature in K
$F_p$	=	the noise factor of the preamplifier = 1.78 (numerical equivalent of 2.5-dB noise figure)
$T_o$	=	ambient thermal temperature of 290 K
$L_c$	=	cable loss factor, dimensionless
$G_p$	=	the gain of the preamplifier = 25 (numerical equivalent of a 14-dB gain)
$Fr_1$	=	the noise factor of the transceiver receiver = 2.5 (numerical equivalent of a 4-dB noise figure)

**C.4 (G/T) IMPROVEMENT**

The 4.6-dB decrease in effective system noise temperature translates to a 4.6-dB increase of antenna gain-to-noise temperature in (G/T) dB/K. However, installation of a preamplifier close to the antenna is not always possible. This is especially true for platforms that employ multiple high-power emitters. These terminal installations require the placement of lossy elements between the antenna and the first amplifier for cosite protection.

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**MIL-STD-188-181A****APPENDIX D****OVERVIEW OF LINK CALCULATIONS****D.1 SCOPE**

This appendix is not a mandatory part of this standard. The information contained herein is intended for guidance only. The purpose of this appendix is to provide a brief tutorial on performing link calculations.

**D.2 INTRODUCTION**

This appendix gives a broad overview of the procedure for determining the bit rates and related bit error ratios (BER) that can be supported between two ultra high frequency (UHF) satellite earth terminals with single access to an ideal satellite channel.

**D.2.1 Basic link parameters**

**D.2.1.1 Basic link equation.** The equation that relates the system parameters to carrier-to-noise density ( $C/kT$ ) is given in equation (D-1). The equation applies to only one path of a repeater system, such as a ground transmitter to satellite receiver, and does not include adjacent channel interference (ACI). The effect of the overall two-path link (see D.2.1.7) is also discussed. The link equation with all terms expressed in dB is

$$\left( \frac{C}{kT} \right) = (EIRP) - (L_P) + \left( \frac{G}{T} \right)_R - (k) - L_o \quad (D-1)$$

The terms are described in D.2.1.2 through D.2.1.6.

**D.2.1.2 Carrier-to-noise density.** In the  $C/kT$  expression,  $C$  is the radio frequency (rf) carrier power into the receiving system in decibels referred to 1 watt (dBW),  $k$  is Boltzmann's constant [-228.6 dBW/Hz/K], and  $T$  is the receiving system noise temperature in K. Note that  $kT$  is the noise power in a bandwidth of 1 Hz (that is, noise power per Hz); hence the equivalent term *noise density*. The significance of this expression comes from this factor's being basic to determining the data rate capability of a satellite communications (SATCOM) link. Once factors such as BER and margin have been determined, data rate can be determined from  $C/kT$ .

**D.2.1.3 Effective isotropically radiated power.** Effective isotropically radiated power (eirp), a term that has been found

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to be convenient for use in describing the power radiated from a terminal, is the product of the transmitter power output and antenna gain, or, in dB,  $\text{eirp} = \text{transmitter power} + \text{antenna gain}$ . For instance, a satellite transponder with an 18-W (12.6-dBW) final amplifier and an antenna with a gain of 4 dB has an eirp of 45.2 W or 16.6 dBW.

**D.2.1.4 Path loss.** Path loss ( $L_p$ ) is the loss experienced by an electromagnetic wave of frequency  $f$  traveling a distance  $d$ . The  $L_p$  is described by

$$L_p = 36.58 + 20 \log f + 20 \log d \quad (\text{D-2})$$

where

$$\begin{aligned} L_p &= \text{path loss in dB} \\ f &= \text{frequency in MHz} \\ d &= \text{distance in statute miles} \end{aligned}$$

**D.2.1.5 Receiving system figure of merit ( $G/T$ ).** The antenna gain-to-noise temperature in dB/K ( $G/T$ ) figure of merit is the ratio of antenna gain to effective system noise temperature, both referred to the same reference point. The units of  $G/T$  are dB/K. System noise temperature is defined by the equation

$$T_s = T_a + (L_c - 1)T_o + L_c (Fr_1 - 1)T_o + \frac{L_c (Fr_2 - 1)T_o}{Gr_1} \quad (\text{D-3})$$

For high-quality receiving systems, the ratio of ( $G/T$ ) describes how well the antenna and receiver front-end combination acts to achieve a high  $C/kT$  at the receiver. As indicated by equation (D-3), antenna design affects not only  $G$ , but also  $T$  through the contribution of  $T_a$ .

**D.2.1.6 Transmission losses.** Transmission losses ( $L_o$ ) include such items as polarization mismatch between satellite and ground antennas and antenna pointing errors.

**D.2.1.7 Two-path link.** The two-path earth terminal-to-satellite and satellite-to-earth terminal link results in the  $C/kT$  at the earth terminal's being affected to some extent by the  $C/kT$  at the satellite. The extent affected is a function of the transmitted eirp and the type of transponder,



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linear or hard-limited. For a linear transponder, the  $C/kT$  at the ground terminal receiver is

$$\left( \frac{C}{kT} \right)_R = \frac{1}{\frac{1}{\left( \frac{C}{kT} \right)_{UL}} + \frac{1}{\left( \frac{C}{kT} \right)_{DL}}} \quad (D-4)$$

where

- $(C/kT)_R$  = two-way  $C/kT$  at the ground station receiver
- $(C/kT)_{UL}$  = uplink  $C/kT$  at the satellite receiving antenna
- $(C/kT)_{DL}$  = downlink  $C/kT$  at the earth terminal antenna

Hard-limiting increases the  $C/kT$  if the input  $C/kT$  is large, and it causes a 2-dB degradation if the input  $C/kT$  is low.

**D.2.2 Use of basic link equation**

**D.2.2.1 Downlink considerations and examples.** To predict the  $C/kT$  at the earth terminal, the values of the contributing parameters have to be known. These parameters have a statistical distribution; thus, a margin (excess transmitted power) has to be available so that minimum allowable  $C/kT$  is achieved for a given percentage of the time. The right side (downlink) of Figure D-1 presents typical values of the important parameters for a link through a 5-kHz channel in UHF Fleet Satellite communications (FLTSATCOM). In the figure, the  $G/T$  of the ground terminal is typical of current terminals.

**D.2.2.2 Uplink consideration and examples.** The left side of Figure D-1 presents typical uplink values.

**D.2.3 Analysis of digital requirements**

**D.2.3.1 Energy-per-bit to noise-power-spectral-density ratio ( $E_b/N_o$ ).** The usual basis for evaluation of performance of digital systems is the ratio  $E_b/N_o$  required at the input to the demodulator to obtain a given BER for the demodulated data. In terms of carrier power and bit rate,

$$\frac{E_b}{N_o} = \frac{\text{carrier power}}{N_o \times \text{bit rate}} = \frac{C}{kT \times \text{bit rate}} \quad (D-5)$$

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thus

$E_b/N_o$  = the carrier-power to noise-power ratio in a bandwidth equal to the bit rate

Uncoded phase-shift keying (PSK), which is used in the narrowband mode, requires a practical  $E_b/N_o$  of 12.5 dB at the receiver to achieve the requirement of a maximum average error rate of 1 error in  $10^5$  bits ( $P_e = 1 \times 10^{-5}$ ). Note that coherent frequency-shift keying (FSK) requires approximately 2 dB more than PSK, and noncoherent FSK requires approximately 4 dB more than PSK for the same performance.

**D.2.3.2 Relationship of data rates to satellite power (eirp).** The relationship between  $C/kT$  and data rate,  $R$ , can be written as

$$C/kT = (E_b/N_o) + R + M \quad (D-6)$$

where

$R$  = the data rate in dB-Hz (for 2.4 kbps, this is 33.8 dB-Hz)  
 $M$  = the desired margin in dB

By substituting the uplink and downlink  $C/kT$  shown in Figure D-1, in equation (D-1) the received  $C/kT$  is calculated to be 49 dB-Hz. Using equation (D-6), it can be shown that a  $C/kT$  of 49 dB-Hz can support a 2.4-kbps link with a  $P_e$  of  $1 \times 10^{-5}$  and a 2.7-dB margin, using PSK, when the required  $E_b/N_o$  is 12.5 dB.

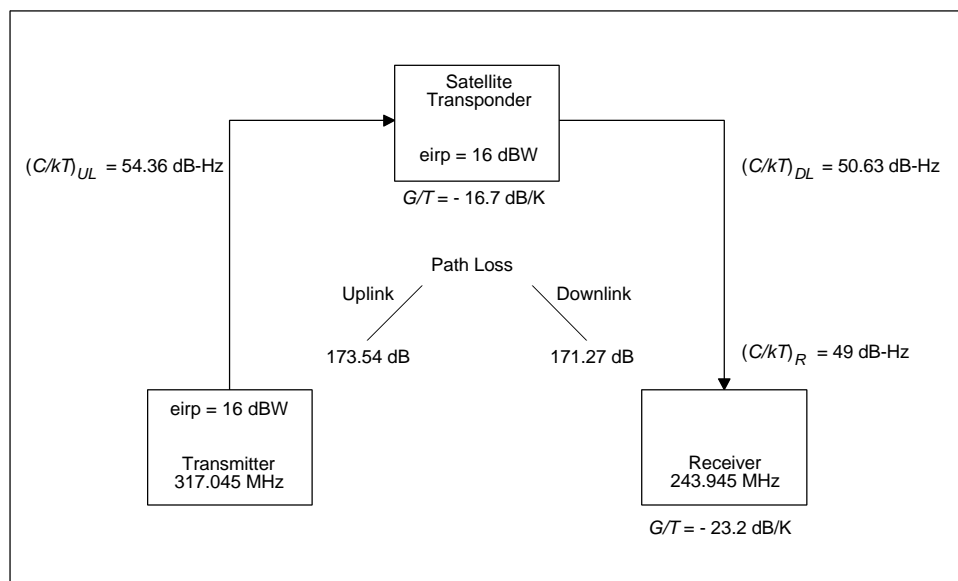


FIGURE D-1. Typical single-access link.

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