FEDERAL STANDARD

TELECOMMUNICATIONS: CODING AND MODULATION REQUIREMENTS FOR DUPLEX 600 and 1200 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 duplex 600 bit/s and/or 1200 bit/s modems owned or leased by the Federal Government for use over analog transmission channels terminated by "two-wire" circuits. It is based upon CCITT provisional Recommendation V.22.

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

1.3 Application

1.3.1 All Federal departments and agencies shall comply with this standard in the design and procurement of duplex 600 bit/s modems and/or 1200 bit/s modems (and equipment containing such modems) for use over nominal 4 kHz analog channels terminated by "two-wire" (in contrast to "four-wire") circuits except when such modems are acoustically coupled to telephone instruments. Typically, nominal 4 kHz analog channels are derived from frequency division multiplex equipment associated with microwave, coaxial cable, and satellite transmission systems.

1.3.2 Modems described by this standard may also be used on entirely nonmultiplexed transmission systems such as those using metallic cable.

1.3.3 Modems described by this standard may also have additional capabilities.

2. Requirements

2.1 Line Signals

2.1.1 Carrier Frequencies. Carrier frequencies shall be 1200±0.5 Hz for the Low Channel and 2400±1 Hz for the High Channel.

2.1.2 Data and Modulation Rates. The data rate shall be 600 bits/s ±.01 percent or 1200 bits/s ±.01 percent. The modulation (symbol) rate shall be 600 baud ±.01 percent.

2.1.3 Encoding Bits

2.1.3.1 600 Bits/s. Each bit shall be encoded as a phase change relative to the phase of the preceding signal element as shown below.

Bit Value (600 Bits/s)	Dibit Value (1200 Bits/s)	Phase Change
0	00	$+90^{\circ}$
-	01	0°
1	11	$+270^{\circ}$
-	10	$+180^{\circ}$

Note: 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.

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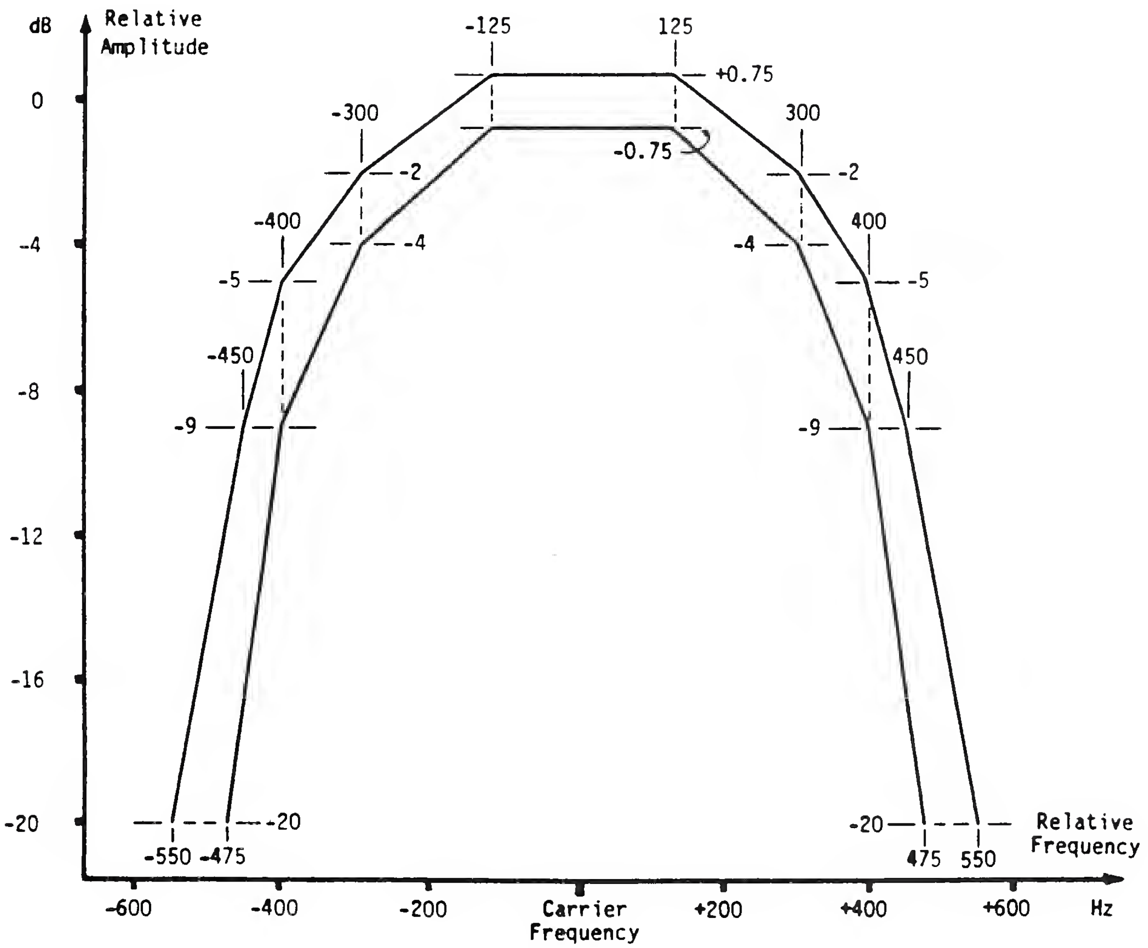
Federal Standard 1008 has been redesignated as Federal Information Processing Standards Publication (FIPS PUB) 136. Issued by the National Institute of Standards and Technology pursuant to Section 111(d) of the Federal Property and Administrative Services Act of 1949 as amended by the Computer Security Act of 1987, Public Law 100-235.

2.1.3.2 1200 Bits/s. The data stream to be transmitted shall be divided into groups of two consecutive bits (dibits). Each dibit shall be encoded as a phase change relative to the phase of the preceding signal element as shown in the table of paragraph 2.1.3.1. At the receiver, the dibits shall be decoded and the bits reassembled in correct order. The left-most digit of the dibit is the one occurring first in the data stream immediately prior to encoding.

2.1.4 Equalization. Fixed compromise equalization shall be incorporated in all modems. Equalization shall be equally shared between associated transmitters and receivers. Equalizer characteristics are dependent upon communications system application.

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



2.1.6 Envelope Delay Distortion. Before the insertion of the fixed compromise equalizer, the envelope delay distortion in the transmitter output should not exceed ±100 microseconds over the frequency range 800- 1600 Hz (Low Channel) and 2000-2800 Hz (High Channel).

2.2 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.

2.2.1 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.

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

2.2.3 Deletion of Stop Bits. When the character rate multiplied by the number of bits per character is greater than 600 or 1200 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 (DTE).

2.2.4 Addition of Stop Bits. When the character rate multiplied by the number of bits per character is less than 600 or 1200 bits/s, the start-stop to synchronous converter shall insert extra stop bits between transmitted characters as necessary.

2.2.5 Break Signal

2.2.5.1 If a start-stop to synchronous converter detects from M to 2M+3 bits of "start" polarity, where 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.

2.2.5.2 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.

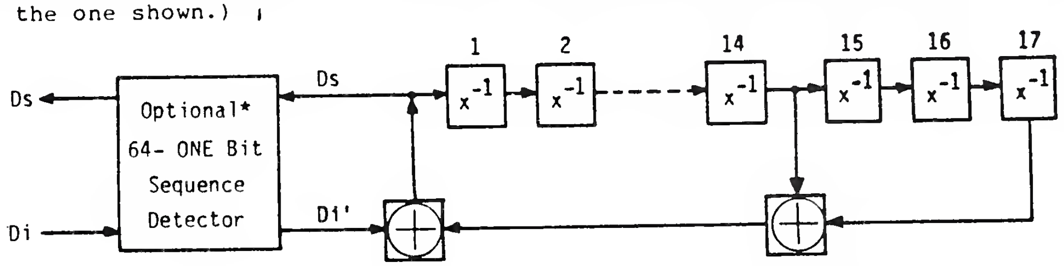
Note: Transmitting DTE's shall be expected to send at least 2M bits of "stop" polarity immediately following break signals to enable receiving modems to regain character synchronism.

2.3 Scrambler/Descrambler. A self-synchronizing 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.

2.3.1 Scramber. A diagram showing the scrambler and optional sequence detector (64-ONE bits) is given below. (Logically equivalent configurations may be utilized in place of the one shown.)

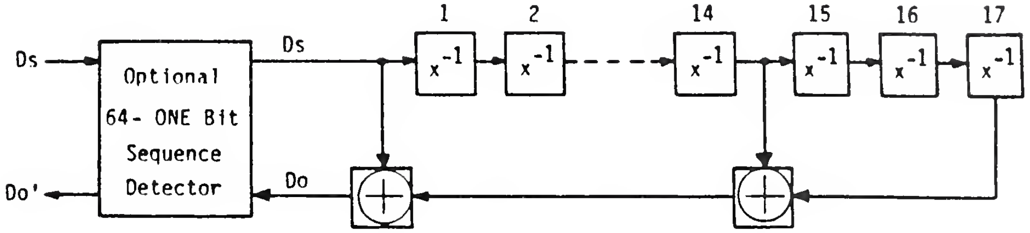


*Required with optional remote loopback capability (Section 2.5)

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 (bit 0).

To prevent occasional inadvertent activation of remote loopback, the use of a sequence detector (64-ONE bits) associated with the scrambler is required in modems having remote loopback capability and is a desirable option for modems not having remote loopback capability. During operation, the 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). Scrambler input bits shall not be inverted during the synchronization sequence or during the start of remote loopback.

2.3.2 Descrambler. A diagram showing the descrambler and optional 64-ONE bit sequence detector 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.

A sequence detector (64-ONE bits) may optionally be used. (NOTE: The performance advantage associated with use of such a sequence detector at a descrambler, in addition to scrambler, will be small.) The sequence detector shall detect a sequence of 64 consecutive ONE bits at the input to the descrambler (Ds) and, if detected, shall 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 any inversion by a sequence detector.

2.4 Operational Procedures

2.4.1 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 allocations shall be decided by bilateral agreement.

2.4.2 Synchronization Sequence. Modems shall be capable of utilizing the sequence described below to achieve synchronism. For the purpose of the following explanation, modems transmitting on the Low Channel shall be considered to be at calling locations and modems transmitting on the High Channel shall be considered to be at called locations.

2.4.2.1 Calling Modem. After detecting an unscrambled binary 1 condition for 155±50 ms, the modem shall wait 456±10 ms more and then transmit continuous scrambled binary 1. After detecting a scrambled binary 1 condition for 270±40 ms, the modem shall wait 765±10 ms more and then, if appropriate, shall indicate Clear to Send (CS) to its associated DTE and transmit data. (Note: Calling modems shall not require the transmission of nominal 2100 Hz answer tone by distant modems for their proper operation.)

2.4.2.2 Called Modem. After establishment of the connection, the modem shall wait 1.8 to 2.5 seconds. Then, when 2100 Hz answer tone is employed, the modem shall transmit a nominal 2100 Hz answer tone for 2.6 to 4 seconds and afterward cease transmission for 55 to 95 microseconds. (Note: This optional answer tone is needed to disable non-North American echo suppressors. See paragraph 2.4.2.4.) Next, the modem shall begin transmitting either continuous unscrambled binary 1 or 2225 Hz tone. (Note: Unscrambled binary 1 has a primary spectral component near 2225 Hz.) After detecting scrambled binary 1 condition for 270±40 ms, the modem shall transmit continuous scrambled binary 1. After waiting 765±10 ms more, the modem shall, if appropriate, indicate Clear to Send (CS) to its associated DTE and transmit data.

2.4.2.3 State Sequence. The state sequence outlined in Table 1 depicts the synchronization sequence described in the previous two paragraphs.

TABLE 1

CALLING MODEM (LOW CHANNEL TRANSMIT)	CALLED MODEM (HIGH CHANNEL TRANSMIT)
1. Silence after connection	
	2. Silence after connection for 1.8-2.5 seconds
	3. Transmit nominal 2100 Hz answer tone for 2.6-4 seconds*
	4. Silent period for 55-95 micro-seconds*
	5. Transmit continuous unscrambled binary 1 or 2225 Hz tone
6. Detect unscrambled binary 1 for 155±50 ms	
7. Wait 456±10 ms more	
8. Transmit continuous scrambled binary 1	
	9. Detect scrambled binary 1 for 270±40 ms
	10. Transmit continuous scrambled binary 1
11. Detect scrambled binary 1 for 270±40 ms	
	12. Wait 765±10 ms more
	13. Indicate Clear to Send (CS) and transmit data as appropriate
14. Wait 765±10 ms more	
15. Indicate Clear to Send (CS) and transmit data as appropriate	

*Optional. See paragraph 2.4.2.4.

2.4.2.4 <u>2100 Hz Answer Tone (Optional)</u>. A nominal 2100 Hz answer tone may be needed to disable echo suppressors on telephone circuits outside of North America and when transmitting unscrambled binary 1 instead of 2225 Hz tone in North America. Continuous guard tone (CCITT recommends 1800±20 Hz in the High Channel) may also be needed for proper operation on some international and foreign nation circuits.

2.4.2.5 <u>Interchange Circuit Conditions</u>. When utilized, the Data Mode (DM) circuit should be turned ON upon detection of unscrambled binary 1 in the calling modem and upon the transmission of unscrambled binary 1 in the called modem. Likewise, the Receiver Ready (RR) circuit should be turned ON immediately after the detection period for detecting scrambled binary 1 in the calling modem and simultaneous with Clear to Send (CS) indication in the called modem.

2.4.3 <u>Loss of Synchronization</u>. When operating in a switched network, modems should initiate call termination upon detection of a prolonged loss of line signal, or other conditions resulting in loss of modem synchronization. Modems shall not resynchronize because of a loss of line signal shorter than that which would cause call termination.

2.5 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.

2.5.1 Start of Remote Loopback. The following signals are transmitted after the Synchronization Sequence (see paragraph 2.4.2) has been completed. When instructed by the local DTE to conduct a Remote Loopback test (interchange circuit RL turned 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 (interchange circuit Test Mode (TM) turned ON).

2.5.2 Termination of Remote Loopback. When Modem A is instructed to terminate a remote loopback test (interchange circuit RL turned 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.

2.6 General Characteristics

2.6.1 Impedance. Modems shall be capable of presenting an impedance to the analog line of 600±60 ohms, balanced.

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

2.6.3 Input Sensitivity. The demodulator shall have an input sensitivity adjustable to -45±4 dBm. When the above-stated input sensitivity is used, the input level dynamic range shall be at least 30 dB above the input sensitivity.

2.6.4 Digital Interface. Digital interface characteristics for modems, when applicable, are specified in other Federal standards. These standards include Federal Standards 1020A, 1030A, and 1031.

3. Changes. When a Federal agency considers that this standard does not provide for its essential needs, a statement citing inadequacies shall be sent in duplicate to the General Services Administration (C), Washington, D.C. 20405, in accordance with provisions of Federal Property Management Regulations 41 CFR 101-29.3. 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, D.C. 20305