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FIPS PUB 134-1

FEDERAL INFORMATION PROCESSING STANDARDS PUBLICATION
(Former Federal Standard 1006)

CODING AND MODULATION REQUIREMENTS FOR 4,800 BIT/SECOND MODEMS

CATEGORY: TELECOMMUNICATIONS STANDARD

1988 NOVEMBER 4

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CATEGORY: TELECOMMUNICATIONS STANDARD

National Computer Systems Laboratory
National Institute of Standards and Technology
(formerly National Bureau of Standards)
Gaithersburg, MD 20899

NOTE: As of 23 August 1988, the National Bureau of Standards (NBS) became the National Institute of Standards and Technology (NIST) when President Reagan signed into law the Omnibus Trade and Competitiveness Act.

Issued November 4, 1988

U.S. Department of Commerce
Robert A. Mosbacher, Secretary

Ernest Ambler, Acting Under Secretary for Technology

National Institute of Standards and Technology
Raymond G. Kammer, Acting Director

This Standard was developed under a Memorandum of Understanding between NIST and NCS.

Foreword

The Federal Information Processing Standards Publication Series of the National Institute of Standards and Technology (NIST) is the official publication relating to standards and guidelines adopted and promulgated under the provisions of 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. These mandates have given the Secretary of Commerce and NIST important responsibilities for improving the utilization and management of computer and related telecommunications systems in the Federal Government. The NIST through its National Computer Systems Laboratory provides leadership, technical guidance, and coordination of Government efforts in the development of standards and guidelines in these areas.

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James H. Burrows, Director
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Abstract

This standard establishes coding and modulation requirements for 4,800 bit/s modems owned or leased by the Federal Government for use over analog transmission channels. It is based upon techniques described in CCITT Recommendations V.27 bis, V.27 ter, and V.32. This standard supersedes former Federal Standard (FED-STD) 1006 in its entirety.

Key words: analog transmission channels; coding; communications equipment; Federal Information Processing Standard; modulation; telecommunications.

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Announcing the Standard for

CODING AND MODULATION REQUIREMENTS FOR 4,800 BIT/SECOND MODEMS

Federal Information Processing Standards Publications (FIPS PUBS) are issued by the National Institute of Standards and Technology after approval by the Secretary of Commerce 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.

1. Name of Standard. Coding and Modulation Requirements for 4,800 Bit/Second Modems (FIPS PUB 134-1).

2. Category of Standard. Telecommunications Standard.

3. Explanation. This standard establishes coding and modulation requirements for 4,800 bit/s modems owned or leased by the Federal Government for use over analog transmission channels. It is based upon techniques described in CCITT Recommendations V.27 bis, V.27 ter, and V.32. This standard supersedes former Federal Standard (FED-STD) 1006 in its entirety.

4. Approving Authority. Secretary of Commerce.

5. Maintenance Agency. National Communications System, Office of Technology and Standards.

6. Cross Index. Former Federal Standard (FED-STD) 1006, Coding and Modulation Requirements for 4,800 Bit/Second Modems.

7. Related Document. Federal Information Resources Management Regulation 201-8.1, Federal ADP and Telecommunications Standards.

8. Objectives. This standard is to facilitate interoperability between telecommunication facilities and systems of the Federal Government.

9. Applicability. This standard shall be used by all Federal departments and agencies in the design and procurement of 4,800 bit/s modems for use with switched or dedicated nominal 4 kHz channels.

10. Specifications. Affixed.

11. Implementation. The use of this standard by Federal departments and agencies is compulsory and binding, effective April 21, 1989.

12. Waivers. Under certain exceptional circumstances, the heads of Federal departments and agencies may approve waivers to Federal Information Processing Standards (FIPS). The head of such agency may redelegate such authority only to a senior official designated pursuant to section 3506(b) of Title 44, United States Code. Waivers shall be granted only when:

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b. Cause a major adverse financial impact on the operator which is not offset by Government-wide savings.

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Copies of the CCITT Recommendations V.27 and V.32 can be obtained from the National Technical Information Service.

Federal Information Processing Standards Publication 134-1

1988 November 4

Specifications for

CODING AND MODULATION REQUIREMENTS FOR 4,800 BIT/SECOND MODEMS

1. SCOPE

1.1 Description

This standard establishes coding and modulation requirements for 4,800 bit/s modems owned or leased by the Federal Government for use over analog transmission channels. It is based upon techniques described in CCITT Recommendations V.27 bis, V.27 ter, and V.32.

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 departments and agencies in the design and procurement of 4,800 bit/s modems for use with switched or dedicated nominal 4 kHz channels.

2. REQUIREMENTS

2.1 Overview

This standard describes two alternative modem types: 2-wire half-duplex and/or 4-wire duplex modems (section 2.2) and 2-wire duplex modems utilizing echo cancellation technology (section 2.3). Section 2.4 describes common, general characteristics.

2.2 2-Wire Half-Duplex and 4-Wire Duplex Modems

2.2.1 4,800 Bit/s Operation

2.2.1.1 Carrier Frequency

The carrier frequency shall be 1,800±1 Hz.

2.2.1.2 Spectrum

A 50 percent raised cosine energy spectrum shaping shall be equally divided between the modulator and demodulator. The modulator energy spectrum shall be shaped in such a way that, with continuous binary 1 applied to the input of the scrambler, the resulting spectrum shall have a substantially linear phase characteristic over the range of 1,100 Hz to 2,500 Hz and an energy density at 1,000 Hz and 2,600 Hz attenuated 3±2 dB with respect to the maximum energy density between 1,000 Hz and 2,600 Hz.

2.2.1.3 Data and Modulation Rate

The data rate shall be 4,800 bits/s ±.01 percent, i.e., the modulation (symbol) rate shall be 1,600 baud ±.01 percent.

2.2.1.4 Encoding Bits

The data stream to be modulated shall be divided into groups of three consecutive bits (tribits). Each tribit 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 signal element as indicated below.

TRIBIT VALUE			PHASE CHANGE
0	0	1	0°
0	0	0	45°
0	1	0	90°
0	1	1	135°
1	1	1	180°
1	1	0	225°
1	0	0	270°
1	0	1	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 tribits are decoded and the bits are reassembled in correct order. The left-hand digit of the tribit is the one occurring first in the data stream as it enters the modulator portion of the modem after the scrambler.

2.2.2 2,400 Bit/s Operation (Optional)

2,400 bit/s operation, when utilized, shall follow one of the two alternatives described below.

2.2.2.1 Alternative I

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

2.2.2.1.2 Spectrum. A minimum of 50 percent raised cosine energy spectrum shaping shall be equally divided between the modulator and demodulator. The modulator energy spectrum shall be shaped in such a way that, with continuous binary 1 applied to the input of the scrambler, the resulting spectrum shall have a substantially linear phase characteristic over the range of 1,300 Hz to 2,300 Hz and an energy density at 1,200 Hz and 2,400 Hz attenuated 3±2 dB with respect to the maximum energy density between 1,200 Hz and 2,400 Hz.

2.2.2.1.3 Data and Modulation Rate. The data rate shall be 2,400 bits/s ±.01 percent, i.e., the modulation (symbol) rate shall be 1,200 baud ±.01 percent.

2.2.2.1.4 Encoding Bits. For 2,400 bit/s operation, the data stream shall be divided into groups of two 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 signal element as indicated below.

DIBIT VALUE		PHASE CHANGE
0	0	0°
0	1	90°
1	1	180°
1	0	270°

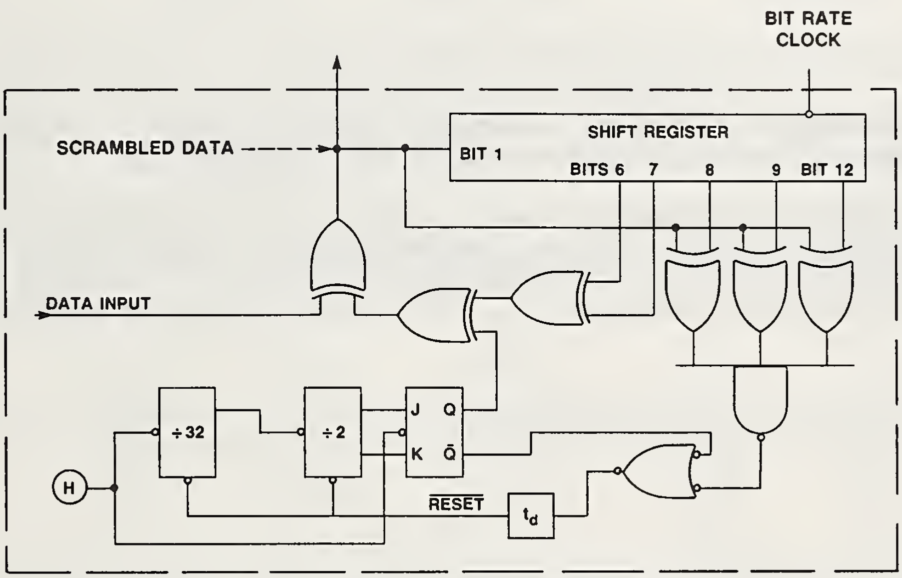
The phase change is the actual on-line phase shift in the transition region from the center of one signal element to the center of the following signal element. At the demodulator, the dibits are decoded and reassembled in the correct order. The left-hand digit of the dibit is the one occurring first in the data stream.

2.2.2.2 Alternative II

FIPS PUB 133 (2,400 bit/s modems) shall be followed completely for 2,400 bit/s operation in lieu of this standard.

2.2.3 Scrambler/Descrambler

A scrambler/descrambler having the generating polynomial $1+x^{-6}+x^{-7}$ with additional guards against repeating patterns of 1, 2, 3, 4, 6, 8, 9, and 12 bits shall be utilized. The purpose of this scrambler is randomization of the data stream in order to maintain convergence of the automatic adaptive equalizer at the demodulator. A typical implementation of such a scrambler is shown below. Logically equivalent circuit designs may be utilized in place of the one shown.



2.2.4 Operating Sequences

Modems shall be capable of operation in accordance with the operating sequences described in this section. However, this does not preclude the use of other, additional operating sequences in applications such as fast-polling.

2.2.4.1 "Turn-On" Sequence

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 being given (e.g., CCITT Interchange Circuit 106 ON), synchronization signals shall be generated by transmitting modems. Two synchronization sequences are defined:

a) A short sequence for operation over well conditioned duplex or one way only channels, and for subsequent turn-around operation over half-duplex channels, and

b) A longer sequence for operation over less conditioned duplex or one way only channels, and for initial establishment of connections over half-duplex channels.

During half-duplex operation, sequence (b) is only used after the first OFF to ON transition of Request to Send indication following the OFF to ON transition of Data Mode indication (e.g., CCITT Interchange Circuit 107), or at the OFF to ON transition of Data Mode indication if Request to Send indication is already ON. After every subsequent OFF to ON transition of Request to Send indication, sequence (a) is used. The "turn-on" sequences, for both data rates, are divided into three segments as follows:

	Segment 1	Segment 2	Segment 3	Total of Segments	
Type of Signal	Continuous 180° Phase Reversals	0° and 180° Conditioning Pattern	Continuous Scrambled Binary 1	Nominal Total "Turn-on" Sequence Time	
				4,800	2,400
Number of Symbol Intervals (S.I.)	a) 14 S.I. b) 50 S.I.	a) 58 S.I. b) 1,074 S.I.	a) 8 S.I. b) 8 S.I.	50 ms 708 ms	67 ms 943 ms

2.2.4.1.1 The composition of segment 1 is continuous 180° phase reversals, for 14 symbol intervals in the case of sequence (a) and for 50 symbol intervals in the case of sequence (b).

2.2.4.1.2 Segment 2 is composed of an equalizer conditioning pattern containing either 58 or 1,074 0° and 180° phase changes. This pattern shall follow the following numerical sequence, where 1 = 0° and 7 = 180°. For 58 symbol intervals of pattern, the first 58 numbers are used. For 1,074 symbol intervals, the 127 numbers are repeated eight times and then the first 58 numbers are repeated a ninth time.

17777	71111	77717	11717	11777	71777
17711	17111	17177	71177	11717	71177
71117	71717	17111	71717	71771	71111
11177	11111	71171	11777	77717	17777
11711	77				

2.2.4.1.3 Segment 3 simulates scrambled binary 1 for eight symbol intervals. At the end of this segment, Clear to Send indication (e.g., CCITT Interchange Circuit 106) is turned ON and data is applied to the input to the scrambler. The segment 3 patterns for 4,800 and 2,400 bits/s are 270°, 225°, 315°, 90°, 45°, 45°; 180°, 180° and 270°, 90°, 270°, 270°, 270°, 270°, 0°, 0°, respectively. At the end of segment 3, scrambler shift register bit positions 1–12 contain 11111 10000 00 for 4,800 bit/s operation, and 00000 10101 01 for 2,400 bit/s operation.

[Note: these segments are equivalent to CCITT Recommendations V.27 bis and ter].

2.2.4.2 Echo Protection

Modems capable of half-duplex operation shall:

2.2.4.2.1 Be capable of transmitting, immediately prior to the "turn-on" sequence, an echo protection sequence consisting of 185 to 200 ms of unmodulated carrier followed by 20 to 25 ms of no transmitted energy.

2.2.4.2.2 When using the echo protection sequence described above, be capable of withholding Receiver Ready indication (e.g., CCITT Interchange Circuit 109 ON) after the end of each modem transmission for 150±25 ms to protect against the effect of line echoes.

2.2.4.2.3 Withhold Receiver Ready indication (e.g., CCITT Interchange Circuit 109 ON) during reception of unmodulated carrier.

2.2.4.3 "Turn-Off" Sequence

Line signals shall be transmitted after the ON to OFF transition of Request to Send indication (e.g., CCITT Interchange Circuit 105) as indicated below:

Type of Line Signal	Remaining Data Followed by Continuous Scrambled Binary 1	No Transmitted Energy	Total "Turn-off" Time
Duration	5–10 ms	20–22 ms	25–32 ms

If an OFF to ON transition of the Request to Send occurs during transmission of the "turn-off" sequence, it is not taken into account until the end of the "turn-off" sequence.

2.2.5 Secondary Channel (Optional)

2.2.5.1

Characteristic frequencies of the 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 secondary channel shall be 6.0±0.6 dB lower in power level than the primary channel.

2.2.5.3

When the 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 fast-polling and 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 Input Sensitivity

The modem demodulator shall have an input sensitivity adjustable to −42±3 dBm and −32±3 dBm. When the above-stated input sensitivities are used, the input level dynamic range shall be at least 30 dB above the input sensitivity.

2.3 2-Wire Duplex, 4,800 Bit/s Modems

2.3.1 Carrier Frequency

The carrier frequency shall be 1,800±1 Hz.

2.3.2 Spectrum

The modulator energy spectrum shall be shaped in such a way that, with continuous binary 1 applied to the input of the scrambler, the resulting spectrum shall have an energy density at 600 Hz and 3,000 Hz attenuated 4.5±2.5 dB with respect to the maximum energy density between 600 Hz and 3,000 Hz.

2.3.3 Data and Modulation Rate

The data rate shall be 4,800 bits/s ±.01 percent, i.e., the modulation (symbol) rate shall be 2,400 baud ±.01 percent.

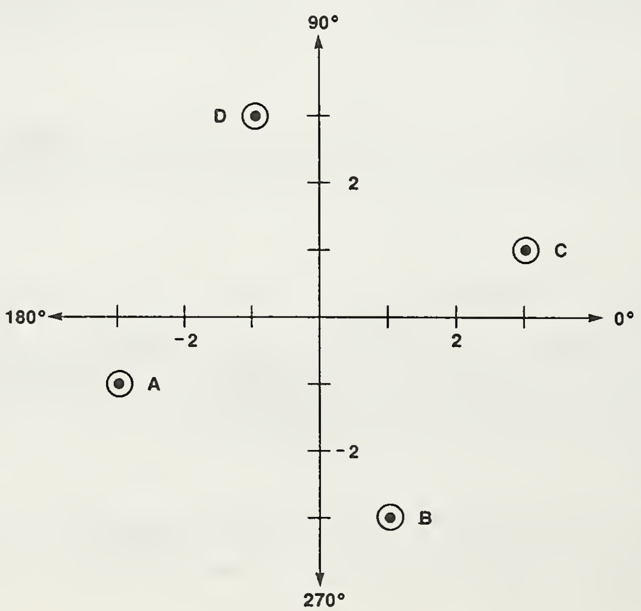
2.3.4 Encoding Bits

The data stream shall be divided into groups of two 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 signal element as indicated below.

DIBIT VALUE		PHASE CHANGE
0	0	90°
0	1	0°
1	0	180°
1	1	270°

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 reassembled in the correct order. The left-hand digit of the dibit is the one occurring first in the data stream.

The four permitted signal states are shown in the following diagram. (The letters A, B, C, and D in the diagram are referred to in section 2.3.7.)



2.3.5 Modem Configuration

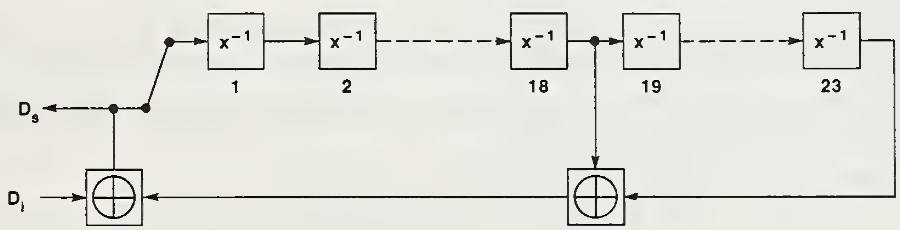
When operating on circuit switched (e.g., telephone) networks and utilizing automatic answering equipment, modems at calling locations shall be configured as calling modems. Likewise, modems at called locations shall be configured as called modems. In other cases, the determination as to which modems shall act as calling and called modems shall be decided by bilateral agreement.

2.3.6 Scrambler/Descrambler

The scrambler in the calling modem and descrambler in the called modem shall have the generating polynomial:

$$1+x^{-18}+x^{-23}$$

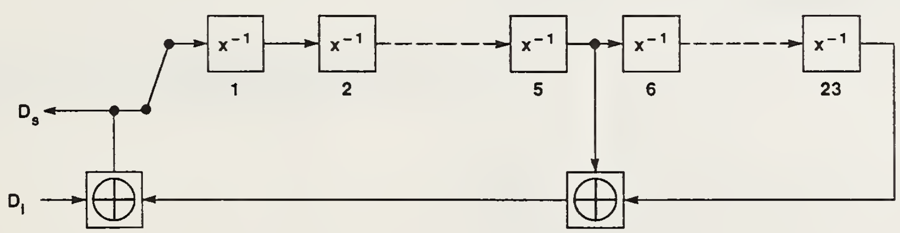
A diagram showing such a scrambler, where Di represents input data to the scrambler and Ds represents scrambled output data, is shown below. (Logically equivalent configurations may be utilized in place of the one shown.)



The scrambler in the called modem and descrambler in the calling modem shall have the generating polynomial:

$$1+x^{-5}+x^{-23}$$

A diagram showing such a scrambler, where Di represents input data to the scrambler and Ds represents scrambled output data, is shown below. (Logically equivalent configurations may be utilized in place of the one shown.)



2.3.7 Operational Procedures

2.3.7.1 Overview

Prior to describing start-up and retrain procedures, it is necessary to define a particular Training Sequence, Rate Signal, and Ending Rate Signal.

2.3.7.2 Training Sequence

The Training Sequence is generated by scrambling binary 1's. The initial state of the scrambler shift register is all ZEROs. For the first 256 symbol intervals, if the first bit in time of the dibits produced by the scrambler is a ZERO, signal state A shall be transmitted, and if a ONE, signal state C shall be transmitted (see diagram in section 2.3.4). Immediately following, for the remainder of the 1,280 to 8,192 symbol interval long Training Sequence, signal states shall be transmitted using the following table.

DIBIT VALUE		SIGNAL STATE
0	0	A
0	1	B
1	1	C
1	0	D

2.3.7.3 Rate Signal

The 16-bit Rate signal shall have bits 1, 2, 3, 4, 8, 12, and 16 set to 0, 0, 0, 0, 1, 1, and 1 respectively for synchronization and identification. The remaining nine bits are allocated as follows:

Bit 5 a ONE denotes ability to receive data at a 2,400 bits/s "fallback" rate [technique to be determined]

Bit 6 a ONE denotes ability to receive data at 4,800 bits/s

Bit 7 a ONE denotes ability to receive data at 9,600 bits/s

Note: If bits 5, 6, and 7 are all set to ZERO, the call should be terminated.

Bit 9 a ONE denotes availability of trellis coding at highest data rate (i.e. 9,600 bits/s)

Bits 10, 11, 13, 14, and 15

Normally ZERO (ONE coding reserved for future use)

2.3.7.4 Ending Rate Signal

The 16-bit Ending Rate signal shall have bits 1, 2, 3, 4, 8, 12, and 16 set to all ONEs. The coding of the remaining nine bits shall be as in the previous section, except that the coding shall only indicate the data rate (and use of trellis coding) of the scrambled binary 1's and data following transmission of the Ending Rate Signal.

2.3.7.5 Start-Up Procedure

The following state sequence shall be followed for start-up operation.

CALLING MODEM | **CALLED MODEM**

1. Silence after establishment of connection.

2. Silence after establishment of connection for 1.8 –2.5 s.

3. Transmit 2,100 ± 15 Hz Answer Tone, optionally containing 180° ± 10° phase reversals every 450 ± 25 ms to disable network echo cancellers, for 3.3 ± 0.7 s.

4. Silent period for 75 ± 20 ms.

5. Upon detection of 2,100 Hz Answer Tone for at least 1 s, repetitively transmit signal state A (see figure in sec. 2.3.4).

6. Transmit alternating signal states A and C (see figure in sec. 2.3.4). After both transmitting alternating signal states A and C for an even number of symbol intervals greater than 127 and signal state A has been detected for at least 64 symbol intervals, start a timer (used to determine round trip transmission delay) and change to transmitting alternating signal states C and A.

7. After detection of the A and C to C and A reversal, start a timer (used to determine round trip transmission delay) and change to transmitting repetitive signal state C. The time delay between the reception of the start of alternating C and A at the input to the modem and the transmission of repetitive signal state C by the modem shall be 64 ± 2 symbol intervals.

8. Upon detection of signal state C, stop the timer and, after transmitting an even number of C and A signal states, change to transmitting alternating signal states A and C. The time delay between the reception of the start of signal state C at the input to the modem and the transmission of alternating signal states A and C shall be 64 ± 2 symbol intervals.

9. Upon detection of the C and A to A and C reversal, stop the timer and cease transmission.

10. When a silent period is detected, the modem may temporarily continue transmitting alternating signal states A and C but shall then cease transmission for 16 symbol intervals. Then, optionally, an unspecified pattern may be transmitted to help train the local modem echo canceller.

11. Next, transmit 256 symbol intervals of alternating signal states A and B; 16 symbol intervals of alternating signal states C and D; and the Training Sequence described in section 2.3.7.2.

12. Transmit the Rate Signal (R1) described in section 2.3.7.3, repetitively.

13. Upon successful detection of the Rate Sequence (R1), transmit alternating signal states A and B for a period equal to the previously timed round trip delay. Then, optionally, an unspecified pattern may be transmitted to help train the local modem echo canceller.

14. Upon detection of alternating signal states A and B, cease transmission.

15. Transmit the signals described in step 11 above.

16. Transmit the Rate Signal (R2) repetitively, taking into account the rates and coding previously indicated.

17. After waiting the previously timed round trip delay, receiving the alternating patterns and Training Sequence, and upon successful detection of the Rate Signal (R2), transmit the signals described in step 11 above.

18. Transmit the Rate Signal (R3), repetitively, indicating the rate and coding to be used.

19. Upon successful detection of the Rate Signal (R3), transmit a single Ending Rate Signal (ER2) and then transmit continuous scrambled binary 1.

20. Upon detecting the Ending Rate Signal (ER2), complete transmitting any partially transmitted Rate Signal (R3), transmit the Ending Rate Signal (ER3), and transmit scrambled binary 1 for 128 symbol intervals. Then, indicate Clear to Send (e.g., CCITT Interchange Circuit 106 ON) and begin transmitting data.

21. After detecting the Ending Rate Signal (ER3), continue transmitting continuous scrambled binary 1 for 128 symbol intervals. Then, indicate Clear to Send (e.g., CCITT Interchange Circuit 106 ON) and begin transmitting data.

2.3.7.6 Retrain Procedure

Retrain may be initiated during data transmission by either the calling or called modem. During retrain, modems shall perform the following:

a) Calling Modem. When initiating retrain or upon detection of alternating signal states A and C (see section 2.3.4) for more than 128 symbol intervals, the modem shall turn off Clear to Send indication (e.g., CCITT Interchange Circuit 106 OFF) and repetitively transmit signal state A.

b) Called Modem. Upon detection of signal state A for more than 128 symbol intervals, the modem shall turn off Clear to Send indication (e.g., CCITT Interchange Circuit 106 OFF), start a timer, and transmit alternating signal states A and C for an even number of symbol intervals equal to or greater than 64. When initiating retrain, the modem shall turn off Clear to Send indication (e.g., CCITT Interchange Circuit 106 OFF), start a timer, and transmit alternating signal states A and C for an even number of symbol intervals equal to or greater than 64.

The retrain sequence then follows the Start-up Sequence, section 2.3.7.5, starting at step 7.

2.3.8 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.

2.3.8.1 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.

2.3.8.2 Intra-character Rate Tolerance

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

2.3.8.3 Deletion of Stop Bits

When the character rate multiplied by the number of bits per character is greater than 4,800 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.

2.3.8.4 Addition of Stop Bits

When the character rate multiplied by the number of bits per character is less than 4,800 bits/s, the start-stop to synchronous converter shall insert extra stop bits between transmitted characters as necessary.

2.3.8.5 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.

2.3.9 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.

2.3.9.1 Start of Remote Loopback

The following signals are transmitted, at the operating data rate, as would digital data entering a modem (e.g., on CCITT Interchange Circuit 103). When instructed by data terminal equipment to conduct a remote loopback test (e.g., CCITT Interchange Circuit 140 ON), Modem A shall transmit a 2,048 bit Preparatory Pattern, produced by scrambling constant binary 0 with the polynomial $1+x^{-4}+x^{-7}$. (The scrambler shift register may be in any state at the start of operation.) Modem B, upon recognition of the Preparatory Pattern, shall transmit an Acknowledgment Pattern, produced by scrambling constant binary 1 with the polynomial $1+x^{-4}+x^{-7}$ (The shift register may be in any state at the start of operation) and activate the remote loopback function. Modem A, upon recognition of the Acknowledgement Pattern, shall wait a 2,048 bit-time period and then indicate remote loopback has been established (e.g., CCITT Interchange Circuit 142 ON).

2.3.9.2 Termination of Remote Loopback

When Modem A is instructed to terminate a remote loopback test (e.g., CCITT Interchange Circuit 140 OFF), it shall transmit a 8,192 bit Termination Pattern, produced by scrambling constant binary 1 with the polynomial $1+x^{-4}+x^{-7}$ followed by 64 binary 1's. (The scrambler shift register may be in any state at the start of operation.) Modem B shall terminate the remote loopback: 1) upon recognition of the Termination Pattern; 2) if receive signal is absent for greater than 1 s; or, optionally, upon time-out of a timer started at the beginning of remote loopback.

2.4 General Characteristics

2.4.1 Impedance

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

2.4.2 Output Signal Level

The 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.

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