INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

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TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU

SERIES V: DATA COMMUNICATION OVER THE TELEPHONE NETWORK

Interfaces and voiceband modems

A simultaneous voice plus data modem, operating at a voice plus data signalling rate of 4800 bit/s, with optional automatic switching to data-only 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.61

(Previously "CCITT Recommendation")

ITU-T V-SERIES RECOMMENDATIONS

DATA COMMUNICATION OVER THE TELEPHONE NETWORK

1 – General
2 – **Interfaces and voiceband modems**
3 – Wideband modems
4 – Error control
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For further details, please refer to ITU-T List of Recommendations.

FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union (ITU). The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation V.61 was prepared by ITU-T Study Group 14 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 16th of August 1996.

NOTE

1. In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

2. The status of annexes and appendices attached to the Series V Recommendations should be interpreted as follows:

- an *annex* to a Recommendation forms an integral part of the Recommendation;
- an *appendix* to a Recommendation does not form part of the Recommendation and only provides some complementary explanation or information specific to that Recommendation.

CONTENTS

A SIMULTANEOUS VOICE PLUS DATA MODEM, OPERATING AT A VOICE PLUS DATA SIGNALLING RATE OF 4800 bit/s, WITH OPTIONAL AUTOMATIC SWITCHING TO DATA-ONLY 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

(Geneva, 1996)

1 Introduction

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) Framed Quadrature Audio/Data Modulation (Framed QADM) transmission with simultaneous transmission of duplex audio information and a synchronous audio plus data signalling rate of 4800 bit/s;

b) optional automatic switching between the data-only signalling rate and the audio plus data signalling rate to increase the data signalling rate to up to 14 400 bit/s during periods of audio silence;

c) optional user controlled switching between the data-only signalling rate and the data plus audio signalling rate;

d) independence of data plus audio and data-only modes in each direction of transmission;

e) call establishment procedures from both the audio interface and the data interface;

f) call establishment procedures from the data interface before or after voice connection establishment;

g) separation of audio and data channels during audio plus data transmission via quadrature audio/data modulation;

h) Quadrature Amplitude Modulation (QAM) transmission with the following synchronous data-only signalling rates implemented in the modem:

- 14 400 bit/s,
- 12 000 bit/s,
- 9600 bit/s,
- 7200 bit/s,
- 4800 bit/s;

i) duplex mode of operation on GSTN and point-to-point 2-wire leased circuits;

j) channel separation of both data and audio by echo cancellation techniques;

k) quadrature amplitude modulation for each channel with synchronous line transmission at either 3000 symbols/s or 2800 symbols/s;

l) exchange of symbol rate determination signals during start-up to establish the symbol rate;

m) exchange of rate sequences during start-up to establish the data signalling rates;

n) a procedure to change the data signalling rates without retraining;

o) a duplex auxiliary control channel with a conditional signalling rate up to 342 bit/s.

NOTE – The transmit and receive data-only signalling rates in each modem shall be the same. The instantaneous transmit and receive data signalling rates may not be the same due to data-only transmission due to audio silence or user control in either direction.

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 currently valid ITU-T Recommendations is regularly published.

- ISO 2110:1989, *Information technology – Data communication – 25-pole DTE-DCE interface connector and contact number assignments*.
- CCITT Recommendation V.2 (1980), *Power levels for data transmission over telephone lines*.
- ITU-T Recommendation V.8 *bis* (1996), *Procedures for the identification and selection of common modes of operation between Data Circuit-terminating Equipments (DCEs) and between Data Terminal Equipments (DTEs) over the general switched telephone network and on leased point-to-point telephone-type circuits.*
- 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 (1993), *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*.
- ITU-T Recommendation V.24 (1993), *List of definitions for interchange circuits between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE)*.
- CCITT Recommendation V.25 (1984), *Automatic answering equipment and/or parallel 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.*
- CCITT Recommendation V.32 *bis* (1991), *A duplex modem operating at data signalling rates of up to 14 400bis/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 (1993), *Error correcting procedures for DCEs using asynchronous-to-synchronous conversion*.
- CCITT Recommendation V.54 (1988), *Loop test devices for modems*.

3 Definitions

For the purposes of the Recommendation, the following definitions apply:

3.1 answer mode modem: The modem which initiates the start-up procedure with the V.25 answer sequence. Note that, when this sequence follows completion of V.8 *bis* procedures, either modem may be designated as answer mode modem, regardless of which modem physically answers a call.

3.2 audio plus data operation: Operation in which audio information is being transmitted in addition to data bits, using QADM modulation.

3.3 auxiliary channel: A variable bit rate data channel (up to 342 bit/s) which, along with the user data and additional control data, is multiplexed into the bit stream transmitted by the modem. Data conveyed in the auxiliary channel is independent from the user data and is conveyed as part of the control data.

3.4 **call mode modem:** The modem which is conditioned to detect the V.25 answer sequence as initiation of the start-up procedure. Note that, when this sequence follows completion of V.8 *bis* procedures, either modem may be designated as call mode modem, regardless of which modem physically places a call.

3.5 **control data:** Data which is transmitted during the control segment of each frame and used to control modem operation. The control data is independent from the user data.

3.6 **data-only operation:** Operation in which only data bits are being transmitted, using QAM modulation.

3.7 **frame:** A period 70 symbols in length, comprising a user data segment and a control segment.

3.8 **pre-emphasis:** A linear equalization method in which the transmitted audio signal is filtered to compensate for the spectral characteristics of the signal. Pre-emphasis may be fixed, in which case the filtering compensates for the expected long-term average of the spectrum, or adaptive, in which case the filtering compensates for the short-term spectral content of the audio signal. The pre-emphasis filtering applied to the audio signal in the transmitter is reversed by a complementary de-emphasis filter in the receiver.

3.9 **synchronizing signal elements:** Signal elements A, B, C, and D in the signal space diagrams, which are used during the start-up, retrain, and rate negotiation procedures.

3.10 **user data:** Data which is provided by the user for transmission. The user data is independent from the control data.

3.11 **variable data rate operation:** Operation in which either QADM or QAM modulation may be used in any given frame. Determination of which type of modulation to use in each frame is based on audio silence detection in the transmitter, and communicated to the remote receiver via control data.

4 Abbreviations

For the purposes of this Recommendation, the following abbreviations are used:

CCITT	International Telegraph and Telephone Consultative Committee
GPA	Generating Polynomial – Answer modem
GPC	Generating Polynomial – Call modem
GSTN	General Switched Telephone Network
ISO	International Organization for Standardization
ITU-T	International Telecommunications Union – Telecommunication Standardization Sector
QADM	Quadrature Audio/Data Modulation
QAM	Quadrature Amplitude Modulation

5 Line signals

5.1 Carrier frequency and modulation rate

Two modulation rates are provided. The first is 3000 symbols/s ± 0.01%. The second is 2800 symbols/s ± 0.01%.

When the modulation rate is 3000 symbols/s, the carrier frequency is to be 1800 ± 1 Hz. When the modulation rate is 2800 symbols/s, the carrier frequency is to be 1680 ± 1 Hz. In both cases, the receiver must be able to operate with a maximum received frequency offset of up to ± 7 Hz.

5.2 Transmitted spectrum

The transmitted power level must conform to Recommendation V.2. With continuous binary ones applied to the data input of the multiplexer and a long-term stationary audio signal applied to the audio input of the transmitter, the transmitted energy density at the band edges shall be attenuated 4.5 ± 2.5 dB with respect to the maximum in-band energy density. When the modulation rate is 3000 symbols/s, the band edges shall be measured at 300 Hz and 3300 Hz. When the modulation rate is 2800 symbols/s, the band edges shall be measured at 280 Hz and 3080 Hz.

5.3 Audio frames

5.3.1 Frame structure

A frame structure is used to transmit both user data and control information in the data signal elements. Each frame is 70 symbols in length and comprises two main segments. The first segment contains user data. The second segment contains control information including audio parameters. Both segments may contain audio information.

Symbols within a frame shall be identified as symbol 1 through symbol 70. When the modulation rate is 3000 symbols/s, user data is transmitted in symbols 1 through 56 and control information is transmitted in symbols 57 through 70. When the modulation rate is 2800 symbols/s, user data is transmitted in symbols 1 through 60 and control information is transmitted in symbols 61 through 70.

There are two types of frames. In audio plus data frames, audio information is combined with user or control data and transmitted in the QADM constellation described in 5.5.1.1. In data-only frames, user or control data is transmitted at the data-only rate negotiated during the most recent start-up, retrain, or rate negotiation procedure, using the QAM constellation defined for that rate in 5.4.

5.3.2 Optional variable data rate operation

The modem optionally may employ variable data rate operation, increasing the transmitted data signalling rate from the data plus audio signalling rate to the data-only signalling rate during frames in which silence is detected in the input audio signal. If variable data rate operation is employed, the modem shall determine during each frame whether there is sufficient information in the audio signal to transmit data plus audio in the succeeding frame. The modem shall then transmit information regarding the state of the succeeding frame during the control segment of the current frame (see 5.6). The modem shall condition itself to transmit signal elements using the selected (data-only or data plus audio) constellation for the new frame beginning with the first symbol of the data segment of the new frame.

If variable data rate operation is not employed, the modem shall indicate during audio plus data operation in each control segment that the succeeding frame is to be a data plus audio frame.

The modem shall accept both data-only and data plus audio frames in the receiver, whether or not variable data rate operation is employed.

A modem may inhibit variable data rate operation in the remote modem's transmitter by setting the appropriate bit in rate word 3 to zero (see 8.7) in the start-up, retrain, or rate renegotiation procedure.

5.3.3 Optional user controlled data-only operation

The modem optionally may allow data-only frames to be transmitted under user control, regardless of the information content in the audio signal. If user controlled data-only operation is employed, the modem shall determine during each frame whether the user is requesting data-only operation in the succeeding frame. The modem shall then transmit information regarding the state of the succeeding frame during the control segment of the current frame (see 5.6). If both variable data rate operation and user controlled data-only operation are employed, a user request for data-only operation preempts variable data rate operation. If user-controlled data-only operation is employed, a user request for data-only operation shall cause data-only operation whether or not variable data-rate operation is inhibited. If the state of the succeeding frame is data-only due to user control, this shall be indicated in the control information (see 5.6). The modem shall condition itself to transmit signal elements using the selected (data-only or data plus audio) constellation for the new frame beginning with the first symbol of the data segment of the new frame.

The modem shall accept both data-only and data plus audio frames in the receiver, whether or not the transmitter employs user controlled data-only operation.

5.4 Data-only coding

TABLE 1/V.61

Differential quadrant coding

Inputs		Previous outputs		Phase quadrant change	Outputs		Signal state for 4800 bit/s
$Q1_n$	$Q2_n$	$Y1_{n-1}$	$Y2_{n-1}$		$Y1_n$	$Y2_n$	
0	0	0	0	+90°	0	1	B
0	0	0	1		1	1	C
0	0	1	0		0	0	A
0	0	1	1		1	0	D
0	1	0	0	0°	0	0	A
0	1	0	1		0	1	B
0	1	1	0		1	0	D
0	1	1	1		1	1	C
1	0	0	0	+180°	1	1	C
1	0	0	1		1	0	D
1	0	1	0		0	1	B
1	0	1	1		0	0	A
1	1	0	0	+270°	1	0	D
1	1	0	1		0	0	A
1	1	1	0		1	1	C
1	1	1	1		0	1	B

5.4.1 Signal element coding for 14 400 bps

At 14 400 bit/s, the scrambled data stream to be transmitted is divided into groups of six consecutive data bits. The first two bits in time $Q1_n$ and $Q2_n$ in each group, where $Q1_n$ is the first bit in time, where the subscript n designates the sequence number of the group, are first differentially encoded into $Y1_n$ and $Y2_n$ according to Table 1. The six bits $Y1_n$, $Y2_n$, $Q3_n$, $Q4_n$, $Q5_n$, and $Q6_n$ are then mapped into the coordinates of the signal element to be transmitted according to the signal space diagram shown in Figure 1. In the figure, binary numbers refer to bits $Y1_n$, $Y2_n$, $Q3_n$, $Q4_n$, $Q5_n$, and $Q6_n$. A, B, C, and D refer to synchronizing signal elements.

5.4.2 Signal element coding for 12 000 bit/s

At 12 000 bit/s, the scrambled data stream to be transmitted is divided into groups of five consecutive data bits. The first two bits in time $Q1_n$ and $Q2_n$ in each group, where $Q1_n$ is the first bit in time, where the subscript n designates the sequence number of the group, are first differentially encoded into $Y1_n$ and $Y2_n$ according to Table 1. The five bits $Y1_n$, $Y2_n$, $Q3_n$, $Q4_n$, and $Q5_n$ are then mapped into the coordinates of the signal element to be transmitted according to the signal space diagram shown in Figure 2. In the figure, binary numbers refer to bits $Y1_n$, $Y2_n$, $Q3_n$, $Q4_n$, and $Q5_n$. A, B, C, and D refer to synchronizing signal elements.

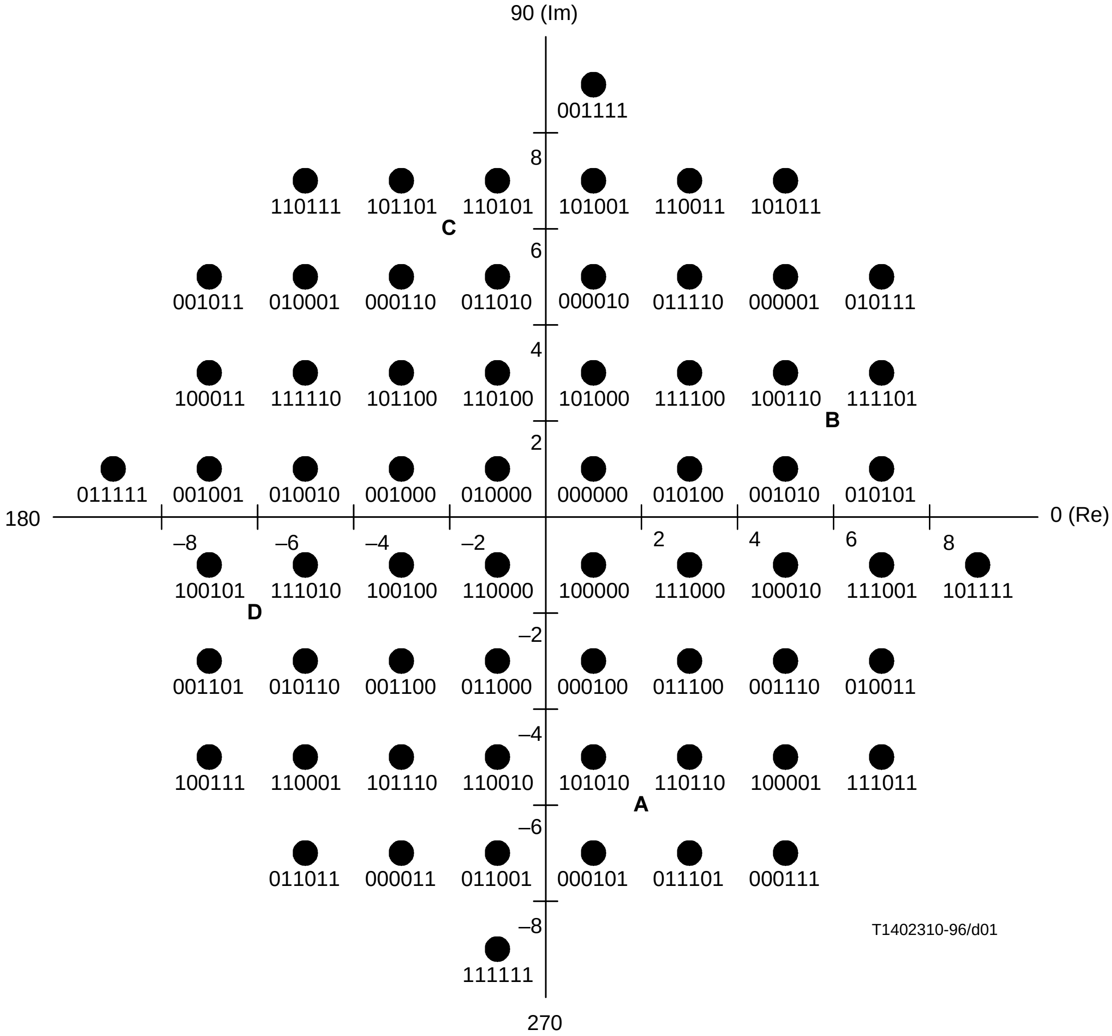


FIGURE 1/V.61

Signal space diagram and mapping for modulation at 14 400 bit/s

5.4.3 Signal element coding for 9600 bit/s

At 9600 bit/s, the scrambled data stream to be transmitted is divided into groups of four consecutive data bits. The first two bits in time $Q1_n$ and $Q2_n$ in each group, where $Q1_n$ is the first bit in time, where the subscript n designates the sequence number of the group, are first differentially encoded into $Y1_n$ and $Y2_n$ according to Table 1. The four bits $Y1_n$, $Y2_n$, $Q3_n$, and $Q4_n$ are then mapped into the coordinates of the signal element to be transmitted according to the signal space diagram shown in Figure 3. In the figure, binary numbers refer to bits $Y1_n$, $Y2_n$, $Q3_n$, and $Q4_n$. A, B, C, and D refer to synchronizing signal elements.

5.4.4 Signal element coding for 7200 bit/s

At 7200 bit/s, the scrambled data stream to be transmitted is divided into groups of three consecutive data bits. The first two bits in time $Q1_n$ and $Q2_n$ in each group, where $Q1_n$ is the first bit in time, where the subscript n designates the sequence number of the group, are first differentially encoded into $Y1_n$ and $Y2_n$ according to Table 1. The three bits $Y1_n$, $Y2_n$, and $Q3_n$ are then mapped into the coordinates of the signal element to be transmitted according to the signal space diagram shown in Figure 4. In the figure, binary numbers refer to bits $Y1_n$, $Y2_n$, and $Q3_n$. A, B, C, and D refer to synchronizing signal elements.

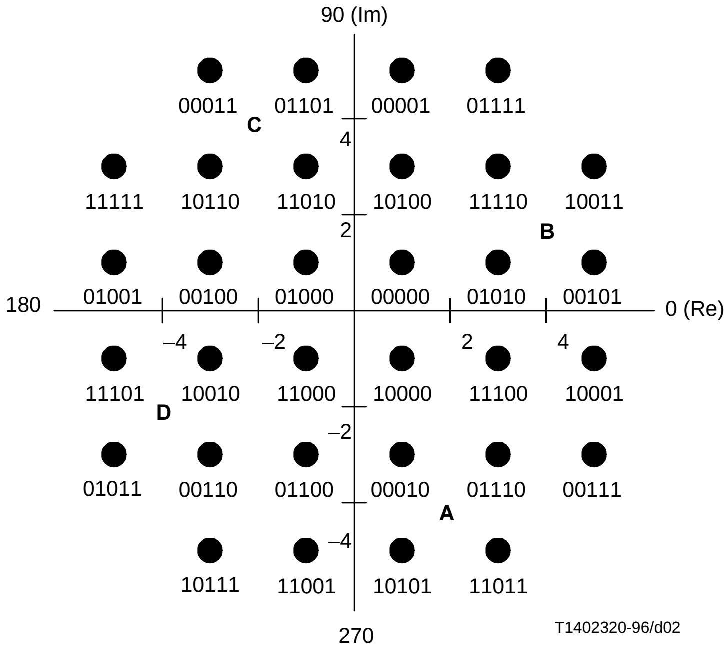


FIGURE 2/V.61

Signal space digram and mapping for modulation at 12 000 bit/s

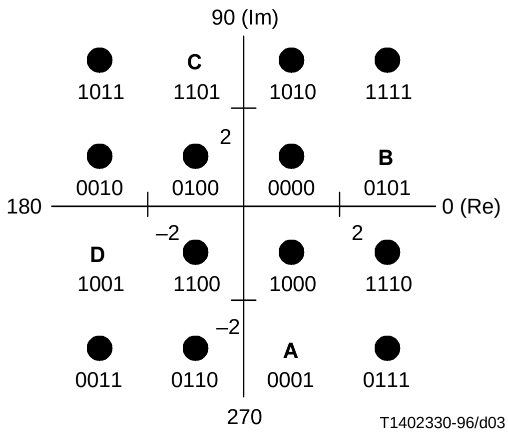


FIGURE 3/V.61

Signal space diagram and mapping for modulation at 9600 bit/s

5.4.5 Signal element coding for 4800 bit/s

At 4800 bit/s, the scrambled data stream to be transmitted is divided into groups of two consecutive data bits. The two bits $Q1_n$ and $Q2_n$, where $Q1_n$ is the first bit in time, where the subscript n designates the sequence number of the group, are first differentially encoded into $Y1_n$ and $Y2_n$ according to Table 1. The two bits $Y1_n$ and $Y2_n$ are then mapped into the coordinates of the signal element to be transmitted according to the signal space diagram shown in Figure 5. In the figure, binary numbers refer to bits $Y1_n$ and $Y2_n$. A, B, C, and D refer to synchronizing signal elements.

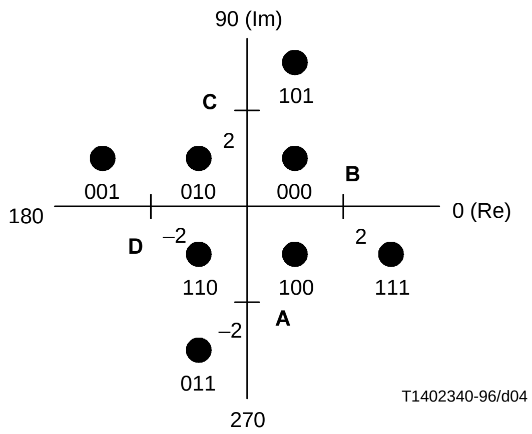


FIGURE 4/V.61

Signal space diagram and mapping for modulation at 7200 bit/s

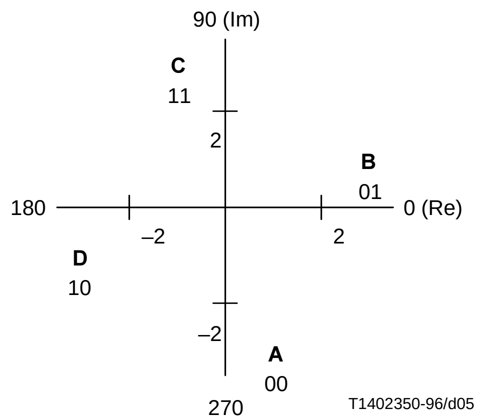


FIGURE 5/V.61

Signal space diagram and mapping for modulation at 4800 bit/s

5.5 Audio plus data coding

5.5.1 Audio processing system description

5.5.1.1 Signal element coding for 4800 bit/s plus audio

At 4800 bit/s, the scrambled data stream to be transmitted is divided into groups of two consecutive data bits. The two bits $Q1_n$ and $Q2_n$, where $Q1_n$ is the first bit in time, where the subscript n designates the sequence number of the group, are first differentially encoded into $Y1_n$ and $Y2_n$ according to Table 1. The two bits $Y1_n$ and $Y2_n$ are then mapped into the coordinates of the data signal element according to the signal space diagram shown in Figure 6. In the figure, binary numbers refer to bits $Y1_n$ and $Y2_n$.

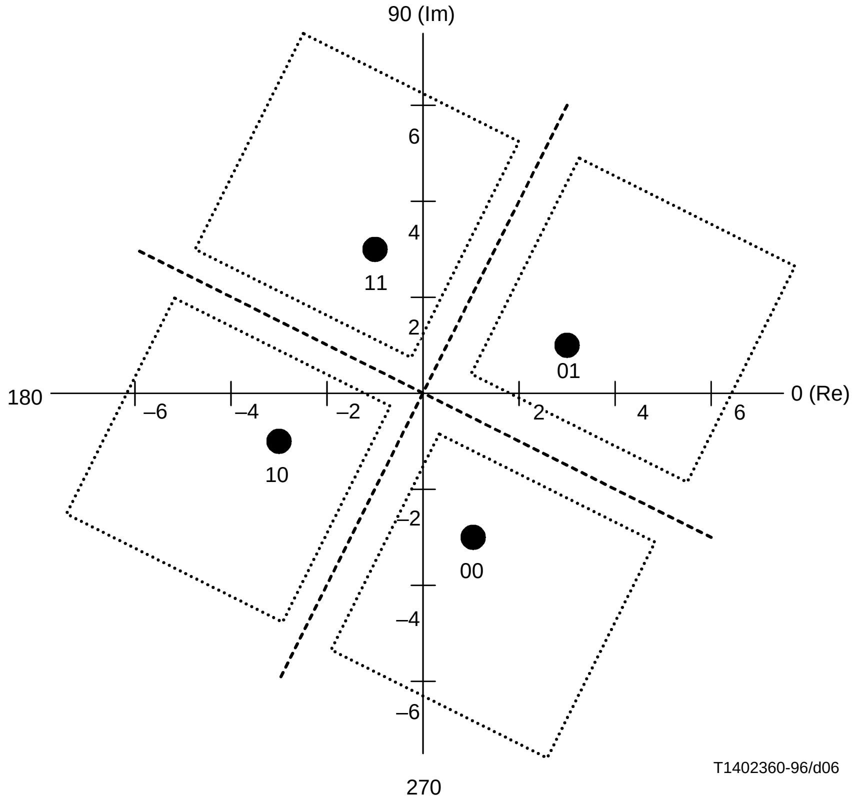


FIGURE 6/V.61

Signal space diagram and mapping for audio plus data modulation at 4800 bit/s

The audio signal is processed as described in 5.5.2 to generate complex-valued audio signal elements at the modem symbol rate. The audio signal element is summed with the data signal element to produce the audio plus data signal element to be transmitted.

The audio plus data constellation shall be scaled such that, when the complex-valued audio signal elements have zero magnitude, the transmitted power level is –2.5 dB relative to the transmitted power of the data-only constellations.

NOTE – The audio signal element is scaled and limited such that the audio plus data signal element generated will remain in the region (shown by dotted lines in Figure 6) designated by the data signal element.

5.5.1.2 Functional elements

Figure 7 shows the block diagram of the audio processing functions in the modem transmitter. Bold arrows indicate that the values passed from one functional block to another are complex-valued. Shaded blocks indicate data-only modem functions, or groups of functions, that do not change significantly with the addition of audio processing. The **S** designation next to arrows indicates symbol rate information. The **MS** designation indicates information at either 3 or 4 samples/symbol, and the **F** designation indicates audio frame rate information.

NOTE – Other equivalent methods may be used in place of the audio frequency translation and filtering functions shown in Figure 7 and described in this Recommendation.

5.5.1.3 Audio carrier frequency and processing rates

The audio carrier is shown in Figure 7 as *w*. The carrier frequency is 1600 Hz when the modulation rate is 3000 symbols/s and 1493.3 Hz when the modulation rate is 2800 symbols/s.

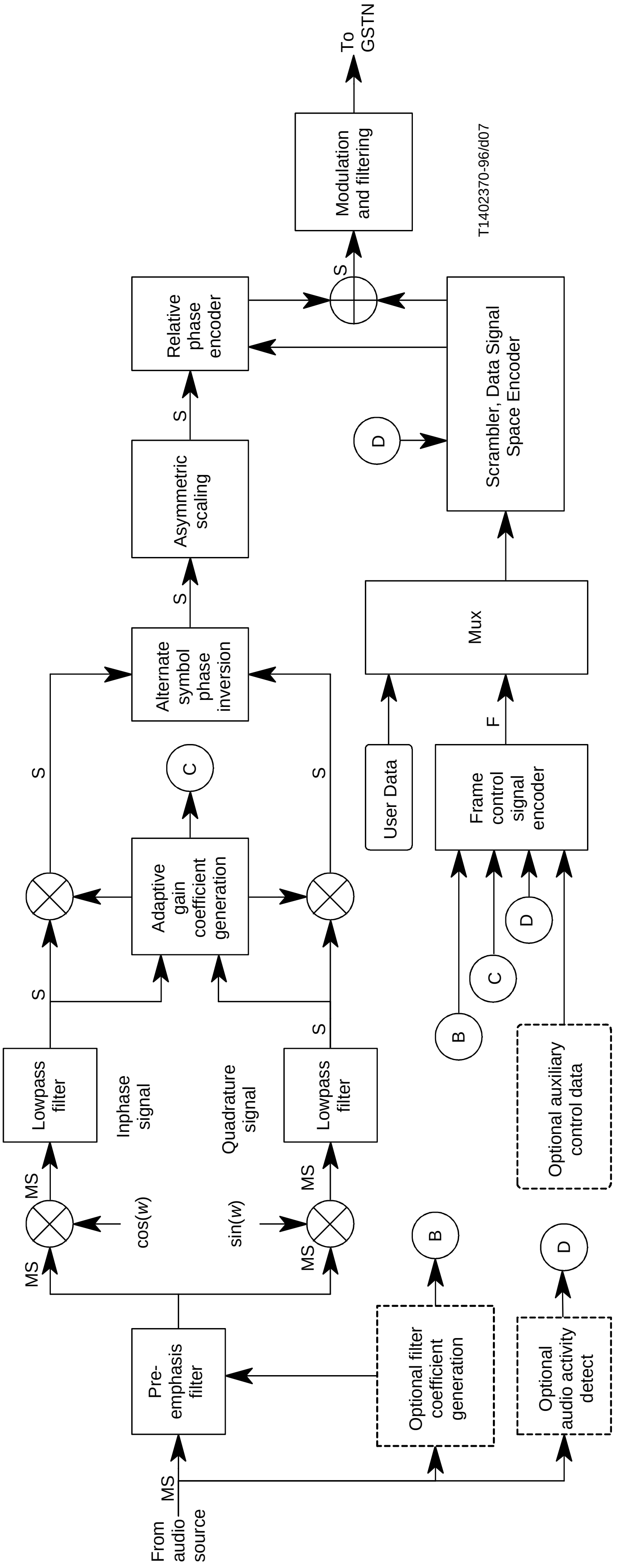


FIGURE 7/V.61

Audio functional block diagram

Processes which operate on signals at the symbol rate, shown in Figure 7 as **S**, occur at 3000 samples/s when the modulation rate is 3000 symbols/s and at 2800 samples/s when the modulation rate is 2800 symbols/s.

Processes which operate on signals at an integer multiple of the symbol rate, shown in Figure 7 as **MS**, occur at either 3 or 4 samples/symbol. At 3000 symbols/s, the **MS** rate is either 9000 samples/s or 12 000 samples/s. At 2800 symbols/s, the **MS** rate is either 8400 samples/s or 11 200 samples/s.

Processes which operate on signals at the frame rate, shown in Figure 7 as **F**, occur at 42.857 samples/s when the modulation rate is 3000 symbols/s and at 40 samples/s when the modulation rate is 2800 symbols/s. In either case, there are 70 symbols/frame.

5.5.2 Audio functions

5.5.2.1 Pre-emphasis filter

A pre-emphasis filter is applied to the audio source signal. The filter operates at the **MS** rate and is of the form:

$$y(k) = c_0 x(k) + c_1 x(k-1) + c_2 x(k-2)$$

where $x(k)$ is the signal input to the pre-emphasis filter and $y(k)$ is the output of the pre-emphasis filter.

The coefficients c_0, c_1 and c_2 of the pre-emphasis filter shall be selected from the coefficient sets in Table 2 (for 3 samples/symbol) or Table 3 (for 4 samples/symbol). The coefficients may be adaptively selected or fixed. If adaptive, they shall be updated once per frame.

The index indicating the filter coefficient set in use in the pre-emphasis filter shall be transmitted in the control information once per frame to the receiver. The index shall be transmitted regardless of whether the pre-emphasis coefficients are fixed or adaptive. The index for each set of filter coefficients is shown in Table 2 (for 3 samples/symbol) or Table 3 (for 4 samples/symbol).

NOTE – If the coefficients are fixed, they should be set to values which provide compromise compensation for the expected spectral content in the input signal.

5.5.2.1.1 Pre-emphasis coefficient interpolation

If adaptively selected, the filter coefficients in the transmitter shall be interpolated over a 70 symbol period in the manner described below. The filter coefficients in the receiver shall be interpolated regardless of whether the transmit pre-emphasis in the modem is fixed or adaptive.

In the following discussion, the subscript *f* designates the frame number in which the symbol is transmitted. Control information transmitted during the control segment at the end of frame *f* is used on data starting in frame $f + 1$. Coefficient set **C** refers to a matrix representation of $[c_0, c_1, c_2]$.

1) During the control segment at the end of frame *f*, the index for coefficient set $\mathbf{C}_f$ is transmitted.

2) The audio signal element transmitted in symbol 70_f is most closely associated with pre-emphasis filter coefficient set $\mathbf{C}_{f-1}$ (see Note).

3) During frame $f + 1$, the audio signal elements transmitted in symbols m_{f+1} (where $1 \le m \le 70$) are most closely associated with filter coefficient sets **C** as expressed by:

$$\mathbf{C} = \frac{70 - m}{70} \mathbf{C}_{f-1} + \frac{m}{70} \mathbf{C}_f$$

4) The audio signal element transmitted in symbol 70_{f+1} is most closely associated with pre-emphasis filter coefficient set $\mathbf{C}_f$.

NOTE – Due to the group delay in filtering which takes place in the system between the pre-emphasis filter in the transmitter and the de-emphasis filter in the receiver, there is not an exact relationship between an audio signal element and the filter coefficients which were used to process it. For this reason, the phrase “most closely associated with” is used.

TABLE 2/V.61

Pre-emphasis filter coefficient sets for 3 samples/symbol

Index	c_0	c_1	c_2	Index	c_0	c_1	c_2
0	1	0.884995209	0.78321652	32	1	–0.7964956881	0.626573216
1	1	0.7964956881	0.626573216	33	1	–0.7079961672	0.469929912
2	1	0.7079961672	0.469929912	34	1	–0.6194966463	0.313286608
3	1	0.6194966463	0.313286608	35	1	–0.5309971254	0.156643304
4	1	0.5309971254	0.156643304	36	1	–1.0471404528	0.78321652
5	1	0.6855143412	0.78321652	37	1	–0.9424264075	0.626573216
6	1	0.6169629071	0.626573216	38	1	–0.8377123623	0.469929912
7	1	0.54841147291	0.469929912	39	1	–0.7329983170	0.313286608
8	1	0.47986003881	0.313286608	40	1	–0.6282842717	0.156643304
9	1	0.41130860471	0.156643304	41	1	–1.1873456683	0.78321652
10	1	0.39578188941	0.78321652	42	1	–1.0686111014	0.626573216
11	1	0.3562037005	0.626573216	43	1	–0.9498765346	0.469929912
12	1	0.3166255115	0.469929912	44	1	–0.8311419678	0.313286608
13	1	0.2770473226	0.313286608	45	1	–0.7124074010	0.156643304
14	1	0.2374691337	0.156643304	46	1	–1.3126600260	0.78321652
15	1	0.0	0.78321652	47	1	–1.1813940234	0.626573216
16	1	0.0	0.626573216	48	1	–1.0501280208	0.469929912
17	1	0.0	0.469929912	49	1	–0.9188620182	0.313286608
18	1	0.0	0.313286608	50	1	–0.7875960156	0.156643304
19	1	0.0	0.156643304	51	1	–1.4270118962	0.78321652
20	1	0.0	0.0	52	1	–1.2843107066	0.626573216
21	1	–0.3957818894	0.78321652	53	1	–1.1416095170	0.469929912
22	1	–0.3562037005	0.626573216	54	1	–0.9989083273	0.313286608
23	1	–0.3166255115	0.469929912	55	1	–1.5328566664	0.78321652
24	1	–0.2770473226	0.313286608	56	1	–1.3795709998	0.626573216
25	1	–0.2374691337	0.156643304	57	1	–1.2262853332	0.469929912
26	1	–0.6855143412	0.78321652	58	1	–1.0729996665	0.313286608
27	1	–0.6169629071	0.626573216	59	1	–1.6318505348	0.78321652
28	1	–0.5484114729	0.469929912	60	1	–1.4686654813	0.626573216
29	1	–0.4798600388	0.313286608	61	1	–1.3054804278	0.469929912
30	1	–0.4113086047	0.156643304	62	1	–1.7251732597	0.78321652
31	1	–0.884995209	0.78321652	63	1	–1.5526559337	0.626573216

5.5.2.2 Audio signal modulation, lowpass filtering, and decimation

The audio signal output of the pre-emphasis filter is multiplied by cosine ($2\pi wt$) and sine ($2\pi wt$) to create inphase and quadrature modulated signals, respectively, at the **MS** sample rate. The inphase and quadrature signals are then each identically lowpass filtered to attenuate signals above **S/2** Hz. The requirements for the lowpass filters are shown in Figure 8 and Table 4. The filtered signals are then decimated to the **S** sample rate.

TABLE 3/V.61

Pre-emphasis filter coefficient sets for 4 samples/symbol

Index	c_0	c_1	c_2	Index	c_0	c_1	c_2
0	1.291801095	0.000000001	0.854577894	32	1.454143027	–1.174453159	0.685964906
1	1.253001035	0.004652322	0.741849221	33	1.390928825	–1.048767118	0.534687377
2	1.211947717	0.022543164	0.623057212	34	1.305238620	–0.888876106	0.361066453
3	1.160100525	0.066482360	0.497823414	35	1.208268991	–0.677907190	0.175101482
4	1.063671483	0.190003279	0.360982958	36	1.541979855	–1.385400088	0.824850632
5	1.343202202	–0.173901619	0.850489181	37	1.491599502	–1.269345607	0.688436094
6	1.305885180	–0.158333233	0.735208444	38	1.424215030	–1.135631197	0.537687835
7	1.266239381	–0.131552552	0.613716842	39	1.333388274	–0.967231349	0.364988292
8	1.218625758	–0.084171440	0.485428491	40	1.238844149	–0.765323288	0.188173066
9	1.138659463	0.020103969	0.345529877	41	1.574660760	–1.472367261	0.826003040
10	1.406945306	–0.407838344	0.845979494	42	1.521748946	–1.350044569	0.690228267
11	1.370832625	–0.376500123	0.727813850	43	1.449898382	–1.209199697	0.539626902
12	1.332396683	–0.335851653	0.603311019	44	1.353909219	–1.033882302	0.367923950
13	1.289181062	–0.279852639	0.471869219	45	1.254021095	–0.841230369	0.198811940
14	1.225243356	–0.187489440	0.328973513	46	1.603163888	–1.549144645	0.826994789
15	1.506727543	–0.703260338	0.844292514	47	1.546371500	–1.421036526	0.691471735
16	1.464649643	–0.651320813	0.724186792	48	1.469501400	–1.273542024	0.540711285
17	1.419828482	–0.591107647	0.596477195	49	1.367871103	–1.092915062	0.370438450
18	1.369213221	–0.518449464	0.458852970	50	1.336680055	–0.951055284	0.227407580
19	1.305449423	–0.423148509	0.305665425	51	1.628155194	–1.618416872	0.827822156
20	1.0	0.0	0.0	52	1.566972155	–1.484928514	0.692356904
21	1.562504948	–0.976674295	0.840253011	53	1.482500745	–1.330616101	0.540823538
22	1.521298510	–0.904039665	0.717476775	54	1.375737036	–1.147888806	0.373643470
23	1.477755491	–0.823766959	0.587185121	55	1.648395124	–1.681683047	0.828318973
24	1.430686770	–0.733208631	0.447143226	56	1.581111763	–1.542699566	0.692414482
25	1.382067466	–0.630494861	0.293371280	57	1.485939833	–1.381276648	0.539647380
26	1.597831664	–1.166594845	0.837739334	58	1.472867882	–1.238964738	0.402374618
27	1.557337037	–1.079047023	0.713330369	59	1.639566778	–1.737433844	0.826003040
28	1.514781808	–0.984079589	0.581511866	60	1.597386728	–1.597260935	0.693350179
29	1.469443518	–0.879549356	0.439843960	61	1.552962164	–1.449716190	0.554969725
30	1.168137086	–0.576426823	0.160640671	62	1.683775159	–1.795340535	0.829310356
31	1.502307230	–1.283251581	0.823367311	63	1.622302338	–1.651513607	0.696904208

TABLE 4/V.61

Reference frequencies for lowpass filter response

Symbol rate	A	B	C
3000 symboles/s	1350 Hz	1500 Hz	1600 Hz
2800 symboles/s	1260 Hz	1400 Hz	1493 Hz

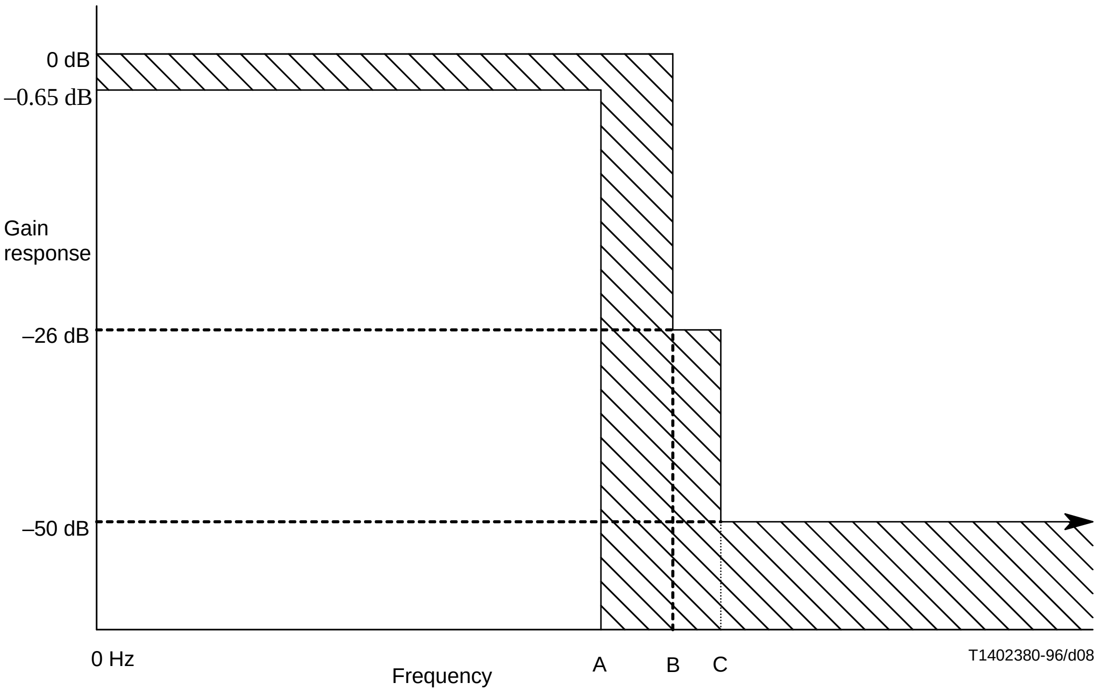


FIGURE 8/V.61

Lowpass filter response

5.5.2.3 Adaptive gain

The inphase and quadrature output signals from the decimator are scaled by adaptive gain factors which are updated once per frame. The permissible values of the gain factors are controlled by the following rules:

- The reference value is 1 (0 dB).
- Values are permitted in a series of 32 geometric steps with a ratio of $\sqrt[4]{2}$ (≈ 1.505 dB) between adjacent values. The highest value is $\left(\sqrt[4]{2}\right)^{31}$ (≈ 46.66 dB).
- The values applied to the inphase and quadrature signals must be within 3 steps (≈ 4.515 dB) of each other.

A combined adaptive gain index representing the inphase and quadrature gain factors used in the transmitter shall be transmitted in the control information once per frame to the receiver. The index transmitted in frame *n* shall indicate the gain factors applied to the audio signal in symbols 1 through 70 of frame $n + 1$. The index shall be generated using the following rules:

- The desired gain factors are determined for the inphase and quadrature signals. The signal with the smaller of the two gain factors is referred to as the *base signal*. The signal with the larger gain factor is referred to as the *delta signal*.
- If necessary, the gain factor for the delta signal is limited so that it is no more than 3 steps larger than the gain factor for the base signal.
- The index contains 8 bits. Bits G4 through G0 represent the gain factor for the base signal, with G4 the most significant bit. Bits D1 and D0 represent the delta between the gain factors for the base signal and the delta signal, with D1 the most significant bit. Bit GF is a flag bit used to indicate which signal is the base signal. Refer to 5.6.1.
- Bits G4 through G0 represent the number of gain steps above unity gain applied to the base signal. A value of 0 represents unity gain (0 dB). A value of 31 represents gain of: $\left(\sqrt[4]{2}\right)^{31}$ (≈ 46.66 dB)
- Bits D1 through D0 represent the number of gain steps that must be added to the base signal gain factor to produce the delta signal gain factor. A value of 0 indicates that the base signal and delta signal use the same gain factor. A value of 3 indicates that the gain factor for the delta signal is 3 steps (≈ 4.515 dB) larger than the gain factor for the base signal.
- Bit GF is set to 0 to indicate that the inphase signal is the base signal, or 1 to indicate that the quadrature signal is the base signal.

5.5.2.4 Alternate symbol phase inversion

The gain-adapted inphase and quadrature signals together constitute a complex-valued signal, sampled at the symbol rate, the inphase signal being the real component and the quadrature signal being the imaginary component. In each symbol, the complex-valued audio signal is phase rotated 180° relative to the previous symbol.

5.5.2.5 Asymmetric scaling

The real and imaginary components of the complex-valued samples generated by the alternate symbol phase inverter are each scaled asymmetrically. Negative-going components are scaled such that the maximum excursion of the combined signal element in the direction from one data signal element to an adjacent data signal element will be approximately 0.7 times the distance from the data signal element to a line dividing the signal quadrants (the dashed lines shown in Figure 6). Positive-going components are multiplied by a scalar twice as large as that used for negative-going components. The resulting range of the combined signal elements is shown by the regions enclosed within the dotted lines in Figure 6.

5.5.2.6 Relative phase encoding

The audio signal elements generated by the asymmetric scalar are rotated through a phase angle which is dependent on the data signal element associated with that symbol. The rotation phase angle for each data signal element is defined in Table 5, with reference to the data signal elements shown in Figure 6.

5.6 Control segment encoding

At 3000 symbols/s, there are 14 symbols per frame in the control segment. At 2800 symbols/s, there are 10 control segment symbols per frame. The encoding uses the first two bits in time in each symbol period, for a total of 28 bits per frame at 3000 symbols/s and 20 bits per frame at 2800 symbols/s (see Table 6). In addition, during frames in which more than two bits per symbol are transmitted, the third bit in time in each symbol period is transmitted as a redundant copy of the D bit defined in Table 6. During frames in which more than three bits per symbol are transmitted, bits after the third bit in time in each symbol are transmitted as zeros.

The audio parametric and control information transmitted in each control segment applies to the succeeding frame.

TABLE 5/V.61

Phase rotation applied to audio signal elements

Data signal element	Phase angle for rotation
00	243.43°
01	333.43°
11	63.43°
10	153.43°

5.6.1 Dibit encoding

The encoding applied to the first two bits in each symbol of the control segment is shown in Table 6. Bits 1 and 2 in the table are the dibit in the first symbol transmitted within the control segment. Of these two bits, bit 2 is first in time in the serial bit stream. At 3000 symbols/s, bits 27 and 28 are transmitted in the last symbol, with bit 28 first in time in the serial bit stream. At 2800 symbols/s, bits 19 and 20 are transmitted in the last symbol, with bit 20 first in time in the serial bit stream.

Five bits at 3000 symbols/s, and four bits at 2800 symbols/s, are transmitted twice within the control segment. The bits are inverted and transmitted a second time to provide a check of frame synchronization and to enable biased decisions at the receiver in the event of potential bit errors.

5.6.2 Redundant bit data-only encoding

When data-only frames are transmitted at rates that allow transmission of more than 2 bits per symbol, the third bit in time in the serial bit stream for each symbol transmitted in the control segment is used as a redundant Data-Only bit. This bit is transmitted with the same polarity as the Data-Only bit and may be used at the receiver to provide additional assurance of the received state of that indicator.

5.6.3 Auxiliary control channel

Eight bits per control segment (C7 through C0) are allocated within data-only frames for transmission of auxiliary control data. The nature of the auxiliary data is beyond the scope of this Recommendation.

An additional bit (AC) is used within data-only frames to indicate whether bits C7 through C0 contain auxiliary control information. Refer to Table 6.

5.7 Multiplexing/demultiplexing of data and control segments

The control information in the control segment of each frame is multiplexed with user data to form a single serial data stream at the input to the scrambler in the transmitter. The control and data segments are demultiplexed from the serial data stream at the output of the descrambler in the receiver.

6 Interfaces

6.1 DTE interface

When a standardized physical interface for the interchange circuits is not present, the equivalent functionality of the circuits must still be provided (Table 7).

TABLE 6/V.61

Dibit encoding in control segment

Bit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
A+D	1*	1*	0*	1*	1*	1*	0*	P5	P4	P3	P2	P1	P0	D	L	G4	G3	G2	G1	G0	D1	D0	$\underline{D}$	$\underline{L}$	$\underline{G4}$	$\underline{G3}$	$\underline{G2}$	GF
D uniquement	1*	1*	0*	1*	1*	1*	0*	1*	1*	1*	0*	AC	DB	D	C7	C6	C5	C4	C3	C2	C1	C0	$\underline{D}$	$\underline{C7}$	$\underline{C6}$	$\underline{C5}$	$\underline{C4}$	1*

a) Dibit encoding at 3000 symbols/s

Bit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A+D	P5	P4	P3	P2	P1	P0	D	L	G4	G3	G2	G1	G0	D1	D0	$\underline{D}$	$\underline{L}$	$\underline{G4}$	$\underline{G3}$	GF
D only	1*	1*	1*	0*	AC	DB	D	C7	C6	C5	C4	C3	C2	C1	C0	$\underline{D}$	$\underline{C7}$	$\underline{C6}$	$\underline{C5}$	1*

b) Dibit encoding at 2800 symbols/s

A + D	Audio+Data Mode. Control bit definitions within an audio plus data frame
D uniquement	Data-Only Mode. Control bit definitions within a data-only frame
P5-P0	Pre-emphasis filter coefficient index. P5 is the most significant bit, P0 is the least significant bit. Refer to 5.5.2.1
D, $\underline{D}$	Data-Only bit which defines the state of the succeeding frame. 1 = data-only, 0 = data+audio. $\underline{D}$ is the inverted state of D (see Note 1). When there are more than 2 bit/symbol, an additional redundant bit is added in each symbol as described in 5.6. Refer to 5.6.2
L, $\underline{L}$	Control loop lock bit. 1 = lock, 0 = unlock. $\underline{L}$ is the inverted state of L (see Note 2). A 1 in this bit indicates that the magnitude of the audio information in the frame is sufficiently large in one or more symbols to recommend locking of control loop update algorithms in the receiver
G4 - G0, D1 - D0, GF, $\underline{G4}$, $\underline{G3}$, $\underline{G2}$	Adaptive gain combined index. $\underline{G4}$, $\underline{G3}$, and $\underline{G2}$ are the inverted states of G4, G3, and G2, respectively (see Note 3). Refer to 5.5.2.3
DB	Indicates whether Data-Only mode is due to user control or audio silence. 0 = silence, 1 = user control. Refer to 5.3.3
C7 - C0	Auxiliary control channel bits. When the auxiliary control channel is not in use, the suggested default polarities for C7 through C0 are 01110111, with C7 in the leftmost position and C0 in the rightmost position. Refer to 5.6.3
AC	Auxiliary control channel enable. 1 = control segment contains auxiliary control data, 0 = control segment contains default state. Refer to 5.6.3
*	Suggested default state (see Note 4)

NOTES

1 Redundant bits may be combined using the logical OR function at receiver (after check bit inversion) to bias the decision towards data-only frames.

2 Redundant bits may be combined using the logical OR function at receiver (after check bit inversion) to bias towards locked decision.

3 Redundant bits may be combined using the logical OR function at receiver (after check bit inversion) to bias towards maximum attenuation of audio signal in receiver.

4 All undefined bit positions may be defined at a future date. The polarities shown are suggested default states for the transmitter, but should not be relied upon in the receiver

6.1.1 Synchronous interfacing (see Note 1)

The modems shall accept synchronous data from the DTE on circuit 103 (see Recommendation V.24) under control of circuit 113 or 114 (see Note 2). The modem shall pass synchronous data to the DTE on circuit 104 under the control of circuit 115. The modem shall provide to the DTE, 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 (see Note 2). In some applications, it may be necessary to slave the transmitter timing to the receiver timing inside the modem (see Note 3).

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 should occur solely with the operating sequences defined in clause 8. Thresholds and response times are inapplicable because a line signal detector cannot be expected to distinguish wanted received signals from unwanted talker echos.

NOTES

1 The subject of synchronous mode operation with variable data rates may require further study. It may be necessary to revise Recommendation V.24 (or other Recommendations) to specify timing effects during data rate transitions.

2 Since the transmitted data rate must change synchronously with the beginning of new audio frames, circuit 113 shall not be used to control transmit signal element timing when variable data rates are enabled.

3 The transmitter timing may not be slaved to the receiver timing when variable data rates are enabled in either direction.

6.1.2 Asynchronous character-mode interfacing

The modulation process operates synchronously. However, the modem may be associated with an asynchronous-to-synchronous conversion entity interfacing to the DTE in an asynchronous (or start-stop character) mode. The protocol for conversion shall be in accordance with Recommendation V.14 or V.42. Other facilities such as V.42 *bis* data compression may also be employed.

6.1.3 Electrical characteristics of interchange circuits

When a standardized physical interface is provided, the electrical characteristic conforming to Recommendation V.28 will normally be used. Alternatively, the electrical characteristics conforming to Recommendations V.10 and V.11 may be used. The connector and pole assignments specified by ISO 2110, corresponding to the electrical characteristics provided, shall be used.

6.1.4 Fault condition on interchange circuits

The DTE shall interpret a fault condition on circuit 107 as an OFF condition using failure detection type 1.

The DTE shall interpret a fault condition on circuits 105 and 108 as an OFF condition using failure detection type 1.

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

NOTE – See clause 7/V.28 and clause 11/V.10.

6.2 Audio interface

Definition of the physical characteristics of the audio interface is beyond the scope of this Recommendation.

7 Scrambler and descrambler

A self-synchronizing scrambler and descrambler shall be included in the modem. Each transmission direction uses a different scrambler. The method of allocating the scramblers is described in 7.1. According to the direction of transmission, the generating polynomial is:

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

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

TABLE 7/V.61

Interchange circuits

Interchange circuit		
No.	Description	
102	Signal ground or common return	
103	Transmitted data	
104	Received data	
105	Request to send	
106	Ready for sending	
107	Data set ready	
108/1 or	Connect data set to line	(Note 1)
108/2	Data terminal ready	(Note 1)
109	Data channel received line signal detector	
113	Transmitter signal element timing (DTE source)	(Notes 2, 4)
114	Transmitter signal element timing (DCE source)	(Notes 3, 5)
115	Receiver signal element timing (DCE source)	(Notes 3, 5)
125	Calling indicator	
135	Received energy present	(Note 6)
140	Loopback/maintenance	
141	Local loopback	
142	Test indicator	

NOTES

1 This circuit shall be capable of operation as circuit 108/1 or circuit 108/2 depending on its use. Operation of circuits 107 and 108/1 shall be in accordance with 4.4/V.24.

2 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.

3 When the modem is not operating at 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.

4 When the modem is transmitting with variable data rates due to silence detection, this circuit shall not be used.

5 The subject of synchronous mode operation with variable data rates may require further study.

6 Implementation of signal 135 is required only if it is intended that the modem support text telephony.

At the transmitter, the scrambler shall effectively divide the message 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. At the receiver, the received data sequence shall be multiplied by the scrambler generating polynomial to recover the message sequence.

7.1 Scrambler/descrambler allocation

On the general switched telephone network, the call mode modem shall use the scrambler with the GPC generating polynomial and the descrambler with the GPA generating polynomial. The answer mode modem shall use the scrambler with the GPA generating polynomial and the descrambler with the GPC generating polynomial. On point-to-point leased circuits or when calls are established on the GSTN by operators or users, the call mode/answer mode designation will be by bilateral agreement between Administrations or users and the scrambler/descrambler allocation will be the same as used on the GSTN.

8 Operating procedures

8.1 Call establishment, capabilities exchange, and mode selection procedures

For connections on the GSTN, the call establishment, capabilities exchange, and mode selection procedures to be used shall be as defined in Recommendation V.8 *bis*. For point-to-point leased connections, use of Recommendation V.8 *bis* is optional.

8.2 V.25 automatic answering sequence

If the mode selection procedures as defined in Recommendation V.8 *bis* are used (see 8.1), the answer mode modem shall transmit the answering sequence specified in those procedures. If Recommendation V.8 *bis* is not used, the start-up procedure shall be initiated with the V.25 automatic answering sequence.

8.3 Symbol rate determination signal

The symbol rate determination signal shall be used in the start-up procedure defined in clause 9 below. The signal is denoted by S or AA in Figure 9 and may consist of either of the two signals. If S, the signal consists of alternations between states A and B as shown in Figure 5. If AA, the signal consists of repetitions of state A as shown in Figure 5. In either case, the signal is transmitted for a duration of 256 symbol intervals. This signal is always transmitted at a symbol rate of 3000 symbols/s.

8.4 Channel holding signal

The channel holding signal shall be used in the start-up procedure defined in clause 9 below. The signal, denoted by DCBA in Figure 9 consists of repetitions of the sequence of states D, C, B, and A as shown in Figure 5. This signal is always transmitted at a symbol rate of 3000 symbols/s.

8.5 Round trip delay estimating signals

The round trip delay estimating signals shall be used in the start-up and retrain procedures defined in clauses 9 and 10 below. The calling modem shall transmit signal G and signal $\underline{G}$, and the answering modem shall transmit signal F and signal $\underline{F}$, as defined in Table 8 for each symbol rate. Signals $\underline{F}$ and $\underline{G}$ are at the same frequencies as, but inverted in phase with respect to, signals F and G.

TABLE 8/V.61

Round-trip delay estimating signals

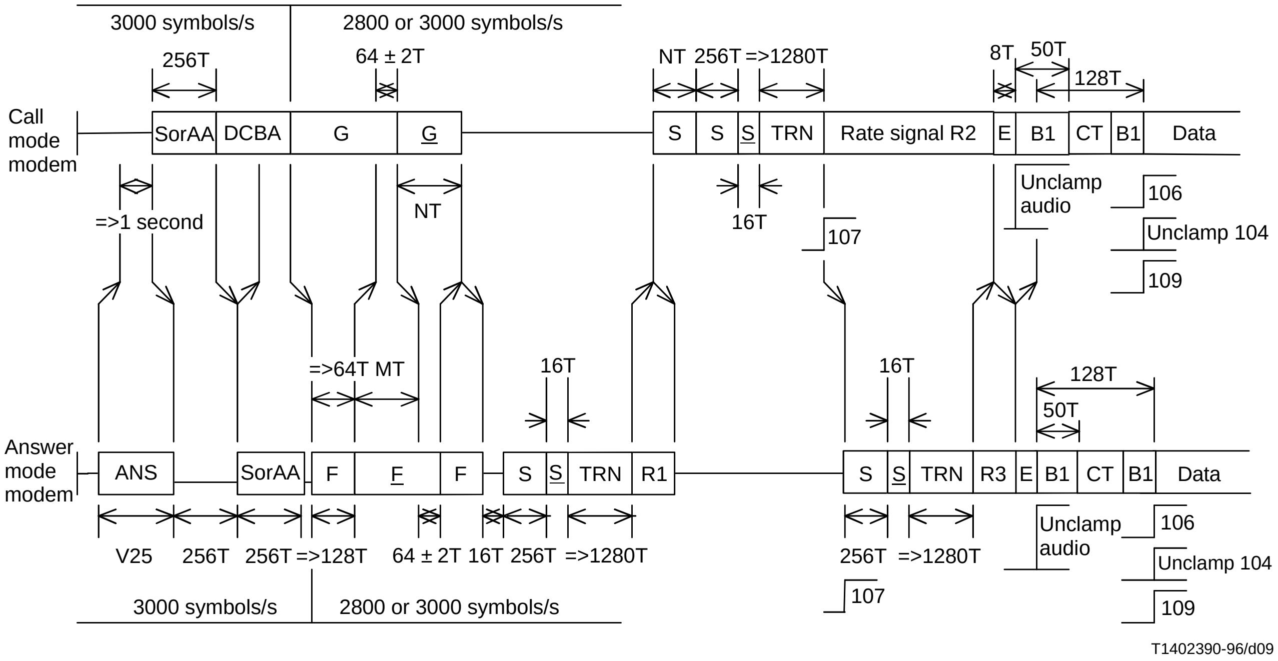
Symbol rate	F	G
3000 symbols/s	2100 ± 1 Hz	1500 ± 1 Hz
2800 symbols/s	1960 ± 1 Hz	1400 ± 1 Hz

8.6 Receiver conditioning signal

The receiver conditioning signal shall be used in the start-up and retrain procedures defined in clauses 9 and 10 below. The signal consists of three segments:

8.6.1 Segment 1

Segment 1, denoted by S in Figures 9 and 10, consists of alternations between states A and B as shown in Figure 5, for a duration of 256 symbol intervals.



S, S	Signal states ABAB... AB, CDCD... CD
AA	Signal states AAAA... A
DCBA	Signal states DCBADCBA... DCBA
F, F	2100 Hz (or 1960 Hz) tone, tone 180° out of phase relative to signal F
G, G	1500 Hz (or 1400 Hz) tone, tone 180° out of phase relative to signal G
MT, NT	Round trip delays observed from answer and call modems respectively, including 64T ± 2T modem turn around delay
TRN	Scrambled ones using the 4-phase data constellation with dibits encoded directly to states A, B, C, and D
R1, R2, R3	Each a repeated sequence consisting of three 16-bit rate words, using the 4-phase data constellation, scrambled and differentially encoded as in Table 1
E	A single 16-bit sequence marking and following the end of a whole number of 16-bit rate words in R2 and R3
B1	Binary ones scrambled and encoded for the subsequent transmission of data
CT	First control segment

FIGURE 9/V.61

Start-up procedure

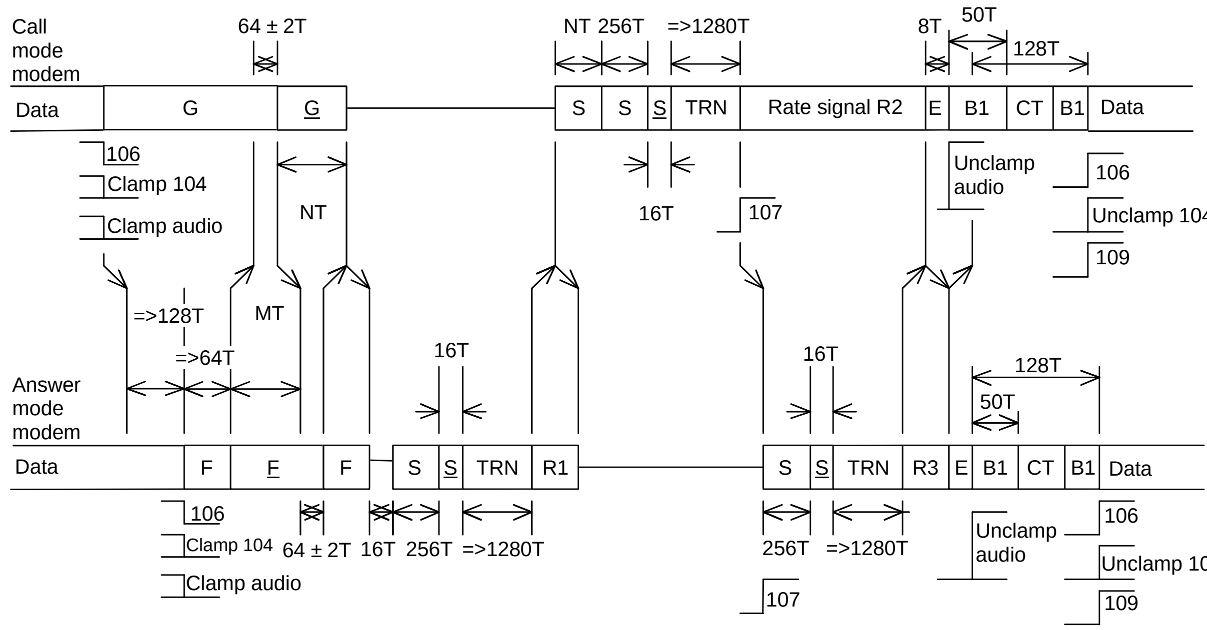
8.6.2 Segment 2

Segment 2, denoted by S in Figures 9 and 10, consists of alternations between states C and D as shown in Figure 5, for a duration of 16-symbol intervals.

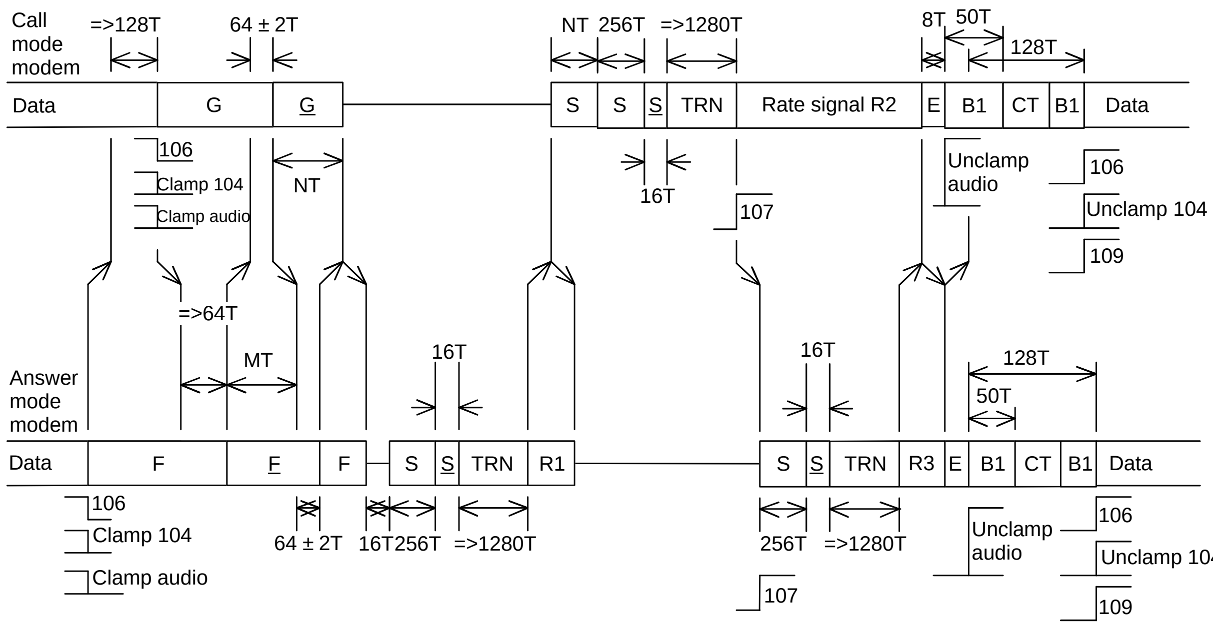
NOTE – The transition from segment 1 to segment 2 provides a well-defined event in the signal that may be used for generating a time reference in the receiver.

8.6.3 Segment 3

Segment 3, denoted by TRN in Figures 9 and 10, is a sequence derived by scrambling binary ones using the 4-phase constellation shown in Figure 5 with the scrambler defined in clause 7. During the transmission of this segment, the differential quadrant encoding shall be disabled. The initial state of the scrambler shall be all zeroes, and a binary one applied to the input for the duration of segment 3. Successive dibits are encoded onto transmitted signal states.



a) Retrain initiated by the calling modem



b) Retrain initiated by the answering modem

T1402400-96/d10

F, F	2100 Hz (or 1960 Hz) tone, tone 180º out of phase relative to signal F
G, G	1500 Hz (or 1400 Hz) tone, tone 180º out of phase relative to signal G
MT, NT	Round trip delays observed from answer and call modems respectively, including 64T ± 2T modem turn around delay
S, S	Signal states ABAB... AB, CDCD... CD
TRN	Scrambled ones using the 4-phase data constellation with dibits encoded directly to states A, B, C, and D
R1, R2, R3	Each a repeated sequence consisting of three 16-bit rate words, using the 4-phase data constellation, scrambled and differentially encoded as in Table 1
E	A single 16-bit sequence marking and following the end of a whole number of 16-bit rate words in R2 and R3
B1	Binary ones scrambled and encoded for the subsequent transmission of data
CT	First control segment

FIGURE 10/V.61

Retrain procedures

The first 256 transmitted signal states are determined from the state of the first bit occurring (in time) in each dibit. When this bit is ZERO, signal state A is transmitted; when this bit is ONE, signal state C is transmitted. Depending on whether the modem is in call or answer mode, the scrambler output patterns and corresponding signal states will then begin as below, where the bits and the signal states are shown in time sequence from left to right.

Call mode modem:

GPC:	11	11	11	11	11	11	11	11	11	00	00	01	11	11	11
	C	C	C	C	C	C	C	C	C	A	A	A	C	C	C

Answer mode modem:

GPA:	11	11	10	00	00	11	11	10	00	00	11	10	01	11	11
	C	C	C	A	A	C	C	C	A	A	C	C	A	C	C

Immediately after 256 such symbols, successive scrambled dibits are encoded onto transmitted signal states in accordance with Table 9 directly without differential encoding for the remainder of segment 3. The duration of segment 3 shall be at least 1280 and not exceed 8192 symbol intervals.

Segment 3 is intended for training the adaptive equalizer in the receiving modem and the echo canceller in the transmitting modem.

TABLE 9/V.61

Encoding the TRN segment after the first 256 symbols

Dibit	Signal state
00	A
01	B
11	C
10	D

8.7 Rate signal

The rate signal shall be used in the start-up, retrain, and rate re-negotiating procedures.

The rate signal consists of a set of three 16-bit binary sequences, as defined in Tables 10, 11, and 12, scrambled and transmitted using the 4-phase data constellation shown in Figure 5 with dibits differentially encoded as in Table 1. The three 16-bit sequences are transmitted sequentially, with rate word 1 transmitted first, followed by rate words 2 and 3, respectively. Each 16-bit binary sequence is repeated a whole number of times. In the start-up and retrain procedures (see clauses 9 and 10), the differential encoder shall be initialized using the final symbol of the transmitted TRN segment.

In the rate negotiation procedure (see clause 11), the differential encoder shall be initialized using the final symbol of the transmitted preamble and the scrambler shall be initialized to all zeros.

The first two bits and each successive dibit of the rate sequence shall be encoded to form the transmitted signal states.

8.7.1 Detecting a rate signal

The minimum requirement for detection is the receipt of two identical occurrences of rate word 1, the start of the second occurring 48-bit periods in time after the start of the first, each with bits B0-B3, B7, B11, and B15 conforming to Table 10.

TABLEAU 10/V.61

Coding of rate word 1

B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
0	0	0	0	1	–	–	1	1	–	–	1	–	0	0	1

B0-B3, B7, B11, B15	For synchronizing on a rate signal
B4, B8	= 1, 1 for rate word 1
B5	1 denotes that data-only operation at 4800 bit/s is enabled
B6	1 denotes that data-only operation at 9600 bit/s is enabled
B9	1 denotes that data-only operation at 7200 bit/s is enabled
B10	1 denotes that data-only operation at 12 000 bit/s is enabled
B12	1 denotes that data-only operation at 14 400 bit/s is enabled
B13, B14	= 0, 0 (Note 1)

NOTES

1 B13 and B14 shall be set to zero when transmitting and ignored during the reception of rate word 1; they are reserved for future definition and must not be used by manufacturers.

2 B4-B6, B9-B10, B12 set to zero calls for a GSTN cleardown.

TABLEAU 11/V.61

Coding of rate word 2

B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
0	0	0	0	1	1	0	1	0	0	0	1	0	0	0	1

B0-B3, B7, B11, B15	For synchronizing on a rate signal
B4, B8	= 1, 0 for rate word 2
B5	1 denotes that voice plus data operation at 4800 bit/s is enabled
B6, B9, B10, B12-B14	= 0 (Note)

NOTE – B6, B9, B10, B12, B13, and B14 shall be set to zero when transmitting and ignored during the reception of rate word 2; they are reserved for future definition and must not be used by manufacturers.

8.7.2 Ending the rate signal

In order to mark the end of transmission of any rate signal other than R1 (see Figure 9), the modem shall first complete the transmission of the current 16-bit rate word, and then transmit one 16-bit sequence E, coded as shown in Table 13.

Bits B4-B12 in sequence E shall be encoded as in Table 10 except the only data rate to be indicated shall relate to the transmission of scrambled binary ones immediately following signal E.

9 Start-up procedure

The procedure for achieving synchronism between the calling modem and the answering modem on GSTN connections is shown in Figure 9. The procedure includes the estimating of channel transmission bandwidth in each direction and negotiation of symbol rate, the estimating of round trip delay from each modem, the training of echo cancellers and receivers initially with half-duplex transmissions, and the exchanging of rate signals for automatic bit-rate and mode selection.

TABLE 12/V.61

Coding of rate word 3

B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
0	0	0	0	0	0	0	1	1	0	0	1	0	0	–	1

B0-B3, B7, B11, B15	For synchronizing on a rate signal
B4, B8	= 0, 1 for rate word 3
B14	1 denotes that silence detection should be enabled at the receiving modem's transmitter
B5, B6, B9, B10, B12, B13	= 0 (Note)

NOTE – B5, B6, B9, B10, B12, and B13 shall be set to zero when transmitting and ignored during the reception of rate word 3; they are reserved for future definition and must not be used by manufacturers.

TABLE 13/V.61

Coding of sequence E

B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
1	1	1	1	1	–	–	1	1	–	–	1	–	0	0	1

The procedures defined in this clause apply regardless of whether they occur at call establishment on the GSTN, after a call has been established on the GSTN in voice-only mode, or on point-to-point leased circuits. On point-to-point leased circuits or when calls are pre-established on the GSTN by operators or users, the call mode/answer mode designation will be by bilateral agreement between Administrations or users. The start-up procedures will be as defined below, with the call establishment, capabilities exchange, and mode selection procedure initiated by either user.

9.1 Call mode modem

On connection to the GSTN line, the modem shall be conditioned to detect start-up signals specified in Recommendation V.8 *bis*. On point-to-point leased connections, the modem shall be conditioned to detect start-up signals specified in Recommendation V.8 *bis*, or answer tone as specified in Recommendation V.25, or both of the above signals.

If start-up signals, as specified in Recommendation V.8 *bis*, are detected the procedures specified in that Recommendation shall be followed. Upon completion of the mode selection protocol defined in Recommendation V.8 *bis*, the modem shall be conditioned to detect answer tone as specified in Recommendation V.25.

After receiving the answer tone, as specified in Recommendation V.25, for a period of at least 1 s, the modem shall be connected to line (see Note 2) and shall condition the scrambler and descrambler in accordance with 7.1.

The modem shall transmit a symbol rate determination signal (see 8.3) for 256 symbol intervals at a symbol rate of 3000 symbols/s. If the modem is configured for 3000 symbols/s, it shall send S as the symbol rate determination signal. If the modem is configured for 2800 symbols/s, it shall send AA as the signal. After completing transmission of the symbol rate determination signal, the modem shall continuously transmit the DCBA sequence (see 8.4) at a symbol rate of 3000 symbols/s.

After a delay of 256 symbol intervals after detection of the end of answer tone, the modem shall condition itself to detect the symbol rate determination signal from the remote modem.

On detection of the symbol rate determination signal, the modem shall determine whether the received sequence is S or AA. If the received sequence is AA, the modem shall condition itself to continue at 2800 symbols/s. If the received sequence is S, the modem may condition itself to continue at either 2800 symbols/s or 3000 symbols/s (See Note 1).

The modem shall continuously transmit the G tone (see 8.5).

The modem shall be conditioned to detect an incoming F tone (see 8.5), and subsequently to detect a phase reversal in that tone.

On detection of one such phase reversal, the modem shall be conditioned to detect a second phase reversal in the same tone, start a counter/timer and transmit a phase reversal in the transmitted G tone. The time delay between reception of this phase reversal at the line terminals and the transmitted phase reversal appearing at the line terminals shall be 64 ± 2 symbol periods.

On detection of a second phase reversal in the same incoming tone, the modem shall stop the counter/timer and cease transmitting.

When the modem detects an incoming S sequence (see 8.6), it shall proceed to train its receiver, and then seek to detect at least two consecutive identical occurrences of rate word 1 (see 8.7.1) as defined in Table 10.

On detection of the rate signal (R1), the modem shall transmit an S sequence for a period NT already estimated by the counter/timer.

After this period has expired, the modem shall transmit the receiver conditioning signal as defined in 8.6, starting with an S sequence for 256 symbol intervals.

Transmission of the TRN segment of the receiver conditioning signal may be extended in order to ensure a satisfactory level of echo cancellation (see Note 3).

After the TRN segment, the modem shall apply an ON condition to circuit 107 and transmit a rate signal (R2) in accordance with 8.7 to indicate the currently available data rates and modes. R2 shall exclude rates not appearing in the previously received rate signal R1. It is recommended that R2 also take account of the likely receiver performance of the estimated GSTN connection. If it appears that satisfactory performance cannot be attained at any of the available data rates, then R2 should be used to call for a GSTN cleardown in accordance with Table 10.

Transmission of R2 shall continue until an incoming rate signal R3 is detected. The modem shall then, after completing its current 16-bit rate word, transmit a single 16-bit sequence E in accordance with 8.7.2 indicating the data rate called for in R3. If, however, R3 is calling for GSTN cleardown in accordance with Table 10, then the call modem shall disconnect (see Note 4) from line and effect a cleardown.

The modem shall then transmit continuous scrambled binary ones at the data rate called for in R3. After a delay of 50 symbol intervals following transmission of the E sequence, the modem shall transmit the first symbol of the first control segment as described in 5.6. Following completion of the transmission of this control segment, the modem shall continue to transmit binary ones, either at the data rate called for in R3 (if the frame defined by the transmitted control segment is data-only) or at 4800 bit/s plus audio (if the frame defined by the transmitted control segment is audio plus data).

On detecting an incoming 16-bit E sequence as defined in 8.7.2, the modem shall condition itself to receive data at the rate indicated by the incoming E sequence. After a delay of 50 symbols following detection of the E sequence, the modem shall condition itself for receipt of the first symbol of the first control segment as described in 5.6. Following receipt of the control segment, the modem shall condition itself to receive data, either at the data rate indicated by the incoming E sequence (if the frame defined by the incoming control segment is data-only) or at 4800 bit/s plus audio (if the frame defined by the incoming control segment is audio plus data). After a delay of 128-symbol intervals following detection of the incoming E sequence, it shall apply an ON condition to circuit 109, and unclamp circuit 104.

The modem shall then enable circuit 106 to respond to the condition of circuit 105 and be ready to transmit data.

NOTES

1 Manufacturers are cautioned that the ITU-T is considering the transmission of energy at frequencies above 3400 Hz during transmission of the symbol rate determination signal. Detection of energy resulting from transmission at these frequencies should be ignored during the determination of symbol rate.

2 Once an incoming G tone is detected, the calling modem may proceed with the start-up sequence even if no F tone has been detected.

3 Manufacturers are cautioned that a period of 650 ms is needed for training any network echo cancellers conforming to Recommendation G.165 that may be encountered on GSTN connections.

4 If the voice terminal equipment is enabled (i.e. on-hook) when a data session is disconnected, such action shall not physically disconnect the voice terminal equipment from the line. The modem shall relinquish on-hook control of the line to the voice terminal equipment.

9.2 Answer mode modem

On connection to the GSTN line, the modem shall be conditioned to detect the signals specified in Recommendation V.8 *bis* and shall transmit the start-up signals specified in that Recommendation. Upon initiation of a start-up procedure on point-to-point leased connections, the modem shall transmit either the V.25 answer sequence or the start-up signals specified in Recommendation V.8 *bis*. If Recommendation V.8 *bis* is used, the modem shall follow the procedures specified in that Recommendation. Following the procedures specified in Recommendation V.8 *bis*, or upon initiation of a start-up procedure if Recommendation V.8 *bis* is not used, the modem shall condition the scrambler and descrambler in accordance with 7.1 and shall transmit the V.25 answer sequence. On transmission of the answer sequence, the modem shall be conditioned to detect the symbol rate determination signal (see 8.3).

On detection of the symbol rate determination signal, the modem shall stop sending answer tone.

The modem shall determine whether the received sequence is S or AA. If the received sequence is AA, the modem shall condition itself to send AA as the return symbol rate determination signal. If the received sequence is S, the modem may condition itself to send S or AA as the return symbol rate determination signal (see Note 1).

On detecting the transition from the symbol rate determination signal to the DCBA sequence, the modem shall send the return symbol rate determination signal for 256 symbol intervals. The modem shall be conditioned to detect the G signal at either 1500 Hz or 1400 Hz.

On detection of the G signal, the modem shall determine whether the received signal is at 1500 Hz or 1400 Hz. If the sequence is received at 1500 Hz, the modem shall condition itself to continue at 3000 symbols/s. If the sequence is received at 1400 Hz, the modem shall condition itself to continue at 2800 symbols/s. The modem shall then continuously transmit the F tone.

After the F tone has been transmitted for a number of symbol intervals greater than or equal to 128 *and* an incoming G tone has been detected for 64 symbol periods (see Note 3), the modem shall be conditioned to detect a phase reversal in the incoming tone, start a counter/timer, and transmit a phase reversal in the transmitted F tone.

On detecting a phase reversal in the incoming tone, the modem shall stop the counter/timer and transmit a second phase reversal in the transmitted F tone. The time delay between the reception of the incoming phase reversal at the line terminals and the transmitted phase reversal appearing at the line terminals shall be 64 ± 2 symbol periods.

When an amplitude drop is detected in the incoming tone, the modem shall cease transmitting for a period of 16-symbol intervals and then transmit the receiver conditioning signal as defined in 8.6.

Transmission of the TRN segment of the receiver conditioning signal may be extended in order to ensure a satisfactory level of echo cancellation (see Note 2).

After the TRN segment, the modem shall transmit a rate signal (R1) in accordance with 8.7 to indicate the data rates currently available in the answer modem and associated DTE.

On detection of an incoming S sequence, the modem shall cease transmitting.

The modem shall wait for a period MT already estimated by the counter/timer and then, if an incoming S sequence persists, the modem shall proceed to train its receiver.

After training its receiver, the modem shall seek to detect at least two consecutive identical incoming 16-bit rate words as defined in 8.7.1.

On detection of a rate signal (R2), the modem shall apply an ON condition to circuit 107 and transmit a second receiver conditioning signal as defined in 8.6.

After the TRN segment, the modem shall transmit a second rate signal (R3) in order to indicate the data rates to be used by both modems. The data rates selected by R3 shall be within those indicated by R2. It is recommended that R3 also take account of the likely performance of the answer modem receiver with the particular GSTN connection established. If R2 is calling for a GSTN cleardown (see Table 10) and/or it appears that satisfactory performance cannot be attained by the answer modem at any of the available data rates, then R3 should call for a GSTN cleardown, in accordance with Table 10.

When the modem detects an incoming 16-bit E sequence as defined in 8.7.2, it shall condition itself to receive data at the rate indicated by the E sequence. After a delay of 50 symbols following detection of the E sequence, the modem shall condition itself for receipt of the first symbol of the first control segment as described in 5.6. Following receipt of the control segment, the modem shall condition itself to receive data, either at the data rate indicated by the incoming E sequence (if the frame defined by the incoming control segment is data-only) or at 4800 bit/s plus audio (if the frame defined by the incoming control segment is audio plus data).

The modem shall complete the current 16-bit rate word and then transmit a single 16-bit E sequence indicating the data rate to be used in the subsequent transmission of scrambled binary ones.

The modem shall transmit scrambled binary ones for 50-symbol intervals. The modem shall then transmit the first symbol of the first control segment as described in 5.6. Following completion of the transmission of this control segment, the modem shall continue to transmit binary ones, either at the data rate called for in R3 (if the frame defined by the transmitted control segment is data-only) or at 4800 bit/s plus audio (if the frame defined by the transmitted control segment is audio plus data). After a total of 128-symbol intervals has elapsed following transmission of the E sequence, the modem shall enable circuit 106 to respond to the condition of circuit 105 and be ready to transmit data.

The modem shall also apply an ON condition to circuit 109 and unclamp circuit 104.

NOTES

1 Manufacturers are cautioned that the ITU-T is considering the transmission of energy at frequencies above 3400 Hz during transmission of the symbol rate determination signal. Detection of energy resulting from transmission at these frequencies should be ignored during the determination of symbol rate.

2 Manufacturers are cautioned that a period of 650 ms is needed for training any network echo cancellers conforming to Recommendation G.165 that may be encountered on GSTN connections.

3 The answering modem may disconnect from the line (see Note 5) if the G tone is not detected following initial transmission of the F tone. However, to assure compatibility with manual originating data stations, it shall not disconnect (see Note 5) for at least 3 seconds after the F tone has been transmitted.

4 If R3 is calling for a GSTN cleardown, the modem shall repeat the transmission of signal R3 for not less than 64 symbol intervals before clearing the connection.

5 If the voice terminal equipment is enabled (i.e. on-hook) when a data session is disconnected, such action shall not physically disconnect the voice terminal equipment from the line. The modem shall relinquish on-hook control of the line to the voice terminal equipment.

10 Retrain procedure

A retrain may be initiated during data transmission if either modem incorporates a means of detecting unsatisfactory signal reception. Figure 10 a) shows a retrain event initiated by the calling modem and Figure 10 b) shows a retrain event initiated by the answering modem. The procedure is as follows:

10.1 Call mode modem

Following detection of unsatisfactory signal reception or detection of the F tone for more than 128-symbol intervals, the modem shall turn OFF circuit 106, clamp circuit 104 to binary 1 and continuously transmit the G tone, using the frequency previously assigned for the symbol rate established during the start-up procedure. It shall then proceed in accordance with 9.1 beginning with the seventh paragraph.

10.2 Answer mode modem

Following detection of unsatisfactory signal reception or detection of the G tone for more than 128-symbol intervals, the modem shall turn OFF circuit 106, clamp circuit 104 to binary 1 and continuously transmit the F tone, using the frequency previously assigned for the symbol rate established during the start-up procedure. It shall then proceed in accordance with 9.2 beginning with the seventh paragraph.

10.3 Operation of circuits 107 and 109 during retrain procedure

Circuit 107 shall be maintained in the ON condition during the retrain procedure.

Circuit 109 shall be maintained in the ON condition except that the OFF condition may optionally be applied if transmission of the first G segment in the call modem or the first F segment in the answer modem continues for a period exceeding 45 seconds. If the retrain procedure is subsequently completed, the ON condition shall be re-applied to circuit 109 at the time the circuit 104 is unclamped.

11 Rate renegotiating procedure

The following procedure shall be provided to enable modems to change their data signalling rates without retraining. Either modem may transmit a proposal for desired data signalling rates. The procedure comprises a preamble followed by a rate code.

The preamble transmitted by the call mode modem consists of signal AA for a period 56T followed by signal CC for a period 8T. The preamble transmitted by the answer mode modem consists of signal AC for a period 56T followed by a signal CA for a period 8T.

The rate signal is as defined in 8.7. The initial state of the scrambler shall be all zeros and the differential encoder shall be initialized using the final symbol of the transmitted preamble.

The rate renegotiating procedure is shown in Figure 11. Figure 11 a) shows the procedure as initiated by the calling modem; Figure 11 b) shows the procedure as initiated by the answering modem.

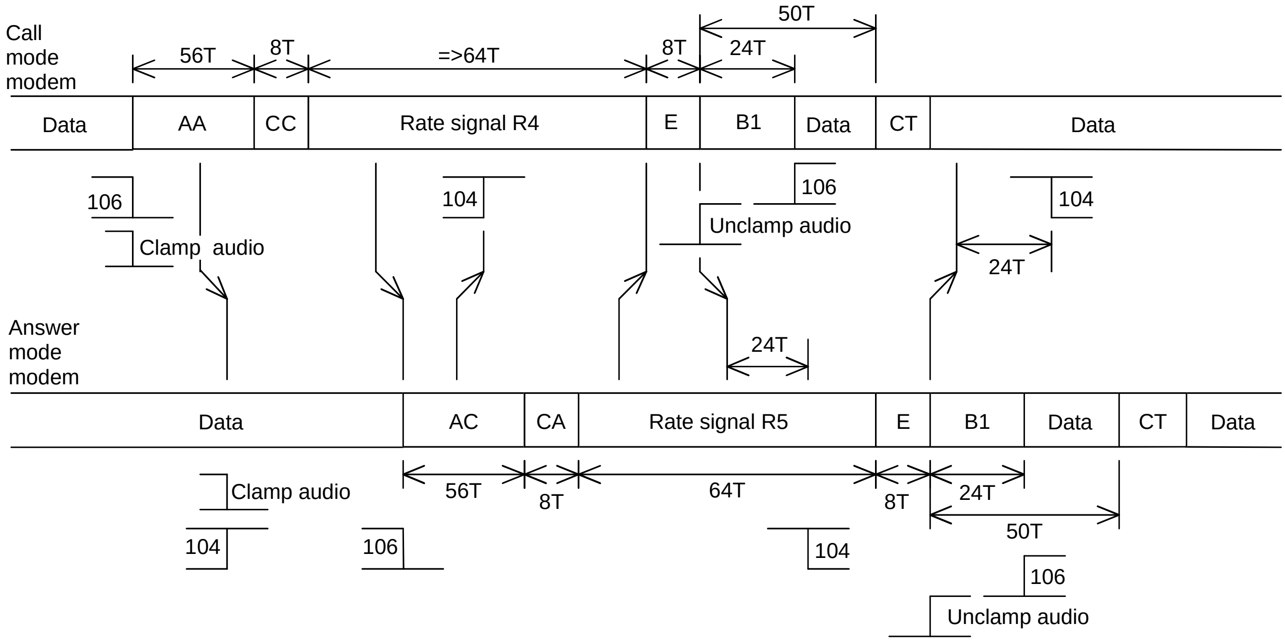
11.1 Initiating procedure

Rate negotiation may be initiated at any time during data transmission.

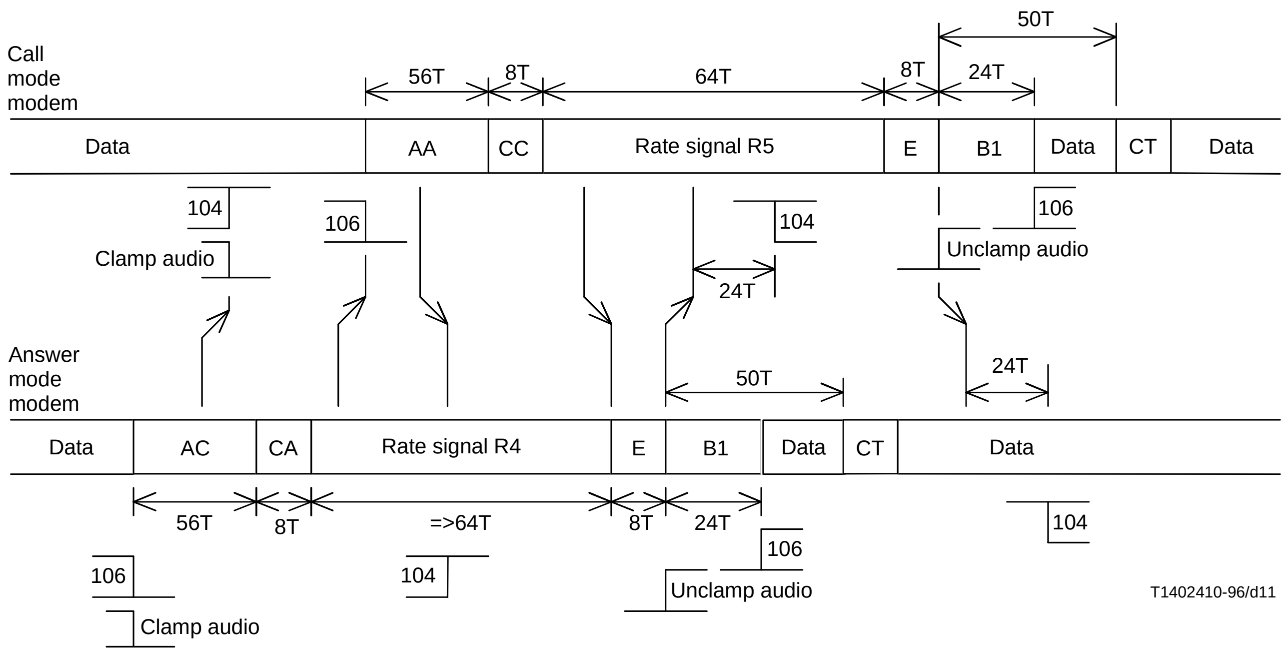
When a data signalling rate change is desired, the initiating modem shall turn circuit 106 OFF and transmit the appropriate preamble followed by a rate signal R4. R4 shall indicate the desired rates in the initiating modem and all lower data signalling rates at which the initiating modem is enabled to operate.

Following detection of the preamble (this might occur during transmission of a preamble if both modems initiate the procedure almost simultaneously), the initiating modem shall clamp circuit 104 to binary one and condition its receiver to detect rate signal R5.

On detection of rate signal R5, the initiating modem shall condition its receiver to detect sequence E. Then, when R4 has been transmitted for a minimum of 64T, it shall complete the current 16-bit rate word and transmit sequence E in accordance with 8.7.2 indicating the highest data signalling rates common to R4 and R5 (see Notes 1, 2). The initiating modem shall then transmit scrambled binary ones at the data-only signalling rate for 24T. The initiating modem shall then enable circuit 106 to respond to the condition of circuit 105 and be ready to transmit data.



a) Rate negotiation initiated by the calling modem



b) Rate negotiation initiated by the answering modem

FIGURE 11/V.61

Rate negotiation procedure

After a delay of 50-symbol intervals following transmission of the E sequence, the modem shall transmit the first symbol of the first control segment as described in 5.6. Following completion of the transmission of this control segment, the modem shall continue to transmit data, either at the highest data-only signalling rate common to both R4 and R5 (if the frame defined by the transmitted control segment is data-only) or at 4800 bit/s plus audio (if the frame defined by the transmitted control segment is audio plus data).

On detecting sequence E, the initiating modem shall condition itself to receive data at the highest data-only signalling rate common to both R4 and R5 and, after a delay of 24T, shall unclamp circuit 104.

After a delay of 50 symbols following detection of the E sequence, the modem shall condition itself for receipt of the first symbol of the first control segment as described in 5.6. Following receipt of the control segment, the modem shall condition itself to receive data, either at the highest data-only signalling rate common to both R4 and R5 (if the frame defined by the incoming control segment is data-only) or at 4800 bit/s plus audio (if the frame defined by the incoming control segment is audio plus data).

11.2 Responding procedure

A modem shall be conditioned to detect an incoming preamble at any time while receiving data.

When a preamble is detected, the modem shall clamp circuit 104 to binary one and shall condition its receiver to detect rate signal R4. On detection of R4, the responding modem shall turn circuit 106 OFF and shall transmit the appropriate preamble.

Following the transmission of the preamble, the responding modem shall begin transmitting signal R5. R5 shall indicate the desired rate in the responding modem and all lower data signalling rates at which the responding modem is enabled to operate irrespective of the rates indicated in R4 (see Note 1).

After R5 has been transmitted for a period of 64T, the responding modem shall transmit sequence E in accordance with 8.7.2 indicating the highest signalling rate common to R4 and R5 (see Note 2). The modem shall then transmit scrambled binary ones at the data-only signalling rate for 24T. The responding modem shall then enable circuit 106 to respond to the condition of circuit 105 and be ready to transmit data.

After a delay of 50-symbol intervals following transmission of the E sequence, the modem shall transmit the first symbol of the first control segment as described in 5.6. Following completion of the transmission of this control segment, the modem shall continue to transmit data, either at the highest data-only signalling rate common to both R4 and R5 (if the frame defined by the transmitted control segment is data-only) or at 4800 bit/s plus audio (if the frame defined by the transmitted control segment is audio+data).

On detecting sequence E, the responding modem shall condition itself to receive data at the highest data-only signalling rate common to both R4 and R5 and, after a delay of 24T, shall unclamp circuit 104.

After a delay of 50 symbols following detection of the E sequence, the modem shall condition itself for receipt of the first symbol of the first control segment as described in 5.6. Following receipt of the control segment, the modem shall condition itself to receive data, either at the highest data-only signalling rate common to both R4 and R5 (if the frame defined by the incoming control segment is data-only) or at 4800 bit/s plus audio (if the frame defined by the incoming control segment is audio plus data).

NOTES

1 If the highest data-only signalling rate indicated in R5 is less than the desired rate requested in R4, this may be either because line conditions do not permit the responding modem to operate currently at the desired rate or because this rate has been disabled in the responding modem. Both possibilities should be taken into account in determining the desirability of further rate negotiation.

2 If R4 or R5 is calling for a GSTN cleardown in accordance with Table 10 or R4 and R5 have no rates in common, the modem shall complete the renegotiation procedure by repeating the transmission of sequence E for not less than 64T before clearing the connection.

12 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. Operation of test loops 2 and 3 shall be limited to data-only mode.

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