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FEDERAL STANDARD 1005A

GENERAL SERVICES ADMINISTRATION

CODING AND MODULATION REQUIREMENTS FOR 2,400 BIT/SECOND MODEMS

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FEDERAL STANDARD

TELECOMMUNICATIONS: CODING AND MODULATION REQUIREMENTS FOR 2,400 BIT/SECOND MODEMS

This standard is issued by the General Services Administration pursuant to the Federal Property and Administrative Services Act of 1949, as amended.

1. Scope

1.1 Description. This standard establishes coding and modulation requirements for 2,400 bit/s modems owned or leased by the Federal government for use over analog transmission channels other than those derived from high-frequency radio facilities. It is based upon techniques described in CCITT Recommendations V.22 bis, V.26, and V.26 bis.

1.2 Purpose. This standard is to facilitate interoperability between telecommunication facilities and systems of the Federal government.

1.3 Application. This standard shall be used by all Federal agencies in the design and procurement of 2,400 bit/s modems for use with switched or dedicated nominal 4 kHz channels with the following exception. Secure (i.e. encrypted) voice terminals conforming to North Atlantic Treaty Organization (NATO) Standardization Agreement 4291 may deviate from the requirements of this standard.

2. Requirements

2.1 Overview. This standard describes two alternative modem types: (1) a 2-wire half-duplex and/or 4-wire duplex modem (section 2.2) with optional fallback to 1,200 bit/s operation (section 2.3) and (2) a 2-wire duplex modem with optional fallback to 1,200 bit/s operation (section 2.4). Section 2.5 describes general characteristics.

2.2 2,400 Bit/s, 2-wire Half-duplex and 4-wire Duplex Operation

2.2.1 Carrier Frequency. The transmit carrier frequency shall be 1,800±1 Hz.

2.2.2 Data and Modulation Rates. The data rate shall be 2,400 bits/s ±.01 percent. The modulation (symbol) rate shall be 1,200 baud ±.01 percent.

2.2.3 Encoding Bits. The data stream to be modulated shall be divided into pairs of consecutive bits (dibits). Each dibit shall be encoded as a phase change of the 1,800 Hz carrier relative to the phase of the carrier during transmission of the immediately preceding dibit as indicated below.

DIBIT	PHASE CHANGE
00	+ 45°
01	+135°
11	+225°
10	+315°

The phase change is the actual on-line phase shift in the transition region from the center of one signal element to the center of the following signal element. At the demodulator, the dibits are decoded and the bits are reassembled in the correct order. The left-most bit of each dibit is the one occurring first in the data stream upon entering the modulator portion of the modem.

2.2.4 Synchronization. During the interval between Request to Send indication (e.g. CCITT Interchange Circuit 105 ON) from associated data terminal equipment and Clear to Send indication (e.g. CCITT Interchange Circuit 106 ON) from the modem, continuous 225° phase changes (dibit 11) shall be transmitted. Modems capable of 2-wire, half-duplex operation shall have the ability to delay Clear to Send indication for a period of at least 185 ms following the receipt of Request to Send indication. During 2-wire, half-duplex operation using the above delay, modems shall also withhold Receiver Ready indication (e.g. CCITT Interchange Circuit 109) after the end of each modem transmission for a period not to exceed 175 ms, to protect against the effect of line echoes.

2.2.5 Secondary Channel (Optional)

2.2.5.1 Characteristic frequencies of binary 1 (MARK) and binary 0 (SPACE) shall be 390±1 Hz and 450±1 Hz, respectively.

2.2.5.2 When simultaneous transmission of the primary channel and secondary channel occur in the same direction, the power level of the secondary channel shall be 6±0.6 dB lower than that of the primary channel.

2.2.5.3 When a secondary channel is used to transmit data or control information between data terminal equipment, the modulation rate for such transmission should not exceed 75 baud. Secondary channel communication between modems themselves, for applications such as diagnostic testing (possibly at modulation rates in excess of 75 baud), is permitted so long as the capability for interoperation with other modems, using the primary channel, is retained.

2.2.6 Equalization. Fixed compromise equalization shall be incorporated in each modem receiver. Equalizer characteristics are dependent upon communications system application.

2.3 1,200 Bit/s, 2-wire Half-duplex and 4-wire Duplex Operation (Optional)

2.3.1 Data Rate. The data rate shall be 1,200 bits/s ±.01 percent.

2.3.2 Encoding Bits. 1,200 bit/s operation shall be achieved, when available, by encoding binary 0 and 1 bits as +90° and +270° phase changes, respectively.

2.3.3 Other Characteristics. All other characteristics shall be as specified above, in section 2.2.

2.4 2-wire Duplex Operation

2.4.1 Carrier Frequencies. Transmit carrier frequencies shall be 1,200±0.5 Hz for the Low Channel and 2,400±1 Hz for the High Channel.

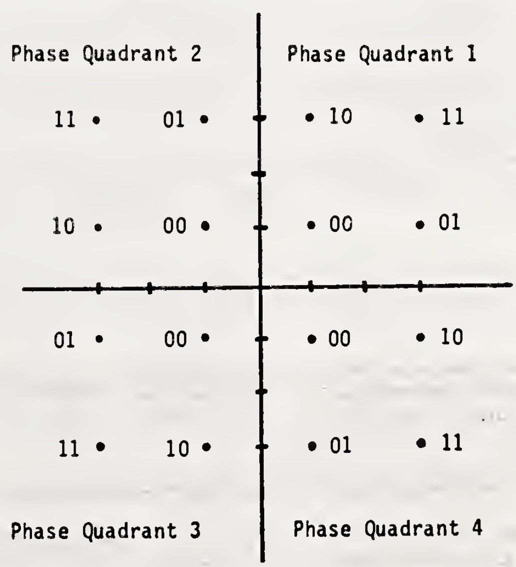
2.4.2 Data and Modulation Rates. The data rates shall be 2,400 bits/s ±.01 percent and 1,200 bits/s ±.01 percent. The modulation (symbol) rate shall be 600 baud ±.01 percent.

2.4.3 Guard Tone (Optional). Continuous guard tone may be needed for proper operation on some international and foreign nation circuits. The CCITT recommends a guard tone of 1,800±20 Hz, 6±1 dB below the level of the data signal, in the High Channel.

2.4.4 Encoding Bits

2.4.4.1 2,400 Bits/s. The data stream to be transmitted shall be divided into groups of four consecutive bits (quadbits). The first two bits of each quadbit shall be encoded as a phase quadrant change relative to that of the previous quadbit, as shown in the table and phase-amplitude constellation below. The last two bits of each quadbit shall be encoded as a phase-amplitude position within the selected phase quadrant, as shown in the phase-amplitude constellation below.

FIRST TWO BITS OF QUADBIT	PHASE QUADRANT CHANGE
00	+ 90°
01	+ 0°
10	+180°
11	+270°

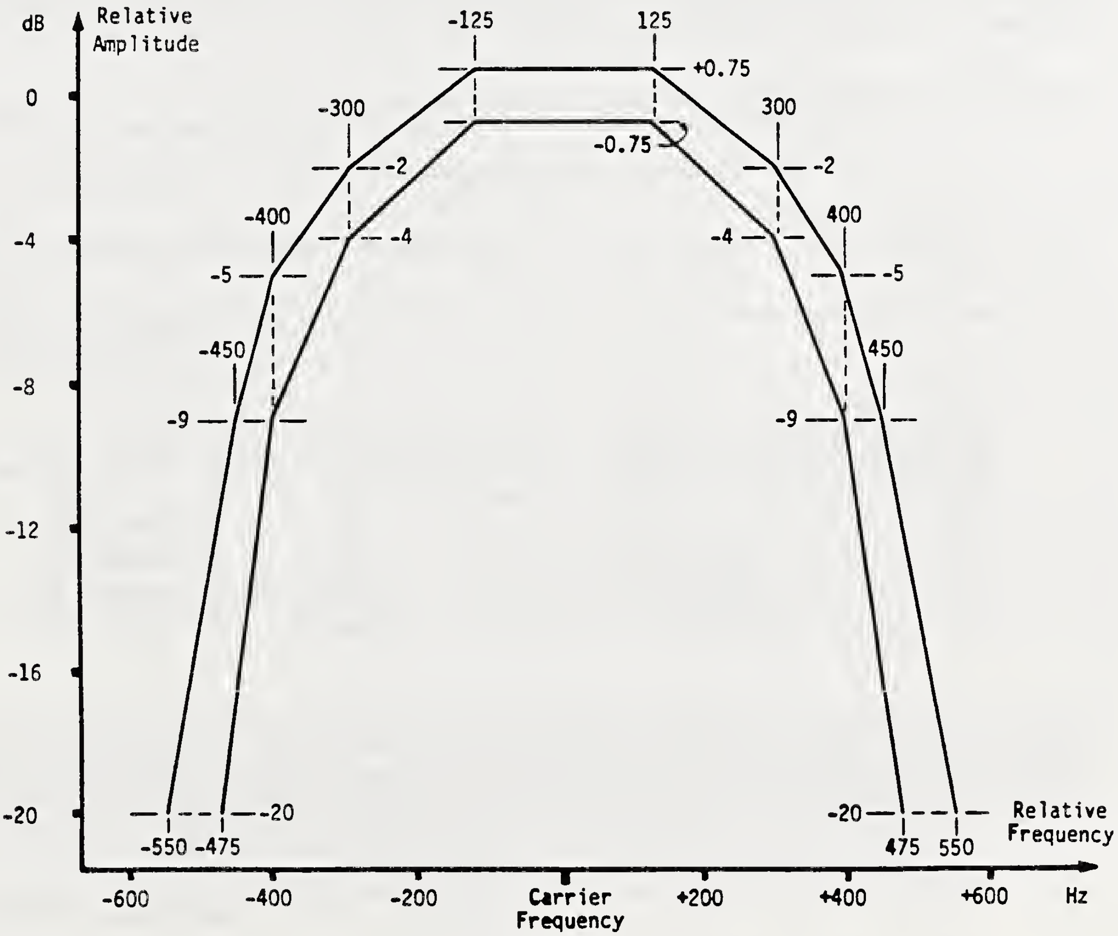


At the demodulator, quadbits shall be decoded and the bits reassembled in the correct order. The left-most bits of each quadbit are the ones occuring first in the data stream upon entering the modulator portion of the modem.

2.4.4.2 1,200 Bits/s. The data stream to be transmitted shall be divided into groups of two consecutive bits (dibits). The dibits shall be encoded in the same manner as the first two bits of the quadbit described in the previous section. The phase-amplitude position within each phase quadrant shall be as it would be during 2,400 bit/s operation if the last two bits of each quadbit were 01. Note: this permits interoperation with 2-wire duplex 1,200 bit/s modems conforming to Federal Standard 1008.

2.4.5 Equalization. Fixed compromise equalization shall be in each modem transmitter. Adaptive equalization shall be incorporated in each modem receiver. Equalizer characteristics are dependent upon communications system application.

2.4.6 Frequency Spectrum. Before insertion of the fixed compromise equalizer, transmitted line signal should have a frequency spectrum equivalent to the square root of raised cosine shaping with 75 percent roll-off, and be within the limits shown in the following drawing.



2.4.7 Envelope Delay Distortion. Before insertion of the fixed compromise equalizer, the envelope delay distortion in the transmitter output should not exceed ±150 microseconds over the frequency range 900-1,500 Hz (Low Channel) and 2,100-2,700 Hz (High Channel).

2.4.8 Start-Stop to Synchronous Conversion (Optional). When asynchronous start-stop characters are utilized, the conversion of asynchronous start-stop characters into a form suitable for synchronous transmission shall be accomplished as follows.

2.4.8.1 Character Format. Characters to be transmitted must begin with a start element of one bit-length and end with a stop element of one or more bit-lengths. Modems shall be capable of handling 10-bit length characters.

2.4.8.2 Intra-character Rate Tolerance. Intra-character rate tolerance to transmitted data shall be readily configurable to from +1.0 percent to -2.5 percent.

2.4.8.3 Deletion of Stop Bits. When the character rate multiplied by the number of bits per character is greater than 1,200 or 2,400 bits/s, the start-stop to synchronous converter shall delete stop bits from incoming characters as often as necessary. However, not more than one stop bit shall be deleted from any eight consecutive characters.

Note: The length of the last stop bit of any character may be reduced up to 12.5 percent in receiving modems to allow for any overspeed in transmitting data terminal equipment.

2.4.8.4 Addition of Stop Bits. When the character rate multiplied by the number of bits per character is less than 1,200 or 2,400 bits/s, the start-stop to synchronous converter shall insert extra stop bits between transmitted characters as necessary.

2.4.8.5 Break Signal. If a start-stop to synchronous converter detects from M to 2M+3 bits of "start" polarity, when M is the number of bits per character, the converter shall transmit 2M+3 bits of "start" polarity. If a converter detects more than 2M+3 bits of "start" polarity, it shall transmit all of these bits as "start" polarity. The previously mentioned periods of "start" polarity are designated break signals. After receiving 2M+3 or more bits of "start" polarity from transmitting modems, receiving modems shall regain character synchronism from the next "stop" to "start" transition.

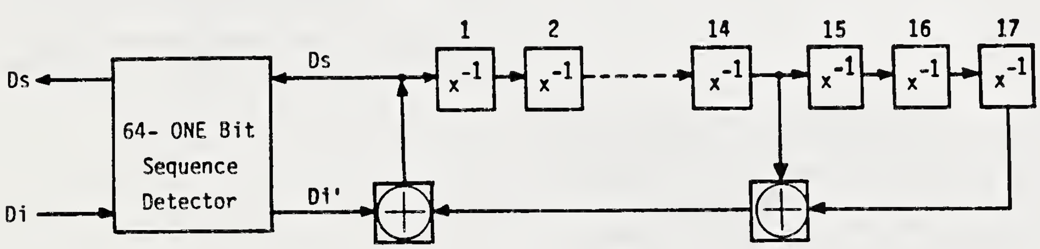
Note: Transmitting data terminal equipment shall be expected to send at least 2M bits of "stop" polarity immediately following break signals to enable receiving modems to regain character synchronism.

2.4.9 Scrambler/Descrambler. A scrambler/descrambler having the generating polynomial:

$$1 + x^{-14} + x^{-17}$$

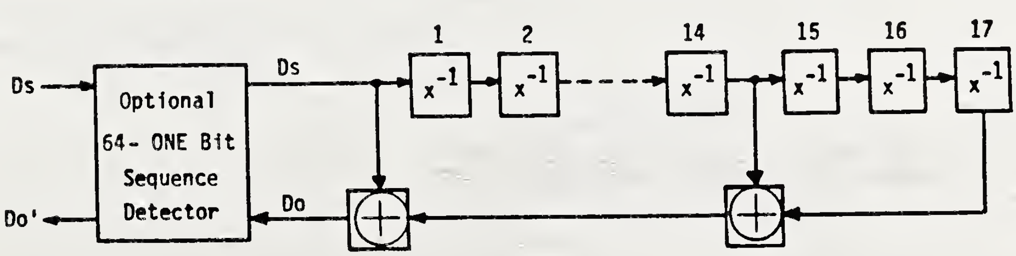
shall be utilized. The purpose of this scrambler is randomization of the data stream to assist in distribution of the energy spectrum.

2.4.9.1 Scrambler. A diagram showing the scrambler is given below. (Logically equivalent configurations may be utilized in place of the one shown.)



In the diagram above, Di' represents input data to the scrambler and Ds represents scrambled output data. During operation, the 17-bit shift register is clocked at the data rate. Shift register bits 14 and 17 are modulo-2 added and the resulting sum is then modulo-2 added with input Di' to produce Ds. Ds, the scrambler output, is then also fed to the shift register input. A sequence detector shall detect a sequence of 64 consecutive ONE bits at the scrambler output (Ds) and, if detected, shall invert the next input bit (Di) and reset the consecutive ONE bit counter. Scrambler input bits shall not be inverted during the synchronization sequence or during the start of remote loopback.

2.4.9.2 Descrambler. A diagram showing the descrambler is given below. (Logically equivalent configurations may be utilized in place of the one shown.)



In the diagram above, Ds represents scrambled input data and Do represents descrambled output data. The operation of the descrambler is basically the same as that of the scrambler described in the previous section. An optional sequence detector can detect a sequence of 64 consecutive ONE bits at the input to the descrambler (Ds) and, if detected, invert the next output bit (Do). The existence of scrambled binary 1 during the synchronization sequence and the start of remote loopback shall be detected ahead of inversion by the sequence detector.

2.4.10 Channel Allocation. When operating on circuit switched (e.g., telephone) networks and utilizing automatic answering equipment, modems at calling locations shall transmit on the Low Channel and receive on the High Channel. Likewise, modems at called locations shall transmit on the High Channel and receive on the Low Channel. Otherwise, channel allocation shall be decided by bilateral agreement.

2.4.11 Syncnronization Sequences

2.4.11.1 2,400 bit/s Operation. The state sequences shown below shall be followed to start 2,400 bit/s operation.

CALLING MODEM (LOW CHANNEL TRANSMIT)	CALLED MODEM (HIGH CHANNEL TRANSMIT)
1. Silence after establishment of connection	
	2. Silence after establishment of connection for 1.8-2.5 seconds
	3. Transmit nominal 2,100 Hz answer tone for 2.6-4 seconds
	4. Silent period for 55-95 ms
	5. Transmit continuous unscrambled binary 1 at 1,200 bits/s
6. Detect unscrambled binary 1 at 1,200 bits/s or 2,225 Hz tone for 155$\pm$10 ms (Note: 2,225 Hz tone detection is for interworking with 1,200 bit/s modems at fallback data rate)	
7. After 456$\pm$10 ms, transmit unscrambled 0011 pattern at 1,200 bits/s for 100$\pm$3 ms	
8. Transmit continuous scrambled binary 1 at 1,200 bits/s	
	9. Monitor for unscrambled 0011 pattern at 1,200 bits/s and, optionally, for scrambled binary 1. If scrambled binary 1 at 1,200 bits/s is detected for 270$\pm$40 ms first, fall back to 1,200 bit/s operation (section 2.4.11.2) However, if unscrambled 0011 pattern at 1,200 bits/s is detected first, at the end of receiving this pattern unscrambled 0011 pattern is transmitted at 1,200 bits/s for 100$\pm$3 ms
	10. Transmit continuous scrambled binary 1 at 1,200 bits/s
11. Monitor for unscrambled 0011 pattern at 1,200 bits/s and, optionally, for scrambled binary 1. If scrambled binary 1 at 1,200 bits/s is detected for 270$\pm$40 ms first, fall back to 1,200 bit/s operation (section 2.4.11.2) However, if unscrambled 0011 pattern at 1,200 bits/s is detected first, at the end of receiving this pattern wait 600$\pm$10 ms and then transmit continuous scrambled binary 1 at 2,400 bits/s	
12. After 200$\pm$10 ms, indicate Clear to Send and transmit data at 2,400 bits/s	
	13. After 600$\pm$10 ms, transmit scrambled binary 1 at 2,400 bits/s
	14. After 200$\pm$10 ms, indicate Clear to Send and transmit data at 2,400 bits/s

2.4.11.2 1,200 Bit/s Operation (Optional). The state sequences shown below shall be followed to start 1,200 bit/s operation when interworking with 1,200 bit/s 2-wire duplex modems conforming to Federal Standard 1008.

CALLING MODEM (LOW CHANNEL TRANSMIT)	CALLED MODEM (HIGH CHANNEL TRANSMIT)
2,400 and 1,200 Bit/s Modem	1,200 Bit/s Modem
1. Silence after establishment of connection	
	2. Silence after establishment of connection for 1.8-2.5 seconds
	3. Transmit nominal 2,100 Hz answer tone for 2.6-4 seconds (optional)
	4. Silent period for 55-95 ms
	5. Transmit continuous unscrambled binary 1 at 1,200 bits/s or 2,225 Hz tone
6. Detect unscrambled binary 1 at 1,200 bits/s or 2,225 Hz tone for 155±10 ms	
7. After 456±10 ms, transmit unscrambled 0011 pattern at 1,200 bits/s for 100±3 ms	
8. Transmit continuous scrambled binary 1 at 1,200 bits/s	
	9. Detect scrambled binary 1 at 1,200 bits/s for 270±40 ms
	10. Transmit continuous scrambled binary 1 at 1,200 bits/s
	11. After 765±10 ms, indicate Clear to Send and transmit data at 1,200 bits/s
12. Detect scrambled binary 1 at 1,200 bits/s for 270±40 ms	
13. After 765±10 ms, indicate Clear to Send and transmit data at 1,200 bits/s	

CALLING MODEM (LOW CHANNEL TRANSMIT) 1,200 Bit/s Modem	CALLED MODEM (HIGH CHANNEL TRANSMIT) 2,400 and 1,200 Bit/s Modem
1. Silence after establishment of connection	
	2. Silence after establishment of connection for 1.8-2.5 seconds
	3. Transmit nominal 2,100 Hz answer tone for 2.6-4 seconds
	4. Silent period for 55-95 ms
	5. Transmit continuous unscrambled binary 1 at 1,200 bits/s
6. Detect unscrambled binary 1 at 1,200 bits/s for 155±10 ms	
7. After 456±10 ms, transmit continuous scrambled binary 1 at 1,200 bits/s	
	8. Detect scrambled binary 1 at 1,200 bits/s for 270±40 ms
	9. Transmit continuous scrambled binary 1 at 1,200 bits/s
10. Detect scrambled binary 1 at 1,200 bits/s for 270±40 ms	
11. After 765±10 ms, indicate Clear to Send and transmit data at 1,200 bits/s	
	12. After 765±10 ms, indicate Clear to Send and transmit data at 1,200 bits/s

2.4.11.3 Retraining. During 2,400 bit/s operation, retraining shall be accomplished whenever a modem detects loss of proper equalization. Modem receivers must monitor for unscrambled 0011 pattern at 1,200 bits/s during 2,400 bit/s operation. The state sequence shown below shall be followed during retraining. The modem requesting retraining is called Modem A and the distant modem is called Modem B.

MODEM A	MODEM B
1. Transmit unscrambled 0011 pattern at 1,200 bits/s for 100±3 ms	
2. Transmit continuous scrambled binary 1 at 1,200 bits/s	
	3. Detect unscrambled 0011 pattern at 1,200 bits/s
	4. Transmit unscrambled 0011 pattern at 1,200 bits/s for 100±3 ms
	5. Transmit continuous scrambled binary 1 at 1,200 bits/s
	6. 600±10 ms after detecting the end of unscrambled binary 0011 pattern at 1,200 bits/s, transmit scrambled binary 1 at 2,400 bits/s
	7. After 200±10 ms, indicate Clear to Send and transmit data at 2,400 bits/s
8. 600±10 ms after detecting the end of unscrambled binary 0011 pattern at 1,200 bits/s, transmit scrambled binary 1 at 2,400 bits/s	
9. After 200±10 ms, indicate Clear to Send and transmit data at 2,400 bits/s	

Note: If a modem has transmitted unscrambled 0011 pattern and has not received unscrambled 0011 pattern within a reasonable time period, the modem should try again. If a modem has not been able to equalize properly, the retrain sequence should be repeated.

2.4.12 Remote Loopback (Optional). When implemented, the remote loopback (CCITT Test Loop 2) test shall be started and terminated by the modem location requesting the test in the manner described below. The modem at the location requesting the loopback test shall be called Modem A and the modem at the remote location shall be called Modem B.

2.4.12.1 Start of Remote Loopback. The following signals are transmitted, at the operating data rate, after the Synchronization Sequence (section 2.4.11) has been completed. When instructed by local data terminal equipment to conduct a Remote Loopback test (e.g. CCITT Interchange Circuit 140 ON), Modem A shall transmit continuous unscrambled binary 1. Modem B, upon detecting from 154 to 231 ms of unscrambled binary 1, shall transmit a pattern of scrambled alternating binary 0 and binary 1. When Modem A detects from 231 to 308 ms of scrambled binary 0 and binary 1 alternations, it shall then transmit continuous scrambled binary 1. Modem B, upon detecting the transition from unscrambled to scrambled binary 1, shall activate the remote loopback function. Modem A, upon receiving 231 to 308 ms of scrambled binary 1, shall indicate that remote loopback has been established (e.g. CCITT Interchange Circuit 142 ON).

2.4.12.2 Termination of Remote Loopback. When Modem A is instructed to terminate a remote loopback test (e.g. CCITT Interchange Circuit 140 OFF), the line signal shall be disabled for a period of 77±10 ms, after which the line signal shall be restored. Modem B shall detect the loss of line signal and immediately terminate the remote loopback function. Modems shall subsequently resume normal operation.

2.5 General Characteristics

2.5.1 Impedance. Modems shall be capable of presenting an impedance to the analog line of 600±120 ohms, balanced.

2.5.2 Output Signal Level. The total power transmitted by the modem to the line shall be: (1) adjustable from at least -12 dBm to -3 dBm in no greater than 1 dB steps and/or (2) the modem shall be directly connectable to the public telephone network in conformance with Part 68 of the Federal Communications Commission's (FCC) Rules.

2.5.3 Input Sensitivity. The demodulator shall have an input sensitivity adjustable to -44±6 dBm. When the above-stated input sensitivity is used, the input level dynamic range shall be at least 30 dB above the input sensitivity.

3. Effective Date. The use of this standard by U.S. government departments and agencies is mandatory, effective 180 days following the date of this standard.

4. Changes. When a Government department or agency considers that this standard does not provide for its essential needs, a statement citing specific requirements shall be sent in duplicate to the General Services Administration (K), Washington, DC 20405, in accordance with the provisions of Federal Property Management Regulation 41 CFR 101-29.403-1. The General Services Administration will determine the appropriate action to be taken and will notify the agency.

PREPARING ACTIVITY:

National Communications System
Office of Technology and Standards
Washington, DC 20305-2010

MILITARY INTERESTS:

Military Coordinating Activity
DCA--DC

Custodians
Army--SC
Navy--EC
Air Force--90

Review Activities
Army--CR
Navy--AS, OM
Air Force--17
USMC--MC
JTC3A--JT
NSA--NS

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