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SERIES V: DATA COMMUNICATION OVER THE
TELEPHONE NETWORK

Interfaces and voiceband modems

**A modem operating at data signalling rates
of up to 33 600 bit/s for use on the general
switched telephone network and on leased
point-to-point 2-wire telephone-type circuits**

ITU-T Recommendation V.34

(Previously CCITT Recommendation)

ITU-T V-SERIES RECOMMENDATIONS
DATA COMMUNICATION OVER THE TELEPHONE NETWORK

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ITU-T RECOMMENDATION V.34

A MODEM OPERATING AT DATA SIGNALLING RATES OF UP TO 33 600 bit/s FOR USE ON THE GENERAL SWITCHED TELEPHONE NETWORK AND ON LEASED POINT-TO-POINT 2-WIRE TELEPHONE-TYPE CIRCUITS

Source

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FOREWORD

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**A MODEM OPERATING AT DATA SIGNALLING RATES OF UP
TO 33 600 bit/s FOR USE ON THE GENERAL SWITCHED TELEPHONE
NETWORK AND ON LEASED POINT-TO-POINT 2-WIRE
TELEPHONE-TYPE CIRCUITS**

(revised in 1998)

1 Scope

This modem is intended for use on connections on General Switched Telephone Networks (GSTNs) and on point-to-point 2-wire leased telephone-type circuits. The principal characteristics of the modem are as follows:

- a) duplex and half-duplex modes of operation on GSTN and point-to-point 2-wire leased circuits;
- b) channel separation by echo cancellation techniques;
- c) Quadrature Amplitude Modulation (QAM) for each channel with synchronous line transmission at selectable symbol rates including the mandatory rates of 2400, 3000, and 3200 symbols/s and the optional rates of 2743, 2800 and 3429 symbols/s;
- d) synchronous primary channel data signalling rates of:
 - 33 600 bit/s (Optional);
 - 31 200 bit/s (Optional);
 - 28 800 bit/s;
 - 26 400 bit/s;
 - 24 000 bit/s;
 - 21 600 bit/s;
 - 19 200 bit/s;
 - 16 800 bit/s;
 - 14 400 bit/s;
 - 12 000 bit/s;
 - 9600 bit/s;
 - 7200 bit/s;
 - 4800 bit/s;
 - 2400 bit/s;
- e) trellis coding for all data signalling rates;
- f) an optional auxiliary channel with a synchronous data signalling rate of 200 bit/s, a portion of which may be provided to the user as an asynchronous secondary channel;
- g) adaptive techniques that enable the modem to achieve close to the maximum data signalling rate the channel can support on each connection;
- h) exchange of rate sequences during start-up to establish the data signalling rate;
- i) automoding to V-Series modems supported by V.32 bis automode procedures and Group 3 facsimile machines.

2 References

The following Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; all users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent editions of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

- ITU-T Recommendation T.30 (1996), Procedures for document facsimile transmission in the general switched telephone network.
- ITU-T Recommendation V.8 (1998), Procedures for starting sessions of data transmission over the public switched telephone network.
- ITU-T Recommendation V.10 (1993), Electrical characteristics for unbalanced double-current interchange circuits operating at data signalling rates nominally up to 100 kbit/s.
- ITU-T Recommendation V.11 (1996), Electrical characteristics for balanced double-current interchange circuits operating at data signalling rates up to 10 Mbit/s.
- ITU-T Recommendation V.14 (1993), Transmission of start-stop characters over synchronous bearer channels.
- CCITT Recommendation V.21 (1984), 300 bits per second duplex modem standardized for use in the general switched telephone network.
- ITU-T Recommendation V.24 (1996), List of definitions for interchange circuits between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE).
- ITU-T Recommendation V.25 (1996), Automatic answering equipment and general procedures for automatic calling equipment on the general switched telephone network including procedures for disabling of echo control devices for both manually and automatically established calls.
- ITU-T Recommendation V.28 (1993), Electrical characteristics for unbalanced double-current interchange circuits.
- ITU-T Recommendation V.32 (1993), A family of 2-wire, duplex modems operating at data signalling rates of up to 9600 bit/s for use on the general switched telephone network and on leased telephone-type circuits.
- CCITT Recommendation V.32 bis (1991), A duplex modem operating at data signalling rates of up to 14 400 bit/s for use on the general switched telephone network and on leased point-to-point 2-wire telephone-type circuits.
- ITU-T Recommendation V.42 (1996), Error-correcting procedures for DCEs using asynchronous-to-synchronous conversion.
- CCITT Recommendation V.54 (1988), Loop test devices for modems.
- ISO 2110:1989, Information technology – Data communication – 25-pole DTE/DCE interface connector and contact number assignments.
- ISO/IEC 11569:1993, Information technology – Telecommunications and information exchange between systems – 26-pole interface connector mateability dimensions and contact number assignments.

3 Definitions

This Recommendation defines the following terms.

3.1 auxiliary channel: A 200 bit/s data channel which, along with the primary channel, is multiplexed into the bit stream transmitted by the modem. Data conveyed in the auxiliary channel is independent from the primary channel and may consist of secondary channel data and modem control data. Modem control channel procedures that may be used between consenting modems are detailed in Annex A.

3.2 constellation shaping: A method for improving noise immunity by introducing a non-uniform two-dimensional probability distribution for transmitted signal points. The degree of constellation shaping is a function of the amount of constellation expansion.

- 3.3 data mode modulation parameters:** Parameters determined during start-up and used during data mode transmission.
- 3.4 frame switching:** A method for sending a fractional number of bits per mapping frame, on average, by alternating between sending an integer $b - 1$ bits per mapping frame and b bits per mapping frame according to a periodic switching pattern.
- 3.5 line probing:** A method for determining channel characteristics by sending periodic signals, which are analysed by the modem and used to determine data mode modulation parameters.
- 3.6 nominal transmit power:** Reference transmit power that is configured by the user. A modem that has negotiated a transmit power reduction in Phase 2 of the start-up procedures is said to be transmitting below the Nominal Transmit Power.
- 3.7 non-linear encoding:** A method for improving distortion immunity near the perimeter of a signal constellation by introducing a non-uniform two-dimensional (2D) signal point spacing.
- 3.8 precoding:** A non-linear equalization method for reducing equalizer noise enhancement caused by amplitude distortion. Equalization is performed at the transmitter using precoding coefficients provided by the remote modem.
- 3.9 pre-emphasis:** A linear equalization method where the transmit signal spectrum is shaped to compensate for amplitude distortion. The pre-emphasis filter is selected using a filter index provided by the remote modem.
- 3.10 primary channel:** The main data channel which, together with auxiliary channel data, constitutes the bit stream transmitted by the modem.
- 3.11 recipient modem:** The modem which receives primary channel data in half-duplex mode.
- 3.12 secondary channel:** A portion of the auxiliary channel that is made available to the user.
- 3.13 shell mapping:** A method for mapping data bits to signal points in a multi-dimensional signal constellation, which involves partitioning a two-dimensional signal constellation into rings containing an equal number of points.
- 3.14 source modem:** The modem which transmits primary channel data in half-duplex mode.
- 3.15 trellis encoding:** A method for improving noise immunity using a convolutional coder to select a sequence of subsets in a partitioned signal constellation. The trellis encoders used in this Recommendation are all four-dimensional (4D) and they are used in a feedback structure where the inputs to the trellis encoder are derived from the signal points.

4 Abbreviations

This Recommendation uses the following abbreviations:

abs[]	Absolute value
AMP	Auxiliary channel Multiplexing Pattern
CCITT	International Telegraph and Telephone Consultative Committee
CME	Circuit Multiplication Equipment
CRC	Cyclic Redundancy Check
DCE	Data Circuit-terminating Equipment
DPSK	Differential Phase Shift Keying
DTE	Data Terminal Equipment
GPA	Generating Polynomial – Answer modem
GPC	Generating Polynomial – Call modem
GSTN	General Switched Telephone Network
IEC	International Electrotechnical Commission

ISO	International Organization for Standardization
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
LSB	Least Significant Bit
MSB	Most Significant Bit
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RTDEa	Round Trip Delay Estimate – Answer modem
RTDEc	Round Trip Delay Estimate – Call modem
SWP	Switching Pattern

5 Line signals

5.1 Data signalling rates

The primary channel shall support synchronous data signalling rates of 2400 bit/s to 33 600 bit/s in multiples of 2400 bit/s. An auxiliary channel with a synchronous data signalling rate of 200 bit/s may also be optionally supported. The primary and auxiliary data signalling rates shall be determined during Phase 4 of modem start-up according to the procedures described in 11.4 or 12.4. The auxiliary channel shall be used only when the call and answer modems have both declared this capability. The primary channel data signalling rates can be asymmetric.

5.2 Symbol rates

The symbol rate shall be $S = (a/c) \cdot 2400 \pm 0.01\%$ two-dimensional (2D) symbols per second, where a and c are integers from the set specified in Table 1 (in which symbol rates are shown rounded to the nearest integer). The symbol rates 2400, 3000, and 3200 are mandatory; 2743, 2800, and 3429 are optional. The symbol rate shall be selected during Phase 2 of modem start-up according to the procedures described in 11.2 or 12.2. Asymmetric symbol rates are optionally supported and shall be used only when the call and answer modems have both declared this capability.

Table 1/V.34 – Symbol rates

Symbol rate, S	a	c
2400	1	1
2743	8	7
2800	7	6
3000	5	4
3200	4	3
3429	10	7

5.3 Carrier frequencies

The carrier frequency shall be $(d/e) \cdot S$ Hz, where d and e are integers. One of two carrier frequencies can be selected at each symbol rate, as specified in Table 2, which gives the values of d and e and the corresponding frequencies rounded to the nearest integer. The carrier frequency shall be determined during Phase 2 of modem start-up according to the procedures specified in 11.2 or 12.2. Asymmetric carrier frequencies shall be supported.

Table 2/V.34 – Carrier frequencies versus symbol rate

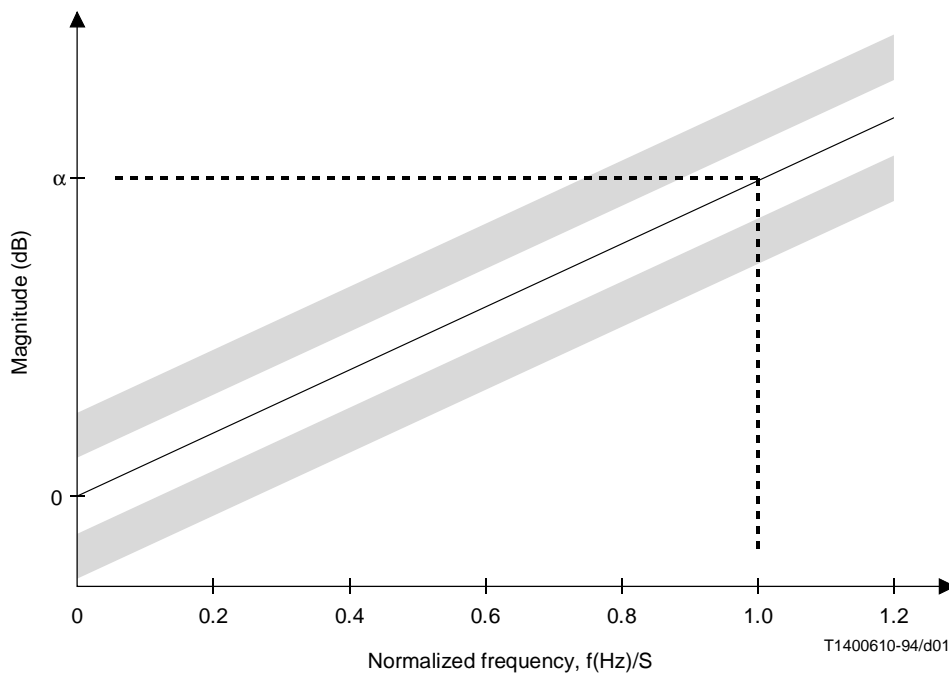
Symbol rate, S	Low carrier			High carrier		
	Frequency	d	e	Frequency	d	e
2400	1600	2	3	1800	3	4
2743	1646	3	5	1829	2	3
2800	1680	3	5	1867	2	3
3000	1800	3	5	2000	2	3
3200	1829	4	7	1920	3	5
3429	1959	4	7	1959	4	7

5.4 Pre-emphasis

5.4.1 Transmit spectrum specifications

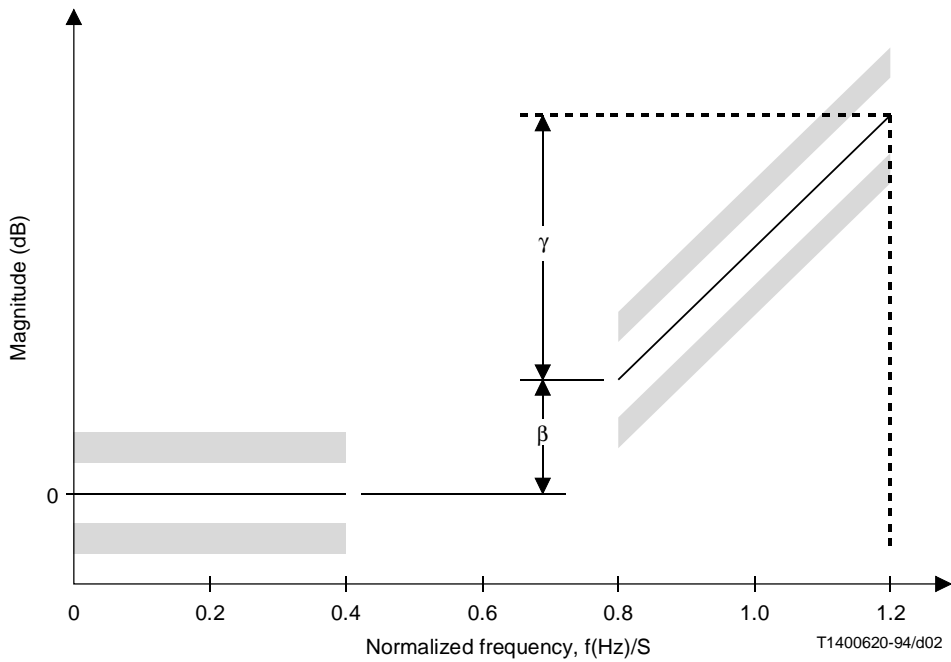
The transmit spectrum specifications use a normalized frequency, which is defined as the ratio f/S , where f is the frequency in Hz and S is the symbol rate.

The magnitude of the transmitted spectrum shall conform to the templates shown in Figures 1 and 2 for normalized frequencies in the range from $(d/e - 0.45)$ to $(d/e + 0.45)$. The transmitted spectrum shall be measured using a 600Ω pure resistive load. See also Tables 3 and 4.



NOTE – Tolerance for transmit spectrum is ± 1 dB.

Figure 1/V.34 – Transmit spectra templates for indices 0 to 5



NOTE – Over the range specified, the tolerance for the transmit spectrum magnitude is ± 1 dB.

Figure 2/V.34 – Transmit spectra templates for indices 6 to 10

Table 3/V.34 – Parameter α for indices 0 to 5

Index	α
0	0 dB
1	2 dB
2	4 dB
3	6 dB
4	8 dB
5	10 dB

Table 4/V.34 – Parameters β and γ for indices 6 to 10

Index	β	γ
6	0.5 dB	1.0 dB
7	1.0 dB	2.0 dB
8	1.5 dB	3.0 dB
9	2.0 dB	4.0 dB
10	2.5 dB	5.0 dB

5.4.2 Selection method

The transmitted spectrum shall be specified by a numerical index. The index shall be provided by the remote modem during Phase 2 of start-up by the procedures defined in 11.2. or 12.2.

6 DTE interfaces

Where external physical interfaces for the interchange circuits are not present, the equivalent functionality of the circuits must still be provided (see Table 5).

Table 5/V.34 – Interchange circuits for combined primary and secondary channel interfaces

Interchange circuit		Notes
No.	Description	
102 103 104 105 106	Signal ground or common return Transmitted data Received data Request to send Ready for sending	
107 108/1 or 108/2 109	Data set ready Connect data set to line Data terminal ready Data channel received line signal detector	
113 114 115 125 133 140 141 142	Transmitter signal element timing (DTE source) Transmitter signal element timing (DCE source) Receiver signal element timing (DCE source) Calling indicator Ready for receiving Loopback/maintenance Local loopback Test indicator	1 2 2 3
118 119 120 121 122	Transmitted secondary channel data Received secondary channel data Transmit secondary channel line signal Secondary channel ready Secondary channel received line signal detector	4 4 4, 5 4, 5 4, 5, 6
<p>NOTE 1 – When the modem is not operating in a synchronous mode at the interface, any signals on this circuit shall be disregarded. Many DTEs operating in an asynchronous mode do not have a generator connected to this circuit.</p> <p>NOTE 2 – When the modem is not operating in a synchronous mode at the interface, this circuit shall be clamped to the OFF condition. Many DTEs operating in an asynchronous mode do not terminate this circuit.</p> <p>NOTE 3 – Operation of Circuit 133 shall be in accordance with 7.3.1/V.42.</p> <p>NOTE 4 – This circuit is provided where the optional secondary channel is implemented without a separate interface.</p> <p>NOTE 5 – This circuit need only be provided where required by the application.</p> <p>NOTE 6 – This circuit is in the ON condition if Circuit 109 is in the ON condition and the optional secondary channel is enabled.</p>		

Where a separate interface is provided for the optional secondary channel, interchange circuits as specified in Table 6 shall be provided.

Table 6/V.34 – Interchange circuits for a separate secondary channel interface

Interchange circuit		Notes
No.	Description	
102 103 104 105 106	Signal ground or common return Transmitted data Received data Request to send Ready for sending	1
107 108/2 109	Data set ready Data terminal ready Data channel received line signal detector	1, 2 1 1, 2
NOTE 1 – This circuit need only be provided where required by the application.		
NOTE 2 – This circuit is in the ON condition if the corresponding interchange circuit of the primary channel is in the ON condition and the optional secondary channel is enabled.		

6.1 Synchronous interfacing (primary channel only)

The modems shall accept synchronous data from the DTE on Circuit 103 (see Recommendation V.24) under control of Circuit 113 or 114. The modem shall pass synchronous data to the DTE on Circuit 104 under control of Circuit 115. The modem shall provide to the DTE a clock on Circuit 114 for transmit-data timing, and a clock on Circuit 115 for receive-data timing. The transmit-data timing may, however, originate in the DTE and be transferred to the modem via Circuit 113. In some applications, it may be necessary to synchronize the transmitter timing to the receiver timing inside the modem.

After the start-up and retrain sequences, Circuit 106 must follow the state of Circuit 105 within 2 ms.

OFF to ON and ON to OFF transitions of Circuit 109 shall occur solely in accordance with the operating sequences defined in clauses 11 and 12.

6.2 Asynchronous character-mode interfacing

6.2.1 Primary channel

The modem may include an asynchronous-to-synchronous converter interfacing to the DTE in an asynchronous (or start-stop character) mode. The protocol for the conversion shall be in accordance with Recommendation V.14 or V.42. Data compression may also be employed.

6.2.2 Secondary channel

The secondary channel is for asynchronous mode only. However, since the modulation process operates synchronously, an asynchronous-to-synchronous conversion combined with a data flow control shall be provided, as specified in 6.2.2.1.

6.2.2.1 DTE-to-DCE flow control on the secondary channel interface

The modem shall indicate to the secondary channel DTE a temporary inability to accept data on either Circuit 103 or 118 (DCE-not-ready condition). Upon receiving such an indication, the DTE should complete transmission of any partially transmitted character and then cease transmitting data on Circuit 103 (118) and clamp Circuit 103 (118) to binary 1. When the DCE-not-ready condition is cleared, the DTE may resume the transmission of data on Circuit 103 (118). The flow control indication may be performed in one of two ways:

- a) Using Circuit 106 (121) – A DCE-not-ready condition may be indicated by turning Circuit 106 (121) OFF and cleared by turning Circuit 106 (121) ON.
- b) Using DC1/DC3 characters (XON/XOFF functions) – A DCE-not-ready condition may be indicated by transmitting a DC3 character and cleared by transmitting a DC1 character on Circuit 104 (119).

Both techniques a) and b) shall be provided. The choice of technique is a user-configurable option.

The response time of the DTE to an indication of a DCE-not-ready condition is for further study. This time should be kept as short as possible. DCEs shall accommodate latency in the DTE recognition of the DCE-not-ready indication by accepting additional characters on Circuit 103 (118) after the indication is given.

If a break signal is the next item to be delivered across the DTE/DCE interface, it shall be delivered regardless of the flow control state. In the case of a non-expedited/non-destructive break, data to be delivered prior to the break remains subject to flow control.

NOTE 1 – No DCE-to-DTE flow control is provided on the secondary channel.

NOTE 2 – The alternative use of the asynchronous-to-synchronous conversion in accordance with Recommendation V.14 is still under consideration; in this case, DTE-to-DCE flow control may be optional.

6.3 Half-duplex mode interfacing

Where the modem is operating in the half-duplex mode, the primary channel and control channel share the primary channel interchange circuits given in Table 5. The mechanism for allocation of data to the primary or control channel is beyond the scope of this Recommendation.

6.4 Electrical characteristics of interchange circuits

6.4.1 Primary channel

Where an external physical interface is provided, electrical characteristics conforming to Recommendations V.10 and V.11 shall be used. The connector and pole assignments specified by ISO 2110 or ISO/IEC 11569, column "V-Series > 20 000 bit/s", shall be used. Alternatively, when the DTE-DCE interface speed is not designed to exceed 116 kbit/s, these same connectors may be used with characteristics conforming to Recommendation V.10 only (see Note).

NOTE – In this case, ISO is presently considering assigning the same pole assignments in ISO 2110 and ISO/IEC 11569 as those presently assigned for interfaces using V.28 electrical characteristics under the heading "V-Series < 20 000 bit/s".

6.4.2 Secondary channel

Where an external physical interface is provided for the secondary channel, electrical characteristics in accordance with Recommendation V.10 shall be used (see Note under 6.4.1).

6.5 Fault condition on interchange circuits

The DCE shall interpret a fault condition on Circuits 105, 108 and 120 (where provided) as an OFF condition using failure detection type 1.

All other circuits not referred to may use failure detection type 0 or 1.

NOTE 1 – The DTE interprets a fault condition on Circuit 107 as an OFF condition using failure detection type 1.

NOTE 2 – See clause 10/V.10 for the definition of failure detection types.

6.6 Thresholds and response times of Circuit 109

6.6.1 Duplex mode

Thresholds and response times are not applicable in duplex mode because a line signal detector cannot be expected to distinguish wanted received signals from unwanted talker echoes.

6.6.2 Half-duplex mode

Circuit 109 shall turn OFF 20 to 25 ms after the level of the received signal appearing at the line terminals of the modem falls below the relevant threshold defined as follows:

- Greater than – 43 dBm: Circuit 109 ON.
- Less than – 48 dBm: Circuit 109 OFF.

The condition of Circuit 109 between the ON and OFF levels is not specified except that the signal detector shall provide hysteresis, such that the level at which the OFF to ON transition occurs shall be at least 2 dB greater than that for the ON to OFF transition.

7 Scrambler

A self-synchronizing scrambler shall be included in the modem for the primary channel data. Auxiliary channel data is not scrambled. Each transmission direction uses a different scrambler. According to the direction of transmission, the generating polynomial is:

Call mode modem generating polynomial: $(GPC) = 1 + x^{-18} + x^{-23}$ (7-1)

or:

Answer mode modem generating polynomial: $(GPA) = 1 + x^{-5} + x^{-23}$ (7-2)

At the transmitter, the scrambler shall effectively divide the primary channel data sequence by the generating polynomial. The coefficients of the quotients of this division, taken in descending order, form the data sequence which shall appear at the output of the scrambler.

8 Framing

8.1 Overview

Figure 3 provides an overview of the frame structure.

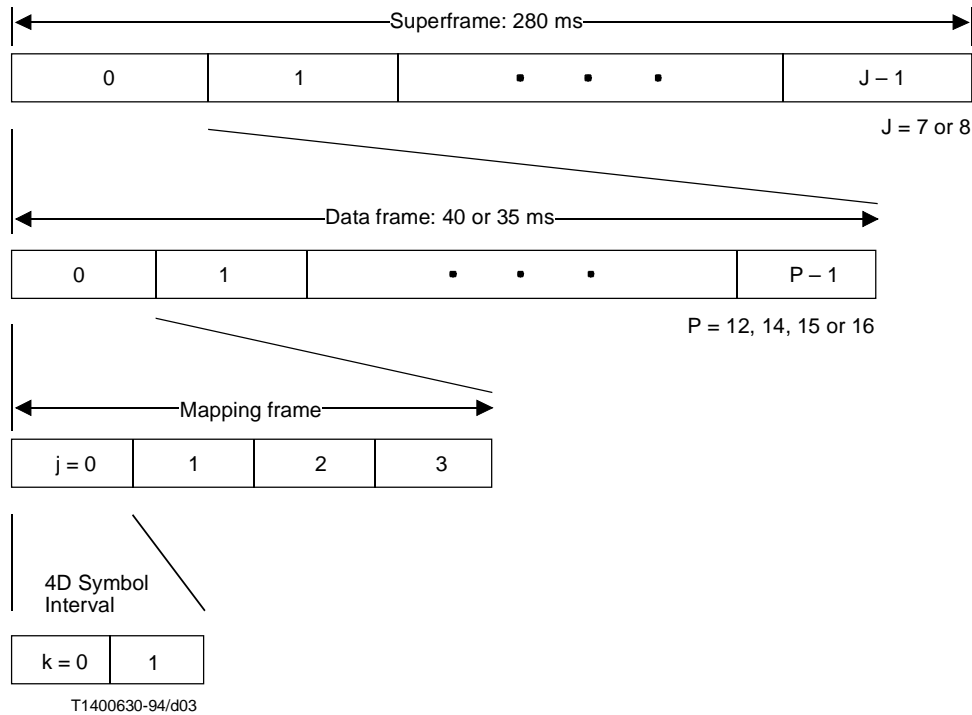


Figure 3/V.34 – Overview of framing and indexing

The duration of a superframe is 280 ms. A superframe shall consist of J data frames, where J = 7 at symbol rates 2400, 2800, 3000, and 3200, and J = 8 at symbol rates 2743 and 3429. A data frame shall consist of P mapping frames, where P is specified in Table 7. A mapping frame shall consist of four four-dimensional (4D) symbol intervals. A 4D symbol interval shall consist of two 2D symbol intervals. A bit inversion method shall be used for superframe synchronization (see 9.6.3).

Table 7/V.34 – Framing parameters

Symbol rate, S	J	P
2400	7	12
2743	8	12
2800	7	14
3000	7	15
3200	7	16
3429	8	15

Mapping frames are indicated by the time index i , where $i = 0$ for the first mapping frame of signal B1 defined in 10.1.3.1, and is incremented by 1 for each mapping frame thereafter. 4D symbol intervals are indicated by the time index $m = 4i + j$, where $j (= 0, 1, 2, 3)$ is a cyclic time index that indicates the position of the 4D symbol interval in a mapping frame. 2D symbol intervals are indicated by the time index $n = 2m + k$, where $k (= 0, 1)$ is a cyclic time index that indicates the position of the 2D symbol interval in a 4D symbol interval.

8.2 Mapping frame switching

An integer number of data bits shall be transmitted in every data frame. The total number of primary and auxiliary channel data bits transmitted in a data frame is denoted by:

$$N = R \cdot 0.28/J \quad (8-1)$$

where R is the sum of the primary channel data signalling rate and the auxiliary channel data signalling rate.

The total number of (primary and auxiliary channel) data bits transmitted in a mapping frame shall vary between $b - 1$ ("low frame") and b ("high frame") bits according to a periodic switching pattern SWP, of period P , such that the average number of data bits per mapping frame is N/P . The value of b is defined as the smallest integer not less than N/P . The number of high frames in a period is the remainder:

$$r = N - (b - 1)P \quad (8-2)$$

where:

$$1 \leq r \leq P$$

SWP is represented by 12- to 16-bit binary numbers where 0 and 1 represent low and high frames, respectively. The left-most bit corresponds to the first mapping frame in a data frame. The right-most bit is always 1.

SWP may be derived using an algorithm which uses a counter as follows: Prior to each data frame the counter is set to zero. The counter is incremented by r at the beginning of each mapping frame. If the counter is less than P , send a low frame; otherwise, send a high frame and decrement the counter by P .

Table 8 gives the values for b and SWP for all combinations of data rate and symbol rate. In Table 8, SWP is represented as a hexadecimal number. For example, at 19 200 bit/s and symbol rate 3000, SWP is 0421 (hex) or 000010000100001 (binary).

8.3 Multiplexing of primary and auxiliary channel bits

The auxiliary channel bits shall be time-division multiplexed with the scrambled primary channel bits.

The number of auxiliary channel bits transmitted per data frame is $W = 8$ at symbol rates 2400, 2800, 3000 and 3200, and $W = 7$ at symbol rates 2743 and 3429. In each mapping frame, the bit $I_{1,0}$ is used to send either an auxiliary channel bit or a primary channel bit according to the Auxiliary Channel Multiplexing Pattern, AMP, of period P (see Figure 4). AMP can be represented as a P -bit binary number where a 1 indicates that an auxiliary channel bit is sent and a 0 indicates that a primary channel bit is sent. AMP depends only upon the symbol rate and is given in Table 9 as a hexadecimal number. The left-most bit corresponds to the first mapping frame in a data frame.

Table 8/V.34 – [b, Switching Pattern (SWP)] as a function of data rate and symbol rate

Data rate, R	2400 sym/s		2743 sym/s		2800 sym/s		3000 sym/s		3200 sym/s		3429 sym/s	
	P = 12		P = 12		P = 14		P = 15		P = 16		P = 15	
	b	SWP	b	SWP	b	SWP	b	SWP	b	SWP	b	SWP
2 400	8	FFF	–	–	–	–	–	–	–	–	–	–
2 600	9	6DB	–	–	–	–	–	–	–	–	–	–
4 800	16	FFF	14	FFF	14	1BB7	13	3DEF	12	FFFF	12	0421
5 000	17	6DB	15	56B	15	0489	14	1249	13	5555	12	36DB
7 200	24	FFF	21	FFF	21	15AB	20	0421	18	FFFF	17	3DEF
7 400	25	6DB	22	56B	22	0081	20	3777	19	5555	18	0889
9 600	32	FFF	28	FFF	28	0A95	26	2D6B	24	FFFF	23	14A5
9 800	33	6DB	29	56B	28	3FFF	27	0081	25	5555	23	3F7F
12 000	40	FFF	35	FFF	35	0489	32	7FFF	30	FFFF	28	7FFF
12 200	41	6DB	36	56B	35	1FBF	33	2AAB	31	5555	29	1555
14 400	48	FFF	42	FFF	42	0081	39	14A5	36	FFFF	34	2D6B
14 600	49	6DB	43	56B	42	1BB7	39	3FFF	37	5555	35	0001
16 800	56	FFF	49	FFF	48	3FFF	45	3DEF	42	FFFF	40	0421
17 000	57	6DB	50	56B	49	15AB	46	1249	43	5555	40	36DB
19 200	64	FFF	56	FFF	55	1FBF	52	0421	48	FFFF	45	3DEF
19 400	65	6DB	57	56B	56	0A95	52	3777	49	5555	46	0889
21 600	72	FFF	63	FFF	62	1BB7	58	2D6B	54	FFFF	51	14A5
21 800	73	6DB	64	56B	63	0489	59	0081	55	5555	51	3F7F
24 000	–	–	70	FFF	69	15AB	64	7FFF	60	FFFF	56	7FFF
24 200	–	–	71	56B	70	0081	65	2AAB	61	5555	57	1555
26 400	–	–	77	FFF	76	0A95	71	14A5	66	FFFF	62	2D6B
26 600	–	–	78	56B	76	3FFF	71	3FFF	67	5555	63	0001
28 800	–	–	–	–	–	–	77	3DEF	72	FFFF	68	0421
29 000	–	–	–	–	–	–	78	1249	73	5555	68	36DB
31 200	–	–	–	–	–	–	–	–	78	FFFF	73	3DEF
31 400	–	–	–	–	–	–	–	–	79	5555	74	0889
33 600	–	–	–	–	–	–	–	–	–	–	79	14A5
33 800	–	–	–	–	–	–	–	–	–	–	79	3F7F

The auxiliary channel multiplexing pattern may be derived using an algorithm similar to the algorithm for SWP, the frame switching pattern. Prior to each data frame, a counter is set to zero. The counter is incremented by W at the beginning of each mapping frame. If the counter is less than P, a primary channel bit is sent; otherwise, an auxiliary channel bit is sent, and the counter is decremented by P.

Table 9/V.34 – Auxiliary channel multiplexing parameters

Symbol rate, S	W	P	AMP
2400	8	12	6DB
2743	7	12	56B
2800	8	14	15AB
3000	8	15	2AAB
3200	8	16	5555
3429	7	15	1555

9 Encoder

The block diagram in Figure 4 is an overview of the encoder.

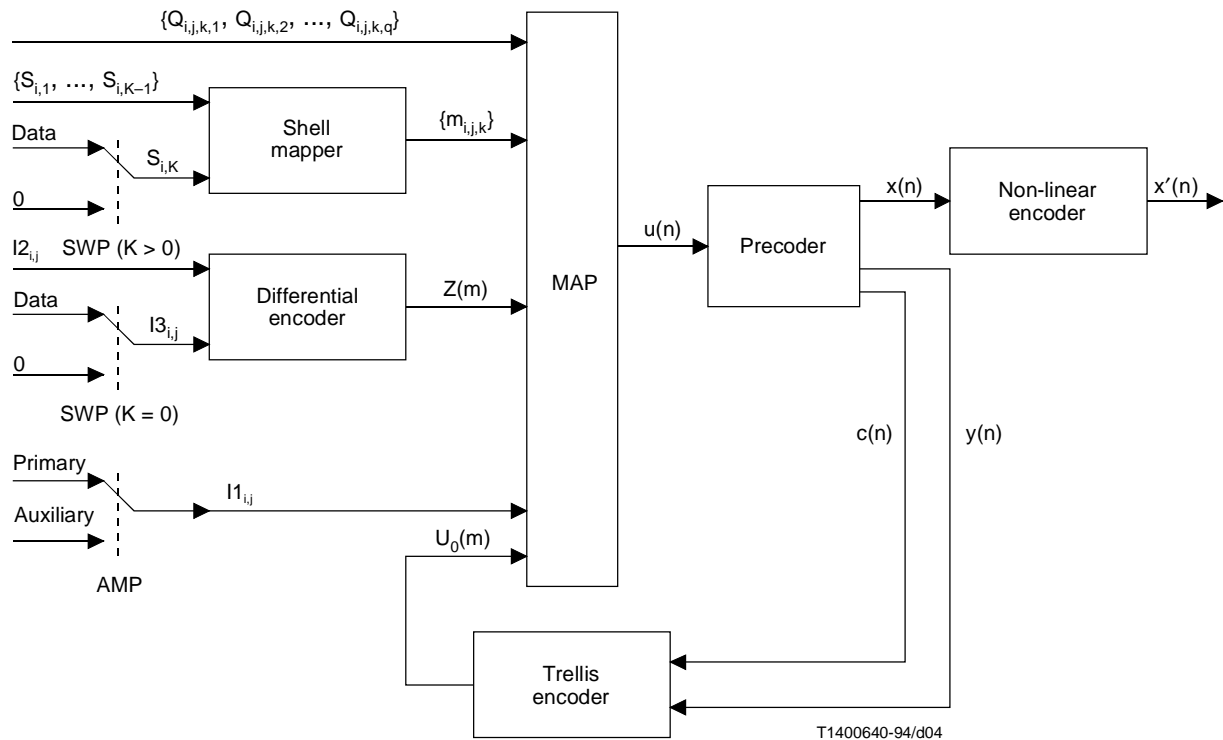


Figure 4/V.34 – Encoder block diagram

9.1 Signal constellations

Signal constellations consist of complex-valued signal points which lie on a two-dimensional rectangular grid.

All signal constellations used in this Recommendation are subsets of a 1664-point superconstellation. Figure 5 shows one-quarter of the points in the superconstellation. These points are labelled with decimal integers between 0 and 415. The point with the smallest magnitude is labelled as 0, the point with the next larger magnitude is labelled as 1, and so on. When two or more points have the same magnitude, the point with the greatest imaginary component is taken first. The full superconstellation is the union of the four quarter-constellations obtained by rotating the constellation in Figure 5 by 0, 90, 180 and 270 degrees.

A signal constellation with L points consists of the $L/4$ points from the quarter-constellation in Figure 5 with labels 0 through $L/4 - 1$, and the $3L/4$ points which are obtained by 90, 180 and 270 degree rotations of these signal points.

Table 10 gives the number of signal points L in the 2D signal constellation. L can also be calculated according to:

$$L = 4M \cdot 2^q \quad (9-2)$$

Table 10/V.34 – Mapping parameters K, M and L at different data rates and symbol rates

Symbol rate, S	Data rate, R	K	M		L	
			Minimum	Expanded	Minimum	Expanded
2400	2 400	0	1	1	4	4
	2 600	0	1	1	4	4
	4 800	4	2	2	8	8
	5 000	5	2	2	8	8
	7 200	12	3	4	12	16
	7 400	13	4	4	16	16
	9 600	20	6	7	24	28
	9 800	21	7	8	28	32
	12 000	28	12	14	48	56
	12 200	29	13	15	52	60
	14 400	28	12	14	96	112
	14 600	29	13	15	104	120
	16 800	28	12	14	192	224
	17 000	29	13	15	208	240
	19 200	28	12	14	384	448
	19 400	29	13	15	416	480
21 600	28	12	14	768	896	
21 800	29	13	15	832	960	
2743	4 800	2	2	2	8	8
	5 000	3	2	2	8	8
	7 200	9	3	3	12	12
	7 400	10	3	3	12	12
	9 600	16	4	5	16	20
	9 800	17	5	5	20	20
	12 000	23	8	9	32	36
	12 200	24	8	10	32	40
	14 400	30	14	17	56	68
	14 600	31	15	18	60	72
	16 800	29	13	15	104	120
	17 000	30	14	17	112	136
	19 200	28	12	14	192	224
	19 400	29	13	15	208	240
	21 600	27	11	13	352	416
	21 800	28	12	14	384	448
24 000	26	10	12	640	768	
24 200	27	11	13	704	832	
	26 400	25	9	11	1 152	1 408
	26 600	26	10	12	1 280	1 536
2800	4 800	2	2	2	8	8
	5 000	3	2	2	8	8
	7 200	9	3	3	12	12
	7 400	10	3	3	12	12

Table 10/V.34 – Mapping parameters K, M and L at different data rates and symbol rates (continued)

Symbol rate, S	Data rate, R	K	M		L	
			Minimum	Expanded	Minimum	Expanded
2800	9 600	16	4	5	16	20
	9 800	16	4	5	16	20
	12 000	23	8	9	32	36
	12 200	23	8	9	32	36
	14 400	30	14	17	56	68
	14 600	30	14	17	56	68
	16 800	28	12	14	96	112
	17 000	29	13	15	104	120
	19 200	27	11	13	176	208
	19 400	28	12	14	192	224
	21 600	26	10	12	320	384
	21 800	27	11	13	352	416
	24 000	25	9	11	576	704
	24 200	26	10	12	640	768
		26 400	24	8	10	1 024
	26 600	24	8	10	1 024	1 280
3000	4 800	1	2	2	8	8
	5 000	2	2	2	8	8
	7 200	8	2	3	8	12
	7 400	8	2	3	8	12
	9 600	14	4	4	16	16
	9 800	15	4	5	16	20
	12 000	20	6	7	24	28
	12 200	21	7	8	28	32
	14 400	27	11	13	44	52
	14 600	27	11	13	44	52
	16 800	25	9	11	72	88
	17 000	26	10	12	80	96
	19 200	24	8	10	128	160
	19 400	24	8	10	128	160
	21 600	30	14	17	224	272
	21 800	31	15	18	240	288
	24 000	28	12	14	384	448
	24 200	29	13	15	416	480
	26 400	27	11	13	704	832
26 600	27	11	13	704	832	
	28 800	25	9	11	1 152	1 408
	29 000	26	10	12	1 280	1 536
3200	4 800	0	1	1	4	4
	5 000	1	2	2	8	8
	7 200	6	2	2	8	8
	7 400	7	2	2	8	8
	9 600	12	3	4	12	16
	9 800	13	4	4	16	16
	12 000	18	5	6	20	24
	12 200	19	6	6	24	24
	14 400	24	8	10	32	40
	14 600	25	9	11	36	44
	16 800	30	14	17	56	68

Table 10/V.34 – Mapping parameters K, M and L at different data rates and symbol rates (concluded)

Symbol rate, S	Data rate, R	K	M		L	
			Minimum	Expanded	Minimum	Expanded
3200	17 000	31	15	18	60	72
	19 200	28	12	14	96	112
	19 400	29	13	15	104	120
	21 600	26	10	12	160	192
	21 800	27	11	13	176	208
	24 000	24	8	10	256	320
	24 200	25	9	11	288	352
	26 400	30	14	17	448	544
	26 600	31	15	18	480	576
	28 800	28	12	14	768	896
	29 000	29	13	15	832	960
	31 200	26	10	12	1 280	1 536
	31 400	27	11	13	1 408	1 664
3429	4 800	0	1	1	4	4
	5 000	0	1	1	4	4
	7 200	5	2	2	8	8
	7 400	6	2	2	8	8
	9 600	11	3	3	12	12
	9 800	11	3	3	12	12
	12 000	16	4	5	16	20
	12 200	17	5	5	20	20
	14 400	22	7	8	28	32
	14 600	23	8	9	32	36
	16 800	28	12	14	48	56
	17 000	28	12	14	48	56
	19 200	25	9	11	72	88
	19 400	26	10	12	80	96
	21 600	31	15	18	120	144
	21 800	31	15	18	120	144
	24 000	28	12	14	192	224
	24 200	29	13	15	208	240
	26 400	26	10	12	320	384
	26 600	27	11	13	352	416
	28 800	24	8	10	512	640
29 000	24	8	10	512	640	
31 200	29	13	15	832	960	
31 400	30	14	17	896	1 088	
33 600	27	11	13	1 408	1 664	
33 800	27	11	13	1 408	1 664	

9.3 Parser

9.3.1 Procedure for $b > 12$

In high mapping frames (b bits), the first K scrambled primary channel data bits are put into the shell mapper, where the values of K are given in Table 10. In low mapping frames ($b - 1$ bits), a zero bit is inserted after the first $K - 1$ bits, and the resulting K bits are then put into the shell mapper.

The first K scrambled data bits in mapping frame i are denoted by $(S_{i,1}, S_{i,2}, \dots, S_{i,K})$. In low frames, $S_{i,K} = 0$.

In each mapping frame the remaining $b - K$ bits are divided into four groups of equal size, corresponding to four 4D symbols. The first three bits in each group are denoted by $(I_{1,j}, I_{2,j}, I_{3,j}), 0 \leq j \leq 3$. (When the auxiliary channel is present, the bit $I_{1,0}$ in the first group is either a primary channel bit or an auxiliary channel bit depending on AMP, the Auxiliary Channel Multiplexing Pattern, as explained in 8.3.) The remaining $2q = (b - K)/4 - 3$ bits are divided into two subgroups of size q denoted by $(Q_{i,j,k,1}, Q_{i,j,k,2}, \dots, Q_{i,j,k,q}), 0 \leq k \leq 1$, corresponding to two 2D symbols. Thus, mapping frame i consists of the following sequence of bits:

$$\begin{aligned} &(S_{i,1}, S_{i,2}, \dots, S_{i,K}), \\ &(I_{1,0}, I_{2,0}, I_{3,0}), (Q_{i,0,0,1}, Q_{i,0,0,2}, \dots, Q_{i,0,0,q}), (Q_{i,0,1,1}, Q_{i,0,1,2}, \dots, Q_{i,0,1,q}), \\ &(I_{1,1}, I_{2,1}, I_{3,1}), (Q_{i,1,0,1}, Q_{i,1,0,2}, \dots, Q_{i,1,0,q}), (Q_{i,1,1,1}, Q_{i,1,1,2}, \dots, Q_{i,1,1,q}), \\ &(I_{1,2}, I_{2,2}, I_{3,2}), (Q_{i,2,0,1}, Q_{i,2,0,2}, \dots, Q_{i,2,0,q}), (Q_{i,2,1,1}, Q_{i,2,1,2}, \dots, Q_{i,2,1,q}), \\ &(I_{1,3}, I_{2,3}, I_{3,3}), (Q_{i,3,0,1}, Q_{i,3,0,2}, \dots, Q_{i,3,0,q}), (Q_{i,3,1,1}, Q_{i,3,1,2}, \dots, Q_{i,3,1,q}). \end{aligned}$$

NOTE – $S_{i,1}$ is the earliest bit in time, and $Q_{i,3,1,q}$ is the latest.

9.3.2 Procedure for $b \leq 12$

For this case, $K = 0$ and the ring indices $m_{i,j,k}$ generated by the shell mapper are always zero. In each mapping frame, the b bits are divided into four groups corresponding to four 4D symbols. The bits in each group are denoted by $(I_{1,j}, I_{2,j}, I_{3,j}), 0 \leq j \leq 3$. (When the auxiliary channel is present, the bit $I_{1,0}$ in the first group is either a primary channel bit or an auxiliary channel bit depending upon AMP, as explained in 8.3.) According to the switching patterns given in Table 8, 8, 9, 11 or 12 bits are transmitted per mapping frame in the following order:

$$\begin{aligned} 8 \text{ bits per mapping frame:} & \quad (I_{1,0}, I_{2,0}, 0), (I_{1,1}, I_{2,1}, 0), (I_{1,2}, I_{2,2}, 0), (I_{1,3}, I_{2,3}, 0) \\ 9 \text{ bits per mapping frame:} & \quad (I_{1,0}, I_{2,0}, I_{3,0}), (I_{1,1}, I_{2,1}, 0), (I_{1,2}, I_{2,2}, 0), (I_{1,3}, I_{2,3}, 0) \\ 11 \text{ bits per mapping frame:} & \quad (I_{1,0}, I_{2,0}, I_{3,0}), (I_{1,1}, I_{2,1}, I_{3,1}), (I_{1,2}, I_{2,2}, I_{3,2}), (I_{1,3}, I_{2,3}, 0) \\ 12 \text{ bits per mapping frame:} & \quad (I_{1,0}, I_{2,0}, I_{3,0}), (I_{1,1}, I_{2,1}, I_{3,1}), (I_{1,2}, I_{2,2}, I_{3,2}), (I_{1,3}, I_{2,3}, I_{3,3}) \end{aligned}$$

9.4 Shell mapper

In every mapping frame, the shell mapper maps K input bits $(S_{i,1}, S_{i,2}, \dots, S_{i,K})$ into 8 output ring indices $\{m_{i,0,0}, m_{i,0,1}, \dots, m_{i,3,0}, m_{i,3,1}\}$, where $0 \leq m_{i,j,k} < M$, according to the algorithm described below which specifies the mapping function between input bits and output indices. The parameters K and M are specified in 9.2.

NOTE – Other implementations are possible but the mapping function must be identical to that given in the algorithm described below.

Definitions

$$\begin{aligned} g_2(p) &= M - \text{abs}[p - M + 1] & 0 \leq p \leq 2(M - 1) \\ &= 0 & \text{otherwise} \end{aligned} \quad (9-3)$$

$$\begin{aligned} g_4(p) &= g_2(0)g_2(p) + g_2(1)g_2(p-1) + \dots + g_2(p)g_2(0) & 0 \leq p \leq 4(M - 1) \\ &= 0 & \text{otherwise} \end{aligned} \quad (9-4)$$

$$g_8(p) = g_4(0)g_4(p) + g_4(1)g_4(p-1) + \dots + g_4(p)g_4(0) \quad 0 \leq p \leq 8(M - 1) \quad (9-5)$$

$$z_8(p) = g_8(0) + g_8(1) + g_8(2) + \dots + g_8(p-1) \quad 0 \leq p \leq 8(M - 1) \quad (9-6)$$

Algorithm

The algorithm shall first determine 8 integers A, B, C, D, E, F, G, H as follows:

1) Represent the K shell mapping bits by an integer R_0 defined by:

$$R_0 = S_{i,1} + 2^1 \cdot S_{i,2} + 2^2 \cdot S_{i,3} + \dots + 2^{K-1} \cdot S_{i,K} \quad (9-7)$$

- 2) Find the largest integer A for which $z_8(A) \leq R_0$.
- 3) Determine the largest integer B such that $R_1 \geq 0$, where:

$$\begin{aligned} R_1 &= R_0 - z_8(A) && \text{if } B = 0 \\ &= R_0 - z_8(A) - \sum_{p=0}^{B-1} g_4(p)g_4(A-p) && \text{if } B > 0 \end{aligned} \quad (9-8)$$

- 4) Determine the integers:

$$R_2 = R_1 \text{ modulo } g_4(B), \text{ where } 0 \leq R_2 \leq g_4(B) - 1 \quad (9-9)$$

$$R_3 = (R_1 - R_2)/g_4(B) \quad (9-10)$$

- 5.1) Determine the largest integer C such that $R_4 \geq 0$, where:

$$\begin{aligned} R_4 &= R_2 && \text{if } C = 0 \\ &= R_2 - \sum_{p=0}^{C-1} g_2(p)g_2(B-p) && \text{if } C > 0 \end{aligned} \quad (9-11)$$

- 5.2) Determine the largest integer D such that $R_5 \geq 0$, where:

$$\begin{aligned} R_5 &= R_3 && \text{if } D = 0 \\ &= R_3 - \sum_{p=0}^{D-1} g_2(p)g_2(A-B-p) && \text{if } D > 0 \end{aligned} \quad (9-12)$$

- 6.1) Determine the integers:

$$E = R_4 \text{ modulo } g_2(C), \text{ where } 0 \leq E \leq g_2(C) - 1 \quad (9-13)$$

$$F = (R_4 - E)/g_2(C) \quad (9-14)$$

- 6.2) Determine the integers:

$$G = R_5 \text{ modulo } g_2(D), \text{ where } 0 \leq G \leq g_2(D) - 1 \quad (9-15)$$

$$H = (R_5 - G)/g_2(D) \quad (9-16)$$

The ring indices are determined from the integers A, B, C, D, E, F, G, H as follows:

- If $C < M$, then $m_{i,0,0} = E$ and $m_{i,0,1} = C - m_{i,0,0}$ (9-17)

- If $C \geq M$, then $m_{i,0,1} = M - 1 - E$ and $m_{i,0,0} = C - m_{i,0,1}$ (9-18)

- If $B - C < M$, then $m_{i,1,0} = F$ and $m_{i,1,1} = B - C - m_{i,1,0}$ (9-19)

- If $B - C \geq M$, then $m_{i,1,1} = M - 1 - F$ and $m_{i,1,0} = B - C - m_{i,1,1}$ (9-20)

- If $D < M$, then $m_{i,2,0} = G$ and $m_{i,2,1} = D - m_{i,2,0}$ (9-21)

- If $D \geq M$, then $m_{i,2,1} = M - 1 - G$ and $m_{i,2,0} = D - m_{i,2,1}$ (9-22)

- If $A - B - D < M$, then $m_{i,3,0} = H$ and $m_{i,3,1} = A - B - D - m_{i,3,0}$ (9-23)

- If $A - B - D \geq M$, then $m_{i,3,1} = M - 1 - H$ and $m_{i,3,0} = A - B - D - m_{i,3,1}$ (9-24)

9.5 Differential encoder

In each 4D symbol interval $m = 4i + j$, the two bits ($I_{2i,j}$, $I_{3i,j}$) shall be converted into an integer:

$$I(m) = I_{2i,j} + 2 \cdot I_{3i,j} \quad (9-25)$$

A differential encoder shall generate an integer $Z(m)$ as the modulo-4 sum of $I(m)$ and the previously generated integer $Z(m - 1)$ as shown in Figure 6.

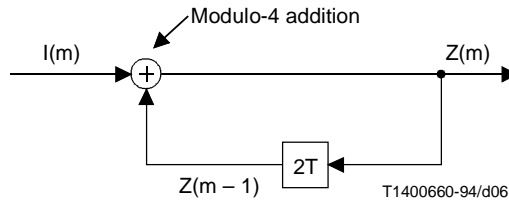


Figure 6/V.34 – Differential encoder

9.6 Mapper, precoder and trellis encoder

The operations to implement the mapper, precoder and the trellis encoder are interdependent. Table 11 gives a sequence of steps for implementing the operations.

Table 11/V.34 – Sequence of operations for mapper, precoder and trellis encoder

Step	Inputs	Operation	Outputs
1	$Z(m)$, $v(2m)$	9.6.1	$u(2m)$
2	$u(2m)$, $c(2m)$, $p(2m)$	9.6.2, item 4)	$y(2m)$, $x(2m)$
3	$x(2m)$	9.6.2, items 1) to 3)	$c(2m + 1)$, $p(2m + 1)$
4	$c(2m)$, $c(2m + 1)$	9.6.3.3	$C_0(m)$
5	$C_0(m)$, $Y_0(m)$, $V_0(m)$	9.6.3	$U_0(m)$
6	$Z(m)$, $U_0(m)$, $v(2m + 1)$	9.6.1	$u(2m + 1)$
7	$u(2m + 1)$, $c(2m + 1)$, $p(2m + 1)$	9.6.2, item 4)	$y(2m + 1)$, $x(2m + 1)$
8	$x(2m + 1)$	9.6.2, items 1) to 3)	$c(2m + 2)$, $p(2m + 2)$
9	$y(2m)$, $y(2m + 1)$	9.6.3.1, 9.6.3.2	$Y_0(m + 1)$

9.6.1 Mapper

For each 2D symbol interval $n = 8i + 2j + k$, from the q -bit subgroup ($Q_{i,j,k,1}$, $Q_{i,j,k,2}$, ..., $Q_{i,j,k,q}$) and the ring index $m_{i,j,k}$, the mapper shall compute a mapping index $Q(n)$:

$$Q(n) = Q_{i,j,k,1} + 2^1 \cdot Q_{i,j,k,2} + 2^2 \cdot Q_{i,j,k,3} + \dots + 2^{q-1} \cdot Q_{i,j,k,q} + 2^q \cdot m_{i,j,k} \quad (9-26)$$

For each 4D symbol interval $m = 4i + j$, the mapping indices $Q(2m)$ and $Q(2m + 1)$ label two signal points $v(2m)$ and $v(2m + 1)$, respectively, from the quarter superconstellation of Figure 5. The output 2D signal points $u(2m)$ and $u(2m + 1)$ are obtained by rotating $v(2m)$ by $Z(m) \cdot 90$ degrees clockwise and $v(2m + 1)$ by $[Z(m) + 2 \cdot I_{1,j} + U_0(m)] \cdot 90$ degrees clockwise, respectively. The bit $U_0(m)$ is the output of the trellis encoder, and is obtained according to the method described in 9.6.3.

NOTE – For precoding interoperability, it is important that $u(2m)$ and $u(2m + 1)$ are generated exactly.

9.6.2 Precoder

The precoder shown in Figure 7 receives the complex-valued signal points $u(n)$ from the mapper and generates the complex-valued signal $x(n)$ according to:

$$x(n) = u(n) + c(n) - p(n) \quad (9-27)$$

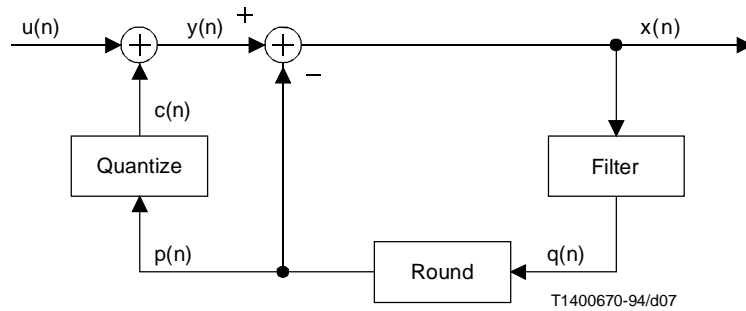


Figure 7/V.34 – Block diagram of precoder

The complex-valued signals $c(n)$ and $p(n)$ are determined according to the algorithm specified below. The precoded signal $x(n)$ is provided to the non-linear encoder and the signals $c(n)$ and $y(n) = u(n) + c(n)$, indicated in Figure 7, are provided to the trellis encoder.

NOTE – To ensure interoperability, the signals $x(n)$, $c(n)$ and $y(n)$ must be precisely the same as in the algorithm specified below.

The complex-valued precoding coefficients $\{h(p), p = 1, 2, 3\}$ are provided by the receiving modem during Phase 4 of the modem start-up procedures described in 11.4. or 12.4. Their real and imaginary components are represented in the 16-bit two's-complement format with 14 bits after the binary point, and assume values in the half-open interval $(-2, 2)$. The coefficients shall be constrained such that the absolute value of the real and imaginary components of $y(n)$ always satisfy $\text{abs}[y_{r,i}(n)] \leq 255$.

The precoder shall determine the signals $x(n)$, $c(n)$ and $y(n)$ based on the input $u(n)$, the precoding coefficients $\{h(p), p = 1, 2, 3\}$ and the three most recent precoded symbols $\{x(n - p), p = 1, 2, 3\}$, as follows:

- 1) Compute the filter output using complex arithmetic according to:

$$q(n) = \sum_{p=1}^3 x(n - p)h(p) \quad (9-28)$$

- 2) Round the real and imaginary components of $q(n)$ to the respective nearest integer multiples of 2^{-7} to obtain $p(n)$. When a component falls exactly half-way between two integer multiples of 2^{-7} , round it to the one with the smaller magnitude.
- 3) Quantize the real and imaginary components of $p(n)$ to the respective nearest integer multiple of 2^w to obtain $c(n)$. When a component falls exactly half-way between two integer multiples of 2^w , quantize it to the one with the smaller magnitude.

Here the scale factor w is:

$$\begin{aligned} w &= 1, \text{ when } b < 56 \\ &= 2, \text{ when } b \geq 56 \end{aligned} \quad (9-29)$$

where b is the number of bits in a high mapping frame as defined in Table 7.

4) Compute the channel output signal $y(n)$ and the precoded signal $x(n)$ according to:

$$y(n) = u(n) + c(n) \quad (9-30)$$

$$x(n) = y(n) - p(n) \quad (9-31)$$

9.6.3 Trellis encoder

The trellis encoder shown in Figure 8 generates the bit $U_0(m)$ for the mapper once every 4D interval m .

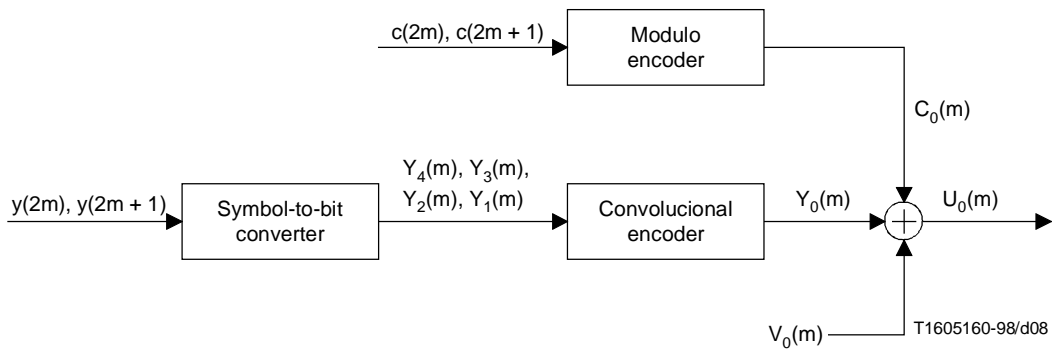


Figure 8/V.34 – Block diagram of trellis encoder

The trellis encoder consists of a convolutional encoder which generates an output bit $Y_0(m)$ and a modulo encoder which generates an output bit $C_0(m)$. $U_0(m)$ is then determined as the modulo 2 sum:

$$U_0(m) = Y_0(m) \oplus C_0(m) \oplus V_0(m) \quad (9-32)$$

where the bit $V_0(m)$ represents bit inversions for purposes of superframe synchronization. Bit inversions are introduced in the 4D symbol interval in the beginning of each half data frame (i.e. when m is an integer multiple of $2P$), according to the periodic bit inversion pattern specified in Table 12. The left-most bit corresponds to the first half data frame of a superframe. The period of the bit inversion pattern is 16 when $J = 8$, and 14 when $J = 7$.

Table 12/V.34 – Bit inversion patterns

J	Pattern
8	01 11 01 11 11 11 10 10
7	01 11 01 11 11 11 10

9.6.3.1 Symbol-to-bit converter

The symbol-to-bit converter generates four bits $[Y_4(m), Y_3(m), Y_2(m), Y_1(m)]$ as follows:

The complex 2D channel output symbols $y(2m)$ and $y(2m + 1)$ lie on a 2D rectangular grid with odd-integer coordinates. The signal points on the grid are represented by a 3-bit subset label in an 8-way set partition. This labelling of points is shown in Figure 9 for a small subset of the points near the origin.

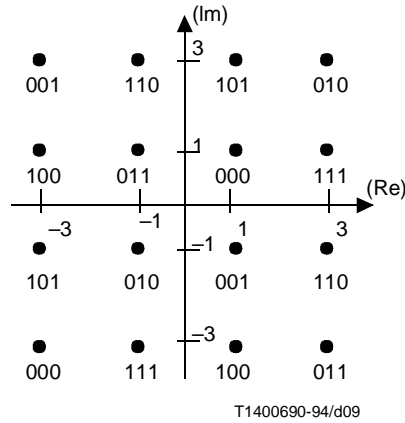


Figure 9/V.34 – Labelling of channel output points $y(2m)$ or $y(2m + 1)$

Two-channel output symbols $y(2m)$ and $y(2m + 1)$ are used to generate two subset labels $s(2m)$ and $s(2m + 1)$, respectively, which are converted into four input bits $[Y_4(m), Y_3(m), Y_2(m), Y_1(m)]$ for the convolutional encoder according to Table 13.

Table 13/V.34 – Table for $[Y_4(m), Y_3(m), Y_2(m), Y_1(m)]$

$s(2m)$	$s(2m + 1)$							
	000	001	010	011	100	101	110	111
000	0000	0000	0001	0001	1000	1000	1001	1001
001	0011	0010	0010	0011	1011	1010	1010	1011
010	0101	0101	0100	0100	1101	1101	1100	1100
011	0110	0111	0111	0110	1110	1111	1111	1110
100	1000	1000	1001	1001	0000	0000	0001	0001
101	1011	1010	1010	1011	0011	0010	0010	0011
110	1101	1101	1100	1100	0101	0101	0100	0100
111	1110	1111	1111	1110	0110	0111	0111	0110

9.6.3.2 Convolutional encoder

The bits $[Y_4(m), Y_3(m), Y_2(m), Y_1(m)]$ are put into one of the systematic convolutional encoders shown in Figures 10, 11 and 12. The convolutional encoder generates an output bit $Y_0(m)$. There is an inherent delay of one 4D symbol interval in the convolutional encoder. Therefore, the output $Y_0(m)$ does not depend on the current input $[Y_4(m), Y_3(m), Y_2(m), Y_1(m)]$.

The encoder shall be selected by the receiving modem during Phase 4 of the start-up procedures specified in 11.4 or 12.4. The following encoders are available:

- 16-state rate-2/3 (Figure 10);
- 32-state rate-3/4 (Figure 11);
- 64-state rate-4/5 (Figure 12).

For the 32-state encoder, the input bit $Y_3(m)$ is not used. For the 16-state encoder, the input bits $Y_4(m)$ and $Y_3(m)$ are not used.

9.6.3.3 Modulo encoder

The modulo encoder uses the 2D integer signals $c(2m)$ and $c(2m + 1)$ to generate the bit $C_0(m)$ as follows: if the sum of the real and imaginary components of $c(2m)/2$ and the sum of the real and imaginary components of $c(2m + 1)/2$ are both even or both odd, then $C_0(m) = 0$; otherwise $C_0(m) = 1$.

9.7 Non-linear encoder

The signal $x(n)$ is non-linear encoded according to:

$$x'(n) = \Phi(n) \times (n) \quad (9-33)$$

where the non-linear projection function is:

$$\Phi(n) = 1 + \zeta(n)/6 + \zeta^2(n)/120 \quad (9-34)$$

and:

$$\zeta(n) = \frac{\Theta[x_r^2(n) + x_i^2(n)]}{[x_r^2(n) + x_i^2(n)]} \quad (9-35)$$

where $\overline{[x_r^2(n) + x_i^2(n)]}$ represents the average energy of the signal $x(n)$. The constant Θ has two possible values, 0 or 0.3125, and is selected during Phase 4 of start-up.

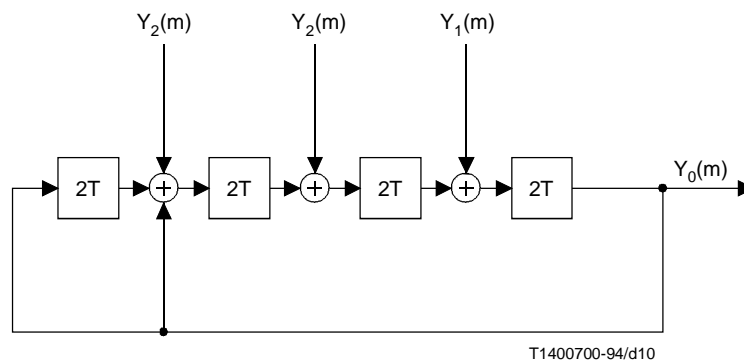


Figure 10/V.34 – 16-state convolutional encoder

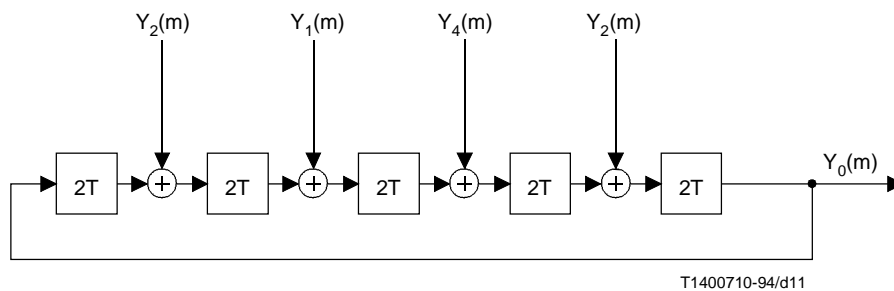


Figure 11/V.34 – 32-state convolutional encoder

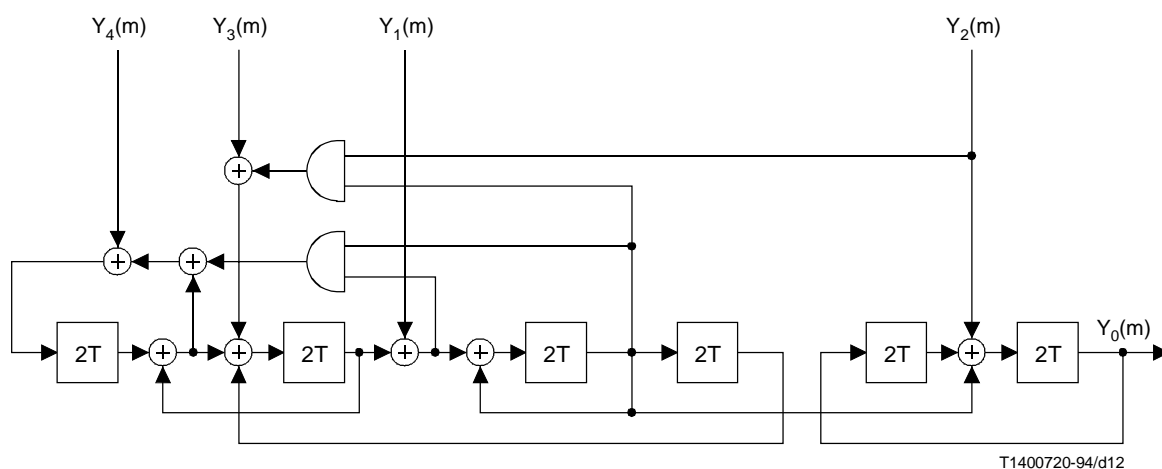


Figure 12/V.34 – 64-state convolutional encoder

10 Start-up signals and sequences

This clause details the various signals and bit sequences used during modem start-up for both duplex and half-duplex operation.

NOTE – Although some of the signals used during start-up have the same nomenclature as variables defined in clauses 5 to 9, they are not related.

10.1 Signals and sequences used in duplex operation

10.1.1 Phase 1

All signals in Phase 1 shall be transmitted at the nominal transmit power level.

10.1.1.1 ANS

Answer tone as defined in Recommendation V.25.

10.1.1.2 ANSam

As defined in Recommendation V.8.

10.1.1.3 CI

As defined in Recommendation V.8.

10.1.1.4 CJ

As defined in Recommendation V.8.

10.1.1.5 CM

As defined in Recommendation V.8.

10.1.1.6 JM

As defined in Recommendation V.8.

10.1.2 Phase 2

During Phase 2, all signals except L1 shall be transmitted at the nominal transmit power level. If a recovery mechanism returns the modem to Phase 2 from a later phase, the transmit level shall revert to the nominal transmit power if the return point is before the L1, L2 probing segments. Otherwise, the previously negotiated transmit power level shall be maintained.

10.1.2.1 A

Tone A is a 2400 Hz tone transmitted by the answer modem. Transitions between A and \bar{A} , and similarly between \bar{A} and A, are 180 degree phase reversals in the 2400 Hz tone. During the transmission of A and \bar{A} , the answer modem sends a 1800 Hz guard tone without any phase reversals. Tone A is transmitted at 1 dB below the nominal transmit power while the guard tone is transmitted at the nominal transmit power.

NOTE – The bandwidth of a tone with phase reversals should not be constrained in a way that appreciably affects the accuracy of round trip delay measurements.

10.1.2.2 B

Tone B is a 1200 Hz tone transmitted by the call modem. Transitions between B and \bar{B} , and similarly between \bar{B} and B, are 180 degree phase reversals in the 1200 Hz tone.

NOTE – The bandwidth of a tone with phase reversals should not be constrained in a way that appreciably affects the accuracy of round trip delay measurements.

10.1.2.3 INFO sequences

INFO sequences are used to exchange modem capabilities, results of line probing, and data mode modulation parameters. Two sets of INFO sequences are used: (INFO_{0a}, INFO_{0c}) and (INFO_{1a}, INFO_{1c}), where "a" identifies INFO sequences sent by the answer modem, and "c" identifies INFO sequences sent by the call modem. During start-up error recovery, two additional sequences are used to indicate an error condition: INFOMARKS_a and INFOMARKS_c.

10.1.2.3.1 Modulation

All INFO sequences are transmitted using binary DPSK modulation at 600 bit/s \pm 0.01%. The transmit point is rotated 180 degrees from the previous point if the transmit bit is a 1, and the transmit point is rotated 0 degrees from the previous point if the transmit bit is a 0. Each INFO sequence is preceded by a point at an arbitrary carrier phase. When multiple INFO sequences are transmitted as a group, only the first sequence is preceded by a point at an arbitrary carrier phase.

INFO sequences are transmitted by the answer modem with a carrier frequency of 2400 Hz \pm 0.01%, at 1 dB below the nominal transmit power, plus a 1800 Hz \pm 0.01% guard tone 7 dB below the nominal transmit power. INFO sequences are transmitted by the call modem with a carrier frequency of 1200 Hz \pm 0.01% at the nominal transmit power.

The transmitted line signal shall have a magnitude spectrum within the limits shown in Figure 13.

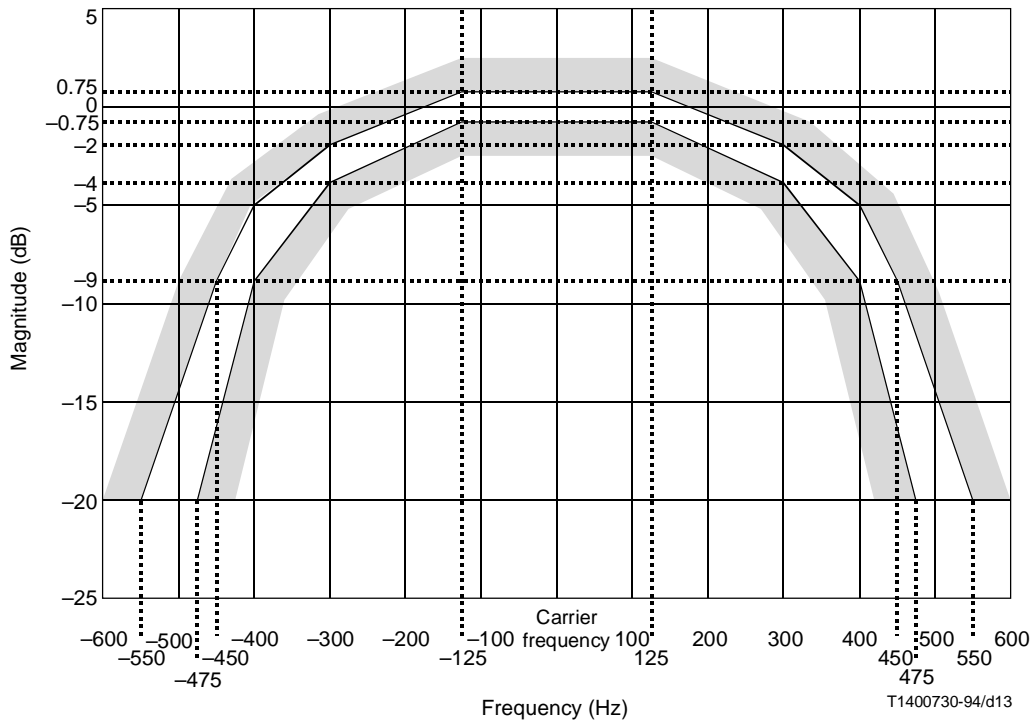


Figure 13/V.34 – Transmit spectrum template for INFO modulation

NOTE – It is highly desirable to design linear phase transmitter channel separation and shaping filters since there are no provisions for adaptive equalizer training.

10.1.2.3.2 CRC generator

The CRC is formed by passing all of the information bits in a sequence, except the frame sync bits, the start bits, and the fill bits, through the CRC generator described in Figure 14.

The CRC is calculated by dividing a binary sequence by the specified polynomial. The polynomial used to compute the CRC is: $x^{16} + x^{12} + x^5 + 1$. The CRC is calculated as follows:

- 1) load the shift register in the CRC generator with all ones;
- 2) shift in the binary sequence;
- 3) output the contents of the shift register, starting with bit 0 in Figure 14. Bit 0 of the CRC is the LSB.

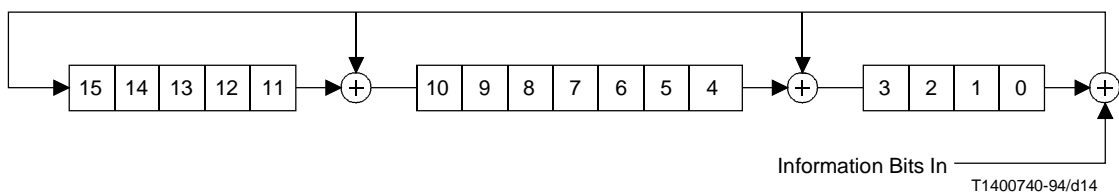


Figure 14/V.34 – CRC generator

10.1.2.3.3 INFO₀ information bits

Table 14 defines the bits in the INFO₀ sequences. Bit 0 is transmitted first.

Table 14/V.34 – Definition of bits in INFO₀ sequences

INFO₀ bits LSB:MSB	Definition
0:3	Fill bits: 1111.
4:11	Frame sync: 01110010, where the left-most bit is first in time.
12	Set to 1 indicates symbol rate 2743 is supported.
13	Set to 1 indicates symbol rate 2800 is supported.
14	Set to 1 indicates symbol rate 3429 is supported.
15	Set to 1 indicates the ability to transmit at the low carrier frequency with a symbol rate of 3000.
16	Set to 1 indicates the ability to transmit at the high carrier frequency with a symbol rate of 3000.
17	Set to 1 indicates the ability to transmit at the low carrier frequency with a symbol rate of 3200.
18	Set to 1 indicates the ability to transmit at the high carrier frequency with a symbol rate of 3200.
19	Set to 0 indicates that transmission with a symbol rate of 3429 is disallowed.
20	Set to 1 indicates the ability to reduce transmit power to a value lower than the nominal setting.
21:23	Maximum allowed difference in symbol rates in the transmit and receive directions. With the symbol rates labelled in increasing order, where 0 represents 2400 and 5 represents 3429, an integer between 0 and 5 indicates the difference allowed in number of symbol rate steps.
24	Set to 1 in an INFO ₀ sequence transmitted from a CME modem.
25	Set to 1 indicates the ability to support up to 1664-point signal constellations.
26:27	Transmit clock source: 0 = internal; 1 = synchronized to receive timing; 2 = external; 3 = reserved for ITU-T.
28	Set to 1 to acknowledge correct reception of an INFO ₀ frame during error recovery.
29:44	CRC.
45:48	Fill bits: 1111.
<p>NOTE 1 – Bits 12 through 14 are used to indicate the modem's capabilities and/or configuration. The values of bits 15 through 20 depend upon regulatory requirements and apply only to the modem's transmitter.</p> <p>NOTE 2 – Bit 24 may be used in conjunction with the GSTN access category octet defined in Recommendation V.8 to determine the optimum parameters for the signal converters and error-control functions in the call and answer modem and any intervening CME.</p>	

10.1.2.3.4 INFO_{1c} information bits

Table 15 defines the bits in the INFO_{1c} sequence. Bit 0 is transmitted first.

Table 15/V.34 – Definition of bits in the INFO_{1c} sequence

INFO_{1c} bits LSB:MSB	Definition
0:3	Fill bits: 1111.
4:11	Frame sync: 01110010, where the left-most bit is first in time.
12:14	Minimum power reduction to be implemented by the answer modem transmitter. An integer between 0 and 7 gives the recommended power reduction in dB. These bits shall indicate 0 if INFO _{0a} indicated that the answer modem transmitter cannot reduce its power.
15:17	Additional power reduction, below that indicated by bits 12-14, which can be tolerated by the call modem receiver. An integer between 0 and 7 gives the additional power reduction in dB. These bits shall indicate 0 if INFO _{0a} indicated that the answer modem transmitter cannot reduce its power.
18:24	Length of MD to be transmitted by the call modem during Phase 3. An integer between 0 and 127 gives the length of this sequence in 35 ms increments.
25	Set to 1 indicates that the high carrier frequency is to be used in transmitting from the answer modem to the call modem for a symbol rate of 2400.
26:29	Pre-emphasis filter to be used in transmitting from the answer modem to the call modem for a symbol rate of 2400. These bits form an integer between 0 and 10 which represents the pre-emphasis filter index (see Tables 3 and 4).
30:33	Projected maximum data rate for a symbol rate of 2400. These bits form an integer between 0 and 14 which gives the projected data rate as a multiple of 2400 bits/s. A 0 indicates the symbol rate cannot be used.
34:42	Probing results pertaining to a final symbol rate selection of 2743 symbols per second. The coding of these 9 bits is identical to that for bits 25-33.
43:51	Probing results pertaining to a final symbol rate selection of 2800 symbols per second. The coding of these 9 bits is identical to that for bits 25-33.
52:60	Probing results pertaining to a final symbol rate selection of 3000 symbols per second. The coding of these 9 bits is identical to that for bits 25-33. Information in this field shall be consistent with the answer modem capabilities indicated in INFO _{0a} .
61:69	Probing results pertaining to a final symbol rate selection of 3200 symbols per second. The coding of these 9 bits is identical to that for bits 25-33. Information in this field shall be consistent with the answer modem capabilities indicated in INFO _{0a} .
70:78	Probing results pertaining to a final symbol rate selection of 3429 symbols per second. The coding of these 9 bits is identical to that for bits 25-33. Information in this field shall be consistent with the answer modem capabilities indicated in INFO _{0a} .
79:88	Frequency offset of the probing tones as measured by the call modem receiver. The frequency offset number shall be the difference between the nominal 1050 Hz line probing signal tone received and the 1050 Hz tone transmitted, $f(\text{received}) - f(\text{transmitted})$. A two's complement signed integer between -511 and 511 gives the measured offset in 0.02 Hz increments. Bit 88 is the sign bit of this integer. The frequency offset measurement shall be accurate to 0.25 Hz. Under conditions where this accuracy cannot be achieved, the integer shall be set to -512 indicating that this field is to be ignored.
89:104	CRC.
105:108	Fill bits: 1111.
NOTE – Projected maximum data rates greater than 12 in bits 30:33 shall only be indicated when the remote modem supports up to 1664-point signal constellations.	

10.1.2.3.5 INFO_{1a} information bits

Table 16 defines the bits in the INFO_{1a} sequence. Bit 0 is transmitted first.

Table 16/V.34 – Definition of bits in the INFO_{1a} sequence

INFO _{1a} bits LSB:MSB	Definition
0:3	Fill bits: 1111.
4:11	Frame sync: 01110010, where the left-most bit is first in time.
12:14	Minimum power reduction to be implemented by the call modem transmitter. An integer between 0 and 7 gives the recommended power reduction in dB. These bits shall indicate 0 if INFO _{0c} indicated that the call modem transmitter cannot reduce its power.
15:17	Additional power reduction, below that indicated by bits 12:14, which can be tolerated by the answer modem receiver. An integer between 0 and 7 gives the additional power reduction in dB. These bits shall indicate 0 if INFO _{0c} indicated that the call modem transmitter cannot reduce its power.
18:24	Length of MD to be transmitted by the answer modem during Phase 3. An integer between 0 and 127 gives the length of this sequence in 35 ms increments.
25	Set to 1 indicates that the high carrier frequency is to be used in transmitting from the call modem to the answer modem. This shall be consistent with the capabilities of the call modem indicated in INFO _{0c} .
26:29	Pre-emphasis filter to be used in transmitting from the call modem to the answer modem. These bits form an integer between 0 and 10 which represents the pre-emphasis filter index (see Tables 3 and 4).
30:33	Projected maximum data rate for the selected symbol rate from the call modem to the answer modem. These bits form an integer between 0 and 14 which gives the projected data rate as a multiple of 2400 bits/s.
34:36	Symbol rate to be used in transmitting from the answer modem to the call modem. An integer between 0 and 5 gives the symbol rate, where 0 represents 2400 and a 5 represents 3429. The symbol rate selected shall be consistent with information in INFO _{1c} and consistent with the symbol rate asymmetry allowed as indicated in INFO _{0a} and INFO _{0c} . The carrier frequency and pre-emphasis filter to be used are those already indicated for this symbol rate in INFO _{1c} .
37:39	Symbol rate to be used in transmitting from the call modem to the answer modem. An integer between 0 and 5 gives the symbol rate, where 0 represents 2400 and a 5 represents 3429. The symbol rate selected shall be consistent with the capabilities indicated in INFO _{0a} and consistent with the symbol rate asymmetry allowed as indicated in INFO _{0a} and INFO _{0c} .
40:49	Frequency offset of the probing tones as measured by the answer modem receiver. The frequency offset number shall be the difference between the nominal 1050 Hz line probing signal tone received and the 1050 Hz tone transmitted, $f(\text{received}) - f(\text{transmitted})$. A two's complement signed integer between -511 and 511 gives the measured offset in 0.02 Hz increments. Bit 49 is the sign bit of this integer. The frequency offset measurement shall be accurate to 0.25 Hz. Under conditions where this accuracy cannot be achieved, the integer shall be set to -512 indicating that this field is to be ignored.
50:65	CRC.
66:69	Fill bits: 1111.
NOTE – Projected maximum data rates greater than 12 in bits 30:33 shall only be indicated when the remote modem supports up to 1664-point signal constellations.	

10.1.2.3.6 INFOMARKS

INFOMARKS_c is transmitted by the call modem by applying binary ones to the DPSK modulator described in 10.1.2.3.1.

INFOMARKS_a is transmitted by the answer modem by applying binary ones to the DPSK modulator described in 10.1.2.3.1.

10.1.2.4 Line probing signals

Two line probing signals, L1 and L2, are used to analyse channel characteristics. L1 is a periodic signal with a repetition rate of $150 \pm 0.01\%$ Hz which consists of a set of tones (cosines) spaced 150 Hz apart at frequencies from 150 Hz to 3750 Hz. Tones at 900 Hz, 1200 Hz, 1800 Hz, and 2400 Hz are omitted. The initial phase of each cosine is given in Table 17. L1 is transmitted for 160 ms (24 repetitions) at 6 dB above the nominal power level. L2 is the same as L1 but is transmitted for no longer than 550 ms plus a round trip delay at the nominal power level.

NOTE – The probing tones should be generated with enough accuracy so as not to appreciably affect the channel distortion and noise measurements in the remote receiver.

Table 17/V.34 – Probing tones

$\cos (2\pi ft + \varphi)$	
f (Hz)	φ (degrees)
150	0
300	180
450	0
600	0
750	0
1050	0
1350	0
1500	0
1650	180
1950	0
2100	0
2250	180
2550	0
2700	180
2850	0
3000	180
3150	180
3300	180
3450	180
3600	0
3750	0

10.1.3 Phases 3 and 4

All signals in Phases 3 and 4 are transmitted using the selected symbol rate, carrier frequency, pre-emphasis filter and power level.

NOTE – The transmitter should compensate for modulation factors including the effects of non-linear encoding and precoding so that the average signal power transmitted in Phases 3 and 4 is maintained in segment B1 and the subsequent data mode.

10.1.3.1 B1

Sequence B1 consists of one data frame of scrambled ones transmitted at the end of start-up using the selected data mode modulation parameters. Bit inversions for superframe synchronization are inserted as if the data frame were the last data frame in a superframe. Prior to transmission of B1, the scrambler, trellis encoder, differential encoder, and the precoding filter tap delay line are initialized to zeroes.

10.1.3.2 E

E is a 20-bit sequence of binary ones used to signal the end of MP. It is mapped into a sequence of symbols chosen from the 4- or 16-point 2D constellation depending on the signal J. The 4-point E sequence is generated as described in 10.1.3.3. The 16-point E sequence is generated as described in 10.1.3.9.

10.1.3.3 J

Sequence J consists of a whole number of repetitions of one of the two 16-bit patterns shown in Table 18. J is used to request the constellation size to be used by the remote modem for transmitting sequences TRN, MP, MP', and E during Phase 4 training. J is a sequence of symbols generated by applying input bits to the scrambler defined in clause 7. Two scrambled bits, I_{1n} and I_{2n} , are transmitted every 2D symbol interval, where I_{1n} is the first bit in time. Integers $I_n = 2 \cdot I_{2n} + I_{1n}$ are differentially encoded to generate the integer Z_n as the modulo 4 sum of I_n and Z_{n-1} . The transmitted points are obtained by rotating point 0 from the quarter-superconstellation of Figure 5 clockwise by $Z_n \cdot 90$ degrees. The differential encoder shall be initialized using the final symbol of the transmitted TRN sequence.

Table 18/V.34 – Definition of bits in J sequence

Constellation size	Bits 0-15
4-point	0000100110010001, where the left-most bit is first in time.
16-point	0000110110010001, where the left-most bit is first in time.

10.1.3.4 J'

Sequence J' is used to terminate J and is transmitted only once. J' is generated as described in 10.1.3.3 except that the 16-bit pattern shown in Table 19 is used.

Table 19/V.34 – Definition of bits in J' sequence

Bits J'	Definition
0-15	1111100110010001, where the left-most bit is first in time.

10.1.3.5 MD

MD is an optional Manufacturer-Defined signal used by a transmitting modem to train its echo canceller if this cannot be accommodated by the TRN signal in Phase 3. The length of the MD signal is indicated in the transmitting modem's INFO₁ sequence. If the signal is not present, the MD length indication will be 0.

10.1.3.6 PP

Signal PP consists of six periods of a 48-symbol sequence and is used by the remote modem for training its equalizer. PP(i), $i = 0, 1, \dots, 287$ is defined as follows:

$$\text{Set } i = 4k + I$$

where:

$$\begin{aligned} k &= 0, 1, 2, \dots, 71; \text{ and} \\ I &= 0, 1, 2, 3 \text{ for each } k \end{aligned}$$

then:

$$\begin{aligned} \text{PP}(i) &= e^{j\pi(kI+4)/6} && \text{if } k \text{ modulo } 3 = 1 \\ &= e^{j\pi kI/6} && \text{otherwise} \end{aligned} \quad (10-1)$$

PP(0) is transmitted first.

10.1.3.7 S

Signal S is transmitted by alternating between point 0 of the quarter-superconstellation of Figure 5 and the same point rotated counterclockwise by 90 degrees. Signal \bar{S} is transmitted by alternating between point 0 rotated by 180 degrees and point 0 rotated counterclockwise by 270 degrees. The signal S shall end with the transmission of point 0 rotated counterclockwise by 90 degrees. Signal \bar{S} shall begin with the transmission of point 0 rotated by 180 degrees.

10.1.3.8 TRN

Signal TRN is a sequence of symbols generated by applying binary ones to the input of the scrambler described in clause 7. The scrambled bits are mapped to a 4- or 16-point 2D constellation depending on the signal J.

The 4-point TRN signal is generated by using two scrambled bits, I_{1n} and I_{2n} , which are transmitted every 2D symbol interval, where I_{1n} is the first bit in time. The transmitted points are obtained by rotating point 0 from the quarter-superconstellation of Figure 5 clockwise by $I_n \cdot 90$ degrees, where $I_n = 2 \cdot I_{2n} + I_{1n}$.

The 16-point TRN signal is generated by using four scrambled bits, I_{1n} , I_{2n} , Q_{1n} , and Q_{2n} , which are transmitted every 2D symbol interval and I_{1n} is the first bit in time. The transmitted points are obtained by using integer $2 \cdot Q_{2n} + Q_{1n}$ to select a point from the quarter-superconstellation of Figure 5 and then rotating that point clockwise by $I_n \cdot 90$ degrees, where $I_n = 2 \cdot I_{2n} + I_{1n}$.

The scrambler is initialized to zero prior to transmission of the TRN signal.

10.1.3.9 Modulation Parameter (MP) sequences

Modulation Parameter (MP) sequences are exchanged between modems during start-up and rate renegotiation and contain modulation parameters to be used for data mode transmission.

Two types of MP sequences are used in duplex mode. Type 0 contains maximum call-to-answer-modem data signalling rate, maximum answer-to-call modem data signalling rate, amount of constellation shaping, trellis encoder choice, non-linear encoding parameter, auxiliary channel enable, data signalling rate capability mask and 16 bits reserved for future use. Type 1 is the same as Type 0 with the addition of fields for precoding coefficients. The bit fields for the two types of MP sequences used in duplex mode are defined in Tables 20 and 21. The CRC generator used is described in 10.1.2.3.2.

An MP sequence with the acknowledge bit set to 1 is denoted by MP'.

MP sequences consist of symbols chosen from a 4- or 16-point constellation depending upon the signal J. The 4-point MP sequence is generated as described in 10.1.3.3.

The 16-point MP sequence is generated by using four scrambled bits I_{1n} , I_{2n} , Q_{1n} and Q_{2n} which are transmitted every 2D symbol interval where I_{1n} is the first bit in time. Integer $2 * Q_{2n} + Q_{1n}$ selects the point from the quarter-superconstellation of Figure 5. Integers $I_n = 2 * I_{2n} + I_{1n}$ are differentially encoded to generate integer Z_n as the modulo 4 sum of I_n and Z_{n-1} . Finally, the transmitted point is obtained by clockwise rotation of the selected point by $Z_n * 90$ degrees. The differential encoder shall be initialized using the final symbol of the transmitted TRN sequence.

Either type (Type 0 or Type 1) of MP sequence may be sent during start-up, retrain, or rate renegotiation. Prior to receiving the first MP sequence in Phase 4, the precoding coefficients are initialized to 0. If a Type 0 sequence is received, the precoding coefficients are unaffected. When multiple MP and MP' sequences are transmitted as a group, they should all contain identical modulation parameter information.

Table 20/V.34 – Definition of bits in MP sequence Type 0

MP bits LSB:MSB	Definition
0:16	Frame sync: 1111111111111111.
17	Start bit: 0.
18	Type: 0.
19	Reserved for ITU-T: This bit is set to 0 by the transmitting modem and is not interpreted by the receiving modem.
20:23	Maximum call modem to answer modem data signalling rate: Data rate = $N * 2400$ where N is a 4-bit integer between 1 and 14.
24:27	Maximum answer modem to call modem data signalling rate: Data rate = $N * 2400$ where N is a 4-bit integer between 1 and 14.
28	Auxiliary channel select bit. Set to 1 if modem is capable of supporting and enables auxiliary channel. Auxiliary channel is used only if both modems set this bit to 1.
29:30	Trellis encoder select bits: 0 = 16 State; 1 = 32 State; 2 = 64 State; 3 = Reserved for ITU-T. Receiver requires remote-end transmitter to use selected trellis encoder.
31	Non-linear encoder parameter select bit for the remote-end transmitter. 0: $\Theta = 0$, 1: $\Theta = 0.3125$.
32	Constellation shaping select bit for the remote-end transmitter. 0: minimum, 1: expanded (see Table 10).
33	Acknowledge bit. 0 = modem has not received MP from far end. 1 = received MP from far end.
34	Start bit: 0.
35:49	Data signalling rate capability mask. Bit 35:2400; bit 36:4800; bit 37:7200; ...; bit 46:28 800; bit 47:31 200; bit 48:33 600; bit 49: Reserved for ITU-T. (This bit is set to 0 by the transmitting modem and is not interpreted by the receiving modem.) Bits set to 1 indicate data signalling rates supported and enabled in both transmitter and receiver of modem.
50	Asymmetric data signalling rate enable. Set to 1 indicates modem capable of asymmetric data signalling rates.
51	Start bit: 0.
52:67	Reserved for ITU-T: These bits are set to 0 by the transmitting modem and are not interpreted by the receiving modem.
68	Start bit: 0.
69:84	CRC.
85:87	Fill bits: 000.
NOTE – Data rates greater than 12 in bits 20:23 and 24:27 shall only be indicated when the remote modem supports up to 1664-point signal constellations.	

Table 21/V.34 – Definition of bits in MP sequence Type 1

MP bits LSB:MSB	Definition
0:16	Frame sync: 1111111111111111.
17	Start bit: 0.
18	Type: 1.
19	Reserved for ITU-T: This bit is set to 0 by the transmitting modem and is not interpreted by the receiving modem.
20:23	Maximum call modem to answer modem data signalling rate: Data rate = $N * 2400$ where N is a four-bit integer between 1 and 14.
24:27	Maximum answer modem to call modem data signalling rate: Data rate = $N * 2400$ where N is a four-bit integer between 1 and 14.
28	Auxiliary channel select bit. Set to 1 if modem is capable of supporting and enables auxiliary channel. Auxiliary channel is used only if both modems set this bit to 1.
29:30	Trellis encoder select bits: 0 = 16 State; 1 = 32 State; 2 = 64 State; 3 = Reserved for ITU-T. Receiver requires remote-end transmitter to use selected trellis encoder.
31	Non-linear encoder parameter select bit for the remote-end transmitter. 0: $\Theta = 0$, 1: $\Theta = 0.3125$.
32	Constellation shaping select bit for the remote-end transmitter. 0: minimum, 1: expanded (see Table 10).
33	Acknowledge bit. 0 = modem has not received MP from far end. 1 = received MP from far end.
34	Start bit: 0.
35:49	Data signalling rate capability mask. Bit 35:2400; bit 36:4800; bit 37:7200; ...; bit 46:28 800; bit 47:31 200; bit 48:33 600; bit 49: Reserved for ITU-T. (This bit is set to 0 by the transmitting modem and is not interpreted by the receiving modem.) Bits set to 1 indicate data signalling rates supported and enabled in both transmitter and receiver of modem.
50	Asymmetric data signalling rate enable. Set to 1 indicates modem capable of asymmetric data signalling rates.
51	Start bit: 0.
52:67	Precoding coefficient h(1) real.
68	Start bit: 0.
69:84	Precoding coefficient h(1) imaginary.
85	Start bit: 0.
86:101	Precoding coefficient h(2) real.
102	Start bit: 0.
103:118	Precoding coefficient h(2) imaginary.
119	Start bit: 0.
120:135	Precoding coefficient h(3) real.
136	Start bit: 0.
137:152	Precoding coefficient h(3) imaginary.
153	Start bit: 0.
154:169	Reserved for ITU-T: These bits are set to 0 by the transmitting modem and are not interpreted by the receiving modem.
170	Start bit: 0.
171:186	CRC.
187	Fill bit: 0.
NOTE – Data rates greater than 12 in bits 20:23 and 24:27 shall only be indicated when the remote modem supports up to 1664-point signal constellations.	

10.2 Signals and sequences used in half-duplex operation

10.2.1 Phase 1

All signals in Phase 1 shall be transmitted at the nominal transmit power level. Signals used in Phase 1 of start-up for half-duplex operation are identical to those specified in 10.1.1.

10.2.2 Phase 2

During Phase 2, all signals except L1 shall be transmitted at the nominal transmit power level. Signals used in Phase 2 of start-up for half-duplex operation are identical to those specified in 10.1.2, except that INFO_{1a} and INFO_{1c} are replaced by INFO_h.

10.2.2.1 INFO_h Bits

Table 22 defines the bits in the INFO_h sequence.

Table 22/V.34 – Definition of bits in INFO_h sequence

INFO _h bits LSB:MSB	Definition
0:3	Fill bits: 1111.
4:11	Frame sync: 01110010, where the left-most bit is first in time.
12:14	Power reduction requested by the recipient modem receiver. An integer between 0 and 7 gives the requested power reduction in dB. These bits shall indicate 0 if the source modem's INFO ₀ indicated that the source modem transmitter cannot reduce its power.
15:21	Length of TRN to be transmitted by the source modem during Phase 3. An integer between 0 and 127 gives the length of this sequence in 35 ms increments.
22	Set to 1 indicates the high carrier frequency is to be used in data mode transmission. This must be consistent with the capabilities indicated in the source modem's INFO ₀ .
23:26	Pre-emphasis filter to be used in transmitting from the source modem to the recipient modem. These bits form an integer between 0 and 10 which represents the pre-emphasis filter index (see Tables 3 and 4).
27:29	Symbol rate to be used for data transmission. An integer between 0 and 5 gives the symbol rate, where 0 represents 2400 and a 5 represents 3429.
30	Set to 1 indicates TRN uses a 16-point constellation, 0 indicates TRN uses a 4-point constellation.
31:46	Code CRC.
47:50	Fill bits: 1111.

10.2.3 Phase 3

All signals in Phase 3 are transmitted using the selected symbol rate, carrier frequency, pre-emphasis filter, and power level.

NOTE – The transmitter should compensate for modulation factors including the effects of non-linear encoding and precoding so that the average signal power transmitted in Phase 3 is maintained in segment B1 and the subsequent data mode.

10.2.3.1 PP

As defined in 10.1.3.6.

10.2.3.2 S

As defined in 10.1.3.7.

10.2.3.3 Sh

Signal Sh is transmitted by alternating between point 0 of the quarter-superconstellation of Figure 5 and the same point rotated counterclockwise by 90 degrees. Signal \overline{Sh} is transmitted by alternating between point 0 rotated by 180 degrees and point 0 rotated counterclockwise by 270 degrees. Signal Sh shall end with the transmission of point 0 rotated counterclockwise by 90 degrees. Signal \overline{Sh} shall begin with the transmission of point 0 rotated by 180 degrees. Signals Sh and \overline{Sh} are transmitted using the control channel modulation described in 10.2.4.

10.2.3.4 TRN

TRN is a sequence of symbols chosen from the 4- or 16-point 2D constellation depending on bit 30 of $INFO_h$.

The 4-point TRN sequence and the 16-point TRN sequence are generated as defined in 10.1.3.8.

10.2.4 Control channel modulation

The control channel is transmitted using 1200 bit/s or 2400 bit/s QAM modulation using a symbol rate of $600 \pm 0.01\%$ symbol/s. Training and synchronization signals for the control channel are transmitted at 1200 bit/s. The control channel data is scrambled using the scrambler defined in clause 7.

The answer modem shall transmit with a carrier frequency of $2400 \pm 0.01\%$ Hz, at 1 dB below the nominal transmit power level, plus a $1800 \pm 0.01\%$ Hz guard tone at a level 7 dB below the nominal transmit power level. The call modem shall transmit with a $1200 \pm 0.01\%$ Hz carrier at the nominal transmit power level. The transmitted line signal shall have a magnitude spectrum within the limits shown in Figure 13.

For a data rate of 1200 bit/s, 2 bits are transmitted every symbol interval. For a data rate of 2400 bit/s, 4 bits are transmitted every symbol interval. These bits are labelled I1, I2, Q1, Q2, where I1 is the first bit in time and Q2 is the last bit in time. If only 2 bits are transmitted, the Q1 and Q2 bits are set to 0. Uncoded transmission is used.

The transmitted point is obtained by using $2 \cdot Q2 + Q1$ to select a point from the quarter superconstellation of Figure 5. Then the point is rotated clockwise by $Z_n \cdot 90$ degrees, where the two-bit integer Z_n is formed from the modulo 4 sum of $2 \cdot I2_n + I1_n$ and Z_{n-1} . If differential encoding is not enabled, $Z_n = 2 \cdot I2_n + I1_n$.

10.2.4.1 AC

Signal AC is the alternating transmission of point 0 of the quarter-superconstellation of Figure 5 and point 0 rotated by 180 degrees.

10.2.4.2 ALT

Signal ALT is transmitted using the control channel modulation with the differential encoder enabled and consists of scrambled alternations of binary 0 and 1 at 1200 bit/s. The initial state of the scrambler shall be all zeroes.

10.2.4.3 E

E is a 20-bit sequence of scrambled binary ones used to signal the beginning of control channel user data. It uses the control channel modulation at 1200 bit/s with the differential encoder enabled.

10.2.4.4 Modulation parameter (MPH) sequences

Modulation parameter (MPH) sequences are exchanged between modems during start-up and control channel resynchronization. They contain modulation parameters to be used for data mode transmission.

MPH sequences are transmitted using the control channel modulation at 1200 bit/s with the differential encoder and scrambler enabled as described in 10.2.4.

There are two types of MP sequences used in half-duplex mode (MPH). Type 0 contains maximum source modem data signalling rate, control channel data signalling rate, trellis encoder choice, non-linear encoding parameter, amount of

shaping, data signalling rate capability mask, asymmetrical control channel data rate enable, and bits reserved for future use. Type 1 is the same as Type 0 with the addition of fields for precoding coefficients. The bit fields for the two types of MPh sequences used in half-duplex mode are defined in Tables 23 and 24.

Either type (Type 0 or Type 1) of MPh sequence may be sent. Prior to receiving the first MPh sequence during control channel start-up, the precoding coefficients are initialized to 0. If a Type 0 sequence is received, the precoding coefficients are unaffected.

Table 23/V.34 – Definition of bits in MPh sequence Type 0

MPh bits LSB:MSB	Definition
0:16	Frame sync: 1111111111111111.
17	Start bit: 0.
18	Type: 0.
19	Reserved for ITU-T: This bit is set to 0 by the transmitting modem and is not interpreted by the receiving modem.
20:23	Maximum data signalling rate: Data rate = $N * 2400$ where N is a 4-bit integer between 1 and 14.
24:26	Reserved for ITU-T: These bits are set to 0 by the transmitting modem and are not interpreted by the receiving modem.
27	Control channel data signalling rate selected for remote transmitter. 0 = 1200 bit/s, 1 = 2400 bit/s (see bit 50 below).
28	Reserved for ITU-T: This bit is set to 0 by the transmitting modem and is not interpreted by the receiving modem.
29:30	Trellis encoder select bits: 0 = 16 State; 1 = 32 State; 2 = 64 State; 3 = Reserved for ITU-T. Receiver requires remote-end transmitter to use selected trellis encoder.
31	Non-linear encoder parameter select bit for the remote-end transmitter. 0: $\Theta = 0$, 1: $\Theta = 0.3125$.
32	Constellation shaping select bit for the remote-end transmitter. 0: minimum, 1: expanded (see Table 10).
33	Reserved for ITU-T: This bit is set to 0 by the transmitting modem and is not interpreted by the receiving modem.
34	Start bit: 0.
35:49	Data signalling rate capability mask. Bit 35:2400; bit 36:4800; bit 37:7200; ...; bit 46:28 800; bit 47:31 200; bit 48:33 600; bit 49: Reserved for ITU-T. (This bit is set to 0 by the transmitting modem and is not interpreted by the receiving modem.) Bits set to 1 indicate data signalling rates supported and enabled in both transmitter and receiver of modem.
50	Enables asymmetric control channel data rates: 0 = Asymmetric mode not allowed; 1 = Asymmetric mode allowed. Asymmetric mode shall be used only when both modems set bit 50 to 1. If different data rates are selected in symmetric mode, both modems shall transmit at the lower rate.
51	Start bit: 0.
52:67	Reserved for ITU-T: These bits are set to 0 by the transmitting modem and are not interpreted by the receiving modem.
68	Start bit: 0.
69:84	CRC.
85:87	Fill bits: 000.
NOTE 1 – Data rates greater than 12 in bits 20:23 shall only be indicated when the remote modem supports up to 1664-point signal constellations.	
NOTE 2 – Source modem does not use bits 29-32, and should set these bits to 0.	

Table 24/V.34 – Definition of bits in MPH sequence Type 1

MPH bits LSB:MSB	Definition
0:16	Frame sync: 1111111111111111.
17	Start bit: 0.
18	Type: 1.
19	Reserved for ITU-T: This bit is set to 0 by the transmitting modem and is not interpreted by the receiving modem.
20:23	Maximum data signalling rate: Data rate = $N * 2400$ where N is a four-bit integer between 1 and 14.
24:26	Reserved for ITU-T: These bits are set to 0 by the transmitting modem and are not interpreted by the receiving modem.
27	Control channel data signalling rate selected for remote transmitter. 0 = 1200 bit/s, 1 = 2400 bit/s (See bit 50 below).
28	Reserved for ITU-T: This bit is set to 0 by the transmitting modem and is not interpreted by the receiving modem.
29:30	Trellis encoder select bits: 0 = 16 State; 1 = 32 State; 2 = 64 State; 3 = Reserved for ITU-T. Receiver requires remote-end transmitter to use selected trellis encoder.
31	Non-linear encoder parameter select bit for the remote-end transmitter. 0: $\Theta = 0$, 1: $\Theta = 0.3125$.
32	Constellation shaping select bit for the remote-end transmitter. 0: minimum, 1: expanded (see Table 10).
33	Reserved for ITU-T: This bit is set to 0 by the transmitting modem and is not interpreted by the receiving modem.
34	Start bit: 0.
35:49	Data signalling rate capability mask. Bit 35:2400; bit 36:4800; bit 37:7200; ...; bit 46:28 800; bit 47:31 200; bit 48:33 600; bit 49: Reserved for ITU-T. (This bit is set to 0 by the transmitting modem and is not interpreted by the receiving modem.) Bits set to 1 indicate data signalling rates supported and enabled in both transmitter and receiver of modem.
50	Enables asymmetric control channel data rates: 0 = Asymmetric mode not allowed; 1 = Asymmetric mode allowed. Asymmetric mode shall be used only when both modems set bit 50 to 1. If different data rates are selected in symmetric mode, both modems shall transmit at the lower rate.
51	Start bit: 0.
52:67	Precoding coefficient h(1) real.
68	Start bit: 0.
69:84	Precoding coefficient h(1) imaginary.
85	Start bit: 0.
86:101	Precoding coefficient h(2) real.
102	Start bit: 0.
103:118	Precoding coefficient h(2) imaginary.
119	Start bit: 0.
120:135	Precoding coefficient h(3) real.
136	Start bit: 0.
137:152	Precoding coefficient h(3) imaginary.
153	Start bit: 0.
154:169	Reserved for ITU-T: These bits are set to 0 by the transmitting modem and are not interpreted by the receiving modem.
170	Start bit: 0.
171:186	CRC.
187	Fill bit: 0.
NOTE 1 – Data rates greater than 12 in bits 20:23 shall only be indicated when the remote modem supports up to 1664-point signal constellations.	
NOTE 2 – Source modem does not use bits 29-32, and should set these bits to 0.	

10.2.4.5 PPh

PPh consists of four periods of an 8-symbol sequence and is used in half-duplex mode for control channel receiver initialization and resynchronization. The sequence PPh(i), $i = 0, 1, \dots, 31$ is defined as follows:

$$\text{Set } i = 2k + I,$$

where:

$$k = 0, 1, 2, \dots, 15; \text{ and}$$

$$I = 0, 1 \text{ for each } k$$

then:

$$\text{PPh}(i) = e^{j\pi \left[\frac{2k(k-1)+1}{4} \right]} \quad (10-2)$$

PPh(0) is transmitted first.

11 Duplex operating procedures

There are two duplex modes of operation defined, GSTN and two-wire leased line. For GSTN operation, the modem shall proceed according to 11.1. For two-wire leased line operation, the modem shall proceed according to 11.8.

11.1 Phase 1 – Network interaction

11.1.1 Call modem

11.1.1.1 Initially, the call modem shall condition its receiver to detect either signal ANS or ANSam as defined in Recommendation V.8, and the modem shall transmit CI, CT CNG or no signal, as defined in Recommendation V.8.

If signal ANSam is detected, the modem shall transmit silence for the period T_e as specified in Recommendation V.8. The modem shall then condition its receiver to detect JM and sends CM with the appropriate bits set in the modulation modes category to indicate that V.34 operation is desired. When a minimum of two identical JM sequences have been received, the modem shall complete the current CM octet and send CJ. After sending CJ, the modem shall transmit silence for 75 ± 5 ms and proceed with Phase 2. This procedure is shown in Figure 15.

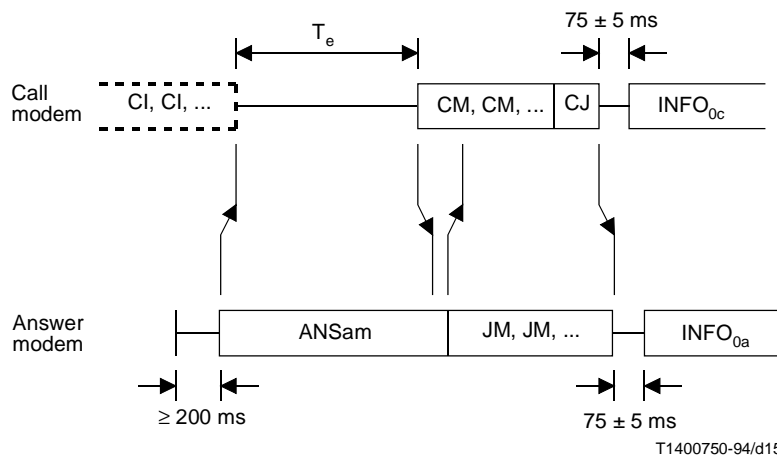


Figure 15/V.34 – Phase 1 – Network interaction with a CM/JM exchange

11.1.1.2 If the JM modulation mode bits indicate V.34 duplex operation, the modem shall proceed in accordance with 11.2. If half-duplex V.34 operation is indicated, the modem shall proceed in accordance with 12.2. If V.34 operation is not indicated, the modem shall proceed in accordance with Recommendation V.8.

11.1.1.3 If signal ANS (rather than ANSam) is detected, the modem shall proceed in accordance with Annex A/V.32 bis, Recommendation T.30, or other appropriate Recommendations.

11.1.2 Answer modem

11.1.2.1 Upon connection to line, the modem shall initially remain silent for a minimum of 200 ms and then transmit signal ANSam according to the procedure in Recommendation V.8. If duplex operation is intended, this signal shall include phase reversals as specified in Recommendation V.8. If half-duplex operation is intended, phase reversals are optional. The modem shall condition its receiver to detect CM and, possibly, calling modem responses from other appropriate Recommendations.

11.1.2.2 If a minimum of 2 identical CM sequences are received and the modulation mode bits indicate V.34 operation, the modem shall send JM and condition its receiver to detect CJ. After receiving all 3 octets of CJ, the modem shall transmit silence for 75 ± 5 ms, and proceed with Phase 2 of start-up. This procedure is shown in Figure 15.

11.1.2.3 If the JM modulation mode bits indicate V.34 duplex operation, the modem shall proceed in accordance with 11.2. If half-duplex V.34 operation is indicated, the modem shall proceed in accordance with 12.2. If V.34 operation is not indicated, the modem shall proceed in accordance with Recommendation V.8.

11.1.2.4 If a call modem response from some other appropriate Recommendation is detected, the modem shall proceed in accordance with the appropriate Recommendation.

11.1.2.5 If neither CM nor a suitable call modem response is detected for the allowed ANSam transmission period as specified in Recommendation V.8, the modem shall transmit silence for 75 ± 5 ms, and then proceed in accordance with Annex A/V.32 bis, Recommendation T.30, or other appropriate Recommendations.

11.2 Phase 2 – Probing/ranging

Channel probing and ranging are performed in Phase 2 of the start-up procedure. The description below details both error-free and recovery procedures in the call and answer modems (see Figures 16, 17 and 18). Capabilities information and modulation parameters are sent in the INFO sequences detailed in 10.1.2.3.

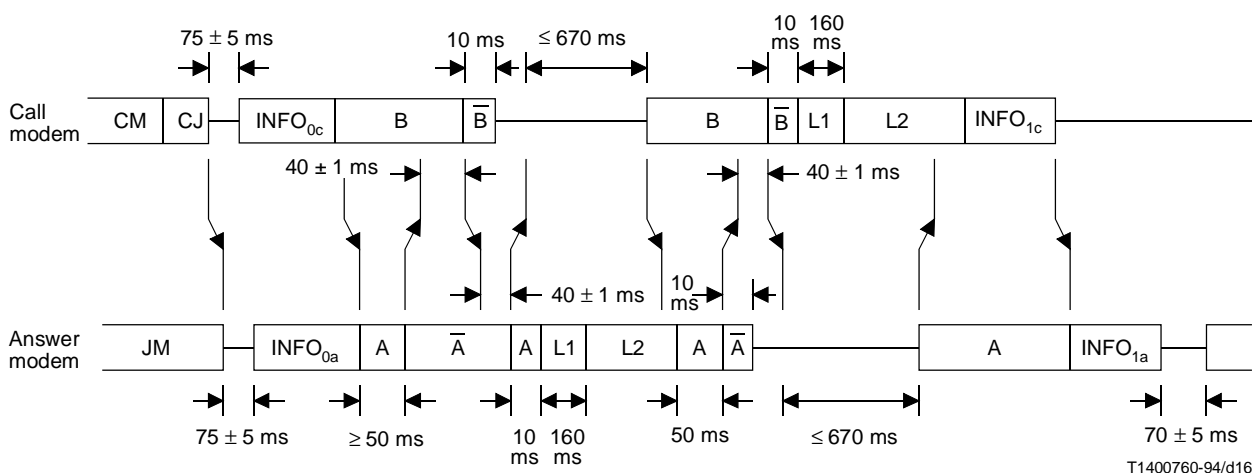


Figure 16/V.34 – Phase 2 – Probing/ranging

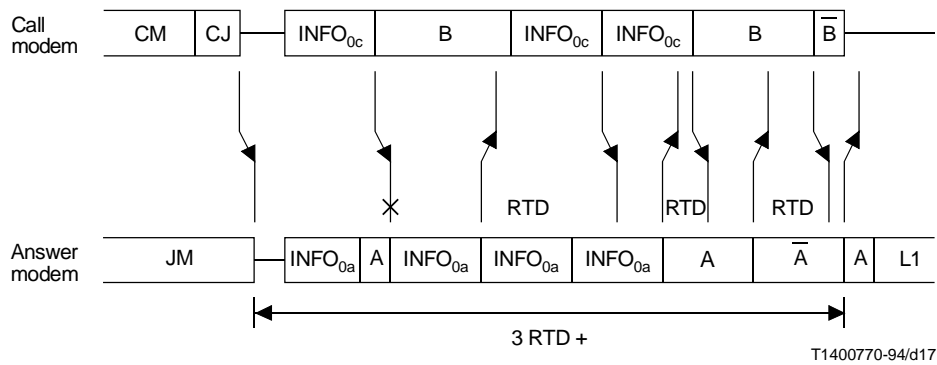


Figure 17/V.34 – Answer modem does not correctly receive INFO_{0c}

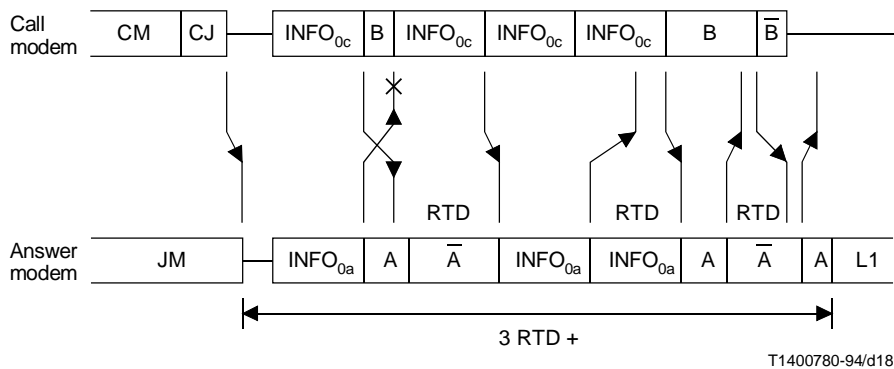


Figure 18/V.34 – Call modem does not correctly receive INFO_{0a}

11.2.1 Error free procedures

11.2.1.1 Call modem

11.2.1.1.1 During the 75 ± 5 ms silent period ending Phase 1, the call modem shall condition its receiver to receive INFO_{0a} and detect Tone A. After the 75 ± 5 ms silent period, the call modem shall send INFO_{0c} with bit 28 set to 0, followed by Tone B.

11.2.1.1.2 After receiving INFO_{0a}, the call modem shall condition its receiver to detect Tone A, receive INFO_{0a} (see recovery mechanisms, 11.2.2), and detect the subsequent Tone A phase reversal.

11.2.1.1.3 After detecting the Tone A phase reversal, the call modem shall transmit a Tone B phase reversal. The Tone B phase reversal shall be delayed so that the time duration between receiving the Tone A phase reversal at the line terminals and the appearance of the Tone B phase reversal at the line terminals is 40 ± 1 ms. Tone B shall be transmitted for another 10 ms after the phase reversal. The modem shall then transmit silence and condition its receiver to detect a second Tone A phase reversal.

11.2.1.1.4 After detecting the second Tone A phase reversal, the call modem can calculate the round trip delay. The round trip delay estimate, RTDEc, is the time interval between the appearance of the Tone B phase reversal at the modem line terminals and receiving the second Tone A phase reversal at the line terminals minus 40 ms. The modem shall then condition its receiver to receive the probing signals L1 and L2.

11.2.1.1.5 The call modem shall receive signal L1 for its 160 ms duration. The call modem may then receive signal L2 for a period of time not to exceed 500 ms. The call modem shall then transmit Tone B and condition its receiver to detect Tone A and the subsequent Tone A phase reversal.

11.2.1.1.6 After detecting Tone A and the subsequent Tone A phase reversal, the call modem shall transmit a Tone B phase reversal. The Tone B phase reversal shall be delayed so that the time duration between receiving the Tone A phase reversal at the line terminals and the appearance of the Tone B phase reversal at the line terminals is 40 ± 1 ms. Tone B shall be transmitted for an additional 10 ms after the phase reversal. The modem shall then transmit signal L1 followed by signal L2 and condition its receiver to detect Tone A.

11.2.1.1.7 After the call modem detects Tone A and has received the local echo of L2 for a period of time not to exceed 550 ms plus a round trip delay, the modem shall send INFO_{1c}.

11.2.1.1.8 After sending INFO_{1c}, the call modem shall transmit silence and condition its receiver to receive INFO_{1a}. After receiving INFO_{1a}, the modem shall proceed to Phase 3 of the start-up procedure.

11.2.1.2 Answer modem

11.2.1.2.1 During the 75 ± 5 ms silent period ending Phase 1, the answer modem shall condition its receiver to receive INFO_{0c} and detect Tone B. After the 75 ± 5 ms silent period, the answer modem shall send INFO_{0a} with bit 28 set to 0, followed by Tone A.

11.2.1.2.2 After receiving INFO_{0c}, the modem shall condition its receiver to detect Tone B and receive INFO_{0c} (see recovery mechanisms, 11.2.2).

11.2.1.2.3 After Tone B is detected and Tone A has been transmitted for at least 50 ms, the answer modem shall transmit a Tone A phase reversal, and condition its receiver to detect a Tone B phase reversal.

11.2.1.2.4 After detecting the Tone B phase reversal, the answer modem can calculate the round trip delay. The round trip delay estimate, RTDE_a, is the time interval between sending the Tone A phase reversal at the line terminals and receiving the Tone B phase reversal at the line terminals minus 40 ms.

11.2.1.2.5 The answer modem shall then transmit a Tone A phase reversal. The Tone A phase reversal shall be delayed so that the time duration between receiving the Tone B phase reversal (as in 11.2.1.2.4) at the line terminals and the appearance of the Tone A phase reversal at the line terminals is 40 ± 1 ms. Tone A shall be transmitted for 10 ms after the phase reversal. Then the modem shall transmit signal L1 followed by signal L2 and condition its receiver to detect Tone B.

11.2.1.2.6 When Tone B is detected and the answer modem has received the local echo of L2 for a period of time not to exceed 550 ms plus a round trip delay, the answer modem shall transmit Tone A for 50 ms followed by a Tone A phase reversal. Tone A shall be transmitted for an additional 10 ms after the phase reversal. Then the modem shall transmit silence and condition its receiver to detect a Tone B phase reversal.

11.2.1.2.7 After detecting the Tone B phase reversal, the modem shall condition its receiver to receive the probing signals L1 and L2.

11.2.1.2.8 The answer modem shall receive signal L1 for its 160 ms duration. The answer modem may then receive signal L2 for a period of time not to exceed 500 ms. The answer modem shall then transmit Tone A and condition its receiver to receive INFO_{1c}.

11.2.1.2.9 After receiving INFO_{1c}, the modem shall send INFO_{1a}. After sending INFO_{1a}, the modem shall proceed to Phase 3 of the start-up procedure.

11.2.2 Recovery mechanisms

11.2.2.1 Call modem

11.2.2.1.1 If, in 11.2.1.1.2 or 11.2.1.1.3, the call modem detects Tone A before receiving INFO_{0a}, or if it receives repeated INFO_{0a} sequences, the call modem shall repeatedly send INFO_{0c} sequences.

If the call modem receives INFO_{0a} with bit 28 set to 1, it shall condition its receiver to detect Tone A and the subsequent Tone A phase reversal, complete sending the current INFO_{0c} sequence, and then transmit Tone B. Alternatively, if the call modem detects Tone A and has received INFO_{0a}, it shall condition its receiver to detect a Tone A phase reversal, complete sending the current INFO_{0c} sequence, and transmit Tone B. In both cases, the call modem shall then proceed according to 11.2.1.1.3.

11.2.2.1.2 If, in 11.2.1.1.3, the call modem does not detect the Tone A phase reversal, the call modem shall continue transmitting Tone B until it does detect a Tone A phase reversal.

11.2.2.1.3 If, in 11.2.1.1.4, the call modem does not detect a Tone A phase reversal within 2000 ms from the phase reversal detected in 11.2.1.1.3, the call modem shall transmit silence and condition its receiver to detect Tone A. After detecting Tone A, the call modem shall transmit Tone B and condition its receiver to detect a Tone A phase reversal and proceed in accordance with 11.2.1.1.3.

11.2.2.1.4 If, in 11.2.1.1.6, the call modem does not detect the Tone A phase reversal within 900 ms plus a round trip delay from the phase reversal detected in 11.2.1.1.4, the modem waits 40 ms, then transmits a Tone B phase reversal. Tone B shall be transmitted for an additional 10 ms after the phase reversal. The modem shall then transmit signal L1 followed by signal L2, condition its receiver to detect Tone A, and proceed in accordance with 11.2.1.1.7.

11.2.2.1.5 If, in 11.2.1.1.7, the call modem does not detect Tone A within 650 ms plus a round trip delay from the beginning of L2, the call modem shall initiate a retrain according to 11.5.1.1.

11.2.2.1.6 If, in 11.2.1.1.8, the call modem does not receive INFO_{1a} within 700 ms plus a round trip delay from the end of INFO_{1c} transmission, the call modem shall condition its receiver to detect either Tone A or INFOMARKS_a. Upon detection of INFOMARKS_a, the call modem shall either initiate a retrain according to 11.5.1.1 or send INFO_{1c} and proceed in accordance with 11.2.1.1.8. Upon detection of Tone A, the call modem shall respond to a retrain and proceed according to 11.5.1.2.

NOTE – The call modem shall set bit 28 of sequence INFO_{0c} to 1 after correctly receiving INFO_{0a}.

11.2.2.2 Answer modem

11.2.2.2.1 If, in 11.2.1.2.2, 11.2.1.2.3, or 11.2.1.2.4, the answer modem detects Tone B before correctly receiving INFO_{0c}, or if it receives repeated INFO_{0c} sequences, the modem shall repeatedly send INFO_{0a}.

If the answer modem receives INFO_{0c} with bit 28 set to 1, it shall condition its receiver to detect Tone B, complete the current INFO_{0a}, and then transmit Tone A. Alternatively, if the answer modem detects Tone B and has received INFO_{0c}, it shall complete the current INFO_{0a}, and transmit Tone A. In both cases, the answer modem shall then proceed according to 11.2.1.2.3.

11.2.2.2.2 If, in 11.2.1.2.4, the answer modem does not detect the Tone B phase reversal within 2000 ms, the answer modem shall condition its receiver to detect Tone B and then proceed according to 11.2.1.2.3.

11.2.2.2.3 If, in 11.2.1.2.6, the answer modem does not detect Tone B within 600 ms plus a round trip delay from the beginning of L2, the modem shall condition its receiver to detect Tone B and transmit Tone A. The answer modem shall then proceed according to 11.2.1.2.3.

11.2.2.2.4 If, in 11.2.1.2.9, the answer modem does not receive INFO_{1c} within 2000 ms plus two round trip delays from the detection of Tone B in 11.2.1.2.6, the modem shall either initiate a retrain according to 11.5.2.1 or send INFOMARKS_a until it receives INFO_{1c} or detects Tone B. If Tone B is detected, the answer modem shall proceed according to 11.5.2.2. If INFO_{1c} is received, the answer modem shall then proceed according to 11.2.1.2.9.

NOTE – The answer modem shall set bit 28 of sequence INFO_{0a} to 1 upon correctly receiving INFO_{0c}.

11.3 Phase 3 – Equalizer and echo canceller training

Equalizer and echo canceller training are performed in Phase 3 of the duplex start-up procedure. The description below details both the error-free and recovery procedures in the call and answer modems (see Figure 19).

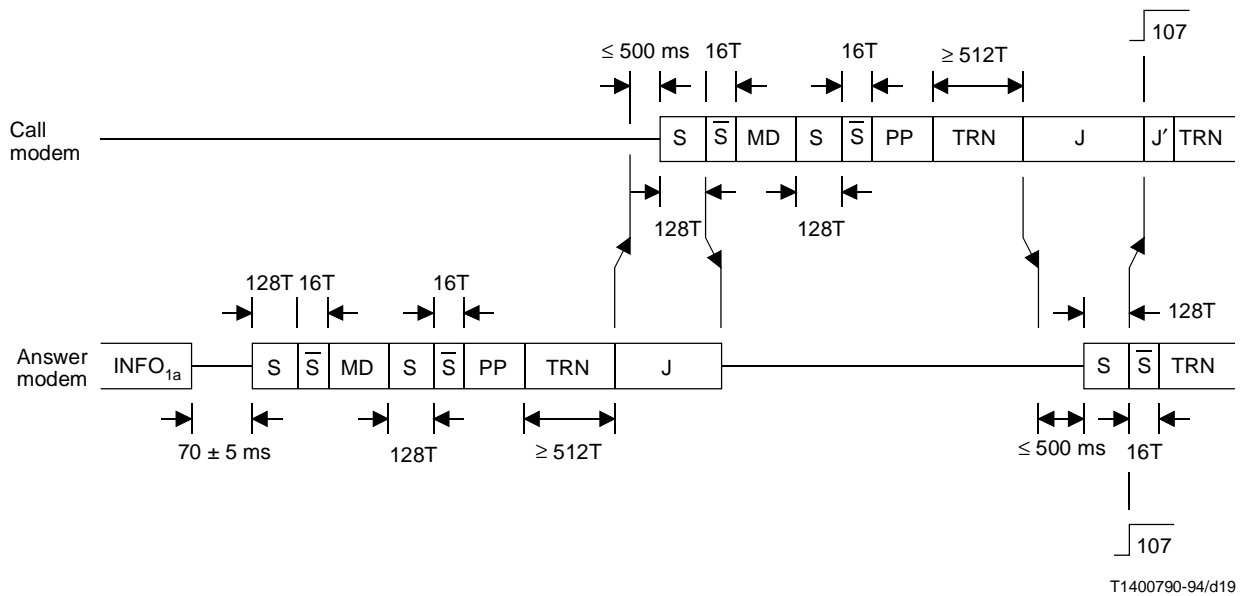


Figure 19/V.34 – Phase 3 – Equalizer and echo canceller training

11.3.1 Error free procedure

11.3.1.1 Call modem

11.3.1.1.1 The call modem shall be initially silent and condition its receiver to detect S and the subsequent \bar{S} . If the duration of signal MD indicated by INFO_{1a} is zero, the modem shall proceed according to 11.3.1.1.2. Otherwise, after detecting the S-to- \bar{S} transition, the modem shall wait for the duration of signal MD as indicated by INFO_{1a} and then shall condition its receiver to receive signal S and the S-to- \bar{S} transition.

11.3.1.1.2 After detecting signal S and the S-to- \bar{S} transition, the modem shall condition its receiver to begin training its equalizer using signal PP. After receiving signal PP, the modem may further refine its equalizer using the first 512T of signal TRN.

11.3.1.1.3 After receiving the first 512T of signal TRN, the modem shall condition its receiver to receive sequence J. After receiving J, the call modem may wait for up to 500 ms and then shall transmit signal S for 128T and signal \bar{S} for 16T.

11.3.1.1.4 If the duration of the call modem's MD signal, as indicated in the previous INFO_{1c}, is zero, the modem shall proceed according to 11.3.1.1.5. Otherwise, the modem shall transmit signal MD for the duration indicated in the previous INFO_{1c} and then transmit S for 128T and signal \bar{S} for 16T.

11.3.1.1.5 The call modem shall then transmit signal PP.

11.3.1.1.6 After transmitting signal PP, the modem shall transmit signal TRN. Signal TRN consists of four constellation points and shall be transmitted for at least 512T. The total time from the beginning of transmission of signal MD to the end of signal TRN shall not exceed two round trip delays plus 2000 ms.

11.3.1.1.7 After transmitting signal TRN, the modem shall send sequence J and condition its receiver to detect signal S. After detecting signal S, the modem shall proceed to Phase 4 of the start-up.

11.3.1.2 Answer modem

11.3.1.2.1 After sending sequence INFO_{1a}, the modem shall transmit silence for 70 ± 5 ms, signal S for 128T and signal \bar{S} for 16T. If the duration of the answer modem's MD signal, as indicated in the INFO_{1a}, is zero, the modem shall proceed according to 11.3.1.2.2. Otherwise, the modem shall transmit signal MD for the duration indicated in INFO_{1a}, signal S for 128T, and signal \bar{S} for 16T.

11.3.1.2.2 The answer modem shall then transmit signal PP.

11.3.1.2.3 After transmitting signal PP, the modem shall transmit signal TRN. Signal TRN consists of four constellation points and shall be transmitted for at least 512T. The total time from the beginning of transmission of signal MD to the end of signal TRN shall not exceed one round trip delay plus 2000 ms.

11.3.1.2.4 After transmitting signal TRN, the modem shall send sequence J and condition its receiver to detect signal S and the S-to- \bar{S} transition. After detecting the S-to- \bar{S} transition, the modem shall transmit silence. If the duration of signal MD indicated by INFO_{1c} is zero, the modem shall proceed according to 11.3.1.2.5. Otherwise, it shall wait for the duration of signal MD as indicated by INFO_{1c} and condition its receiver to detect signal S and the S-to- \bar{S} transition. After detecting the S-to- \bar{S} transition, the modem shall proceed according to 11.3.1.2.5.

11.3.1.2.5 The modem shall condition its receiver to begin its equalizer training using signal PP. The modem may further refine its equalizer using the first 512T of signal TRN.

11.3.1.2.6 After receiving the first 512T of signal TRN, the modem shall condition its receiver to receive sequence J. After receiving J, the answer modem may wait for up to 500 ms and shall then begin transmitting signal S. The modem shall then proceed to Phase 4 of the start-up.

11.3.2 Recovery mechanisms

11.3.2.1 Call modem

The call modem may initiate a retrain during Phase 3 according to 11.5.1.1.

11.3.2.1.1 If, in 11.3.1.1.3, sequence J is not received within 2800 ms plus two round trip delays from the end of INFO_{1c} transmission, the call modem shall condition its receiver to detect Tone A or receive INFOMARKS_a. If Tone A is detected, the call modem shall respond to a retrain in accordance with 11.5.1.2. If INFOMARKS_a is received, the call modem shall send INFO_{1c} and proceed in accordance with 11.2.1.1.8.

11.3.2.2 Answer modem

The answer modem may initiate a retrain during Phase 3 according to 11.5.2.1.

11.3.2.2.1 If, in 11.3.1.2.4, the S-to- \bar{S} transition is not detected within 600 ms plus a round trip delay from the start of sequence J, the answer modem shall transmit silence for 70 ± 5 ms, then send INFOMARKS_a. The answer modem shall continue sending INFOMARKS_a for the duration of the call modem's MD signal, then condition its receiver to detect Tone B or receive INFO_{1c}. If Tone B is detected, the answer modem shall respond to a retrain according to 11.5.2.2. If INFO_{1c} is received, the answer modem shall proceed in accordance with 11.2.1.2.9.

11.3.2.2.2 If, in 11.3.1.2.6, sequence J from the call modem is not received within 2600 ms plus two round trip delays from the end of sequence J in 11.3.1.2.4, the modem shall send INFOMARKS_a and condition its receiver to detect Tone B or receive INFO_{1c}. If Tone B is detected, the answer modem shall respond to a retrain according to 11.5.2.2. If INFO_{1c} is received, the answer modem shall proceed in accordance with 11.2.1.2.9.

11.4 Phase 4 – Final training

Final training of the modem in duplex mode and exchange of final data mode modulation parameters are performed in Phase 4 of the start-up procedure. The description below details both error-free and recovery procedures in the call and answer modems (see Figure 20). Data mode modulation parameters are passed in the MP sequences detailed in 10.1.3.9.

11.4.1 Error free procedure

11.4.1.1 Call modem

11.4.1.1.1 After detecting S followed by \bar{S} , the call modem shall stop sending J sequences, condition its receiver to detect signal TRN, turn on Circuit 107, transmit one J' sequence, and then transmit signal TRN.

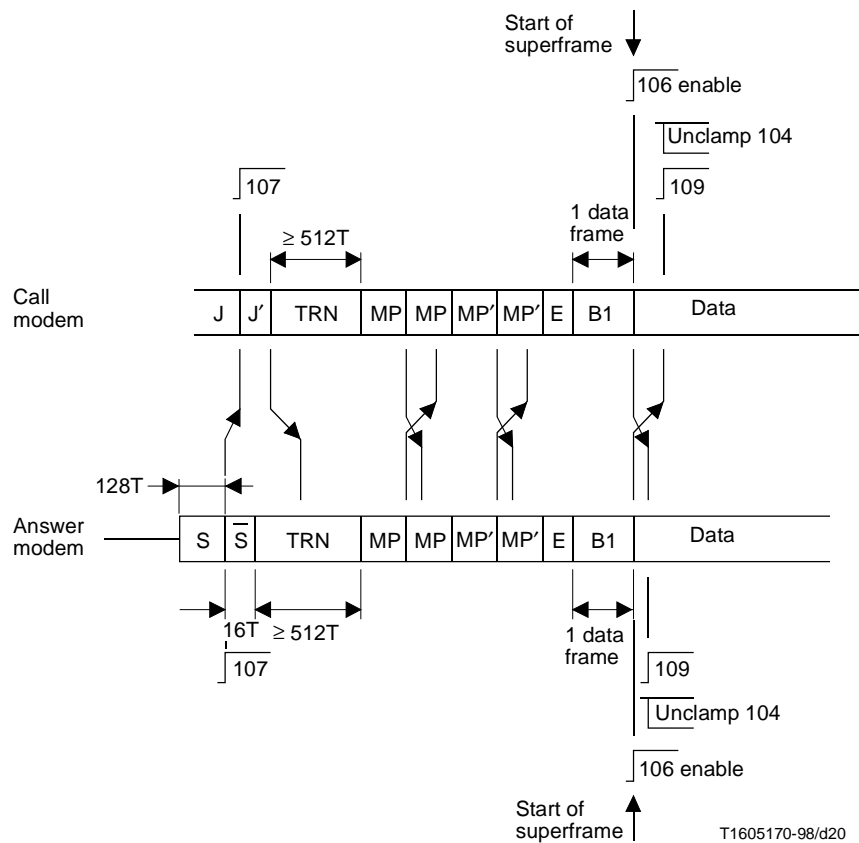


Figure 20/V.34 – Phase 4 – Final training

11.4.1.1.2 After transmitting signal TRN for a minimum of 512T, the modem shall condition its receiver to receive sequence MP and may continue sending TRN for up to 2000 ms. After training adequately, the call modem shall then cease transmitting TRN and send sequence MP. After receiving the answer modem's MP sequence, the call modem shall complete sending the current MP sequence and then send MP' sequences (MP sequences with the acknowledge bit set).

11.4.1.1.3 The call modem shall continue sending MP' sequences until it receives MP' or E from the answer modem. The modem shall then complete the current MP' sequence and then send a single 20-bit E sequence. The modem can then determine the data signalling rates in both directions as follows:

If bit 50 of MP is set to 0 (symmetric rates) by either the call or answer modems, the call modem's transmit and receive rate shall be the maximum rate enabled in both modems that is less than or equal to the call-to-answer and answer-to-call rates specified in both modems' MP sequences.

If both call and answer modems have bit 50 set to 1 (asymmetric rate) the call modem's transmit rate shall be the maximum rate enabled in both modems that is less than or equal to the call-to-answer rates specified in both modems' MP sequences. The call modem's receive rate shall be the maximum rate enabled in both modems that is less than or equal to the answer-to-call rates specified in both modems' MP sequences.

11.4.1.1.4 After sending an E sequence, the call modem shall send B1 at the negotiated data signalling rate using the data mode modulation parameters, enable Circuit 106 to respond to the condition of Circuit 105, start a new superframe, and begin data transmission using the modulation procedures of clauses 5 to 9.

11.4.1.1.5 After receiving a 20-bit E sequence, the modem shall condition its receiver to receive B1. After receiving B1, the modem shall unclamp Circuit 104, turn on Circuit 109, and begin demodulating data.

11.4.1.2 Answer modem

11.4.1.2.1 The answer modem shall transmit signal S for 128T, condition its receiver to detect sequence J' followed by signal TRN, and turn on Circuit 107. The modem shall then transmit signal \bar{S} for 16T followed by signal TRN.

11.4.1.2.2 After receiving 512T of signal TRN, the answer modem shall condition its receiver to receive sequence MP and continue transmitting TRN until its receiver is trained adequately. The modem shall transmit TRN for at least 512T but no longer than 2000 ms plus a round trip delay. It shall then send MP sequences. After receiving the call modem's MP sequence, the modem shall complete sending the current MP sequence, and then send MP' sequences (MP sequences with the acknowledge bit set).

11.4.1.2.3 The answer modem shall continue sending MP sequences until it has sent an MP' sequence and received P' or E from the call modem. The modem shall then complete the current MP' sequence and send a single 20-bit E sequence. The modem shall determine the data signalling rates as follows:

If bit 50 of MP is set to 0 (symmetric rates) by either the call or answer modem, the answer modem's transmit and receive rate shall be the maximum rate enabled in both modems that is less than or equal to the call-to-answer and answer-to-call rates specified in both modems' MP sequences.

If both call and answer modems have bit 50 set to 1 (asymmetric rate), the answer modem's transmit rate shall be the maximum rate enabled in both modems that is less than or equal to the answer-to-call rates specified in both modems' MP sequences. The answer modem's receive rate shall be the maximum rate enabled in both modems that is less than or equal to the call-to-answer rates specified in both modems' MP sequences.

11.4.1.2.4 After sending the E sequence, the answer modem shall send B1 at the negotiated data signalling rate using the data mode modulation parameters. The modem shall then enable Circuit 106 to respond to the condition of Circuit 105, start a new superframe, and begin data transmission using the modulation procedures of clauses 5 to 9.

11.4.1.2.5 After receiving a 20-bit E sequence, the answer modem conditions its receiver to receive B1. After receiving B1, the modem shall unclamp Circuit 104, turn on Circuit 109, and begin demodulating data.

Figure 20 shows the sequence of events during Phase 4.

11.4.2 Recovery mechanism

11.4.2.1 Call modem

If Tone A is detected during Phase 4, the call modem shall respond to a retrain according to 11.5.1.2. The call modem may initiate a retrain during Phase 4 according to 11.5.1.1.

11.4.2.1.1 If, in 11.4.1.1.1, the S-to- \bar{S} transition is not detected within 600 ms plus a round trip delay from the start of sequence J, the call modem shall transmit silence for 70 ± 5 ms, then send INFOMARKS_c. The modem shall then condition its receiver to receive INFOMARKS_a. After receiving INFOMARKS_a, the call modem shall send INFO_{1c} and proceed in accordance with 11.2.1.1.8.

11.4.2.1.2 If, after sending the J' sequence, the modem has not received the E sequence for the following timeout period, it shall initiate the retrain procedure. If bit 24 in INFO_{0a} is set to 1 (the CME bit in Table 14), the timeout period shall be 30 seconds. If bit 24 in INFO_{0a} is set to 0, the timeout period shall be 2500 ms plus two round trip delays.

11.4.2.2 Answer modem

If Tone B is detected during Phase 4, the answer modem shall respond to a retrain according to 11.5.2.2. The answer modem may initiate a retrain during Phase 4 according to 11.5.2.1.

11.4.2.2.1 If, in 11.4.1.2.1, sequence J' is not received within 100 ms plus a round trip delay from the S -to- \bar{S} transition, the answer modem shall condition its receiver to receive INFOMARKS_c or Tone B. If INFOMARKS_c is received, the answer modem shall send INFOMARKS_a , condition its receiver to receive INFO_{1c} , and then proceed in accordance with 11.2.1.2.9. If Tone B is detected, the answer modem shall respond to a retrain according to 11.5.2.2.

11.4.2.2.2 If after transmitting signal \bar{S} , the modem has not received the E sequence for the following timeout period, it shall initiate the retrain procedure. If bit 24 in INFO_{0c} is set to 1 (the CME bit in Table 14), the timeout period shall be 30 seconds. If bit 24 in INFO_{0c} is set to 0, the timeout period shall be 2500 ms plus 3 round trip delays.

11.5 Retrains

11.5.1 Call modem

11.5.1.1 Initiating retrain – To initiate a retrain, the call modem shall turn OFF Circuit 106, clamp Circuit 104 to binary one and transmit silence for 70 ± 5 ms. The call modem shall then transmit Tone B and condition its receiver to detect Tone A and receive INFO_{0a} . If Tone A is detected, the call modem shall condition its receiver to detect a Tone A phase reversal and proceed in accordance with 11.2.1.1.3. If INFO_{0a} is received, the modem shall proceed in accordance with 11.8.1.

11.5.1.2 Responding to retrain – After detecting Tone A for more than 50 ms, the call modem shall turn OFF Circuit 106, clamp Circuit 104 to binary one and transmit silence for 70 ± 5 ms. The call modem shall then transmit Tone B, condition its receiver to detect a Tone A phase reversal, and proceed in accordance with 11.2.1.1.3.

11.5.2 Answer modem

11.5.2.1 Initiating retrain – To initiate a retrain, the answer modem shall turn OFF Circuit 106, clamp Circuit 104 to binary one and transmit silence for 70 ± 5 ms. The answer modem shall then transmit Tone A and condition its receiver to detect Tone B and receive INFO_{0c} . If Tone B is detected and Tone A has been transmitted for at least 50 ms, the answer modem shall transmit a Tone A phase reversal and proceed according to 11.2.1.2.4. If INFO_{0c} is received, the modem shall proceed according to 11.8.2.

11.5.2.2 Responding to retrain – After detecting Tone B for more than 50 ms, the answer modem shall turn OFF Circuit 106, clamp Circuit 104 to binary one and transmit silence for 70 ± 5 ms. The answer modem shall then transmit Tone A and proceed in accordance with 11.2.1.2.3. See Figure 21.

11.6 Rate renegotiation

The rate renegotiation procedure can be initiated at any time during data mode to change to a new data signalling rate. This procedure can also be used to resynchronize the receiver without going through a complete retrain. In this case, signal TRN is transmitted until the receiver is prepared to enter data mode. Then the Modulation Parameters (MPs) sequence is sent. See Figure 22.

The TRN signal and the MP and E sequences are all sent using a 4-point constellation during rate renegotiation.

NOTE – An alternative method of rate renegotiation is detailed in Annex A. A modem control channel is used to enable a change in data signalling rate without disrupting the primary channel.

11.6.1 Error free procedure

11.6.1.1 Initiating modem

11.6.1.1.1 To initiate a rate renegotiation, the modem shall turn OFF Circuit 106, transmit signal S for 128T, followed by signal \bar{S} for 16T. The modem may then transmit signal TRN for a maximum of 2000 ms plus a round trip delay, followed by sequence MP.

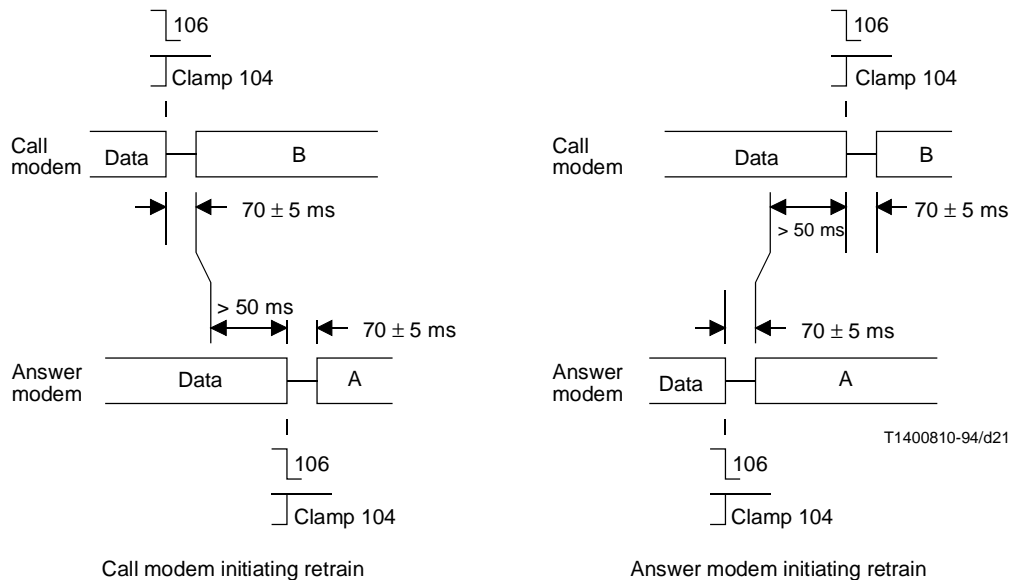


Figure 21/V.34 – Retrain sequences in duplex mode

11.6.1.1.2 After detecting signal S, the modem shall clamp Circuit 104 to binary one and be conditioned to detect the S-to- \bar{S} transition. After detecting the S-to- \bar{S} transition, the modem shall condition its receiver to receive sequence MP. When the modem has received at least one MP sequence, and the modem is sending MP sequences, the modem shall complete sending the current MP sequence and then send MP' sequences.

11.6.1.1.3 The initiating modem shall continue sending MP' sequences until it has sent an MP' sequence and received MP' or E from the responding modem. The modem shall then complete the current MP' sequence and send a single 20-bit E sequence. The initiating modem shall determine the data signalling rates as described in 11.4.1.1.3, if it is the call modem or in 11.4.1.2.3, if it is the answer modem.

11.6.1.1.4 After sending the E sequence, the initiating modem shall send B1 at the negotiated data signalling rate using the data mode modulation parameters. The modem shall then enable Circuit 106 to respond to the condition of Circuit 105, start a new superframe, and begin data transmission using the modulation procedures of clauses 5 to 9.

11.6.1.1.5 After receiving a 20-bit E sequence, the initiating modem shall condition its receiver to receive B1. After receiving B1, the modem shall unclamp Circuit 104, and begin demodulating data.

11.6.1.2 Responding modem

11.6.1.2.1 After detecting signal S, the responding modem shall clamp Circuit 104 to binary one and be conditioned to detect the S-to- \bar{S} transition. After detecting the S-to- \bar{S} transition, the responding modem shall condition its receiver to detect sequence MP.

11.6.1.2.2 The responding modem shall then turn OFF Circuit 106 and transmit signal S for 128T followed by signal \bar{S} for 16T. The modem may then transmit signal TRN for a maximum of 2000 ms, followed by sequence MP. When the modem has received at least one MP sequence, and the modem is sending MP sequences, the modem shall complete sending the current MP sequence and then send MP' sequences.

11.6.1.2.3 The responding modem shall continue transmitting MP' sequences until it receives MP' or E from the initiating modem. The modem shall then complete the current MP' sequence and then send a single 20-bit E sequence. The responding modem shall determine the data signalling rates as described in 11.4.1.1.3, if it is the call modem or in 11.4.1.2.3, if it is the answer modem.

11.6.1.2.4 After sending an E sequence, the responding modem shall send B1 at the negotiated data signalling rate using the data mode modulation parameters, enable Circuit 106 to respond to the condition of Circuit 105, start a new superframe, and begin data transmission using the modulation procedures of clauses 5 to 9.

11.6.1.2.5 After receiving a 20-bit E sequence, the modem shall condition its receiver to receive B1. After receiving B1, the modem shall unclamp Circuit 104, and begin demodulating data.

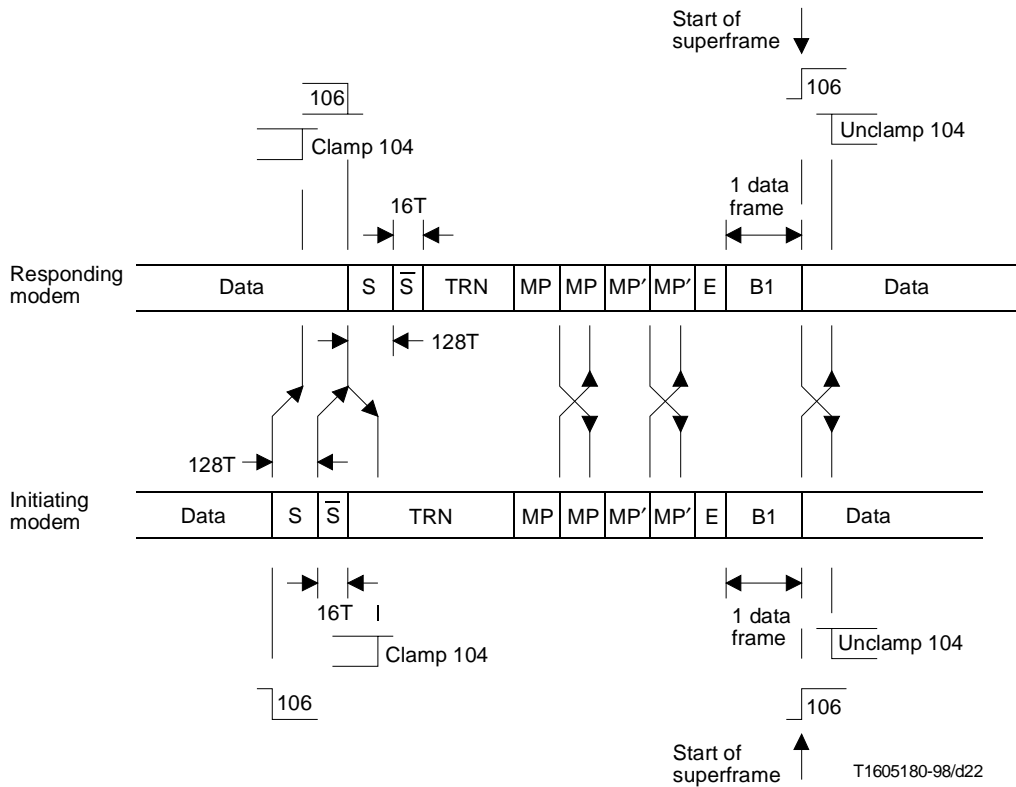


Figure 22/V.34 – Rate renegotiation – MP' represents the MP signal with the acknowledge bit set

11.6.2 Recovery mechanism

11.6.2.1 Initiating modem

If the initiating modem is the call modem and Tone A is detected during rate renegotiation, the modem shall respond to a retrain according to 11.5.1.2, or it may initiate a retrain according to 11.5.1.1. If the initiating modem is the answer modem and Tone B is detected during rate renegotiation, the modem shall respond to a retrain according to 11.5.2.2, or it may initiate a retrain according to 11.5.2.1.

If after transmitting the S-to- \bar{S} transition, the modem has not received sequence E for the following timeout period, it shall initiate the retrain procedure. If bit 24 in INFO₀ is set to 1 (the CME bit in Table 14), the timeout period shall be 30 seconds. If bit 24 in INFO₀ is set to 0, the timeout period shall be 2500 ms plus two round trip delays.

11.6.2.2 Responding modem

If the responding modem is the call modem and Tone A is detected during rate renegotiation, the modem shall respond to a retrain according to 11.5.1.2, or it may initiate a retrain according to 11.5.1.1. If the responding modem is the answer modem and Tone B is detected during rate renegotiation, the modem shall respond to a retrain according to 11.5.2.2, or it may initiate a retrain according to 11.5.2.1.

If after transmitting the S-to- \bar{S} transition, the modem has not received sequence E for the following timeout period, it shall initiate the retrain procedure. If bit 24 in INFO₀ is set to 1 (the CME bit in Table 14), the timeout period shall be 30 seconds. If bit 24 in INFO₀ is set to 0, the timeout period shall be 2500 ms plus three round trip delays.

11.7 Cleardown

The cleardown procedure can be initiated at any time during data mode to terminate a connection gracefully. This procedure is similar to the rate renegotiation procedure.

11.7.1 Initiating modem

11.7.1.1 To initiate a cleardown, the initiating modem shall transmit signal S for 128T and condition its receiver to detect signal S. The modem shall then transmit signal \bar{S} for 16T, and send MP sequences requesting zeroes for the call-to-answer and answer-to-call data rates.

11.7.1.2 After detecting signal S from the responding modem, the initiating modem shall condition its receiver to detect \bar{S} followed by MP sequences.

11.7.1.3 If the MP sequence from the responding modem has already been received, the modem shall send MP' sequences rather than MP sequences. After receiving MP sequences, the initiating modem shall send MP' sequences.

11.7.1.4 When the initiating modem is both receiving and sending MP' sequences, it shall terminate the connection.

11.7.2 Responding modem

11.7.2.1 If a modem in data mode receives signal S followed by \bar{S} , it becomes the responding modem. The responding modem shall stop transmitting data and transmit signal S for 128T followed by signal \bar{S} for 16T.

11.7.2.2 The responding modem shall then send MP sequences and condition its receiver to receive the initiating modem's MP sequence as in a normal rate renegotiation. If the MP sequence from the initiating modem has already been detected, the modem shall send MP' sequences rather than MP sequences. After detecting the MP sequence from the initiating modem, the responding modem shall send MP' sequences.

11.7.2.3 After the responding modem has both received an MP' sequence from the initiating modem requesting zeroes for the call-to-answer and answer-to-call data signalling rates, and has sent an MP' sequence, it shall then terminate the connection.

11.8 Two-wire leased line operation

For two-wire leased line operation, one of the modems shall be configured as the call modem and the other shall be configured as the answer modem. The call modem shall operate according to 11.8.1 and the answer modem shall operate according to 11.8.2.

11.8.1 Call modem

The call modem shall repeatedly send INFO_{0c} sequences and condition its receiver to receive INFO_{0a}. If the call modem receives INFO_{0a} with bit 28 set to 1, it shall condition its receiver to detect Tone A and the subsequent Tone A phase reversal, complete sending the current INFO_{0c} sequence, and then transmit Tone B. The modem shall then proceed according to 11.2.1.1.3.

NOTE – The call modem shall set bit 28 of the INFO_{0c} sequence to 1 after correctly receiving the INFO_{0a} sequence.

11.8.2 Answer modem

The answer modem shall repeatedly send INFO_{0a} sequences and condition its receiver to receive INFO_{0c}. If the answer modem receives INFO_{0c} with bit 28 set to 1, it shall condition its receiver to detect Tone B, complete sending the current INFO_{0a} sequence, and then transmit Tone A. The modem shall then proceed according to 11.2.1.2.3.

NOTE – The answer modem shall set bit 28 of the INFO_{0a} sequence to 1 after correctly receiving the INFO_{0c} sequence.

12 Half-duplex operating procedures

Half-duplex operation in the context of this Recommendation describes a mode of operation where exchange of data alternates between unidirectional transmission of primary channel data from source to recipient modem and simultaneous bidirectional transmission of control channel data between the two modems.

12.1 Phase 1 – Network interaction

Procedures for Phase 1 in half-duplex operation are identical to those specified in 11.1.

12.2 Phase 2 – Probing

Channel probing is performed in Phase 2 of the half-duplex start-up procedure. The description below details both error-free and recovery procedures for the cases when the call modem is the source modem and the answer modem is the source modem. Capabilities information and modulation parameters are sent in the INFO sequences detailed in 10.1.2.3 and 10.2.2.1.

12.2.1 Call modem as source modem

Figure 23 details Phase 2 procedures when the call modem is the source modem.

12.2.1.1 Call modem error-free operation

12.2.1.1.1 During the 75 ± 5 ms silent period ending Phase 1, the call modem shall condition its receiver to receive INFO_{0a} and detect Tone A. After the 75 ± 5 ms silent period, the call modem shall send INFO_{0c} with bit 28 set to 0, followed by Tone B.

12.2.1.1.2 After receiving INFO_{0a}, the modem shall condition its receiver to detect Tone A and the subsequent Tone A phase reversal.

12.2.1.1.3 After detecting the Tone A phase reversal, the call modem shall wait 40 ± 10 ms and transmit a Tone B phase reversal. Tone B shall be transmitted for another 10 ms after the phase reversal, and then the modem shall transmit signal L1 for 160 ms. The modem shall then transmit signal L2 and condition its receiver to detect Tone A.

12.2.1.1.4 After detecting Tone A, the call modem shall transmit Tone B and condition its receiver to receive INFO_h. After receiving INFO_h, the modem shall proceed according to 12.3.1.

12.2.1.2 Answer modem error-free operation

12.2.1.2.1 During the 75 ± 5 ms silent period ending Phase 1, the answer modem shall condition its receiver to receive INFO_{0c} and detect Tone B. After the 75 ± 5 ms silent period, the answer modem shall send INFO_{0a} with bit 28 set to 0 followed by Tone A.

12.2.1.2.2 After receiving INFO_{0c}, the modem shall condition its receiver to detect Tone B and receive INFO_{0c}.

12.2.1.2.3 After Tone B is detected and Tone A has been transmitted for at least 50 ms, the answer modem shall transmit a Tone A phase reversal. Tone A is transmitted for another 10 ms after the phase reversal, and then the modem transmits silence. The modem shall then condition its receiver to detect a Tone B phase reversal.

12.2.1.2.4 After detecting the Tone B phase reversal, the answer modem shall be conditioned to receive probing signals L1 and L2.

12.2.1.2.5 The answer modem shall receive signal L1 for its 160 ms duration. The answer modem may then receive L2 for a period of time not to exceed 500 ms. The answer modem **then transmits Tone A and conditions its receiver to detect Tone B**.

12.2.1.2.6 After Tone B is detected, the answer modem continues transmitting Tone A for 25 ms, then sends INFO_h. After sending INFO_h, the modem proceeds according to 12.3.2.

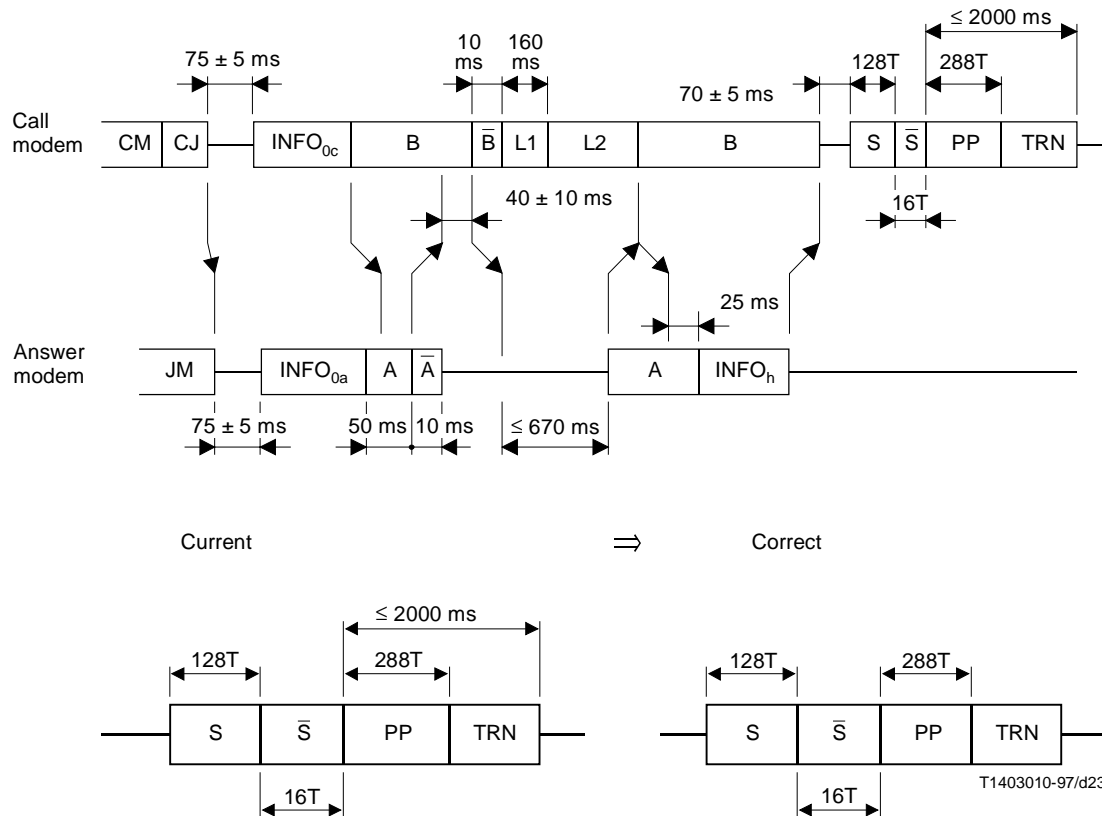


Figure 23/V.34 – Phases 2 and 3 – Call modem is source modem

12.2.1.3 Call modem recovery mechanisms

12.2.1.3.1 If, in 12.2.1.1.2 or 12.2.1.1.3, Tone A is detected before correctly receiving INFO_{0a}, or repeated INFO_{0a} is received, the modem will repeatedly send INFO_{0c}.

If the call modem receives INFO_{0a} with bit 28 set to 1, it will condition itself to detect Tone A followed by a phase reversal in Tone A, complete sending the current INFO_{0c} sequence, and then transmit Tone B. Alternatively, if the call modem detects Tone A having correctly received INFO_{0a}, it will condition itself to detect a phase reversal in Tone A, complete sending the current INFO_{0c} sequence, and transmit Tone B. In either case, the call modem then proceeds according to 12.2.1.1.3.

12.2.1.3.2 If, in 12.2.1.1.3, the Tone A phase reversal is not detected, the call modem continues to transmit Tone B waiting for the answer modem to transmit another phase reversal.

12.2.1.3.3 If, in 12.2.1.1.4, Tone A is not detected within 2700 ms from transmission of the Tone B phase reversal, the call modem transmits Tone B and conditions its receiver to detect Tone A followed by a phase reversal in Tone A. The modem then proceeds in accordance with 12.2.1.1.3.

12.2.1.3.4 If, in 12.2.1.1.4, INFO_h is not detected within 2000 ms from the transmission of Tone B in 12.2.1.1.4, the call modem shall continue to send Tone B and condition its receiver to detect Tone A. Upon detection of Tone A, the call modem proceeds in accordance with 12.2.1.1.4.

NOTE – The call modem shall set bit 28 of the INFO_{0c} sequence to 1 after correctly receiving the INFO_{0a} sequence.

12.2.1.4 Answer modem recovery mechanisms

12.2.1.4.1 If, in 12.2.1.2.2 or 12.2.1.2.3, Tone B is detected before correctly receiving INFO_{0c}, or repeated INFO_{0c} is received, the modem will repeatedly send INFO_{0a}.

If the answer modem receives INFO_{0c} with bit 28 set to 1, it will condition itself to detect Tone B, complete sending the current INFO_{0a} sequence, and transmit Tone A. Alternatively, if the answer modem detects Tone B having correctly received INFO_{0c}, it will complete sending the current INFO_{0a} sequence, and transmit Tone A. In either case, the answer modem then proceeds according to 12.2.1.2.3.

12.2.1.4.2 If, in 12.2.1.2.4, the Tone B phase reversal is not detected within 2000 ms from the transmission of the Tone A phase reversal in 12.2.1.2.3, the answer modem conditions its receiver to detect Tone B. Upon detecting Tone B, the answer modem transmits Tone A and proceeds according to 12.2.1.2.3.

12.2.1.4.3 If, in 12.2.1.2.6, Tone B is not detected within 2000 ms from beginning of transmission of Tone A in 12.2.1.2.5, the answer modem sends INFO_h, and then proceeds to Phase 3 of the half-duplex start-up.

NOTE – The answer modem shall set bit 28 of the INFO_{0a} sequence to 1 after correctly receiving the INFO_{0c} sequence.

12.2.2 Answer modem as source modem

Figure 24 details Phase 2 procedures when the answer modem is the source modem.

12.2.2.1 Call modem error-free operation

12.2.2.1.1 During the 75 ± 5 ms silent period ending Phase 1, the call modem shall condition its receiver to receive INFO_{0a} and detect Tone A. After the 75 ± 5 ms silent period, the call modem shall send INFO_{0c} with bit 28 set to 0, followed by Tone B.

12.2.2.1.2 After receiving INFO_{0a}, the modem shall condition its receiver to detect Tone A and receive INFO_{0a}.

12.2.2.1.3 After Tone A has been detected and Tone B has been transmitted for at least 50 ms, the call modem shall transmit a Tone B phase reversal. Tone B is transmitted for another 10 ms after the phase reversal, and then the modem transmits silence. The modem shall then condition its receiver to detect a Tone A phase reversal.

12.2.2.1.4 After detecting the Tone A phase reversal, the call modem shall be conditioned to receive probing signals L1 and L2.

12.2.2.1.5 The call modem shall receive L1 for its 160 ms duration. The call modem may then receive L2 for a period of time not to exceed 500 ms. The call modem then transmits Tone B and conditions its receiver to detect Tone A.

12.2.2.1.6 After Tone A is detected, the call modem continues transmitting Tone B for 25 ms, then sends INFO_h. After sending INFO_h, the modem proceeds according to 12.3.2.

12.2.2.2 Answer modem error-free operation

12.2.2.2.1 During the 75 ± 5 ms silent period ending Phase 1, the answer modem shall condition its receiver to receive INFO_{0c} and detect Tone B. After the 75 ± 5 ms silent period, the answer modem shall send INFO_{0a} with bit 28 set to 0, followed by Tone A.

12.2.2.2.2 After receiving INFO_{0c}, the modem shall condition its receiver to detect Tone B and the subsequent Tone B phase reversal.

12.2.2.2.3 After detecting the Tone B phase reversal, the answer modem shall wait 40 ± 10 ms and transmit a Tone A phase reversal. Tone A shall be transmitted for another 10 ms after the phase reversal, and then the modem shall transmit signal L1 for 160 ms. The modem shall then transmit signal L2 and condition its receiver to detect Tone B.

12.2.2.2.4 After detecting Tone B, the answer modem shall transmit Tone A and condition its receiver to receive INFO_h. After receiving INFO_h, the modem shall proceed according to 12.3.1.

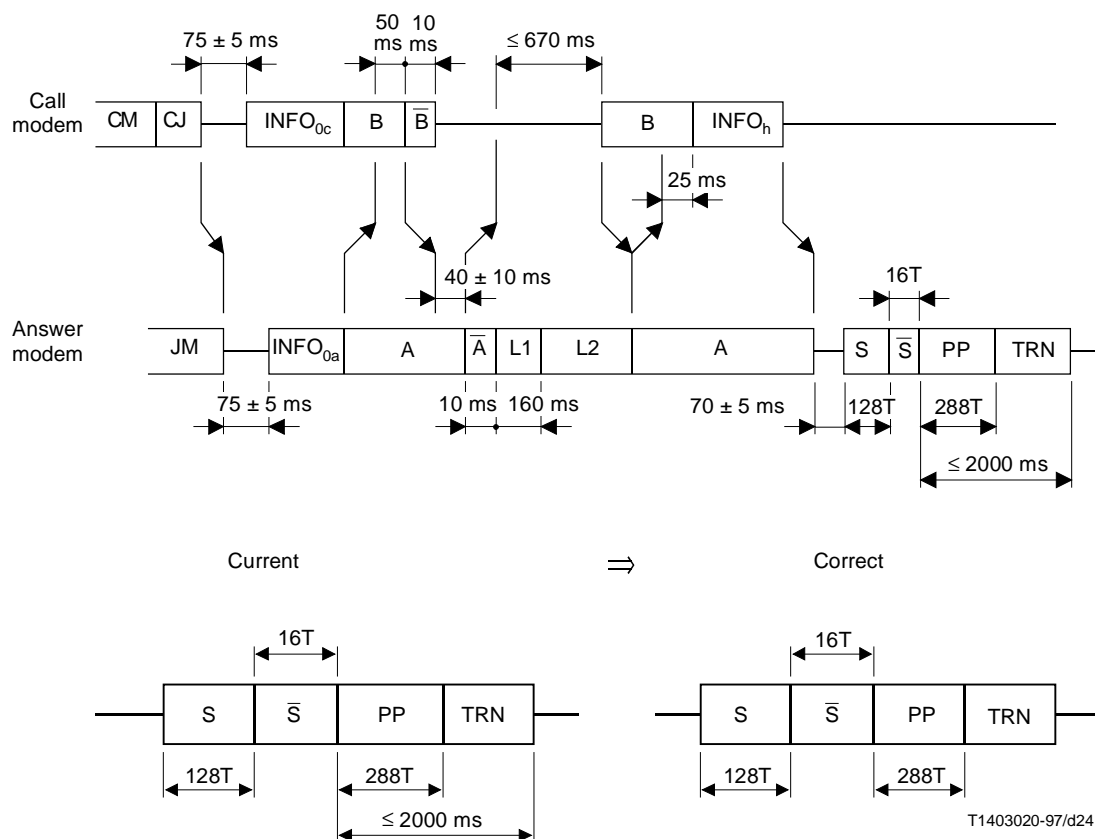


Figure 24/V.34 – Phases 2 and 3 – Answer modem is source modem

12.2.2.3 Call modem recovery mechanism

12.2.2.3.1 If, in 12.2.2.1.2 or 12.2.2.1.3, Tone A is detected before correctly receiving INFO_{0a}, or repeated INFO_{0a} is received, the modem will repeatedly send INFO_{0c}.

If the call modem receives INFO_{0a} with bit 28 set to 1, it will condition itself to detect Tone A and transmit Tone B. Alternatively, if the call modem detects Tone A having correctly received INFO_{0a}, it will transmit Tone B. In either case, the call modem then proceeds according to 12.2.2.1.3.

12.2.2.3.2 If, in 12.2.2.1.4, the Tone A phase reversal is not detected within 2000 ms from transmission of the Tone B phase reversal in 12.2.2.1.3, the call modem conditions its receiver to detect Tone A. Upon detecting Tone A, the call modem transmits Tone B and proceeds according to 12.2.2.1.3.

12.2.2.3.3 If, in 12.2.2.1.6, Tone A is not detected within 2000 ms from transmission of Tone B in 12.2.2.1.5, the call modem sends INFO_h, and then proceeds according to 12.3.2.

NOTE – The call modem shall set bit 28 of the INFO_{0c} sequence to 1 after correctly receiving the INFO_{0a} sequence.

12.2.2.4 Answer modem recovery mechanism

12.2.2.4.1 If, in 12.2.2.2.2 or 12.2.2.2.3, Tone B is detected before correctly receiving INFO_{0c}, or repeated INFO_{0c} is received, the modem shall repeatedly send INFO_{0a}.

If the answer modem receives INFO_{0c} with bit 28 set to 1, it will condition itself to detect Tone B followed by a phase reversal in Tone B, and transmit Tone A. Alternatively, if the answer modem detects Tone B having correctly received INFO_{0c}, it shall be conditioned to detect a phase reversal in Tone B, and transmit Tone A. In either case, the answer modem shall then proceed in accordance with 12.2.2.2.3.

12.2.2.4.2 If, in 12.2.2.2.3, the Tone B phase reversal is not detected, the answer modem shall continue to transmit Tone A while waiting for the call modem to transmit another phase reversal.

12.2.2.4.3 If, in 12.2.2.2.4, Tone B is not detected within 2700 ms from the transmission of the Tone A phase reversal in 12.2.2.2.3, the answer modem shall transmit Tone A and condition its receiver to detect Tone B followed by a phase reversal in Tone B. The modem shall then proceed in accordance with 12.2.2.2.3.

12.2.2.4.4 If, in 12.2.2.2.4, INFO_h is not received within 2000 ms from the transmission of Tone A in 12.2.2.2.4, the answer modem shall continue to send Tone A and condition its receiver to detect Tone B. Upon detection of Tone B, the answer modem shall proceed in accordance with 12.2.2.2.4.

NOTE – The answer modem shall set bit 28 of the INFO_{0a} sequence to 1 after correctly receiving the INFO_{0c} sequence.

12.3 Phase 3 – Primary channel equalizer training

Equalizer training is performed in Phase 3 of the half-duplex start-up. The description below details the procedures in the source and recipient modems (see Figures 23 and 24).

12.3.1 Source modem

12.3.1.1 After receiving INFO_h, the modem shall transmit silence for 70 ± 5 ms, then transmit signal S for 128T followed by \bar{S} for 16T, followed by signal PP.

12.3.1.2 After transmitting signal PP, the source modem shall transmit signal TRN. The constellation size and duration of signal TRN are set according to the INFO_h sequence received from the recipient modem.

12.3.1.3 After transmitting signal TRN, the modem proceeds to transmit and receive using the control channel according to 12.4.

12.3.2 Recipient modem

12.3.2.1 After sending INFO_h, the recipient modem transmits silence and conditions its receiver to detect S followed by \bar{S} .

12.3.2.2 After signal S followed by \bar{S} is detected, the modem conditions its receiver to begin training its main channel equalizer using signal PP. After receiving signal PP, the modem may further refine its equalizer using signal TRN.

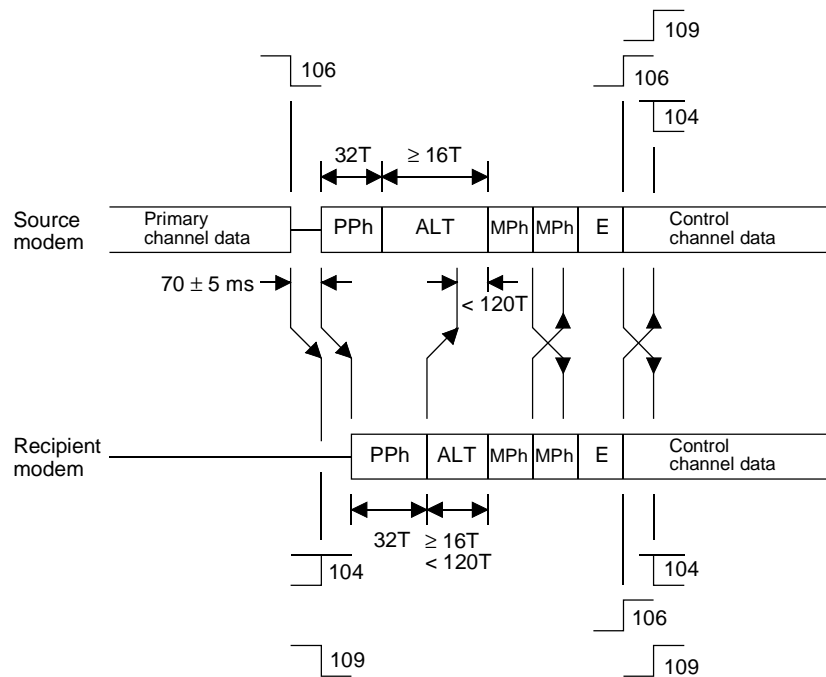
12.3.2.3 After receiving TRN for the duration indicated in INFO_h, the modem proceeds to transmit and receive using the control channel according to 12.4.

12.3.3 Recipient modem error recovery procedures

If, in 12.3.2.2, signal S is not detected within 2000 ms or TRN is not satisfactorily received, if the recipient modem is the answer modem, it shall condition its receiver to detect Tone B and shall transmit Tone A and proceed in accordance with 12.2.1.2.6. If the recipient modem is the call modem, it shall condition its receiver to detect Tone A and shall transmit Tone B and proceed in accordance with 12.2.2.1.6.

12.4 Control channel start-up

The purpose of the control channel is to exchange information before and between the transmission of primary channel user data. Figure 25 shows the procedures for initial training of the control channel and for restarting the control channel when the source modem requests a change. Figure 26 shows the restart procedure when the recipient modem requests a change.



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Figure 25/V.34 – Control channel initial training and restart when source modem requests change

12.4.1 Source modem

12.4.1.1 The source modem shall condition its receiver to detect signal PPh. After a silent interval of 70 ± 5 ms, it sends signal PPh followed by signal ALT for a minimum of $16T$. Upon detection of signal PPh, the source modem shall train its control channel equalizer using signal PPh, and condition its receiver to receive MPh from the recipient modem.

12.4.1.2 After receiving signal PPh, the source modem shall send sequence MPh within $120T$.

12.4.1.3 When the source modem has received at least one MPh sequence and the modem is sending MPh sequences, the modem shall complete the current MPh and send a single 20-bit E sequence. At this time the modem shall determine the data signalling rate for the primary channel as follows:

The source modem's transmit rate shall be the maximum rate enabled that is less than or equal to the data signalling rates specified in both modems' MPh sequences.

12.4.1.4 After sending sequence E, the source modem shall enable Circuit 106 to respond to Circuit 105 and transmit user control channel data using the data signalling rate indicated in the MPh sequence transmitted by the recipient modem. After receiving sequence E, the modem shall unclamp Circuit 104, turn on Circuit 109, and receive control channel user data at the data signalling rate indicated in the MPh sequence sent by the source modem.

12.4.2 Recipient modem

12.4.2.1 The recipient modem conditions its receiver to detect signal PPh. After detecting signal PPh, it shall transmit signal PPh, train its control channel equalizer using signal PPh, and condition its receiver to receive MPh from the source modem.

12.4.2.2 After the recipient modem transmits signal PPh, it shall transmit signal ALT.

12.4.2.3 After transmitting signal ALT for at least $16T$ and no more than $120T$, the recipient modem sends sequence MPh.

12.4.3 Source modem recovery procedures

12.4.3.1 If, in 12.4.1.1, the source modem is the call modem, upon detection of Tone A instead of signal PPh, it shall transmit Tone B. Upon reception of INFO_h, it shall proceed according to 12.3.1. If the source modem is the answer modem, upon detection of Tone B instead of signal PPh, it shall transmit Tone A. Upon detection of INFO_h, it shall proceed according to 12.3.1.

NOTE – This procedure is only applied to the control channel start-up sequence after primary channel equalizer training.

12.4.3.2 If, in 12.4.1.1, PPh from the remote modem is not detected within three seconds after sending PPh, the source modem shall initiate a control channel retrain as defined in 12.8.1.

12.4.3.3 If, in 12.4.1.3, MPh from the remote modem has not been received within three seconds after receiving PPh, the source modem shall initiate a control channel retrain as defined in 12.8.1.

12.4.3.4 If, in 12.4.1.4, the sequence E from the remote modem is not detected within three seconds after receiving MPh, the source modem shall initiate a control channel retrain as defined in 12.8.1.

12.4.4 Recipient modem recovery procedures

12.4.4.1 If, in 12.4.2.1, PPh from the remote modem is not detected within three seconds after receipt of the end of signal TRN or primary channel data, the recipient modem shall initiate a control channel retrain as defined in 12.8.1.

12.4.4.2 If, in 12.4.2.4, MPh from the remote modem has not been received within three seconds after sending PPh, the recipient modem shall initiate a control channel retrain as defined in 12.8.1.

12.4.4.3 If, in 12.4.2.5, the sequence E from the remote modem is not detected within three seconds after receiving MPh, the recipient modem shall initiate a control channel retrain as defined in 12.8.1.

12.5 Primary channel resynchronization procedure

12.5.1 Source modem

The source modem shall first transmit 70 ± 5 ms of silence, then signal S for 128T, followed by \bar{S} for 16T, then signal PP followed by sequence B1. The modem shall then enable Circuit 106 to respond to the condition of Circuit 105 and then transmit user data.

12.5.2 Recipient modem

The recipient modem shall first condition its receiver to detect S and \bar{S} , and then resynchronize its receiver using signal PP. After receiving sequence B1, the modem shall unclamp Circuit 104, turn on Circuit 109, and begin receiving user data.

12.5.3 Primary channel turn-off

12.5.3.1 Source modem

When the source modem is in the primary channel mode and detects the ON to OFF transition of Circuit 105, the modem shall turn OFF Circuit 106, transmit 35 ms of scrambled ones, and then proceed according to 12.6.1.1.

12.5.3.2 Recipient modem

When the recipient modem is in the primary channel mode and detects the OFF to ON transition of Circuit 105, the modem shall turn OFF Circuit 109 and clamp Circuit 104, then proceed according to 12.6.2.

If the received signal level falls below the turn-off threshold as defined in 6.6.2, then the modem shall turn OFF Circuit 109 and clamp Circuit 104. If the received signal level returns above the turn-on threshold defined in 6.6.2, the modem shall turn ON Circuit 109 and unclamp Circuit 104.

12.6 Control channel resynchronization procedure

Figure 27 shows the control channel resynchronization procedure that is used between page transmissions.

12.6.1 Source modem

12.6.1.1 If a change in modulation parameters is desired, the source modem proceeds according to 12.4.1.1. Otherwise, the source modem shall transmit silence for 70 ± 5 ms, then transmit signal Sh for 24T followed by $\overline{\text{Sh}}$ for 8T.

12.6.1.2 The source modem shall then condition its receiver to detect signal PPh or signal Sh followed by $\overline{\text{Sh}}$, and then send sequence ALT.

12.6.1.3 If signal PPh is detected, the modem shall transmit signal PPh followed by sequence ALT for a minimum of 16T, condition its receiver to receive MPh, and then proceed in accordance with 12.4.1.2.

12.6.1.4 If signal Sh followed by $\overline{\text{Sh}}$ is detected, the modem shall condition its receiver to detect sequence E, and then send sequence ALT for a minimum of 16T but no more than 120T, followed by sequence E. The modem shall then enable Circuit 106 to respond to the condition of Circuit 105 and transmit user control channel data using the control channel data signalling rate from the previous transmission. After receiving sequence E, the modem shall unclamp Circuit 104, turn on Circuit 109, and receive user control channel data.

12.6.1.5 If, in 12.6.1.2, neither PPh nor Sh followed by $\overline{\text{Sh}}$ from the remote modem is detected within three seconds after sending Sh followed by $\overline{\text{Sh}}$, the source modem shall initiate a control channel retrain as defined in 12.8.1.

12.6.1.6 If, in 12.6.1.4, the sequence E from the remote modem is not detected within three seconds after sending Sh followed by $\overline{\text{Sh}}$, the source modem shall initiate a control channel retrain as defined in 12.8.1.

12.6.2 Recipient modem

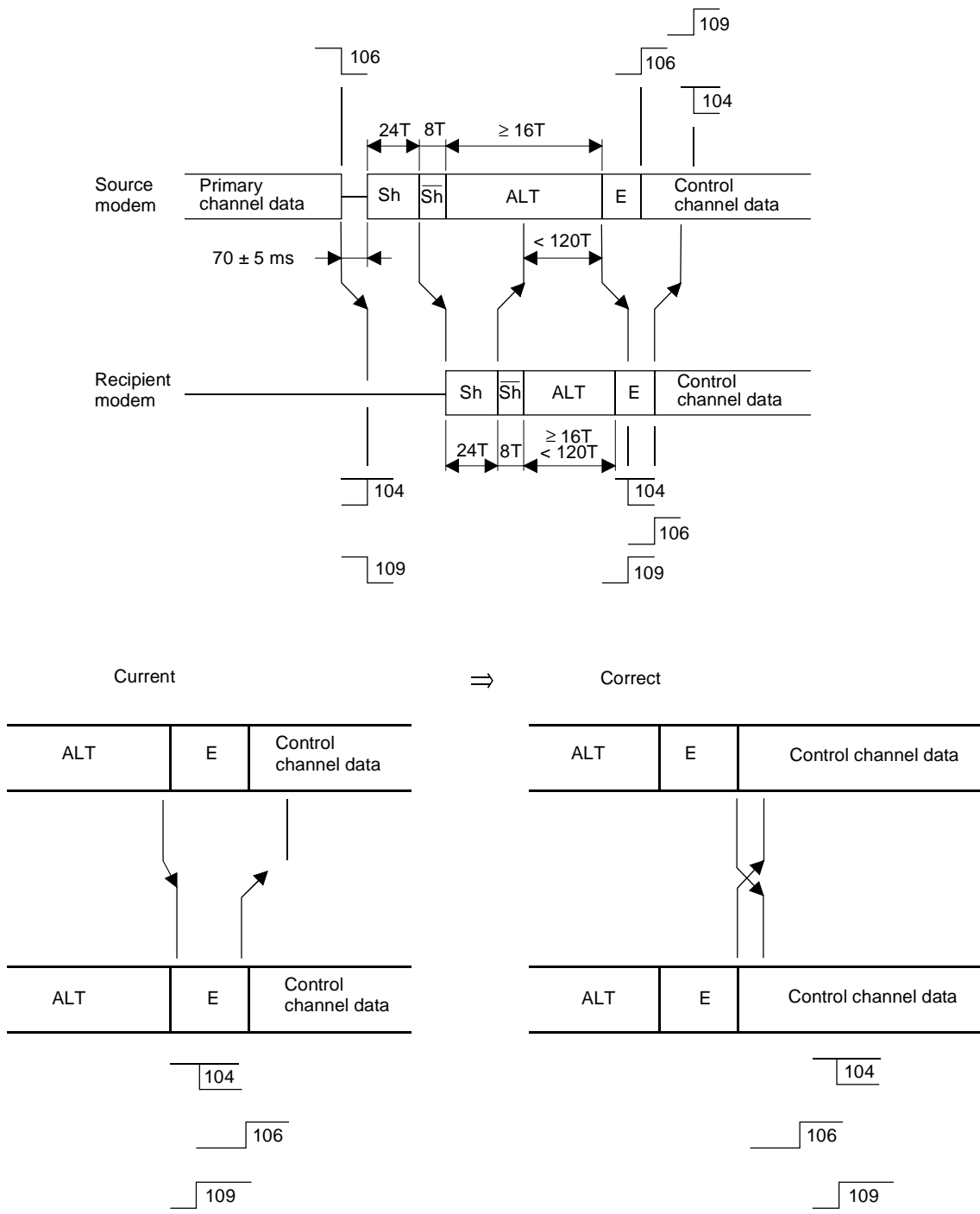
12.6.2.1 The modem shall condition its receiver to detect signal PPh or signal Sh followed by $\overline{\text{Sh}}$. If signal PPh is detected, the modem shall send signal PPh, condition its receiver to receive sequence MPh, and proceed according to 12.4.2.2.

12.6.2.2 If signal Sh followed by $\overline{\text{Sh}}$ is detected and no change in modulation parameters is desired, the modem transmits sequence Sh for 24T, $\overline{\text{Sh}}$ for 8T, and then sends ALT for a minimum of 16T but no more than 120T, followed by sequence E. The modem shall then enable Circuit 106 to respond to Circuit 105 and transmit user control channel data using the control channel data signalling rate from the previous transmission. After receiving sequence E, the modem shall unclamp Circuit 104, turn on Circuit 109, and receive user control channel data.

12.6.2.3 If signal Sh followed by $\overline{\text{Sh}}$ is detected, and changes in modulation parameters are desired, the modem shall transmit signal PPh followed by sequence ALT, and condition its receiver to detect PPh. After PPh is detected, the modem shall proceed in accordance with 12.4.2.3.

12.6.2.4 If, in 12.6.2.1, neither PPh nor Sh followed by $\overline{\text{Sh}}$ from the remote modem is detected within three seconds after the receipt of the end of primary channel data, the recipient modem shall initiate a control channel retrain as defined in 12.8.1.

12.6.2.5 If, in 12.6.2.2, the sequence E from the remote modem is not detected within three seconds after sending Sh followed by $\overline{\text{Sh}}$, the recipient modem shall initiate a control channel retrain as defined in 12.8.1.



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Figure 27/V.34 – Control channel resynchronization – Normal between page signalling

12.6.3 Control channel turn-off

12.6.3.1 Source modem

When the source modem is in the control channel mode and detects the ON to OFF transition of Circuit 105, the modem shall turn OFF Circuit 106, transmit 4T of scrambled ones, and then proceed according to 12.5.1.

If the received signal level falls below the turn-off threshold as defined in 6.6.2, then the modem shall turn OFF Circuit 109 and clamp Circuit 104. If the received signal level returns above the turn-on threshold defined in 6.6.2, the modem shall turn ON Circuit 109 and unclamp Circuit 104.

12.6.3.2 Recipient modem

When the recipient modem is in the control channel mode and detects the ON to OFF transition of Circuit 105, the modem shall turn OFF Circuit 106, transmit 4T of scrambled ones, then transmit silence and proceed according to 12.5.2.

If the received signal level falls below the turn-off threshold as defined in 6.6.2, then the modem shall turn OFF Circuit 109 and clamp Circuit 104. If the received signal level returns above the turn-on threshold defined in 6.6.2, the modem shall turn ON Circuit 109 and unclamp Circuit 104.

12.7 Primary channel retrains

12.7.1 Call modem – Source or recipient

12.7.1.1 Initiating retrain – To initiate a retrain, the call modem shall turn OFF Circuit 106 if it is ON, clamp Circuit 104 to binary one and transmit silence for 70 ± 5 ms. The call modem shall then transmit Tone B and condition its receiver to detect Tone A. After detecting Tone A, the call modem shall condition its receiver to detect a Tone A phase reversal and proceed in accordance with 12.2.1.1.3 (source modem) and 12.2.2.1.3 (recipient modem).

12.7.1.2 Responding to retrain – After detecting Tone A for more than 50 ms, the call modem shall turn OFF Circuit 106 if it is ON, clamp Circuit 104 to binary one and transmit silence for 70 ± 5 ms. The call modem shall then transmit Tone B, condition its receiver to detect a Tone A phase reversal, and proceed in accordance with 12.2.1.1.3 (source modem) and 12.2.2.1.3 (recipient modem).

12.7.2 Answer modem – Source or recipient

12.7.2.1 Initiating retrain – To initiate a retrain, the answer modem shall turn OFF Circuit 106 if it is ON, clamp Circuit 104 to binary one and transmit silence for 70 ± 5 ms. The answer modem shall then transmit Tone A, condition its receiver to detect Tone B, and proceed in accordance with 12.2.2.2.3 (source modem) and 12.2.1.2.3 (recipient modem).

12.7.2.2 Responding to retrain – After detecting Tone B for more than 50 ms, the answer modem shall turn OFF Circuit 106 if it is ON, clamp Circuit 104 to binary one and transmit silence for 70 ± 5 ms. The answer modem shall then transmit Tone A and proceed in accordance with 12.2.2.2.3 (source modem) and 12.2.1.2.3 (recipient modem).

12.8 Control channel retrains

Figure 28 shows the control channel retrain procedure.

12.8.1 Initiating retrain

To initiate a control channel retrain, the initiating modem shall turn OFF Circuit 106, transmit signal AC, and condition its receiver to detect signal PPh. When signal PPh is detected, the modem shall clamp Circuit 104 to binary one, condition its receiver to receive MPh and transmit signal PPh followed by sequence ALT for a minimum of 16T but no more than 120T. If the initiating modem is the recipient modem, it shall then proceed in accordance with 12.4.2.3. If the initiating modem is the source modem, it shall send the MPh sequence and then proceed in accordance with 12.4.1.3. If signal AC is detected from the remote modem while transmitting signal AC, then the modem shall become a responding modem and proceed according to 12.8.2.

12.8.2 Responding to retrain

After detecting signal AC for more than 100 ms, the responding modem shall turn OFF Circuit 106, clamp Circuit 104 to binary one, and transmit PPh. After PPh has been transmitted, ALT should be transmitted for a minimum of 16T. Upon detection of the initiating modem's PPh, the modem may train its control channel equalizer using signal PPh. If the

responding modem is the source modem, it shall condition its receiver to receive MP_h then proceed in accordance with 12.4.1.2. If the responding modem is the recipient modem, after receiving signal PP_h, it shall send MP_h within 120T (of ALT) and then proceed in accordance with 12.4.2.4.

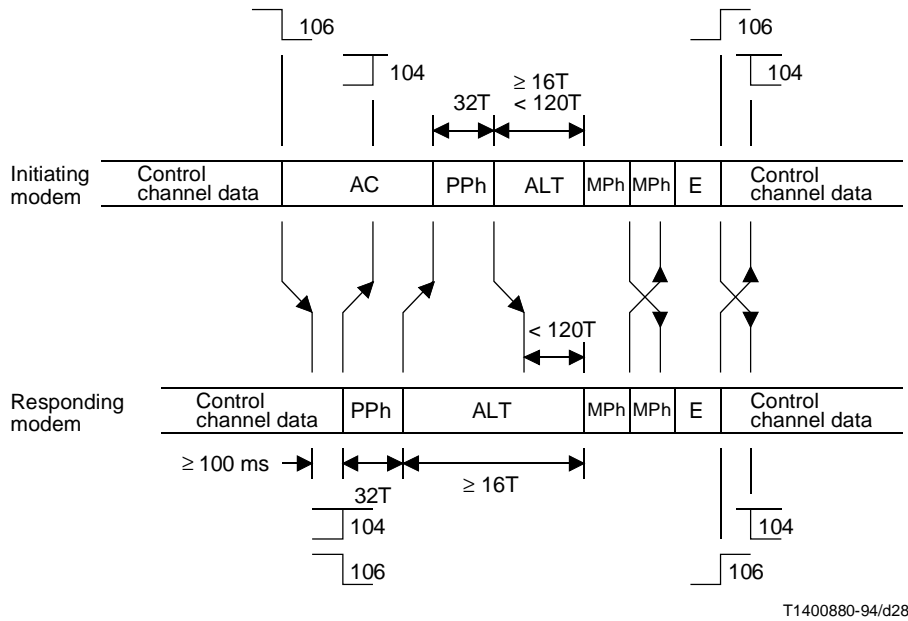


Figure 28/V.34 – Control channel retrains

13 Testing facilities

Test loops 2 and 3 as defined in Recommendation V.54 shall be provided. Provision for test loop 2 shall be as specified for point-to-point circuits. Test loop 2 need only be supported for symmetric data signalling rates.

14 Glossary

14.1 Variables and Parameters used in Data mode (clauses 5 to 9)

- a A parameter in the symbol rate definition
- b Number of bits in a high mapping frame
- c A parameter in the symbol rate definition
- c(n) An input to trellis encoder
- d A parameter in the carrier frequency definition
- e A parameter in the carrier frequency definition
- f Frequency in Hz
- g₂(p) Generating function used in shell mapper
- h(p) Precoding coefficients
- i Mapping frame index
- j A cyclic 4D symbol interval index
- k A cyclic 2D symbol interval index

m	A 4D symbol interval index
$m_{i,j,k}$	A ring index
n	A 2D symbol interval index
$p(n)$	Rounded precoder filter output
$q(n)$	Precoder filter output
q	A parameter used in mapping
r	A parameter used in mapping frame switching
s	Subset label in trellis encoder
u	Precoder input signal
v	A signal point from the quarter-constellation
w	A parameter in precoding
$x(n)$	Non-linear encoder input signal
$x'(n)$	Non-linear encoder output signal
$y(n)$	An input to trellis encoder
$z_8(p)$	A cumulative function used in shell mapping
A-H	Variables used in shell mapping
C_0	Modulo encoder output
I	A data bit
$I(m)$	Differential encoder input
J	Number of data frames per superframe
K	Number of shell mapping input bits
L	Number of 2D signal constellation points
M	Number of rings in shell mapping
N	Number of data bits per data frame
P	Number of mapping frames per data frame
Q	A signal point label
$Q_{i,j,k,1}$	A data bit
R	Aggregate data signalling rate
$R_{0.5}$	Shell mapping variables
S	Symbol Rate
$S_{i,1}$	Shell mapping input bit
T	Symbol interval
U_0	Trellis encoder output
V_0	A bit inversion signal
W	Number of auxiliary channel bits per data frame
$Y_0(m)$	Convolutional encoder output
$Y_{1-4}(m)$	Convolutional encoder inputs
Z	Differential encoder output
α, β, γ	Parameters used in pre-emphasis filter definitions
ζ	A variable used in non-linear encoder
Φ	A variable used in non-linear encoder
Θ	A parameter used in non-linear encoder

Annex A

V.34 modem control channel procedures

A.1 Introduction

This Annex forms an integral part of this Recommendation. It describes the procedures required to establish an optional modem control channel. This control channel can be used for the seamless changing of modem signalling rates or the exchange of precoder coefficients.

NOTE – Other applications of the modem control channel are for further study.

A.2 MP sequences for modem control channel compatibility

The following two tables define the changes to Tables 20/V.34 and 21/V.34, which incorporate the Modem Control Channel and Seamless Rate Change selection bits. Only the lines that have changed have been included here for reasons of brevity.

Table 20/V.34 (Revised) – Partial definition of bits in MP sequence Type 0

MP bits LSB:MSB	Definition
52	Modem Control Channel Enable: 0: disabled, 1: enabled.
53	Seamless Signalling Rate Change Enabled: 0: disabled, 1: enabled.
54	Modem Control Channel mode select. Reserved for future use and should be set to 0 by the transmitting modem and not be interpreted by the receiving modem.
55:67	Reserved for ITU-T: These bits are set to 0 by the transmitting modem and are not interpreted by the receiving modem.

Table 21/V.34 (Revised) – Partial definition of bits in MP sequence Type 1

MP bits LSB:MSB	Definition
154	Modem Control Channel Enable: 0: disabled, 1: enabled.
155	Seamless Signalling Rate Change Enabled. 0: disabled, 1: enabled.
156	Modem Control Channel mode select. Reserved for future use and should be set to 0 by the transmitting modem and not be interpreted by the receiving modem.
157:169	Reserved for ITU-T: These bits are set to 0 by the transmitting modem and are not interpreted by the receiving modem.

NOTE – Further use of the MP bits for the control channel protocol are left for future consideration.

A.3 Auxiliary channel protocol for modem control

The following procedures are applicable only if the modem supports the auxiliary channel (as defined in 8.3) and if bit 28 of MP sequence is set on both sides.

There are 56 auxiliary channel bits transported during a superframe. Each superframe is divided into four groups of 14 bits each. There are three categories of auxiliary channel superframe:

- clear secondary channel superframes;
- framed secondary channel superframes; and
- modem control superframes.

The clear secondary channel superframes are used to transport 56 bits of secondary channel data for a total of 200 bits per second. The framed secondary channel superframes are used to transport 42 bits of secondary channel data for a total of 150 bits per second. When the modem needs to transport modem control data, it will flow control the secondary channel as indicated in 6.2.2 and allocate all 56 bits of the superframe for modem control.

If bit 154 of a Type 1 or bit 52 of a Type 0 MP sequence is 0, then only clear channel superframes will be sent. If bit 154 of a Type 1 or bit 52 of a Type 0 MP sequence is 1, then either a framed secondary channel or a modem control superframe will be sent. The framed secondary channel superframes are indicated by zeros in the first two bits of each 14-bit group. The modem control superframes are indicated by ones in the first two bits of each 14-bit group.

A.3.1 Superframe categories

A.3.1.1 Clear secondary channel superframes

These superframes are constructed as follows (see Table A.1):

Table A.1/V.34 – Clear secondary channel superframes

Bit position	Meaning
0-55	Secondary channel data

Bit 0 is the first superframe bit transmitted and the first bit of the secondary channel data transmitted. For these superframes, the secondary channel data will be received from and then passed on to the secondary channel.

A.3.1.2 Framed secondary channel superframes

These superframes are constructed as follows (see Table A.2):

Table A.2/V.34 – Framed secondary channel superframes

Bit position	Meaning
0-1; 14-15; 28-29; 42-43	All zeros
2-13; 16-27; 30-41; 44-49	Secondary channel data
50-55	Reserved

Bit 0 is the first superframe bit transmitted. Bit 2 is the first bit of the secondary channel data transmitted. For these superframes, the secondary channel data will be received from and then passed on to the secondary channel.

A.3.1.3 Modem control superframes

These superframes are constructed as follows (see Table A.3):

Table A.3/V.34 – Modem control superframes

Bit position	Meaning
0-1; 14-15; 28-29; 42-43	All ones
2-5; 16-19; 30-33; 44-47	Modem control type
6-13; 20-27; 34-41; 48-55	Modem control data

Bit 0 is the first bit transmitted. The definition of these bits is described in the subclauses below on each modem control type. The secondary channel in both the transmitter and receiver are flow controlled. The 4-bit modem control type will be repeated in each of the four 14-bit groups. The 8-bit modem control data may be repeated in each of the four 14-bit groups, or it may contain different data in each of the four 14-bit groups, depending on the modem control type. The definitions of each modem control type are given below.

NOTE 1 – Specific coding of these frames is for further study.

There are four categories of modem control superframes:

- Request;
- Update;
- Precode coefficient; and
- Precode CRC.

Either modem can initiate a request at any time. A modem can only initiate an update in response to a request, although it will only initiate an update for those requests that it chooses to grant. In addition, the parameters of the request may be modified by the modem initiating an update before returning these parameters in the update. More details will be given in the description of each modem control type in the following subclauses. If a modem sends a request and does not receive an update, it shall not repeat the request for at least ten seconds.

NOTE 2 – The duration and conditions of error recovery procedures are for further study.

Redundant bits are sent to ensure valid reception of requests and updates. The receiver shall establish detection criteria, which minimizes the probability of false detection of requests for a given error rate, and maximizes the probability of correct detection of updates. See Table A.4.

Table A.4/V.34 – Modem control superframe categories

Modem control superframe category	Description	Control type bit mapping
RATER	Rate update request	0000
RATEU	Rate update	0011
PRECODER	Precode coefficient update request	0101
PRECODEU	Precode coefficient update	1010
PRECODECOEF	Precode coefficient	0101
PRECODECRC	Precode CRC	0101

A.3.2 Rate request and update

A rate request superframe indicates that the modem initiating the rate request wants to change its transmit and/or receive data rate. A rate update superframe indicates that the modem initiating the rate update will begin transmitting at a new data rate after the next superframe. A rate update can only be initiated in response to a rate request, and the updated transmit data rate must be less than or equal to the requested transmitter data signalling rate.

If modem B receives a rate request from modem A, then modem B can deny the request by not responding, or it can do one or both of the following: initiate a rate update or initiate a rate request. If modem A is requesting a change in modem B's transmit data rate, modem B can respond with a rate update which indicates a transmit data rate which is less than or equal to that requested by modem A. If modem A is requesting a change in modem B's receive data rate, modem B can respond with a rate request which indicates modem B's maximum reliable receive data rate.

Rate requests shall be denied if symmetric data rates are selected because the modem may have to operate at a different transmit and receive data rates while both modems are changing rates.

The bits in the rate request superframe are as follows. Redundant bits are sent to ensure valid transmission. See Table A.5.

Table A.5/V.34 – Rate request superframe bits

Bit position	Meaning
0-1	11
2-5	0000
6-9	Maximum call to answer modem data rate
10-13	Maximum answer to call modem data rate
14-27	Same as 0-13
28-41	Same as 0-13
42-55	Same as 0-13

The bits in the rate update superframe are as follows (see Table A.6):

Table A.6/V.34 – Rate update superframe bits

Bit position	Meaning
0-1	11
2-5	0011
6-9	Updated call to answer modem data rate
10-13	Updated answer to call modem data rate
14-27	Same as 0-13
28-41	Same as 0-13
42-55	Same as 0-13

A call modem shall only update the call to answer data rate. An answer modem shall only update the answer to call data rate.

The superframes transmitted by modem A and modem B are shown graphically below in Figure A.1.

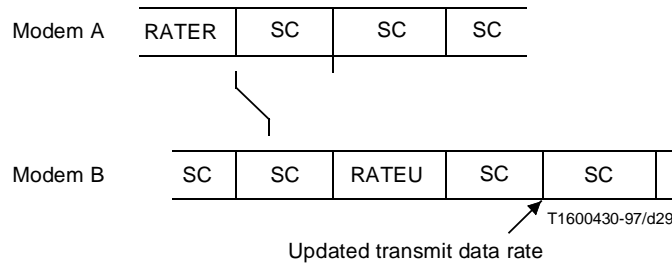


Figure A.1/V.34 – Rate request/update

If bit 155 of a Type 1 or bit 53 of a Type 0 MP sequence is 1, the transmit modem will transmit the TRN sequence and flow control the primary channel as indicated in 11.6 during the last data frame of the superframe prior to updating the data rate. This will allow the transmit modem to update its data mode parameters by overwriting them. If bit 155 of a Type 1 or bit 53 of a Type 0 MP sequence is 0, the transmitter will continue to transmit at the current data rate during this last data frame. If bit 155 of a Type 1 or bit 53 of a Type 0 MP sequence is 1, the receive modem will flow control the primary channel as indicated in 11.6 during the last data frame of the superframe prior to updating the data rate. This will allow the receive modem to update its data mode parameters by overwriting them. If bit 155 of a Type 1 or bit 53 of a Type 0 MP sequence is 0, the receiver will continue at the current data rate during this last data frame.

NOTE – Changing signalling rates at a superframe earlier is for further study.

A.3.3 Precode coefficient request

If modem A determines that its receiver requests to modify precode coefficients, it will initiate a precode coefficient request. A precode coefficient request begins with modem A sending a precode coefficient request superframe, indicating that modem A will send new precode coefficients over the next three superframes followed by a CRC superframe. If modem B receives a valid precode coefficient request, three valid precode coefficients, and a valid CRC, then it can either refuse the request by not responding, or it can grant the request by initiating a precode coefficient update superframe. A precode update superframe indicates that the modem initiating the update will begin transmitting using the new precode coefficients after the next superframe. The bits in the precode coefficient request superframe are as follows (see Table A.7):

Table A.7/V.34 – Precode coefficient request superframe bits

Bit position	Meaning
0-1	11
2-5	0101
6-13	Reserved
14-27	Same as 0-13
28-41	Same as 0-13
42-55	Same as 0-13

The bits in the precode coefficient update superframe are as follows (see Table A.8):

Table A.8/V.34 – Precode coefficient update superframe bits

Bit position	Meaning
0-1	11
2-5	1010
6-13	Reserved
14-27	Same as 0-13
28-41	Same as 0-13
42-55	Same as 0-13

NOTE – The use of the reserved bits as described in Table A.8 for information transfer is for further study.

The bits in the precode coefficient superframes are as follows (see Table A.9):

Table A.9/V.34 – Precode coefficient superframe bits

Bit position	Meaning
0-1	11
2-5	0101
6-13	Real Coefficient (Least significant 8, bit 6 is LSB)
14-15	11
16-19	0101
20-27	Real Coefficient (Most significant 8, bit 27 is MSB)
28-29	11
30-33	0101
34-41	Imaginary Coefficient (Least significant 8, bit 34 is LSB)
42-43	11
44-47	0101
48-55	Imaginary Coefficient (Most significant 8, bit 55 is MSB)

The bits in the precode CRC superframe are as follows (see Table A.10):

Table A.10/V.34 – Precode CRC superframe bits

Bit Position	Meaning
0-1	11
2-5	0101
6-13	CRC (Least significant 8, bit 6 is LSB)
14-15	11
16-19	0101
20-27	CRC (Most significant 8, bit 27 is MSB)
28-29	11
30-33	0101
34-41	Reserved
42-43	11
44-47	0101
48-55	Reserved

The 16-bit CRC is computed by applying the three complex precode coefficients to the 16-bit CRC generator (see 10.1.2.3.2). The bits are applied to the CRC generator in the same order that they are transmitted. The CRC generator is zeroed prior to application of the first precoder bit. See in Figure A.2.

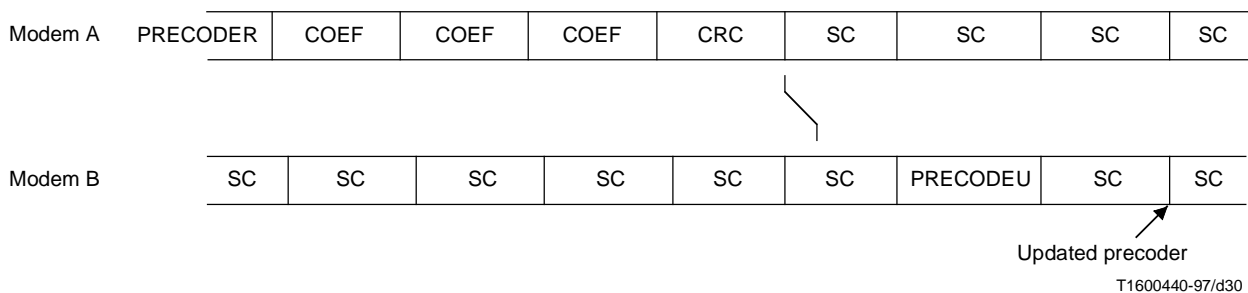


Figure A.2/V.34 – Precode request/update

A.4 Items for further study

Techniques utilizing the primary channel for modem control or information exchange for the improvement of transaction response times are left for further study. Methods also for the reduction of implementation complexity, for when CME is not present and for improving the robustness of transactions are also left for further study. For reasons of compatibility, a bit in the MP sequences has been reserved for control channel mode selection.

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