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APPENDIX II
(to Recommendation G.961)

Electrical characteristics of a 2B1Q transmission system

II.1 *Line code*

The line code shall be 2B1Q (2 binary, 1 quaternary). This is a 4-level code and is used without redundancy.

The bit stream entering the NT1 from the interface at reference point T (or entering the LT from the ET) shall be grouped into pairs of bits for conversion to quaternary symbols that are called quats. Figure II-1/G.961 shows the relationship of the bits in the B and D channels to quats. The B- and D-channel bits are scrambled before coding. M_1 through M_6 bits of the CL channel are also paired, coded and scrambled in the same way.

Figure II-1/G.961 [T14.961] (a traiter comme tableau MEP), p.

Each successive pair of scrambled bits in the binary data stream is converted to a quaternary symbol to be output from the transmitters, as specified below:

H.T. [T7.961]

First bit (sign)	Second bit (magnitude)	Quaternary symbol (quat)
1	0	+ 3
1	1	+ 1
0	1	— 1
0	0	— 3

Table [T7.961], p.

At the receiver, each quaternary symbol is converted to a pair of bits by reversing the table above, descrambled, and formed into a bit stream representing B and D channels and a CL channel containing M bits for maintenance and other purposes. The bits in the B and D channels are properly placed by reversing the relationship in Figure II-1/G.961.

II.2 *Line baud rate*

The line symbol rate is 80 kbauds.

II.2.1 *Clock tolerance*

II.2.1.1 *NT1 clock tolerance*

The tolerance of the free running NT1 clock is ± | 00 ppm.

II.2.1.2 *LT clock tolerance*

The tolerance of the clock provided at the LT is ± | ppm.

II.3 *Frame structure*

A frame shall be 120 quaternary symbols transmitted within a nominally 1.5 ms. interval. Each frame contains a frame word, 2B + D data and CL channel bits shown in Figure II-2/G.961.

Figure II-2/G.961 [T15.961] (a traiter comme tableau MEP), p.

II.3.1 *Frame length*

The number of 2B + D slots in a frame is 12. Each slot contains 18 bits.

II.3.2 *Bit allocation in direction LT-NT1*

The bit allocation of the frames are shown in Figures II-1/G.961 and II-2/G.961.

II.3.3 *Bit allocation in direction NT1-LT*

See § II.3.2.

II.4 *Frame word*

The frame word is used to allocate bit positions to the B, D, and CL channels. It may be also used for baud synchronization.

II.4.1 *Frame word in direction LT-NT1*

The code for the frame word in all frames except the first in a multiframe shall be:

FW = +3 +3 —3 —3 —3 +3 —3 +3 +3

The code for the frame word of the first frame of a multiframe shall be an inverted frame word (IFW):

IFW = —3 —3 +3 +3 +3 —3 +3 —3 —3

II.4.2 *Frame word in direction NT1-LT*

See § II.4.1.

II.5 *Frame alignment procedure*

Not specified.

II.6 *Multiframe*

To enable the allocation of the CL channel bits over more than one frame, a multiframe is used. The start of the multiframe is determined by the inverted frame word (IFW). The number of frames in a multiframe is 8.

II.6.1 *Multiframe word in direction NT1-LT*

See § II.4.1.

II.6.2 *Multiframe word in direction LT-NT1*

See § II.4.1.

II.7 *Frame offset between LT-NT1 and NT1-LT frames*

The NT1 shall synchronize transmitted frames with received frames (LT-NT1 direction). Transmitted frames shall be offset with respect to received frames by 60 ± | quaternary symbols (i.e., about 0.75 ms).

II.8 *CL channel*

II.8.1 *Bit rate*

The bit rate for the CL channel is 4 kbit/s.

II.8.2 *Structure*

Forty eight bits of a multiframe are used for the CL channel and are referred to as M bits.

Twenty four bits per multiframe (2 kbit/s) are allocated to an embedded operations channel (EOC) which supports operations communications needs between the network and the NT1.

Twelve bits per multiframe (1 kbit/s) are allocated to a cyclic redundancy check (CRC) function.

Twelve bits per multiframe (1 kbit/s) are allocated to other functions and spare bits as shown in Figure II-3/G.961.

Figure II-3/G.961 [1T16.961] (a traiter comme tableau MEP), p.3

Figure II-3/G.961 [2T16.961] (NOTES), p.4

II.8.3 *Protocol and procedures*

The CL-channel functions (M bits) specified below are based on the bit allocation for the multiframe defined in Figure II-3/G.961.

II.8.3.1 *Error monitoring function*

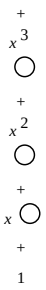
II.8.3.1.1 *Cyclic redundancy check (CRC)*

The CRC bits are the M_5 and M_6 bits in frames 3 through 8 of the multiframe. The CRC is an error detection code that shall be generated from the appropriate bits in the multiframe and inserted into the bit stream by the transmitter. At the receiver a CRC calculated from the same bits shall be compared with the CRC value received in the bit stream. If the two CRCs differ, there has been at least one error in the covered bits in the multiframe.

II.8.3.1.2 *CRC algorithms*

The Cyclic Redundancy Check (CRC) code shall be computed using the polynomial:

$$P(x) = x^{12} \oplus x^{11} \oplus$$



where

$\oplus_+$ = modulo 2 summation.

One method of generating the CRC code for a given multiframe is illustrated in Figure II-4/G.961. At the beginning of a multiframe all register cells are cleared. The multiframe bits to be covered by the CRC are then clocked into the generator from the left. During bits which are not covered by the CRC (FW, IFW, M_1, M_2, M_3, M_5, M_6) the state of the CRC generator is frozen and no change in state of any of the stages takes place. After the last multiframe bit to be covered by the CRC is clocked into register cell 1, the 12 register cells contain the CRC code of the next multiframe. Between this point and the beginning of the next multiframe, the register cell contents are stored for transmisssion in the CRC field of the next multiframe. Notice that bit CRC1 resides in register cell 12, CRC2 in register cell 11, etc.

Note — The binary ONEs and ZEROs from the interface at the T reference point, and corresponding bits from the network (across the V_1 reference point), must be treated as binary ONEs and ZEROs, respectively, for the computation of the CRC.

II.8.3.1.3 *Bits covered by the CRC*

The CRC bits shall be calculated from the bits in the D channel, both B channels, and the M_4 bits.

II.8.3.2 *Other M-bit functions*

A number of transceiver operations and maintenance functions are handled by M_4, M_5, and M_6 bits in the multiframe. These bits are defined in the following paragraphs.

II.8.3.2.1 *Far end block error (FEBE) bit*

A single bit in each multiframe is allocated to carrying the Far End Block Error (FEBE) bit. The FEBE bit shall be set to ONE if there are no CRC errors in the multiframe and ZERO if the multiframe contains a CRC error. The FEBE bit shall be placed in the next available outgoing multiframe and transmitted back to the originator. The FEBE bits may be monitored to determine the performance of the far end receiver.

II.8.3.2.2 *The act bit*

The act bit is the M_4 bit in the first frame of multiframes transmitted by either transceiver. The act bit is used as a part of the start-up sequence to communicate readiness for layer 2 communication progress (see § II.10.5).

II.8.3.2.3 *The DEA Bit*

The DEA bit is the M_4 bit in the second frame of multiframes transmitted from the LT (see § II.3 and Figure II-3/G.961). The DEA bit is used by the LT to communicate to the NT1 its intention to deactivate (see § II.10.1.5.2). To permit reliable detection of the DEA bit when indicating the intention to deactivate, its corresponding status (binary ZERO) shall be transmitted in three successive multiframes before terminating transmission of signal.

II.8.3.2.4 *NT1 power status bits*

Two bits of each multiframe (Figure II-3/G.961) shall be used to indicate NT1 power status. Table II-1/G.961 shows the power status bit assignments and the corresponding messages and definitions.

The NT1 must have sufficient energy storage to transmit the dying gasp indication for a minimum of 3 multiframes.

II.8.3.2.5 *NT1 test mode indicator bit*

One bit, NTM, of each multiframe (Figure II-3/G.961) from the NT1 to the LT shall be used to indicate that the NT1 is in a customer initiated test mode. The NT1 is considered to be in a test mode when the D channel or either one of the B channels are involved in a customer locally-initiated maintenance action. While in test mode, the NT1 may be unavailable for service or the NT1 may be unable to perform actions requested by EOC messages. The bit shall be a binary ONE to indicate normal operation and a

binary ZERO indicate test mode.

Figure II-4/G.961 ITALIENNE, p.5

H.T. [T8.961]

TABLE II-1/G.961

Power status bit assignments and messages

NT1 status *ps* 1 | fIps 2 binary values }	{ Definition	
All power normal Primary and secondary power supplies are both normal }	11	{
Secondary power out Primary power is normal, but the secondary power is marginal, unavailable, or not provided }	10	{
Primary power out Primary power is marginal or unavailable, secondary power is normal }	01	{
Dying gasp Both primary and secondary power are marginal or unavailable. The NT1 may shortly cease normal operation }	00	{

Tableau II-1/G.961 [T8.961], p.6

II.8.3.2.6 *Cold-start-only bit*

The CSO bit is the M_4bit in the fifth frame of the multiframe transmitted by an NT1. It shall be used to indicate the start-up capabilities of the NT1 transceiver. If the NT1 has a cold-start-only transceiver, as defined in part 4) of § II.10, this bit is set to ONE. Otherwise, this bit shall be set to ZERO in SN3.

II.8.3.2.7 *Reserved bits*

All bits in M_4, M_5, and M_6not otherwise assigned are reserved for future standardization. Reserved bits shall be set to ONE before scrambling.

II.8.3.3 *Embedded operations channel (EOC) functions*

Twenty-four bits per multiframe (2 kbps) are allocated to an embedded operations channel (EOC) which supports operations communications needs between the network and the NT1.

II.8.3.3.1 *EOC frame*

The EOC frame shall be composed of 12 bits synchronized to the multiframe:

H.T. [T9.961]

Bits	3	1	8
Functions provided	Address field	Data msg indicator	Info field

Table [T9.961], p.

The three-bit Address Field may be used to address up to 7 locations. Only the specification of addresses of messages for the NT1 are within the scope of this Recommendation. The additional addresses are for intermediate network elements where the system is used to extend access involving carrier systems.

The Data/Message Indicator bit shall be set to ONE to indicate that the Information Field contains an operations message; it shall be set to ZERO to indicate that the Information Field contains numerical data. Up to 256 messages may be encoded in the information field.

Exactly two EOC frames shall be transmitted per multiframe consisting of all M_1, M_2, and M_3 bits (see Figure II-3/G.961).

II.8.3.3.2 *Mode of operation*

The EOC protocol operates in a repetitive command/response mode. Three identical properly-addressed consecutive messages shall be received before an action is initiated. Only one message, under the control of the network shall be outstanding (not yet acknowledged) on a complete basic access EOC at any one time.

The network shall continously send an appropriately addressed message. In order to cause the desired action in the addressed element, the network shall continue to send the message until it receives three identical consecutive EOC frames from the addressed device that agree with the transmitted EOC frame. When the network is trying to activate an EOC function, autonomous messages from the NT1 will interfere with confirmation of receipt of a valid EOC message. The sending by the NT1 and receipt by the network of three identical consecutive properly addressed Unable to Comply messages constitutes notification to the network that the NT1 does not support the requested function, at which time the network may abandon its attempt.

The addressed element shall initiate action when, and only when, three identical, consecutive, and properly addressed EOC frames, that contain a message recognized by the addressed element, have been received. The NT1 shall respond to all received messages. The response should be an echo of the received EOC frame towards the network with two exceptions described below. Any reply or echoed EOC frame shall be in the next available returning EOC frame, which allows a processing delay of approximately 0.75 ms.

If the NT1 does not recognize the message in a properly addressed EOC frame, rather than echo, on the third and all subsequent receipts of that same correctly addressed EOC frame it shall return the Unable to Comply message in the next available EOC frame.

If the NT1 receives EOC frames with addresses other than its own address (000), or the broadcast address (111), it shall, in the next available EOC frame, return an EOC frame toward the network containing the hold state message and its own address (the NT1, address, 000).

The protocol specificaiton has made no provision for autonomous messages from the NT1.

All actions to be initiated at the NT1 shall be latching, permitting multiple eoc-initiated actions to be in effect simultaneously. A separate message shall be transmitted by the network to unlatch.

II.8.3.3.3 *Addressing*

An NT1 shall recognize either of two addreses, an NT1 and a broadcast address. These addresses are as follows:

H.T. [T10.961]

	Node	Address
	NT1	000
Broadcast	(all nodes)	111

Table [T10.961], p.

An NT1 shall use the address 000 in sending the Unable to Comply message.

II.8.3.3.4 *Definition of required EOC functions*

1) *Operate 2B + D loopback:* | his function directs the NT1 to loopback the user-data (2B + D) bit stream toward the network. This loopback is complete and may be transparent or non-transparent but in either case will continue to provide sufficient signal to allow the TE to maintain synchronization to the NT1.

2) *Operate B1-Channel (or B2-Channel) loopback:* | his function directs the NT1 to loopback an individual B channel toward the network. The individual B-channel loopback can provide per-channel maintenance capabilities without totally disrupting service to the customer. This loopback is transparent.

3) *Return to normal:* | he purpose of this message is to release all outstanding EOC controlled operations and to reset the EOC processor to its initial state.

4) *Unable to comply acknowledgement:* | his will be the confirmation that the NT1 has validated the receipt of an EOC message, but that the EOC message is not in the menu of the NT1.

5) *Request corrupt CRC:* | his message requests the sending of corrupt CRCS toward the network, until cancelled with Return to Normal.

6) *Notify of corrupted CRC:* | his message notifies the NT1 that intentionally corrupted CRCS will be sent from the network until cancellation is indicated by Return to Normal.

7) *Hold state:* | his message is sent by the network to maintain the NT1 EOC processor and any active EOC controlled operations in their present state. This message may also be sent by the NT1 toward the network to indicate that the NT1 has received an EOC frame with an improper address.

II.8.3.3.5 *Codes for required EOC functions*

Table II-2/G.961 shows the codes for each of the EOC functions defined in § II.8.3.3.4 above.

H.T. [T11.961]

TABLE II-2/G.961

Messages required for command response EOC mode

Message	Message code	Origin (o) & destination (d)	
		Network	NT1

Operate 2B + D loopback
{
Operate B
1-channel loopback
}
	0101 0000
	
	0101 0001
		o
		
		o
			d
			
			d

{
Operate B
2-channel loopback
}
	
	0101 0010
		
		o
			
			d

Request corrupted CRC	0101 0011	o	d
Notify of corrupted CRC	0101 0100	o	d
Return to normal	1111 1111	o	d
Hold state	0000 0000	d/o	o/d

{
Unable to comply acknowledgement
}
	
	1010 1010
		
		d
			
			o

Table II-2/G.961 [T11.961], p.

Sixty-four EOC messages have been reserved for non-standard applications in the following four blocks of 16 codes each (x is ONE or ZERO): 0100 xxxx, 0011 xxxx, 0010 xxxx, 0001 xxxx. All remaining codes not defined in Table II-2/G.961 and not reserved for non-standard applications are reserved for future standardization. Thus, 184 codes associated with the NT1 (000) and broadcast (111) addresses, are available for future standardization, i.e., 256 total codes minus 8 defined codes from the table minus 64 codes for non-standard applications.

Note — The reservation of codes for non-standard applications does not in any way endorse their use. Any use of such messages shall not interfere with the EOC protocol. An NT1 and an LT that support messages for non-standard applications may not function properly together.

II.9 *Scrambling*

The data stream in each direction of transmission shall be scrambled with a 23rd-order polynomial (see Figure II-5/G.961) prior to the insertion of FW.

In the LT-NT1 direction the polynomial shall be:

$$1 \oplus_{+} x^{D_{lF261}5} \oplus_{+} x^{D_{lF261}23}$$

where

$\oplus_{+}$ = modulo 2 summation.

In the NT1-LT direction the polynomial shall be:

$$1 \oplus_{+} x^{18} \oplus_{+} x^{23}$$

where

$\oplus_{+}$ = modulo 2 summation.

The binary data stream shall be recovered in the receiver by applying the same polynomial to the scrambled data as was used in the transmitter.

Note — Binary ONEs and ZEROs entering the NT1 receiver from the interface at reference point T or entering the LT side transceiver from the network must appear as binary ONEs and ZEROs respectively, at the input of the scrambler. Also, during transmission/reception of the frame word or inverted frame word, the state of the scrambler must remain unchanged. (Caution: It is common for the input bits to be all ONEs, e.g., during idle periods or during start-up. For the ONEs to become scrambled, the initial state of the scrambling shift register must not be all 1s.)

Figure II-5/G.961, p.

II.10 *Activation/deactivation*

This section gives requirements and examples supporting activation/deactivation requests, indicators of activation and deactivation, and indicators of errors. The transmission system is capable of loopbacks but these are not illustrated by examples. The transmission system is also capable of being activated without activating the interface at reference point T. There are no provisions for the support of activation of the transmission system without activating the interface at reference point T, but such a capability is not precluded (e.g., by use of spare CL channel bits).

The following definitions are for the purpose of clarifying requirements that are to follow:

1) *Start-up:* | process characterized by a sequence of signals produced by the LT and by the NT1. Start-up results in establishment of the master-slave mode, i.e., synchronization of the receivers and the training of equalizers and echo cancelers to the point that two-way transmission requirements are met.

2) *Warm start:* | he start-up process that applies to transceivers meeting the optional warm-start activation-time requirements after they have once been synchronized and have subsequently responded to a deactivation request. Warm start applies only if there have been no changes in line characteristics and equipment. Transceivers that meet warm-start requirements are called warm-start transceivers.

3) *Cold-start:* | he start-up process that applies to transceivers that either do not meet optional warm-start activation-time requirements, or have not been continuously in a deactive state that resulted from a deactivation request to the NT1. Cold start also applies if there have been changes in line characteristics or equipment or both. A cold start shall always start from the RESET state.

4) *Cold-start-only* | CSO): NT1 transceivers that do not meet optional warm-start activation-time requirements (see § II.10.6) are called cold-start-only transceivers.

5) *Reset:* | he reset state consists of two sub-states: the receive reset and the full reset states. In other sections of this Recommendation, the term reset is used to refer to the full reset state.

Reset has no implications about the state of convergence of the equalizer or echo canceler coefficients of the transceiver. The reset states are applicable to cold-start-only as well as warm-start transceivers.

For specific transceiver implementations, reset states (or sub-states) may mean different and possibly multiple internal states.

6) *Full Reset:* | he full reset state is one in which a transceiver has detected the loss of signal from the far-end and is not transmitting (sending signal to the loop).

The full reset state shall also be entered following power-up.

While in full reset, NT1s may initiate transmission only to request service. Under all other conditions, where the interface has been deactivated, the NT1s shall remain quiet, i.e., they shall not start transmitting any signal until the NT1 has received the TL signal from the network.

7) *Receive reset:* | he receive reset state is a transient state in which NT1 has detected the loss of signal from the far-end and is not transmitting (sending signal to the loop) and, in addition, is not permitted to initiate the start-up sequence (send wake-up tone) but shall be capable of responding to the start-up sequence (detecting wake-up tone). An NT1 must remain in this state for at least 40 ms, after detecting the loss of received signal, as specified in § II.10.1.5.2 and II.10.2, after which time, the transceiver shall enter the full reset state.

II.10.1 *Signals used for activation*

II.10.1.1 *Signals during start-up*

Figure II-6/G.961 defines the signals produced by the transceivers during start-up. These signals apply during both types of start-up; i.e., cold start, and warm start. During start-up, all signals at the interface shall consist of sequences of symbols of the shape defined in § II.12.2.

Figure II-6/G.961, p.

With the exception of the wake-up tones (TN and TL), the scrambler shall be used in the normal way in formulating the signals. For example, Figure II-7/G.961 shows ONEs for B and D channel bits and the overhead bits in the signal SN1. These ONEs are scrambled before coding, producing random pulses in these positions at the interface.

Except where noted otherwise in Figure II-7/G.961, all the pulse sequences, are framed and multiframed in accordance with the normal frame structure shown in Figures II-1/G.961, II-2/G.961, and II-3/G.961, and all pulses represent scrambled bits except those in the frame word. The signals TN and TL are 10 kHz tones generated by repeating the following unscrambled and unframed symbol pattern:

II.10.1.2 *Line rate during start-up*

During start-up, the network shall produce symbols at the nominal line rate within the tolerance specified in § II.2.1.2.

The symbol rate from the NT1 shall be 80 kbauds ± | 00 ppm.

Figure II-7/G.961 [T17.961] (a traiter comme tableau MEP), p.12

II.10.1.3 *Start-up sequence*

Figure II-6/G.961 shows the sequence of signals at the interface that are generated by the transceivers. The transition points in the sequence are also defined in Figure II-7/G.961. For further information on the events at the interface at reference point T, the reader is referred to Recommendation I.430.

II.10.1.4 *Wake-up*

When transceivers meeting the optional warm-start activation-time requirements, or when cold-start-only NT1s having the optional capability of initiating start-up, are in the RESET state or are deactive as a result of responding to a deactivation request, either transceiver may initiate start-up by sending a tone as defined in Figure II-7/G.961.

II.10.1.5 *Progress indicators*

II.10.1.5.1 *Activation*

In the NT1 to LT direction, the act bit remains set to ZERO until the customer equipment indicates progress in getting ready to transmit. The corresponding action at the T reference point in the customer equipment is receipt of the signal INFO3. To communicate this progress indication, act from the NT1 is set to ONE. Assuming INFO3 occurs before T6 and T7, this progress indication shall not affect overhead symbols at the interface until T6, when the NT1 overhead bits are allowed to be normal, and may not be detected by the LT until T7.

After event T7 (Figure II-6/G.961) and after act = ONE is received from the NT1, the LT sets the act bit to ONE to communicate readiness for layer 2 communication (see § II.8.3.2.2).

II.10.1.5.2 *Deactivation*

Transceivers in the active state that meet optional warm- start activation-time requirements shall cease transmission on the basis of the DEA bit (see § II.8.3.2.3) and subsequent loss of received signal. The DEA bit from the LT shall be set to ONE before activation is initiated. The LT shall announce deactivation by setting DEA to ZERO.

The LT shall send DEA = ZERO in at least three multiframes before ceasing transmission. It shall cease transmission before sending a DEA bit in the multiframe following the multiframe in which DEA = ZERO is sent the last time. During the multiframes with DEA = ZERO the NT1 has time to prepare for deactivation. The NT1 shall, upon the detection of loss of signal from the LT, cease transmission, enter the receive reset state and deactivate. Its response time to a loss of received signal shall be such that the NT1 will enter the

receive reset state within 40 ms. of the occurrence of the transition to no signal at its interface. As specified in the definitions given at the beginning of §II-10, it shall not initiate the transmission of wake-up tone for a period of at least 40 ms. after it ceases transmission and then it shall enter the full reset state. The LT shall enter the full reset state upon the detection of the loss of received signal.

LT transceivers not implementing optional warm-start activation-time requirements shall continuously set DEA to ONE.

II.10.2 *Timers*

Timers shall be used to determine entry into the reset states. Upon the occurrence of any of the following conditions:

1) failure to complete start-up within 15 s. (warm or cold start),

2) loss of received signal for more than 480 ms., or

3) loss of synchronization for more than 480 ms.,

a transceiver shall respond as follows: Upon satisfying conditions 1) or 3), it shall cease transmission and then, upon the subsequent detection of the loss of received signal, the transceiver shall enter the receive reset state. Its response time to a loss of signal (after conditions 1) or 2) have been satisfied) shall be such that it shall enter the receive reset state and be capable of responding to the initiation of wake-up tone by the far-end transceiver within 40 ms. after the far end transceiver ceases transmission. Upon satisfying condition 2), the transceiver shall immediately enter the receive reset state. As specified in part 7) of § II.10, a transceiver shall remain in the receive reset state for at least 40 ms., after which it shall enter the full reset state. The transciever may not initiate transmission of wake-up tone in the receive reset state.

For conditions 2) and 3), the requirements apply to transceivers after start up, i.e., after multiframe synchronization is achieved (see T6 and T7 in Figure II-6/G.961 for NT1 and LT transceivers, respectively).

In addition, an NT1 shall enter the full reset state if signal is not received within 480 ms. after it ceases the transmission of TN, or SN1 if it is sent (see T2 to T3 in Figures II-6/G.961 and II-7/G.961).

II.10.3 *Description of the activation procedure*

II.10.3.1 *Activation from customer equipment*

While the NT1 and LT remain in the deactive state as a result of receiving and responding to a deactivation request, or while they are in RESET, a request for activation from the customer equipment shall result in the TN signal (tone) being sent from the NT1 toward the LT. The LT, on receiving TN shall remain silent until detection of cessation of signal from the NT1. The rest of the sequence then follows as indicated in Figures II-6/G.961 and II-7/G.961. If the LT happens to try to activate at the same time it may send a TL tone during the TN tone without harm.

While in the reset state, NT1 may initiate transmission only to request service. Under all other conditions where the system has been deactivated, the NT1 shall remain quiet, i.e., they shall not start transmitting any signal until the NT1 has received the TL signal from the LT.

II.10.3.2 *Activation from the network*

While the NT1 and LT remain in the deactive state as a result of receiving and responding to a deactivation request, or while they are in RESET, a request for activation from the LT shall result in the TL signal being sent from the LT toward the NT1. The NT1, on receiving TL shall respond with TN within 4 ms from the beginning of TL. The rest of the sequence then follows as indicated in Figures II-6/G.961 and II-7/G.961.

II.10.3.3 *Sequence charts*

Examples of sequence charts for activation by both terminal and ET equipment are given in Figures II-8/G.961 and II-9/G.961.

Figure II-9/G.961, p.

II.10.3.4 *Transparency*

Transparency of the transmission in both directions by the NT1 shall be provided after the NT achieves full operational status (T6), and both act = ONE form the LT and DEA = ONE. Full operational status of the NT1 means that the NT1 has:

1) acquired bit timing and frame synchronization from the incoming signal from the LT,

2) recognized the multiframe marker from the LT,

3) fully converged both its echo canceler and equalizer coefficients.

Transparency of the transmission in both directions at the LT shall be provided when the LT:

1) achieves full operational status (T7),

2) detects the presence of the multiframe marker from the NT1,

3) receives act = ONE from the NT1.

Full operational status at the LT means that the LT has:

1) acquired bit timing phase of the incoming signal from the NT1, and frame synchronization,

2) recognized the multiframe marker from the NT1,

3) fully converged both its echo canceler and equalizer coefficients.

After both the LT and the NT1 achieve transparency in both directions, the act bits shall continue to reflect the state of readiness of the LT and the terminal equipment for layer 2 communication. The act bit in the LT-to-NT1 direction shall reflect the status of the LT side of the interface. The act bit in the NT1-to-LT direction shall reflect the status of the NT1 side of the interface. Whenever either end, for any reason, loses its readiness to communicate at layer 2 (e.g., the terminal is unplugged), that end shall set its transmitted act bit to ZERO. A change of status of this bit shall be repeated in at least three consecutive transmitted multiframes.

II.10.4 *State transition table for the NT1*

Table II-3/G.961 provides an example of a state transition table for the NT1 as a function of INFOs, SIGs, and Timers.

H.T. [T12.961]

TABLE II-3/G.961

State transition table for the NT1 as a function of INFOs, SIGs

and timers

Event	{	Full reset NT0	Alerting NT1 (T0)	EC training NT2	EC cnvrg'd NT3 (T1)	FW sync. NT4 (T2)	IFW sync. NT5 (T5)	Pending active NT6 (T6)
Power on	NT1	—	—	—	—	—	—	—
Loss of power	—	NT0	NT0	NT0	NT0	NT0	NT0	NT0
{ Received T INFO 1 signal (Notes 1 and 2) }	/	ST.T4 NT2	—	—	—	—	—	—
{ Received T INFO 3 signal (Notes 1 and 3) }	/	/	/	/	/	/	NT7	—
{ Received T INFO 0 signal (Notes 1 and 4) }	/	—	—	—	—	—	—	NT11
End of tone TN (9 ms)	/	/	NT3	—	/	/	/	/
Received tone TL	/	ST.T4 NT2	—	/	/	/	/	/
Echo canceler converged	/	—	—	NT4	—	—	—	—
Basic frame sync (FW)	/	/	/	/	NT5	—	—	—
Multiframe sync (IFW)	/	/	/	/	/	STP.T4 NT6	—	—
Received DEA = 0 (Note 6)	/	/	/	/	/	/	NT9	NT9
Received ACT = 0	/	/	/	/	/	/	—	—
Received ACT = 1 and DEA = 1	/	/	/	/	/	/	—	NT8 AI
{ Loss of synchronization (> 480 ms) }	/	/	/	/	/	/	NT10	NT10
Loss of signal (> 480 ms)	/	/	/	/	ST.T6 NT1	ST.T6 NT12	ST.T6 NT12	ST.T6 NT12
{ Expiry of timer T4 (15 seconds) }	/	—	NT10	NT10	NT10	NT10	/	/
Loss of signal (< 40 ms)	/	/	/	/	/	/	/	/
Expiry of timer T6 (40 ms)	/	—	/	/	/	/	/	/

Note — For symbols and abbreviations, see Table II-4/G.961.

II.10.5 *State transition table for the LT*

Table II-4/G.961 provides an example of a state transition table for the LT as a function of FEs, SIGs, and Timers.

H.T. [T13.961]

TABLE II-4/G.732

State transition table for the LT as a function of FEs, SIGs

and timers

Event	State name State code Tx	Power off LT0	Full reset LT1 (T0)	Alerting LT2	Awake LT3 (T1)	EC training LT4 (T3)	
Power on	LT1	—	—	—	—	—	
Loss of power	—	LT0 FE7	LT0 FE7	LT0 FE7	LT0 FE7	LT0 FE7	
Activation request (FE1)	/	ST.T5 LT2	—	—	—	—	
{ Deactivation request (FE5) (Note 8) }	/	—	—	—	—	—	
End of tone TL (3 ms)	/	/	LT3	—	/	/	
Received tone TN	/	ST.T5 LT3	—	—	/	/	
Loss of signal energy	/	—	—	LT4	—	/	
Echo canceler converged	/	—	—	—	LT5	—	
Basic frame sync. (FW)	/	/	/	/	/	LT6	
Multiframe sync. (IFW)	/	/	/	/	/	/	
Received ACT = 0	/	/	/	/	/	/	
Received ACT = 1	/	/	/	/	/	/	
{ Loss of synchronization (> 480 ms) }	/	/	/	/	/	/	
Loss of signal (> 480 ms)	/	/	/	/	/	/	S
{ End of last multiframe with DEA = 0 (Note 9) }	/	/	/	/	/	/	
{ Expiry of timer T5 (15 seconds) }	/	—	LT10 FE7	LT10 FE7	LT10 FE7	LT10 FE7	
Loss of signal (< 40 ms)	/	—	/	/	/	/	
Expiry of timer T7 (40 ms)	/	/	/	/	/	/	

Symbols, abbreviations, and Notes for Tables II-3/G.961 and II-4/G.961

— No change, no action

/ Impossible situation

FE1 Function element — corresponds to primitive Activation request — PH-AR

FE4 Function element — corresponds to primitive Activation indication — PH/MPH-AI

FE5 Function element — corresponds to primitive Deactivation request — MPH-DR

FE6 Function element — corresponds to primitive Deactivation indication — MPH-DI

FE7 Function element — corresponds to primitive Error indication

NTn Go to state ‘‘NTn’’

LTn Go to state ‘‘LTn’’

ST.Tn Start timer Tn

STP.Tn Stop timer Tn

SL0 No signal

Note 1 — These events are initiated by the ‘‘G’’ Finite State Matrix (FSM), as defined in Recommendation I.430, and communicated to the ‘‘NT’’ FSM through messages.

Note 2 — This condition acts as an ‘‘Activation Request’’ event.

Note 3 — This condition indicates that the user data path (2B + D channels) in the TE-to-NT1 direction is transparent to user data.

Note 4 — This condition indicates that the user data path (2B + D channels) in the TE-to-NT1 direction is not transparent to user data.

Note 5 — This event takes priority over received act = ZERO for warm-start NT1s. This event could be ignored for NT1s not wishing to deactivate (cold-start-only NT1s).

Note 6 — Although the INFO signals at the T reference point are shown as transmit signals in the ‘‘NT’’ FSM, the ‘‘NT’’ FSM does not directly control these signals. They are included for information only.

Note 7 — The signals output in this state remain unchanged from signals output during the preceding state (e.g., act = ZERO if NT6 or NT11 preceded, or act = ONE if NT7 or NT8 preceded).

Note 8 — This event will cause deactivation of the NT1 independent of whether the transmitter is cold-start-only or warm-start.

Note 9 — This event must occur after receiving at least three multiframes. See § II.10.1.5.2.

II.10.6 *Activation times*

The LT and the NT1 shall complete the start-up process, including synchronization and training of equalizers to the point of meeting performance criteria within the following lengths of time: Cold-start-only transceivers shall synchronize within 15 s. Transceivers meeting optional warm-start activation-time requirements shall synchronize within 300 ms. on warm starts and within 15 s on cold starts. The 15-second cold-start time requirement is apportioned such that the NT1 is allowed 5 s. and the LT is allowed 10 s. For warm starts the 300 ms. start-up time requirement is apportioned equally between the NT1 and the LT, 150 ms. each. See Figure II-6/G.961 for details.

Note — The 300 ms. requirement applies to laboratory tests only. No 300 ms. timer is involved in actual in-service loops. (See definitions in § II.10 for warm and cold starts.)

As indicated in Figure II-6/G.961, the start time requirements cover the time span from wake-up tone to T7, and do not include time for activation of customer terminal equipment. All activation times apply only to the DLL, and do not apply to the entire customer access link where carrier systems may be involved.

Note — The value in Recommendation G.960 is 10 s. This is a 95% value.

II.11 *Jitter*

To assure support of the jitter requirements of Recommendation I.430, the jitter of the timing signal recovered at the clock of the NT1 shall not exceed the limits given in Figure 9/I.430 and § 8.3.1 of Recommendation I.430. Jitter tolerances are intended to ensure that the limits of Recommendation I.430 are supported by the jitter limits of the transmission system on subscriber lines. The jitter limits given below must be satisfied regardless of the length of the subscriber line and the inclusion of one repeater, provided that they are covered by the transmission media characteristics. The limits must be met regardless of the transmitted signal. In this Recommendation, jitter is specified in terms of unit intervals (UI) of the nominal 80 kbauds signal (12.5 μs.).

II.11.1 *Input signal jitter tolerance*

The NT1 shall meet the performance objectives with wander/jitter at the maximum magnitude indicated in Figure II-10/G.961, for single jitter frequencies in the range of 0.1 Hz to 20 kHz, superimposed on the test signal source with the received signal symbol rate in the range of 80 kbauds ± | ppm. The NT1 shall also meet the performance objectives with wander per day of up to 1.44 UI peak-to-peak where the maximum rate of change of phase is 0.06 UI/hour.

Figure II-10/G.961, p.17

II.11.2 *NT1 output jitter limitations*

With the wander/jitter as specified in § II.11.1, except as noted, superimposed on the NT1 input signal, the jitter on the transmitted signal from the NT1 towards the LT shall conform to the following, with the received signal symbol rate in the range of 80 kbauds ± | ppm, as described in § II.2:

1) The jitter shall be equal to or less than 0.04 UI peak-to-peak and less than 0.01 UI rms when measured with a high-pass filter having a 6 dB/octave roll-off below 100 Hz.

2) The jitter in the phase of the output signal (the signal transmitted towards the LT) relative to the phase of the input signal (from the LT) shall not exceed 0.05 UI peak-to-peak and 0.015 UI rms when measured with a band-pass filter having a 6 dB/octave roll-off above 40 Hz and below 1.0 Hz. (Note that the 1.0 Hz cut-off assures that the average difference in the phase of the input and output signals is substracted.) This requirement applies with superimposed jitter in the phase of the input signal as specified in § II.11.1 for single frequencies up 19 Hz.

3) The maximum (peak) departure of the phase of the output signal from its nominal difference (long term average) from the phase of the input signal (from the LT) shall not exceed 0.1 UI. This requirement applies during normal operation including following a ''warm start''. (Note that this means that, if deactivated and subsequently activated in conformance with the ''warm start'' requirements, the long term average difference in phase of the ouput signal from the phase of the input signal shall be essentially unchanged.)

II.11.3 *Test conditions for jitter measurements*

Due to bidirectional transmission on the 2-wire and due to severe intersymbol interference, no well defined signal transitions are available at the NT1 2-wire point.

Two possible solutions are proposed:

1) A test point in the NT1 is provided to measure jitter with an undisturbed signal.

2) A standard LT transceiver including an artificial transmission line is defined as a test instrument.

II.12 *Transmitter output characteristics of NT1 and LT*

The following specifications apply with a load impedance of 135 ohms resistive over a frequency band of 0 Hz to 160 kHz.

II.12.1 *Pulse amplitude*

The nominal peak of the largest pulse shall be 2.5 Volts (see Figure II-11/G.961).

II.12.2 *Pulse shape*

The transmitted pulse shall have the shape specified in Figure II-11/G.961. The pulse mask for the four quaternary symbols shall be obtained by multiplying the normalized pulse mask shown in Figure II-11/G.961 by 2.5 V, 5/6 V, —5/6 V or —2.5 V. When the signal consists of a framed sequence of symbols with a synchronization word and equiprobable symbols in all other positions, the nominal average power is 13.5 dBm.

II.12.3 *Signal power*

The average power of a signal consisting of a framed sequence of symbols with a frame word and equiprobable symbols at all other positions should be between 13.0 dBm and 14.0 dBm over the frequency band from 0 Hz to 80 kHz.

II.12.4 *Power spectral density*

The upper bound of the power spectral density of the transmitted signal shall be as shown in Figure II-12/G.961.

II.12.5 *Transmitted linearity*

II.12.5.1 *Requirements*

This is a measure of the deviations from ideal pulse heights and the individual pulse non-linearity. The transmitted and received signals shall have sufficient linearity so that the residual rms non-linearity is at least 36 dB below the rms signal at the interface.

H.T. [T18.961]

Unable to convert table **Tableau + Figure calibr´ee dans la r´eservation du tableau [T18.961], p.18**

II.12.5.2 *Linearity test method*

With the transceiver (LT or NT1) terminated in a 135/ohm resistance through a zero-length loop, and driven by an arbitrary binary sequence, the voltage appearing across the resistance is filtered (anti-alias), sampled and converted to digital form ($V_{o\backslash du\backslash dt}$) with a precision of no less than 12 bits (see Figure II-13/G.961). These samples are compared with the output of an adjustable, linear filter, the input of which is the scrambled, framed, and linearly encoded transmitter input. The signals at the substractor may both be in digital form, or they may both be in analog form.

The linear digital filter input (‘‘Quaternary Input Data’’ in Figure II-13/G.961) can be considered a linearity standard. It may be produced from the transmitter output by an errorless receiver (with no descrambler), or from the scrambled transmitter input data if it is available. If the samples input to the adjustable filter are available in digital form, no additional A/D converter is required. Whether analog or digital, these samples are required to be in the ratio 3:1:—1:—3, to an accuracy of at least 12 bits.

The sampling rate of the samplers and filters may be higher than the symbol rate, and generally will be several times the symbol rate for good accuracy. Alternatively, the sample rate may be at the symbol rate, but the rms values are obtained by averaging over all sample phases relative to the transmitter signal.

Because the anti-alias filter, sampler, and A/D converter operating on the transmitter output may introduce a loss or gain, proper calibration requires determining $< V_{o\,du\,dt}^{2} >$ at the filter output, as shown in Figure II-13/G.961, rather than the mean-squared value of the transmitter output itself.

Figure II-12/G.961, p.

Figure II-13/G.961, p.

II.13 *Transmitter/receiver termination*

II.13.1 *Impedance*

The nominal driving point impedance at the interface toward the NT1 shall be 135 ohms.

II.13.2 *Return loss*

The return loss with respect to 135 ohms, over a frequency band from 1 kHz to 200 kHz, shall be as shown in Figure II-14.G.961.

II.13.3 *Longitudinal conversion loss*

II.13.3.1 *Longitudinal Balance*

The longitudinal balance (of impedance to ground) is given by:

$$LBal = 20 \log \left| \frac{f_{le}}{f_{lm}} \right| \; dB$$

where

e_l is the applied longitudinal voltage (referenced to the building green or green wire ground of the NT1).

e_m is the resultant metallic voltage appearing across a 135 ohms termination.

The balance shall be > 60 dB at frequencies up to 4 kHz and > 55 dB at higher frequencies up to 160 kHz.

Figure II-15/G.961 defines a measurement method for longitudinal balance. For direct use of this test configuration, measurement should be performed with the NT1 powered up but inactive (no transmitted signal).

Figure II-14/G.961, p.21

Figure II-15/G.961, p.22

II.13.3.2 *Longitudinal output voltage*

The longitudinal component of the NT1 output signal shall have an rms voltage, in any 4 kHz bandwidth averaged in any 1 second period, less than —50 dBv over the frequency range 100 Hz to 170 kHz, and less than —80 dBv the range from 170 kHz to 270 kHz. Compliance with this limitation is required with a longitudinal termination having an impedance equal to or greater than a 100 ohm resistor in series with a 0.15 uF capacitor.

Figure II-16/G.961 defines a measurement method for longitudinal output voltage. For direct use of this test configuration, the NT1 should be able to generate a signal in the absence of a signal from the LT.

The ground reference for these measurements shall be the building ground.

Figure II-16/G.961, p.

APPENDIX III
(to Recommendation G.961)

Electrical characteristics of an AMI transmission system

III.0 *General*

The system will support the full duplex, transparent transmission of the two 64 kbit/s B channels and one 16 kbit/s D channel, as defined in Recommendation I.412. The bidirectional transmission over symmetric pair cables is based on the echo cancelling techniques. An extra 16 kbit/s capacity is added to the resulting 144 kbit/s data information, to provide a CL channel (for control, supervisory and maintenance purposes) and other transmission facilities.

The frames of the transmitted signal contain framewords which include a time period of absence of line signal. This frame format allows, when the relative offset between the frames in the two transmission direction is lesser than the values specified in § III.7, to simplify the timing recovery, the line equalizer setting and the echo canceller updating.

III.1 *Line code*

For both directions of transmission the line code is AMI.

The binary bit stream shall be coded according to the following rule:

— a binary ONE is represented by no line signal

— a binary ZERO is alternately represented as a positive or a negative pulse.

III.2 *Symbol rate*

The symbol rate is determined by the line code, the bit rate of the information stream and the frame structure. The symbol rate is 160 kbauds.

III.2.1 *Clock requirements*

III.2.1.1 *Free running NT1 clock accuracy*

The accuracy of the free running clock in the NT1 shall be ± | 0 ppm.

III.2.1.2 *LT clock tolerance*

The NT1 and the LT shall accept a clock accuracy from the ET of ± | ppm.

III.3 *Frame structure*

The frame structure contains a frame word, 32 times (2B + D) and a CL channel, besides an auxiliary and a stop bit. In both transmission directions the general structure of the frame is as follows:

H.T. [T19.961]

Frame word	A	4 [8 (2B + D) + CL]	P

Table [T19.961], p.

A = Auxiliary bit

The A bit of the frame is used to distinguish the directions of transmission and to signal the correct establishment of the activation procedure by the polarity inversion.

P = Parity bit

The P bit is used to get an even number of binary ZEROs in the frame; so it is set to binary ZERO or binary ONE according to the number of binary ZEROs if the frame is odd or even respectively.

III.3.1 *Frame length*

The number of (2B + D) slots in one frame is 32; whereas the number of CL bits is 4.

III.3.2 *Bit allocation in direction LT-NT1*

In Figure III-1/G.961 the bit allocation is given.

Figure III-1/G.961 [T20.961] (à traiter comme tableau MEP), p.

III.3.3 *Bit allocation in direction NT1-LT*

Same as § III.3.2.

III.4 *Frame word*

The frame word is used to allocate bit positions to the 2B + D + CL channels and to the A and P bits. It may also be used for timing recovery, echo canceller updating and line equalizer setting.

III.4.1 *Frame word in direction LT-NT1*

The code for the frameword shall be 57 consecutive binary ONE (coded as line absence of signal) and one binary ZERO (positive line pulse).

III.4.2 *Frame word in direction NT1-LT*

Same as § III.4.1.

III.5 *Frame alignment procedure*

The frame alignment procedure shall be as follows:

III.5.1 *State 1: correct frame alignment*

To enter the correct alignment state the frame word, the auxiliary bit and the parity bit must be detected correctly three times consecutively.

III.5.2 *State 2: prealarm for frame alignment*

To enter the prealarm state it is sufficient not to detect the frame word, the auxiliary bit and the parity bit for one time.

III.5.3 *State 3: out of frame alignment*

To enter the out of alignment state eight consecutive negative checks of the condition defined under state 1 must be detected.

III.6 *Multiframe*

To enable bit allocation of the CL channel in more frames next to each other, a multiframe structure shall be used. The start of the multiframe is determined by the content of the CL channel in a frame word as described in § III.6.1. The total number of frames in a multiframe is 4.

III.6.1 *Multiframe word in direction NT1-LT*

The multiframe will be identified by detecting the CL channel bits. CL channel is synchronous with the frame, and the start of a multiframe is assumed when odd parity is verified on the four CL bits in a frame. There are four of CL bits in a frame, coded as follows:

H.T. [T21.961]

{
CL channel structure
}

I	I	I	O	First frame
I	I	I	P	Second frame
I	I	I	P	Third frame
P	P	P	P	Fourth frame

Tableau [T21.961], p.

Where I stands for Information bits and P, O for parity check bits. The P bits of the fourth frame are dedicated to vertical parity of the previous frames, while O is the odd parity of the first frame. The parity evaluation is performed considering the binary ONE's. The first CL frame is also used for multiframing alignment. In the condition of out of multiframe alignment the CL channel shall be disregarded.

III.6.2 *Multiframe word in direction LT-NT1*

Same as § III.6.1.

III.6.3 *Multiframe alignment procedure*

The multiframe alignment is based on a correct detection of the parity (odd and even) of the CL channel. The correct multiframe alignment is assumed when the four parity bits satisfy the horizontal sequence Odd, Even, Even, Even and vertical sequence Even (see § III.6.1). When such sequence is not detected a prealarm multiframe alignment state is assumed, then if the correct detection is not available, out of multiframe alignment is assumed. From the state of out of multiframe alignment or from prealarm multiframe alignment condition only one correct detection of the right sequence enters the system in correct multiframe alignment state.

III.7 *Frame offset between LT-NT1 and NT1-LT frames*

The NT1 shall synchronize its frame with the frames received in the direction LT to NT1 and will transmit its frame with the offset specified in § III.7.1.

In LT the offset between the frames in the two transmission directions shall not exceed the value specified in § III.7.2.

III.7.1 *Relative frame position at the NT1 input output*

The first bit of each frame transmitted from a NT1 towards the LT shall be delayed, nominally, by 583 bit periods with respect to the first bit of the frame received from the LT. Figure III-2 /G.961 illustrated the relative bit positions for both transmitted and received frames.

Figure III-2/G.961, p.

III.7.2 *Relative frame position at the LT input/output*

The time delay between the first bit of each frame transmitted from a LT towards the NT1 and the first bit of each frame received from NT1 shall not exceed 583+13 bit periods. Figure III-3/G.961 shows the relative bit positions for both transmitted and received frames.

Figure III-3/G.961, p.

III.8 *CL channel*

CL channel shall be used to carry information for activation/deactivation, testing and maintenance purposes.

III.8.1 *Bit rate*

The bit rate for the CL channel is 1 kbit/s.

III.8.2 *Structure*

The informations to be transmitted are organized in frames of 16 bit (four quadruplets in a multiframe). Each sixteen bits frame contains:

— 9 information bits;

— 7 bits for parity checks and error detection and multiframe alignment purposes.

Denoting by I the information bits and by O and P the bits for odd and even parity, the generic frame may be represented as indicated in § III.6.1.

III.8.2.1 *CL channel performance*

The performance of the CL channel shall be the following:

With a bit error rate of 10^{D}lF261^{3}

— the frame simulation probability shall be less than 10^{D}lF261^{10}

— the probability of not detecting a right frame in 100 ms shall be less than 10^{D}lF261^{10}

III.8.3 *Protocols and procedures*

The messages on the CL channel may be split into two categories, namely:

a) messages concerned with the activation/deactivation procedure and spontaneous report of maintenance information not sollicited by the ET.

b) auxiliary messages for maintenance purposes. These functions imply actions that can be started only by the ET and that can be performed during the full active state.

The messages of the category a) are present in a continuous mode; this means that they are transmitted continuously on the CL channel until a new message has to be transmitted.

The messages used for the transmission of these messages allows the transmission of both single byte information and multi byte information.

The procedure, that may be started only by LT/ET, shall be as follows:

— The LT/ET sends in a continuous mode the first message containing the first information byte. The first information byte always contains the address of the destination equipment in a downstream direction (regenerator, NT1,). The message is transmitted continuously until the reception of an acknowledged message from the destination equipment.

— The LT/ET sends, in the same way the following messages each containing a byte information. Each message sent by LT/ET is acknowledged by the destination equipment.

— The ET/LT sends and end-message which is acknowledged as any other message.

— When the destination equipment has to send answer information, the procedure is the same as above. In this case it is not necessary to provide the address as the destination equipment is LT/ET.

III.9 *Scrambling*

Scrambling will be applied on (2B + D + CL) channels. The scrambling polynomial is $1 \oplus x^{9} \oplus x^{11}$ in both transmission directions.

Scrambling with a two thresholds guard circuit is used to avoid long sequences of binary ONE's.

Figures III-4/G.961 and III-5/G.961 show the scrambling and descrambling circuit respectively.

Figure III-4/G.961, p.

Figure III-5/G.961, p.

The counter C is incremented at each transmitted binary ONE and cleared at each transmitted binary ZERO. The counter sends a binary ZERO when 16 consecutive ONEs have been transmitted and sets its threshold to 2 if a binary ONE appears again at its input. In this condition, the counter sends a binary ZERO every two consecutive binary ONEs at its inputs. The threshold is resetted to 16 at the first binary ZERO transmitted.

III.10 *Activation/deactivation*

The guidelines taken into account in the definition of activation/deactivation procedures can be summarized as follows:

— In the deactivated state, no signal is present on the line.

— During activation appropriate signals are sent to speed up the convergence of the equalizer, the bit and frame synchronization and the echo canceller convergence.

A master/slave relationship is assumed between LT and NT1, so that, even if NT1 starts to request an activation, it is always the LT (under the ET acknowledgment), that assumes the initiative of continuing the procedure and then the transmission.

The system will support the activation of both the transmission system and the interface at T reference point, the activation of the transmission system only, interface, the deactivation of both the transmission system and the interface at T reference point or of the interface at T reference point only.

Cold and warm activations are possible. Cold activation starts after the power off — power on transition or after some specific maintenance procedures. Cold start refers to NT1 and LT which do not have stored any information about the echo canceller coefficients or equalizers setting, so a long time for activation is expected. Warm activation apply when LT and NT1 contain full information about the echo canceller coefficients and the line equalizers setting, so a short activation time is expected.

Power down mode refers to a state with very low power consumption of both LT and NT1 and with the absence of any line signal, this state allows to statistically reduce the power feeding from the central office. Of course some parts of the system, in particular the receiving sections, are always active to detect the incoming activation requests.

III.10.1 *Signals used for activation*

III.10.1.1 *Signals used for start up (CL not available)*

During the activation/deactivation procedures the following specific signals (SIGS) are exchanged on the line between LT and NT:

Down stream (LT NT1)

INFO U0 (IU0): No signals on the line.

INFO U12 (IU12): 20 kHz burst tone. This line signal is obtained by repeating 72 times the following pattern of 8 line symbols (++++————) every 8 ms. The burst tone is sent in half-duplex way.

INFO U22 (IU22): 80 kHz burst tone. This line signal is obtained by repeating 291 times the following pattern of 2 line symbols (+—) every 8 ms. The burst tone is sent in half-duplex way.

INFO U4 (IU4): Full-duplex transmission. The line signal has the same frame structure of the useful signal but with B1, B2, D and CL bit channels at the binary value ZERO. The binary stream is scrambled with a pseudorandom sequence and encoded according to the AMI rule. The second bit of the frame is set to the binary value ZERO.

INFO U6 (IU6): Full-duplex transmisison of operative data on the B and D channels; CL channel is used to convey layer 1 activation/deactivation, testing and maintenance information. The second bit of the frame is set to the binary value ONE.

Upstream (NT1 LT)

INFO U0 (IU0): No signals on the line.

INFO U11 async.: 20 kHz burst tone. This line signal is obtained by repeating 72 times the following pattern of 8 line symbols (++++————) every 16 ms. The burst tone is sent in half-duplex way.

INFO U11 sync.: 20 kHz burst tone. This line signal is obtained by repeating 72 times the following pattern of 8 line symbols (++++————) every 8 ms. The burst tone is sent in half-duplex way synchronized to the IU12 coming from LT.

INFO U21 (IU21): 80 kHz burst tone. This line signal is obtained by repeating 291 times the following pattern of 2 line symbols (+—) every 8 ms. The burst tone is sent in half-duplex way.

INFO U3 (IU3): Full-duplex transmission. The line signal has the same frame structure of the useful signal but with B1, B2, D and CL bit channels at the binary value ZERO. The binary stream is scrambled with a pseudorandom sequence and encoded according to the AMI rule. The second bit of the frame is set to the binary value ONE.

INFO U5 (IU5): Full-duplex transmission of operative data on the B and D channels; CL channel is used to convey layer 1 activation/deactivation, testing and maintenance information. The second bit of the frame is set to the binary value ZERO.

III.10.1.2 *Bits in the CL channel*

The I bits (see § III.6.1) of the CL channels are used to convey both activation/deactivation commands and testing and maintenance commands/reports, while P and O bits are employed for parity checking and error detecting and coded consequently. Only the activation/deactivation signals that are exchanged between LT and NT1 and conveyed through the CL channel are listed below.

I bits of CL Channel from LT to NT1

000010001 ACTIVATE REQUEST (AR)

Request to activate all the layer 1, both transmission system and interface at T reference point are activated

000001111 TRANSMISSION SYSTEM ACTIVATE REQUEST (UAR)

Request to activate the transmission system only. As in case of an AR command, the activation procedure is automatically performed. In the case in which the interface at T reference point is active, it will be deactivated.

000010011 ACTIVATE REQUEST with LOOPBACK 2 (AR2)

Request to activate with loopback 2 in NT1.

000000001 DEACTIVATE REQUEST (DR)

Request to deactivate the transmission system. The LT and NT1 automatically perform the deactivation procedure.

I bits of CL Channel from NT1 to LT

000001001 RESYNCHRONIZATION (RSY)

The RSY indication is input by the T interface when the synchronization on the interface at T reference point has been lost and not valid data are available.

000011001 ACTIVATE INDICATION (AI)

The activation procedure at the interface at T reference point has been successfully completed up to the terminal equipments when the AI is active.

000011101 ACTIVATE INDICATION with LOOPBACK 2 (AIL)

The connection through loopback 2 at the T-interface has been established. After an ARL command, the AIL indicate signal acknowledges the the receiving of an AI.

000001111 TRANSMISSION SYSTEM ACTIVATION INDICATION (UAI)

The transmission system is activated in NT1 and this information is transferred to LT/ET. The interface at T reference point is not activated.

III.10.2 *Definition of internal timers*

During the activation/deactivation procedures the following timers shall be used:

— *Timer A:* | his timer is located in NT1. It has two different meanings: during the activation procedure its value is 8 seconds and is an upper limit for the activation time. Whenever, the activation is reached its value is 500 ms as a guard time to prevent unwanted deactivations due to interruption of signal or loss of line frame coming from LT.

— *Timer 2:* | his timer is located in NT1. Its value is fixed in 50 ms and its purpose is to prevent from unwanted reactivations from a TE.

III.10.3 *Description of the activation procedure*

III.10.3.1 *Description of the activation procedure from LT*

Figure III-6/G.961 based on arrow sequence summarizes the activation procedure originated from ET. The activation procedure is started from an Activation request (FE1) coming from the ET. LT starts the procedure with an FE2 to ET and transmitting (IU12) on the line. At the reception of (IU11) from NT1, LT transmits (IU22) towards NT1. (IU22) is used by the NT1 for line equalizer setting (only for cold starts), fast timing recovery and AMI decision threshold setting. Once that NT1 finished its training procedure, it transmits towards LT (IU21). This SIG is used by LT for line equalizer setting (only cold starts),

timing recovery and AMI decision thresholds setting. Then LT transmits (IU4) which is used by the NT1 for echo canceller updating (short training period for warm starts, longer for cold starts). At the end of this training period, NT1 sends (IU3) which is used by LT for the same purposes just explained for the NT1. Whenever all the training periods are over, LT sends (IU6) (operative B and D channels) in which the I bits of the CL channel carry FE1 command. NT1 answers with (IU5) (operative B and D channels) with FE3 code in the CL I bits if the interface at T reference point is not active and then (IU5) with FE4 when the interface at T reference point is active.

Figure III-6/G.961, p.

III.10.3.2 *Description of the activation procedure from NT1*

Figure III-7/G.961 based on arrow sequence summarizes the activation procedure originated from the user side. The activation procedure is started from an activation request INFO1 coming from the interface at T reference point. NT1 starts the procedure transmitting IU11asyn towards LT. LT passes this information to the ET with FE2 and waits for the ET FE1 to continue the activation procedure. If ET gives its acknowledgment with FE1, then the activation procedure resumes and is equal to that shown in § III.10.3.1.

III.10.3.3 *Description of the deactivation procedure*

The deactivation of the layer 1 is physically performed only under complete control of the LT/ET. The deactivation is started from ET with FE3 to LT. LT transmit (IU6) with the command DR in the I bits of the CL channel. NT1 send INFO 0 to the interface at T reference point and (IU0) back to LT. Figure III-8/G.961 based on arrow sequence summarizes the deactivation procedure.

III.10.4 *NT1 state transition table*

The detailed behaviour of the activation/deactivation procedure in NT1 is described in the Table III-1/G.961 as a function of INFOs, SIGs and internal timers.

Loopback 2 shall be originated only from a deactivated state, and no transitions from loopback 2 to active state shall be possible.

III.10.5 *LT state transition table*

The detailed behaviour of the activation/deactivation procedure in LT is described in the Table III-2/G.961 as a function of INFOs, SIGs and internal timers.

Loopback 1 shall be originated only from a deactivated state, and no transitions from loopback 1 to active state shall be possible. Loopback 1 shall be transparent or not. It is possible that after loopback 1 a long activation (cold start) will be required, as the system could loose all the information about the line equalizer, echo canceller coefficients and so on.

Figure III-7/G.961, p.32

Figure III-8/G.961, p.33

H.T. [T22.961]

TABLE III-1/G.961
{
State transition table NT1 (NT-states matrix)
}

State	NT1	NT2	NT3	NT4	
Name	Deactivation	Pending activation step 1	Pending activation step 2	Pending activation step 3	Pe
{ IU0 INFO 0		IU11 asy INFO 0	IU11 INFO 0	IU21 INFO 0	
INFO 0	—	—	—	—	
INFO 1	NT2	—	—	—	
INFO 2	|	|	|	|	
INFO 3	/ /	/ /	/ /	/ /	

{
Loss of frame align. at T int.
}
	/ /	/ /	/ /	/ /	

Expiry T2	/ /	/ /	/ /	/ /	
Expiry TA	/ /	ST.T2 NT11	ST.T2 NT11	ST.T2 NT11	
IU0	—	—	ST.TA	ST.TA	
IU12	NT3	NT3	—	ST.TA	
IU22	/ /	/ /	Stop TA NT4	—	
IU4	/ /	/ /	ST.TA	Stop TA NT5	
IU6 + AR on CL	/ /	/ /	/ /	/ /	
IU6 + UAR on CL	/ /	/ /	/ /	/ /	
IU6 + AR2 on CL	/ /	/ /	/ /	/ /	
IU6 + DR on CL	/ /	/ /	/ /	/ /	

{
Loss of frame align. at U int.
}
	/ /	/ /	/ /	/ /	

{
Recovery from loss of frame align. at U int.
}
Stop TA
NT13 or NT14
}
	/ /	/ /	/ /	/ /	

Note — For symbols and abbreviations, see Table III-2/G.961.

Tableau III-1/G.961 [T22.961] (a l'italienne), p.

H.T. [T23.961]

TABLE III-2/G.961
{
State transition table LT (LT-states matrix)
}

State	LT1	LT2	LT3	LT4	LT5
Name	Deactivation	Wait activation	Pending activat. step 1	Pending activat. step 2	Pending activat. step 3
{	IU0 FE 6 (DI)	IU0 FE 2 (AR)	IU12 FE 2 (AR)	IU22 FE 2 (AR)	IU4 FE 2 (AR)
FE 1 (AR)	LT3	LT3	—	—	—
FE 11 (UAR)	LT3	/ /	—	—	—
FE 9 (ARL)	LT4	/ /	/ /	—	—
FE 8 (AR2)	LT3	/ /	—	—	—
FE 10 (AR4)	LT3	/ /	—	—	—
FE 5 (DR)	—	—	LT1	LT1	LT1
IU11 asyn.	LT2	—	—	—	—
IU11	/ /	LT1	LT4	—	—
IU21	/ /	LT1	—	LT5	—
IU3	/ /	LT1	—	—	LT6
IU5 + UAI on CL	/ /	TL1	—	—	—
IU5 + AI on CL	/ /	LT1	—	—	—
IU5 + AR on CL	/ /	/ /	/ /	/ /	/ /
IU0	—	LT1	—	—	—
IU5 + RSY on CL	/ /	LT1	—	—	—

{
Loss of frame align. at U int.
}
	/ /	/ /	/ /	/ /	/ /

{
Recovery from loss of frame at U int.
}
	/ /	/ /	/ /	/ /	/ /

Tableau III-2/G.961 [T23.961] (a l'italienne), p.

Symbols, abbreviations and Notes for Tables III-1/G.961 and III-2/G.961

/ Impossible event

— No change state

| Impossible event by the definition of the layer 1 service

INFO IU5 + X Line signal with X-message on CL channel

INFO IU6 + X Line signal with X-message on CL channel

ST.T2 Start timer T2

ST.TA Start timer TA

INFO U6 + FE Line signal with a message on CL channel related with FE and V1 interface coming from ET1.

Note — NT1 transmits on the CL channel AR instead of UAI.

III.10.6 *Activation times*

The activation time from a warm start shall be less than 300 ms.

The activation time from a cold start shall be less than 4 seconds.

III.11 *Jitter*

Jitter tolerances are intended to ensure that the limits of Recommendation I.430 are supported by the jitter limits of the transmission system on local lines. The jitter limits given below must be satisfied regardless of the length of the line and the inclusion of one regenerator, provided that they are covered by the transmission media characteristics (see § 3). The limits must be met regardless of the transmitted bit patterns in the B, D and CL channel.

III.11.1 *NT input signal jitter tolerance*

The NT1 shall meet the performances objectives with wander/jitter at the maximum magnitudes indicated in Figure III-9/G/961 for single jitter frequencies in the range of 1 Hz to 40 kHz, superimposed on the test signal source. The NT1 shall also meet the performance objectives with wander per day of up to 3 UI peak to peak where the maximum rate of change of phase is 0.6 UI/hour.

Figure III-9/G.961, p.

III.11.2 *NT output jitter limitation*

With the wander/jitter as specified in § III.11.1 superimposed on the NT1 input signal, the jitter on the transmitted signal on the NT1 towards the network shall conform the following:

a) The jitter shall be equal to or less than 0.08 UI peak-to-peak and less than 0.02 UI rms when measured with a high-pass filter having a 20 dB/dec roll-off below 100 Hz.

b) The jitter in the phase of the output signal relative to the phase of the input signal (from the network) shall not exceed 0.08 UI peak-to-peak or 0.02 UI rms when measured with a band-pass filter having a 20 dB/decade roll-off above 200 Hz and a 20 dB/decade roll-off below 0.1 Hz. This requirement applies with a superimposed jitter in the phase of the input signal as specified in § III.11.1 for single frequencies up to 100 Hz.

III.11.3 *Test conditions for jitter measurements*

The jitter measurements have been performed using test points.

III.12 *Transmitter output characteristics of NT1 and LT*

The following specifications apply with a load impedance of 130 ohms.

III.12.1 *Pulse amplitude*

The zero to peak nominal amplitude of the largest pulse shall be 2 V and the tolerance ± | 0%.

III.12.2 *Pulse shape*

The pulse shape shall meet the mask of Figure III-10/G.961.

Figure III-10/G.961, p.

III.12.3 *Signal power*

The average signal power shall be between 8 dBm and 9 dBm.

III.12.4 *Power spectrum*

The upper bound of the power spectral density shall be within the template of Figure III-11/G.961.

III.12.5 *Transmitter signal nonlinearity*

The transmitter signal nonlinearity shall be less than 1%.

III.13 *Transmitter/receiver termination*

III.13.1 *Impedance*

The nominal input/output impedance looking towards to the NT1 or LT respectively shall be 130 ohms.

Figure III-11/G.961, p.38

III.13.2 *Return loss*

The return loss of the impedance shall be greater than 11 dB in the frequency range 5 to 60 kHz and greater than 16 dB in the frequency range 60 to 100 kHz.

III.13.3 *Longitudinal conversion loss*

The minimum longitudinal conversion loss shall be as follows:

— up to 80 kHz 45 dB;

— above 80 kHz 40 dB.