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ITU-T

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STANDARDIZATION SECTOR
OF ITU

G.961

(03/93)

DIGITAL SECTIONS AND DIGITAL LINE SYSTEMS

DIGITAL TRANSMISSION SYSTEM ON METALLIC LOCAL LINES FOR ISDN BASIC RATE ACCESS

ITU-T Recommendation G.961

(Previously "CCITT Recommendation")

FOREWORD

The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the International Telecommunication Union. 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, established the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

ITU-T Recommendation G.961 was revised by the ITU-T Study Group XVIII (1988-1993) and was approved by the WTSC (Helsinki, March 1-12, 1993).

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NOTES

1 As a consequence of a reform process within the International Telecommunication Union (ITU), the CCITT ceased to exist as of 28 February 1993. In its place, the ITU Telecommunication Standardization Sector (ITU-T) was created as of 1 March 1993. Similarly, in this reform process, the CCIR and the IFRB have been replaced by the Radiocommunication Sector.

In order not to delay publication of this Recommendation, no change has been made in the text to references containing the acronyms "CCITT, CCIR or IFRB" or their associated entities such as Plenary Assembly, Secretariat, etc. Future editions of this Recommendation will contain the proper terminology related to the new ITU structure.

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

CONTENTS

DIGITAL TRANSMISSION SYSTEM ON METALLIC LOCAL LINES FOR ISDN BASIC RATE ACCESS

(Melbourne, 1988, revised in Helsinki, 1993)

1 General

1.1 Scope

This Recommendation covers the characteristics and parameters of a digital transmission system at the network side of the NT1 to form part of the access digital section for the ISDN basic rate access. The specification of transmission system characteristics at the network side of the NT1 does not correspond to a reference point defined in the reference configuration for ISDN user-network interfaces in Recommendation I.411.

The system will support the

- full duplex;
- bit sequence independent

transmission of two B-channels and one D-channel as defined in Recommendation I.412 and the supplementary functions of the access digital section defined in Recommendation I.603 for operation and maintenance.

This Recommendation describes 4 transmission systems using different line codes and transmission methods. They are given in Appendices I to IV as examples following the understanding that only one system should be recommended and provided in an annex to this Recommendation when this is achieved in future.

NOTE – The main aspects which have made it impossible to achieve this objective are for example:

- local line electrical conditions;
- maintenance requirements and line testing;
- EMC requirements;
- safety and protection requirements;
- local network evolution aspects.

The individual appendices to this Recommendation distinguish core specifications from extension specifications. The extension specifications are given in an annex to the relevant appendix.

The core specifications consist of those aspects which are expected to be common to all applications using a particular type of transmission technique. They correspond to the functions usually provided within typical VLSI transceiver integrated circuits or are associated with the transmission characteristics at the 2-wire port.

The extension functions generally correspond to NT/LT functions which are in some cases provided external to the transceiver integrated circuits. Where a definition of an extension function is provided and the application is specified in the relevant annex it is strongly recommended that the application is not changed unless there is a need to change the definition of the function itself.

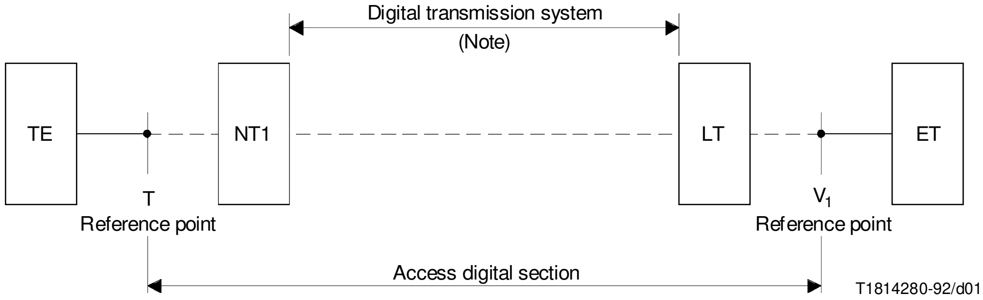
The terminology used in this Recommendation is contained in Recommendations I.112 and G.701.

1.2 Definition

Figure 1 shows the boundaries of the digital transmission system in relation to the access digital section.

The concept of the access digital section is used in order to allow a functional and procedural description and a definition of the network requirements. Note that the reference points T and V_1 are not identical and therefore the access digital section is not symmetric.

The concept of a digital transmission system is used in order to describe the characteristics of an implementation, using a specific medium, in support of the access digital section.



NOTE – In this Recommendation digital transmission system refers to a line system using metallic lines. The use of one intermediate regenerator may be required.

FIGURE 1/G.961

Access digital section and transmission system boundaries

1.3 Objectives

Considering that the access digital section between the local exchange and the customer is one key element of the successful introduction of ISDN into the network the following requirements for the specification have been taken into account:

- to meet the error performance specified in Recommendation G.960;
- to operate on existing 2-wire unloaded lines, open wires being excluded;
- the objective is to achieve 100% cable fill for ISDN basic access without pair selection, cable rearrangements or removal of bridged taps (BT) which exist in many networks;
- the objective to be able to extend ISDN basic access provided services to the majority of customers without the use of regenerators. In the remaining few cases special arrangements may be required;
- coexistence in the same cable unit with most of the existing services like telephony and voice band data transmission;
- various national regulations concerning EMI should be taken into account;
- power feeding from the network under normal or restricted conditions via the basic access shall be provided where the Administration provides this facility;
- the capability to support maintenance functions shall be provided.

1.4 Abbreviations

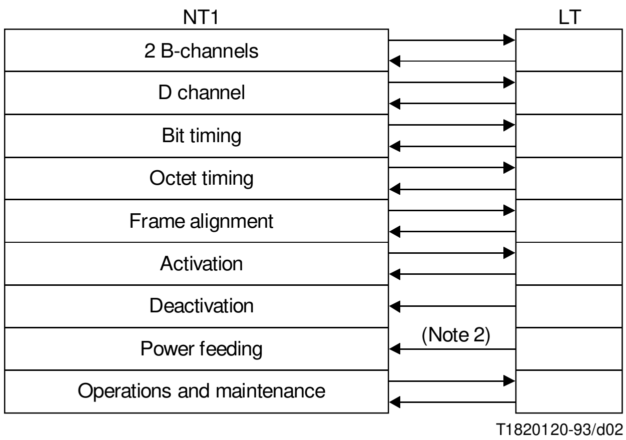
A number of abbreviations are used in this Recommendation. Some of them are commonly used in the ISDN reference configuration while others are created only for this Recommendation. The latter are given below:

BER	bit error ratio
BT	bridged tap
CISPR	Comité international spécial de perturbation radioélectrique (now part of IEC)
C_L	control channel of the line system
ECH	echo cancellation
EMI	electro-magnetic interference
DLL	digital local line

DTS	digital transmission system
NEXT	near-end crosstalk
PSL	power sum loss
TCM	time compression multiplex
UI	unit interval

2 Functions

Figure 2 shows the functions of the DTS on metallic local lines.



NOTES

1 The optional use of one regenerator must be foreseen.

2 This function is optional.

FIGURE 2/G.961

Functions of the digital transmission system

2.1 B-channel

This function provides, for each direction of transmission, two independent 64 kbit/s channels for use as B-channels (as defined in Recommendation I.412).

2.2 D-channel

This function provides, for each direction of transmission, one D-channel at a bit rate of 16 kbit/s, (as defined in Recommendation I.412).

2.3 Bit timing

This function provides bit (signal element) timing to enable the receiving equipment to recover information from the aggregate bit stream. Bit timing for the direction NT1 to LT shall be derived from the clock received by the NT1 from the LT.

2.4 Octet timing

This function provides 8 kHz octet timing for the B-channels. It shall be derived from frame alignment.

2.5 Frame alignment

This function enables the NT1 and the LT to recover the time division multiplexed channels.

2.6 Activation from LT or NT1

This function restores the DTS between the LT and NT1 to its normal operational status. Procedures required to implement this function are described in 6.

Activation from the LT could apply to the access digital section only (partial activation) or to the access digital section plus the customer equipment. In case the customer equipment is not connected, the access digital section can still be activated.

NOTE – The functions required for operation and maintenance of the NT1 and one regenerator (if required) and for some activation/deactivation procedures are combined in one transport capability to be transmitted along with the 2B + D-channels. This transport capability is named the C_L-channel.

2.7 Deactivation

This function is specified in order to permit the NT1 and the regenerator (if it exists) to be placed in a low power consumption mode or to reduce intrasystem crosstalk to other systems. The procedures and exchange of information are described in 6. This deactivation can only be initiated by the exchange (ET). See also note to 2.6.

2.8 Power feeding

This optional function provides for remote power feeding of one regenerator (if required) and NT1. The provision of wetting current is recommended (see 8.5).

NOTE – The provision of line feed power to the user-network interface, normal or restricted power feeding as defined in Recommendation I.430 is required by some Administrations.

2.9 Operations and maintenance

This function provides the recommended actions and information described in Recommendation I.603.

The following categories of functions have been identified:

- maintenance command (e.g. loopback control in the regenerator or the NT1);
- maintenance information (e.g. line errors);
- indication of fault conditions;
- information regarding power feeding in NT1.

See Note to 2.6.

3 Transmission medium

3.1 Description

The transmission medium over which the DTS is expected to operate, is the local line distribution network.

A local line distribution network employs cables of pairs to provide services to customers.

In a local line distribution network, customers are connected to the local exchange via local lines.

A metallic local line is expected to be able to simultaneously carry bi-directional digital transmission providing ISDN basic access between LT and NT1.

To simplify the provision of ISDN basic access, a DTS must be capable of satisfactory operation over the majority of metallic local lines without requirement of any special conditioning. Maximum penetration of metallic local lines is obtained by keeping ISDN requirements at a minimum.

In the following, the term Digital Local Line (DLL) is used to describe a metallic local line that meets minimum ISDN requirements.

3.2 Minimum ISDN requirements

a) No loading coils.

b) No open wires.

c) When BTs are present, some restrictions may apply. Typical allowable BT configurations are discussed in 4.2.1.

3.3 DLL physical characteristics

In addition to satisfying the minimum ISDN requirements, a DLL is typically constructed of one or more twisted-pair segments that are spliced together. In a typical local line distribution network, these twisted-pair segments occur in different types of cables as described in Figure 3.

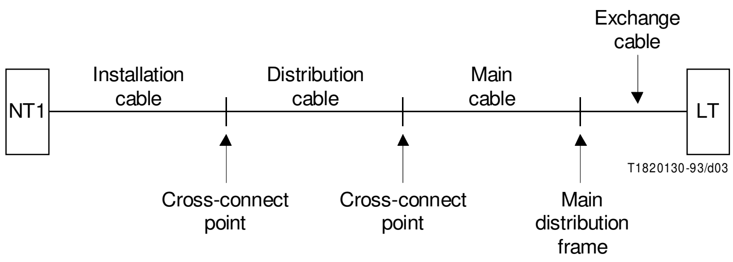


FIGURE 3/G.961

DLL physical model

3.4 DLL electrical characteristics

3.4.1 Insertion loss

The DLL will have non-linear loss versus frequency characteristic. For any DLL of a particular gauge mix, with no BTs and with an insertion loss of x dB at 80 kHz, the typical behaviour of its insertion loss versus frequency is depicted in Figure 4.

3.4.2 Group delay

Typical ranges of values of DLL group delay as a function of frequency are shown in Figure 5.

3.4.3 Characteristic impedance

Typical ranges of values of the real and imaginary parts of the characteristic impedance of twisted pairs in different types of cables are shown in Figure 6.

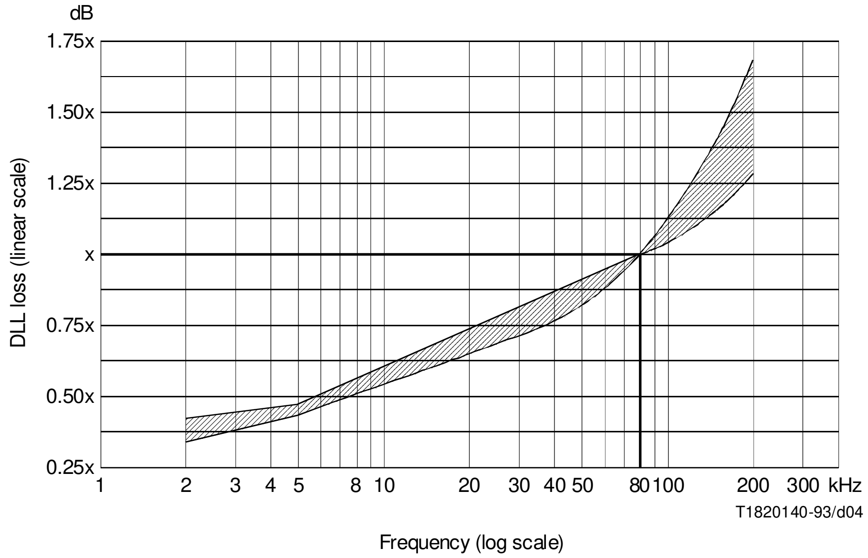
3.4.4 Near-end crosstalk (NEXT)

The DLL will have finite crosstalk coupling loss to other pairs sharing the same cable. Worst-case NEXT power sum loss (PSL) varies from 44 to 57 dB at 80 kHz (refer to 4.2.2).

The DLL loss and PSL ranges have been independently specified. However, it is not required that all points in both ranges be satisfied simultaneously. A combined DLL loss/PSL representation is shown in Figure 7 to define the combined range of operation.

3.4.5 Unbalance about earth

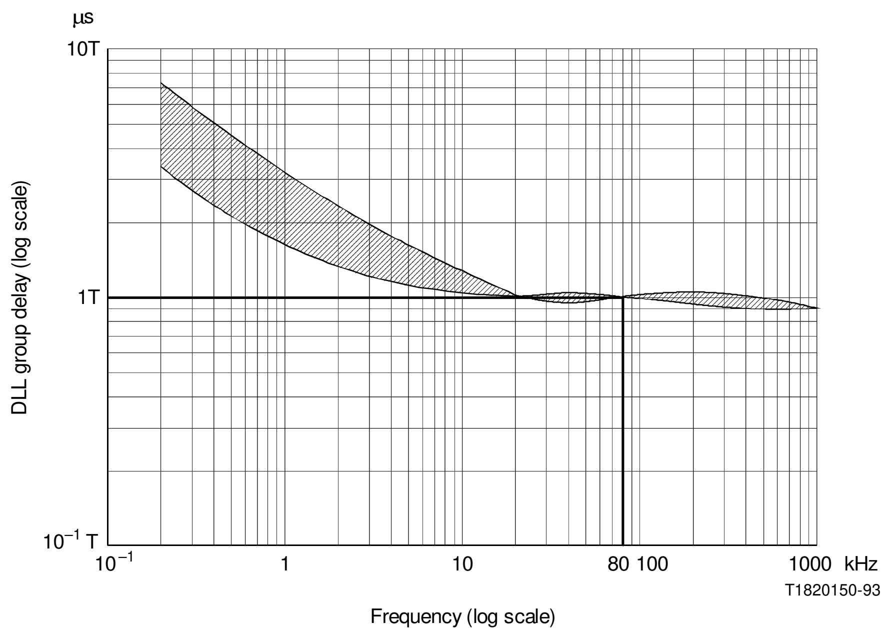
The DLL will have finite balance about earth. Unbalance about earth is described in terms of longitudinal conversion loss. Worst-case values are shown in Figure 8.



NOTE – The maximum value of *x* ranges from 37 dB to 50 dB at 80 kHz. The minimum value could be close to zero.

FIGURE 4/G.961

Typical insertion loss characteristic without presence of BTs



NOTE – The maximum value of one-way group delay (T) ranges from 30 to 60 microseconds at 80 kHz.

FIGURE 5/G.961

Typical group delay characteristic

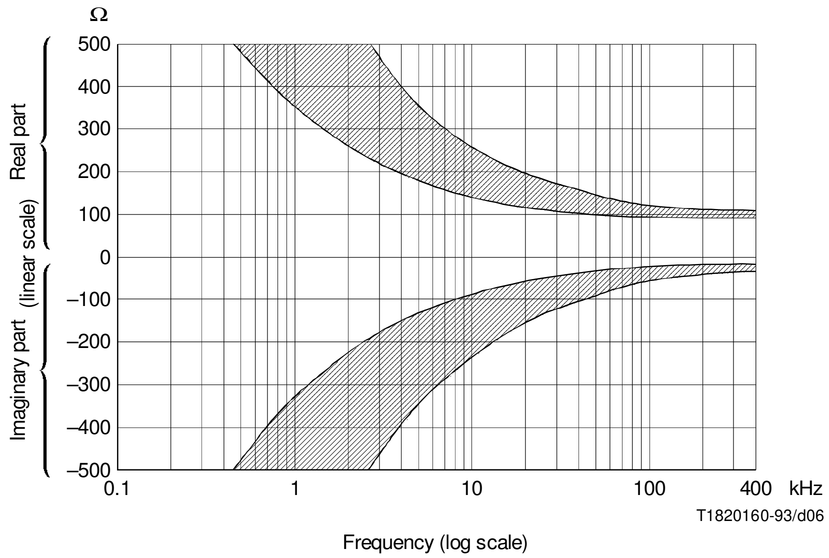


FIGURE 6/G.961

Typical ranges of values of real and imaginary parts of characteristic impedance

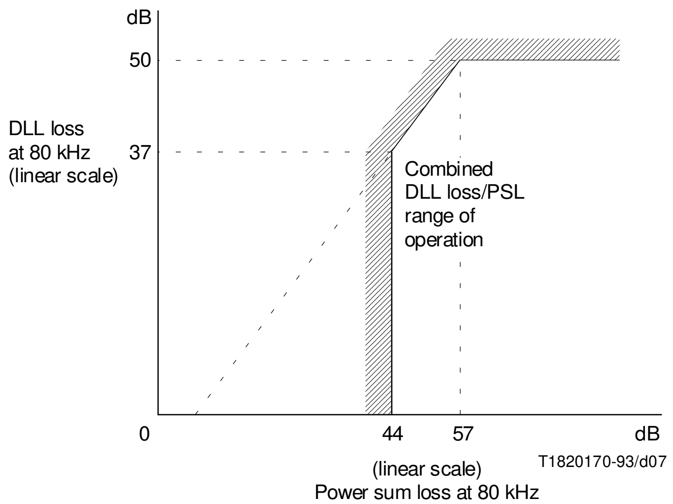


FIGURE 7/G.961

Combined representation of DLL loss/PSL range of operation

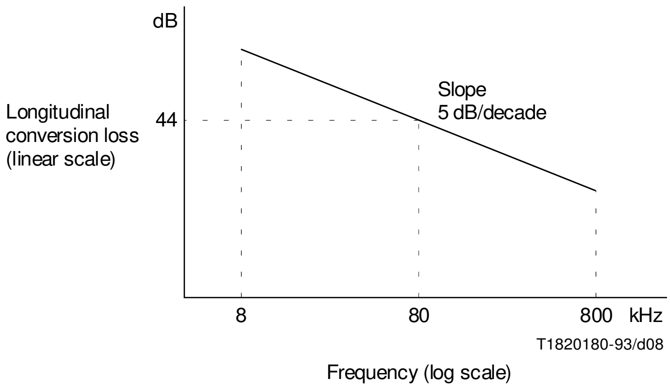


FIGURE 8/G.961

Worst-case longitudinal conversion loss versus frequency

3.4.6 Impulse noise

The DLL will have impulse noise resulting from other systems sharing the same cable as well as from other sources.

4 System performance

4.1 Performance requirements

Performance limits for the access digital section are specified in 4/G.960. The DTS performance must be such that these performance limits are met. For that purpose, a DTS is required to pass specific laboratory performance tests that are defined in the next subclauses.

4.2 Performance measurements

Laboratory performance measurement of a particular DTS requires the following preparations:

a) definition of a number of DLL models to represent physical and electrical characteristics encountered in local line distribution networks;

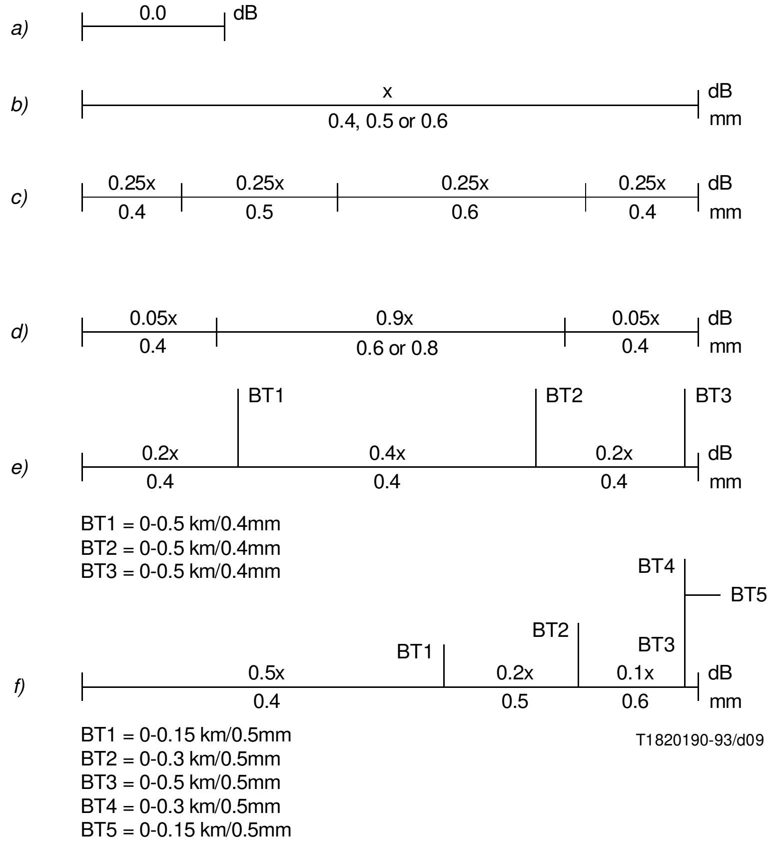
b) simulation of the electrical environment caused by finite crosstalk coupling loss to other pairs in the same cable;

c) simulation of the electrical environment caused by impulse noise;

d) specification of laboratory performance tests to verify that the performance limits referred to in 4.1 will be met.

4.2.1 DLL physical models

For the purposes of laboratory testing of performance of a DTS providing ISDN basic access, some models representative of DLLs to be encountered in a particular local line distribution network are required. The maximum loss in each model is optionally set between 37 and 50 dB at 80 kHz to satisfy requirements of the particular network. Similarly, the lengths of BTs are optionally set within the range defined in Figure 9.



NOTES

1 The value of *x* varies from 37 to 50 dB at 80 kHz.

2 Equivalent gauges can be used. For example 0.6 mm is equivalent to AWG 22. AWG stands for American Wire Gauge.

FIGURE 9/G.961

DLL physical models for laboratory testing

4.2.2 Intrasystem crosstalk modelling

4.2.2.1 Definition of intrasystem crosstalk

Crosstalk noise in general results due to finite coupling loss between pairs sharing the same cable, especially those pairs that are physically adjacent. Finite coupling loss between pairs causes a vestige of the signal flowing on one DLL (disturber DLL) to be coupled into an adjacent DLL (disturbed DLL). This vestige is known as crosstalk noise. Near-end crosstalk (NEXT) is assumed to be the dominant type of crosstalk. Intrasystem NEXT or self NEXT results when all pairs interfere with each other in a cable carrying the same DTS. Intersystem NEXT results when pairs carrying different DTSs interfere with each other. Definition of intersystem NEXT is not part of this Recommendation.

Intrasystem NEXT noise coupled into a disturbed DLL from a number of DLL disturbers is represented as being due to an equivalent single disturber DLL with a coupling loss versus frequency characteristic known as PSL. Worst-case PSL encountered in a local line distribution network is defined in Figure 10. All DLLs are assumed to have fixed resistance terminations of Ro ohms. The range of Ro is 110 to 150 ohms.

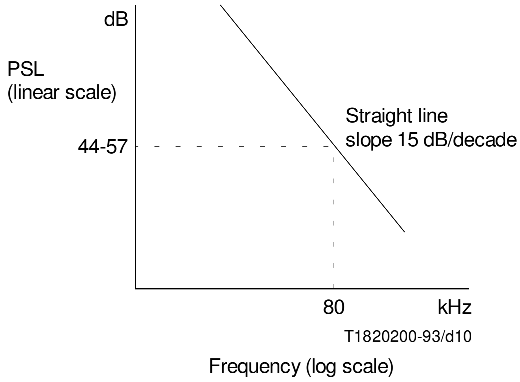


FIGURE 10/G.961

Worst-case power sum loss (PSL)

4.2.2.2 Measurement arrangement

Simulation of intrasystem NEXT noise is necessary for performance testing of DTSs. Intrasystem noise coupled into the receiver of the disturbed DLL depends on:

a) Power spectrum of the transmitted digital signal. The power spectrum is a function of the line code and the transmit filter.

b) Spectrum shaping due to the PSL characteristic of Figure 10.

The measurement arrangement of Figure 11 can be used for testing of performance with intrasystem crosstalk noise.

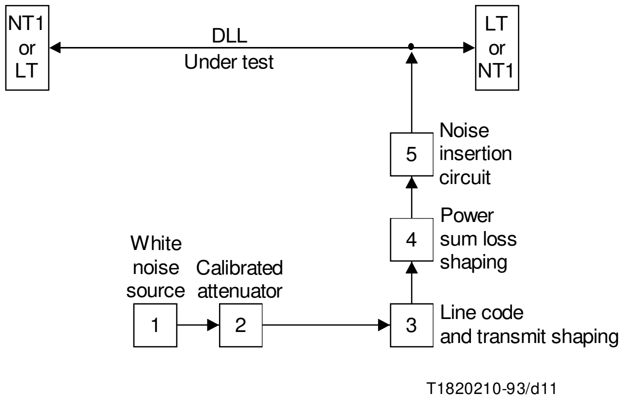


FIGURE 11/G.961

Crosstalk noise simulation and testing

The measurement arrangement in Figure 11 is described in the following:

a) Box 1 represents a white noise source of constant spectral density. Spectrum is flat from 100 Hz to 500 kHz rolling off afterwards at a rate ≥ 20 dB/decade.

b) Box 2 is a variable attenuator.

c) Box 3 is a filter that shapes the power spectrum to correspond to a particular line code and a particular transmit filter.

d) Box 4 is a filter that shapes the power spectrum according to the PSL characteristic of Figure 10.

e) Box 5 is a noise insertion circuit which couples the simulated crosstalk noise into the DLL without disturbing its performance. The insertion circuit therefore must be of sufficiently high output impedance relative to the magnitude of the characteristic impedance of the DLL under test. A value of ≥ 4.0 kohm in the frequency range 0 to 1000 kHz is recommended.

Boxes 3, 4 and 5 in Figure 11 are conceptual. Depending on the particular realization, they could possibly be combined into one circuit. The measurement arrangement in Figure 11 is calibrated according to the following steps:

a) By terminating the output of Box 5 with a resistor of a value of Ro/2 ohm, and measuring the true r.m.s. (root-mean-square) voltage across it in a bandwidth extending from 100 Hz to over 500 kHz. The power dissipated in the Ro/2 resistor is 3 dB higher than the power coupled into the receiver of the DLL under test.

b) The shape of the noise spectrum measured across the Ro/2 resistor should be within:

   – ± 1 dB for values within 0 dB to 10 dB down from the theoretical peak;

   – ± 3 dB for values within 10 dB to 20 dB down from the theoretical peak;

   for measurement purposes a resolution bandwidth of ≤ 10 kHz is recommended.

c) The peak factor of the noise voltage across the Ro/2 resistor should be ≥ 4. This in turn fixes the dynamic range requirements of the circuits used in the measurement arrangement.

With the specified calibrated measurement arrangement, intrasystem crosstalk noise due to a worst-case PSL can be injected into the DLL under test while monitoring its performance. The noise level can be increased or decreased to determine positive or negative performance margins.

4.2.3 Impulse noise modelling

4.2.3.1 Definition of **impulse noise**: Impulse noise energy appears concentrated in random short time intervals during which it attains substantial levels. For the rest of the time impulse noise effects are negligible. The induced noise parameters that should be evaluated are given in Recommendation K.23.

4.2.3.2 Measurement arrangement

Figure 12 shows a possible arrangement for impulse noise testing.

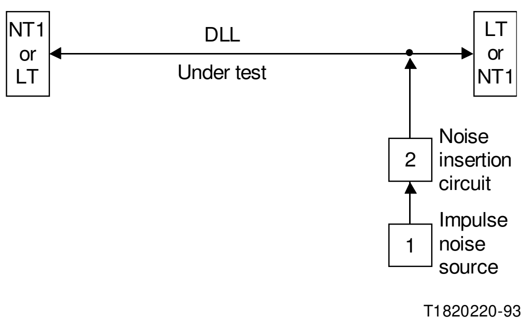
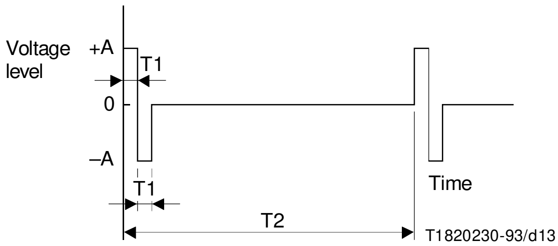


FIGURE 12/G.961

Impulse noise simulation and testing

The impulse noise source in Figure 12 is for further study. Two possible classes of impulse noise signals are described in the following:

- white noise of flat spectral density level of 5-10 $\mu V/\sqrt{Hz}$ and a bandwidth > 4 times the Nyquist frequency of the particular system. The peak factor of the noise must be > 4;
- a particular waveform, as represented in Figure 13.



A Peak level, provisionally set to 100 mV
T1 Pulse width, provisionally set to 3 baud periods
T2 Period » T1

NOTE – In some local line distribution networks and as a national option, crosstalk noise performance tests are considered sufficient to evaluate a particular digital transmission system. In such cases proper DLL engineering rules are applied to guard against impulse noise.

FIGURE 13/G.961

Possible waveform to simulate impulse noise

4.2.4 Performance tests

Five types of tests are required to describe the overall performance of a particular DTS to qualify it for operation over the local line distribution network modelled in this Recommendation.

4.2.4.1 Dynamic range

Dynamic range performance describes the ability of a particular DTS to operate with received signals varying in level over a wide range. DLL models a) and b) in Figure 9 have a loss varying from very low (0 dB) to very high (37-50 dB at 80 kHz).

When testing with DLL models a) and b) in Figure 9, no errors should be observed in any 15 minutes (provisional) measuring interval when monitoring any B-channel.

Specification of data sequences to be used for this measurement are for further study.

4.2.4.2 Immunity to echoes

The remaining DLL models in Figure 9 are used to test performance of DTSs in the presence of BTs and/or diameter changes.

In each model, no errors should be observed in any 15 minutes (provisional) measuring interval when monitoring any B-channel.

Specification of data sequences to be used for this measurement are for further study.

4.2.4.3 Intrasystem crosstalk

Using the crosstalk arrangement described in 4.2.2.2 with simulated crosstalk noise injected in each DLL model in Figure 9 the observed bit error ratio (BER) should be $\leq 10^{-6}$ (provisional).

When BER measurements are performed in a B-channel, a measuring interval of at least 15 minutes (provisional) is required.

In each DLL model, performance margins are determined. Definition of a minimum positive performance margin is left for further study. This is required to account for additional DLL loss due to splices, and environmental effects (e.g. temperature change).

Specification of data sequences to be used for this measurement are for further study.

NOTE – With a burst-synchronized TCM transmission method this performance test is not required (see 5).

4.2.4.4 Impulse noise

For further study.

4.2.4.5 Longitudinal voltages induced from power lines

For further study.

5 Transmission method

The transmission system provides for duplex transmission on 2-wire metallic local lines. Duplex transmission shall be achieved through the use of Echo Cancellation (ECH) or Time Compression Multiplex (TCM).

With the ECH method, illustrated in Figure 14, the echo cancellor produces a replica of the echo of the transmitted signal that is subtracted from the total received signal. The echo is the result of imperfect balance of the hybrid and impedance discontinuities in the line. The maximum allowable loss of operation for the ECH method generally depends on the noise environment as well as the NEXT PSL.

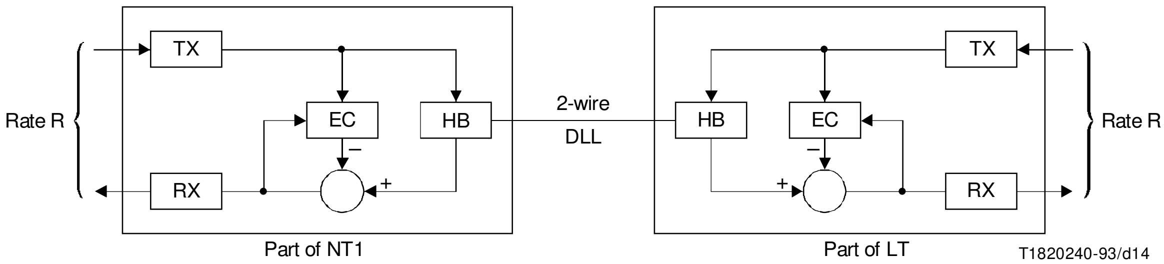


FIGURE 14/G.961

ECH method functional diagram

With the TCM or "burst mode" method, illustrated in Figure 15, transmissions on the DLL are separated in time (bursts). Blocks of bits (bursts) are sent alternatively in each direction. Bursts are passed through buffers at each transceiver terminal such that the bit stream at the input and output of the TCM transceiver terminal is continuous at the rate R. The bit rate on the line is required to be greater than 2R to provide for an idle interval between bursts which is necessary to allow for transmission delay and transmitter/receiver turn-around (switching of Sn and Se in Figure 15). The maximum allowable loss of operation for the TCM method generally depends on the noise environment but is independent of the NEXT PSL assuming that the transmitted bursts from the central office are synchronized for systems sharing the same cable.

This assumption made for the TCM system is based on clearly defined planning rules for installation and operation of the local network to prevent systems with great difference in line loss from using pairs in the same quad or neighbouring quads. Due to the higher frequency spectrum of a TCM system and the high output signal level, greater care must be paid that other transmission systems in the same cable, sensitive in this frequency band, are not effected.

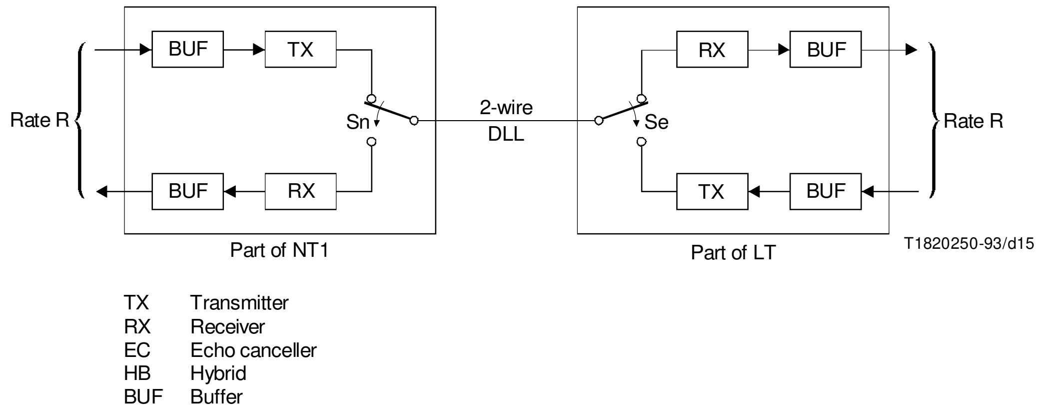


FIGURE 15/G.961

TCM method functional diagram

6 Activation/deactivation

6.1 General

The functional capabilities of the activation/deactivation procedure are specified in Recommendation G.960. The transmission system has to meet the requirements specified in Recommendation G.960. In particular, it has to make provision to convey the signals defined in Recommendation G.960 which are required for the support of the procedures.

6.2 Physical representation of signals

The signals used in the DTS are system-dependent and can be found in the appendices to this Recommendation.

7 Operation and maintenance

7.1 Operation and maintenance functions

The operation and maintenance functions in the DTS using metallic local lines for the ISDN basic rate access, are defined in Recommendation G.960.

7.2 C_L channel

7.2.1 C_L channel definition: This channel is conveyed by the DTS in both directions between LT and NT1 via a possible regenerator. It is used to transfer information concerning operation, maintenance and activation/deactivation of the DTS and of the access digital section.

Even though some of these functions have an optional status, the C_L channel shall have the capability to convey the necessary information to perform the function.

7.2.2 C_L channel requirements

For further study.

The minimum number of functions (optional or mandatory) the C_L channel should support is for further study.

7.3 Transfer mode of operation and maintenance links

For further study.

8 Power feeding

8.1 General

This subclause deals with power feeding of the NT1, one regenerator (if required), and the provision of power to the user-network interface according to Recommendation I.430 under normal and restricted conditions.

When activation/deactivation procedures are applied, power down modes at the NT1, regenerator (if required) and the LT are defined.

8.2 Power feeding options

Power feeding options under normal and restricted conditions are considered. For this purpose, a restricted condition is entered after failure of AC mains power at the NT1 location.

a) Power feeding of NT1 under normal conditions will be provided using one of the following options:

   – AC mains powering;

   – remote powering from the network (or via a regenerator, if required).

In both cases the NT1 may provide power to the user-network interface according to Recommendation I.430. This power is derived from AC mains or remotely from the network.

b) Power feeding of NT1 under restricted conditions, when provided, employs one of the following optional sources:

   – back-up battery;

   – remote powering from the network (or via a regenerator, if required).

In both cases the NT1 may provide power to the user-network interface according to Recommendation I.430.

Power feeding options are chosen to satisfy national regulations.

8.3 Power feeding and recovery methods

Two power feeding and recovery methods are possible and are described in Figure 16.

When no regenerator is present on the DLL connecting the LT and the NT1, for each case in Figure 16 the power source could be either a constant voltage source with current limiting or a constant current source with voltage limiting.

When a regenerator is present, both methods of power feeding and recovery in Figure 16 remain applicable. However, when a constant voltage source is used at the LT, the regenerator power sink is connected in parallel to the DLLs and when a constant current source is used at the LT, the regenerator power sink is connected in series with the DLLs. The resulting configurations are shown in Figure 17.

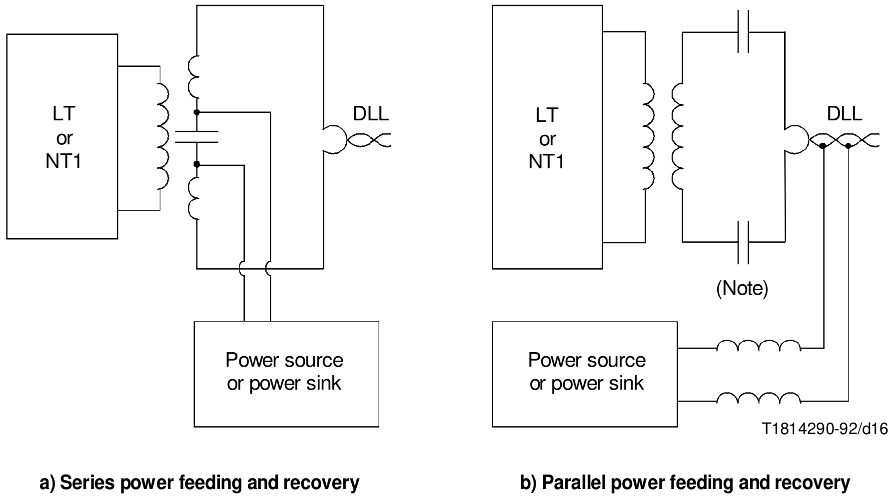
8.4 DLL resistance

This parameter is a particular subject of the individual local network and therefore out of the scope of this Recommendation. Its maximum value depends on the LT output voltage, the power consumption of the NT1 and regenerator (if required) and the power feeding arrangement for the user-network interface.

8.5 Wetting current

The NT1 shall provide a DC termination to allow a minimum wetting current to flow (the value has to be defined) including the power down mode or in case of local power feeding of the NT1.

Wetting current, also known as sealing current, is provided to prevent the degradation of transmission on metallic facilities which may result from the oxidation of wire splices.



NOTE – The use of one capacitor may be sufficient as long as the longitudinal conversion loss requirements is satisfied.

FIGURE 16/G.961

Power feeding and recovery methods

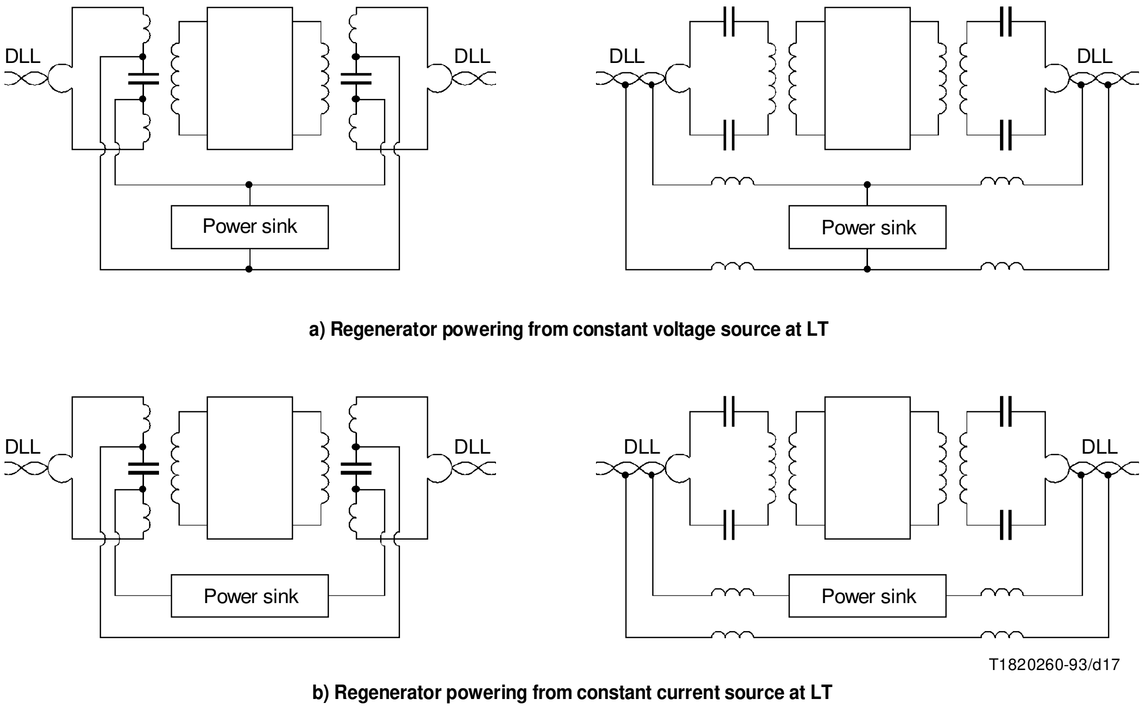


FIGURE 17/G.961

Powering at regenerator

8.6 LT aspects

A current limitation for voltage source configuration or a voltage limitation for current source configuration is required. The values shall take into account the relevant IEC Publications and national safety regulations.

According to IEC 449, Amendment 1 (1979) the maximum voltage allowed for transmission systems on local lines is set at 120 V DC. Even in the case of a fault in the power supply the voltage at the LT shall be less than 120 V DC or the limit defined in a national safety regulation.

The maximum continuous current shall be limited to less than 60 mA. Short-term overflow of the feeding current may be tolerated (charging condition of the capacitor of DC/DC converter in NT1).

8.7 Power requirements of NT1 and regenerator

8.7.1 Power requirements of NT1

a) Active state without powering of user-network interface according to Recommendation I.430 or when normal mode power is supplied: ≤ 500 mW.

b) Active state including restricted mode powering of the user-network interface as defined in Recommendation I.430: ≤ 1100 mW.

The value includes a possible overload or short circuit condition at the user-network interface.

c) Deactivated state without powering of the user-network interface or when normal mode power is supplied: ≤ 120 mW.

NOTE – For a time period until the end of 1994, NTs which cannot meet these requirements may consume ≤ 600 mW for case a) and ≤ 1300 mW for case b), subject to the safe provision of that power by the LT.

8.7.2 Power requirements of regenerator

a) Active state: ≤ 1000 mW.

b) Deactivated state: ≤ 180 mW.

NOTE – For the active state the target value of ≤ 750 mW should be reached in the long term.

8.8 Current transient limitation

The rate of change of current drawn by the NT1 or regenerator, when fitted, shall not exceed 1 mA/µs.

This limit shall apply under all normal operating conditions including activation and deactivation. However, the limit does not apply during initial application of power to the equipment.

9 Environmental conditions

9.1 Climatic conditions

Climatograms applicable to the operation of NT1 and LT equipment in weather protected and non-weather protected locations can be found in IEC Publication 721-3. The choice of classes is under national responsibility.

9.2 Protection

9.2.1 Isolation

Isolation between various points at the NT1 can be identified:

– between line interface and T reference point;

– between line interface or T reference point and AC mains (this is generally defined in IEC Guide 105 and IEC Publication 950 but the test requirements may be different in various countries);

– between line interface and the protective ground of AC mains.

9.2.2 Overvoltage protection

- To conform with Recommendations K.12, K.20 for LT.
- To conform with Recommendations K.12, K.21 for NT1.

9.3 Electromagnetic compatibility

9.3.1 Susceptibility, radiated and conducted emission levels for LT or NT1 equipment

This is outside the scope of this Recommendation. CISPR Publication 22 and national regulations have to be considered.

9.3.2 Limitation of the output power to the line

Due to limited longitudinal conversion, loss of the line at high frequencies and the limitation of radiation according to CISPR Publication 22 and national regulations, the output power shall be limited. The specific values are outside the scope of this Recommendation.

Appendix I

Electrical characteristics of an MMS 43 transmission system

(This appendix does not form an integral part of this Recommendation)

I.1 Line code

For each direction of transmission the line code is a Modified Monitoring State Code mapping 4 bits into 3 ternary symbols with levels +, 0 or – (MMS 43). Details of the coding scheme are given in Figure I.1. Note that the numbers in the columns for each of the 4 alphabets S1 . . . S4 give the numbers of the alphabet to be used for the coding of the next block of 4 bits. The bits and symbols standing left are those transmitted or received first.

	S1	S2	S3	S4
0001	0 - + 1	0 - + 2	0 - + 3	0 - + 4
0111	- 0 + 1	- 0 + 2	- 0 + 3	- 0 + 4
0100	- + 0 1	- + 0 2	- + 0 3	- + 0 4
0010	+ - 0 1	+ - 0 2	+ - 0 3	+ - 0 4
1011	+ 0 - 1	+ 0 - 2	+ 0 - 3	+ 0 - 4
1110	0 + - 1	0 + - 2	0 + - 3	0 + - 4
1001	+ - + 2	+ - + 3	+ - + 4	- - - 1
0011	0 0 + 2	0 0 + 3	0 0 + 4	- - 0 2
1101	0 + 0 2	0 + 0 3	0 + 0 4	- 0 - 2
1000	+ 0 0 2	+ 0 0 3	+ 0 0 4	0 - - 2
0110	- + + 2	- + + 3	- - + 2	- - + 3
1010	+ + - 2	+ + - 3	+ - - 2	+ - - 3
1111	+ + 0 3	0 0 - 1	0 0 - 2	0 0 - 3
0000	+ 0 + 3	0 - 0 1	0 - 0 2	0 - 0 3
0101	0 + + 3	- 0 0 1	- 0 0 2	- 0 0 3
1100	+ + + 4	- + - 1	- + - 2	- + - 3

T1814870-02/d18

NOTE – A received ternary block 000 is decoded as binary 0000.

FIGURE I.1/G.961

MMS 43-Code

I.2 Symbol rate

The symbol rate is 120 kbaud.

I.2.1 Clock symbol requirements

I.2.1.1 NT1 free running clock accuracy

The tolerance of the free running NT1 clock is ± 100 ppm.

I.2.1.2 LT clock tolerance

The tolerance of the clock signal provided at the LT is ± 1 ppm.

I.3 Frame structure

Each frame contains a frame word, 2B + D data and the C_L-channel. Multiframes are not used.

I.3.1 Frame length

The length of each frame is 120 ternary symbols corresponding to 1 ms. Each frame has 108 symbols (corresponding to 144 bits) carrying 2B + D data.

I.3.2 Symbol allocation LT to NT1

In the direction LT to NT1 the 120 symbols of each frame are used as follows:

- Symbols 1 to 84: 2B + D;
- Symbol 85: C_L-channel;
- Symbols 86 to 109: 2B + D
- Symbols 110 to 120: frame word.

The channel allocation to the symbols 1 to 84 and 86 to 109 and the structure of the frame shall be as follows:

8 consecutive blocks of B1 + B2 + D, in total 144 bits, shall be scrambled and coded into 108 ternary symbols according to Figure I.1. The first B1 channel shall start with symbol number 1.

After 84 of such coded symbols the C_L-channel-symbol shall be inserted continued with the remaining 24 coded symbols. The 11 symbols forming the frame word shall be added after symbol 109.

I.3.3 Symbol allocation NT1 to LT

In the direction NT1 to LT, the frame structure is identical to that of the direction LT to NT1.

The frame transmitted by the NT1 is synchronized to that received from the LT.

I.4 Frame word

I.4.1 Frame word in direction LT to NT1

The frame word in the direction LT to NT1 is

+ + + – – – + – – + –

I.4.2 Frame word in direction NT1 to LT

The frame word in the direction NT1 to LT is

– + – – + – – – + + +

I.5 Frame alignment procedure

The transmission system is considered to be synchronous if the frame word has been identified in the same position for 4 immediately succeeding frames. Loss of synchronization is assumed, if the detected frame position does not coincide with the expected position during 60 . . . 200 successive frames.

I.6 Multiframe

Not used.

I.7 Frame offset at NT1

On the line at the NT1 the frame word transmitted by the NT1 occurs 60 ± 1 symbols (0.5 ms) later than that received at the NT1 input, measured between the first symbols of each frame word.

I.8 C_L- channel

I.8.1 Bit rate

The bit rate for the C_L-channel (maintenance-channel) is 1 kbit/s.

I.8.2 Structure

No specific structure is defined for transparent messages.

I.8.3 Protocols and procedures

Transparent messages in the C_L-channel use "0" and "–" polarity of the C_L-symbol of the line signal. "0" and "+" polarity are used to request a loopback 2B + D in the NT1 or an intermediate repeater. Transparent use of the C_L- channel may override these loopback commands.

Continuous "0" polarity is used as idle code.

The command/information channel protocol shall use "0" and "+" polarity codings.

Loopback commands are coded as follows:

- Loopback 1A activation (in regenerator): continuous "+0";
- Loopback 2 activation (in NT1): continuous "+";
- Loopback deactivation: continuous "0".

An activation or deactivation command is identified when 8 consecutive symbols according to the coding rule have been detected.

a) *Transmission error detection and report*

Transmission errors shall be detected by monitoring frames received with one or more line code violations. An errored frame detected by the NT1 shall be reported back to the LT by setting one C_L- symbol to "+" polarity.

b) *Transparent channel*

The transparent channel shall use "–" polarity for ZERO, "0" and "+" polarity shall be interpreted as ONE. "0" or "+" polarity shall be considered as idle code.

Messages of the transparent channel shall have priority.

I.9 Scrambling

In order to minimize correlation between incoming and transmitted symbols scrambling is used. Scrambling is applied only to the 2B + D-channels.

The scrambling polynomial is different in both NT1 to LT and LT to NT1 directions.

- In direction LT to NT1: $1 \oplus x^{-5} \oplus x^{-23}$
- In direction NT1 to LT: $1 \oplus x^{-18} \oplus x^{-23}$,

$\oplus$ is the modulo two sum and x^{-k} is the scrambled data delayed by k symbol intervals.

I.10 Activation/deactivation

Activation/deactivation is provided to enable the use of a power down state especially for applications, where the NT1 is powered from the LT via the local line. Activation from the power state may be initiated from both ends using a 7.5 kHz burst signal. Collisions are handled through appropriate duration and repetition rate of these bursts.

The procedures on the line system support the procedures at reference point T for call control in accordance with Recommendation I.430 and the operation of loopbacks 1 (in the LT), 1A (in the regenerator) and 2 (in the NT1) in accordance with Recommendation I.603. The loopbacks are transparent.

Timer 1 and timer 2, as defined in Recommendation I.430, are located as follows:

- Timer 1 in the ET layer 1 or the ET;
- Timer 2 in the NT1.

The activation of the line system for maintenance purposes e.g. error performance monitoring, is possible, even if no TE is connected to the interface at T reference point.

Transmission of INFO 2 on the interface of T reference point is initiated when the line system is synchronized in the direction LT to NT1.

I.10.1 Signals used for activation

To provide means to control/indicate progress during activation/deactivation across the local line the following signal elements are used:

SIG 0 NT1 to LT and LT to NT1

No signal.

SIG 1W NT1 to LT

Awake signal (7.5 kHz tone); signals the layer 1 entity in the local exchange that it has to enter the power-up state and provide for the activation of the line system and the interface at T reference point.

This signal is also used as awake acknowledge on the receipt of SIG 2W.

SIG 2W LT to NT1

Awake signal (7.5 kHz tone); signals the NT1 that it has to enter the power-up state and prepare for synchronization on an incoming signal from the LT.

This signal is also used as awake acknowledge on the receipt of SIG 1W.

SIG 1 NT1 to LT

Signal which contains framing information and allows the synchronization of the receiver in the LT. It informs the LT that the NT1 has synchronized on SIG 2.

SIG 2 LT to NT1

Signal which contains framing information and allows the synchronization of the receiver in the NT1.

SIG 1A NT1 to LT

Signal similar to SIG 1 but without framing information.

SIG 3 NT1 to LT

Signal which contains framing information and allows the synchronization of the receiver in the LT. It indicates to the ET that the interface at T reference point is synchronized in both directions of transmission (except in the case of loopback 2 and 1A).

SIG 4H LT to NT1

Signal which requires the NT1 to establish full layer 1 information transfer capability in both directions of transmission.

SIG 4 LT to NT1

Signal which contains framing information and operational data on B and D channels.

SIG 5 NT1 to LT

Signal which contains framing information and operational data on B and D channels.

SIG 2-L2 LT to NT1

Signal similar to SIG 2, but includes a loopback 2 request.

SIG 4H-L2 LT to NT1

Signal which requires the NT1 to operate loopback 2 and to establish layer 1 information transfer capability in the direction LT to TE (transparent loopback 2).

SIG 4-L2 Signal similar to SIG 4, but includes a loopback 2 request.

All SIGs, except SIG 1W and SIG 2W, are continuous signals. The awake signals SIG 1W and SIG 2W are sent for a specified period of time only, but may be repeated if no acknowledgement is received. The repetition times are specified in a way to assure a proper interworking with the normal activation procedure.

The loopback requests are transmitted making use of the C_L channel. All other SIGs do not require the C_L channel.

The C_L channel is provided with all SIGs except SIG 0, SIG 1W, SIG 2W and SIG 1A.

I.10.2 Definition of internal timers

In the state transition tables and arrow diagrams the following internal timers are used:

Tn1 = 13 ms: timer to supervise repetition of the awake signal SIG 2W from the LT

Tl1 = 7 ms: timer to supervise repetition of the awake signal SIG 1W from the NT1

Tl2 = 1 ms: timer which defines the duration of SIG 4H and SIG 4H-L2

Tl3 = 1 ms: timer which assures that, under non-failure conditions, the PH-AI is passed first in the TE and then in the LT/ET. This protects the first layer 2 frame (layer 3 – SETUP message) from the network side.

Tl4 = 12 ms: timer used to start transmission of SIG 2 when loopback 1 is requested.

Tl5 = 0.1 … 1 s: timer to supervise the deactivation procedure (within ET).

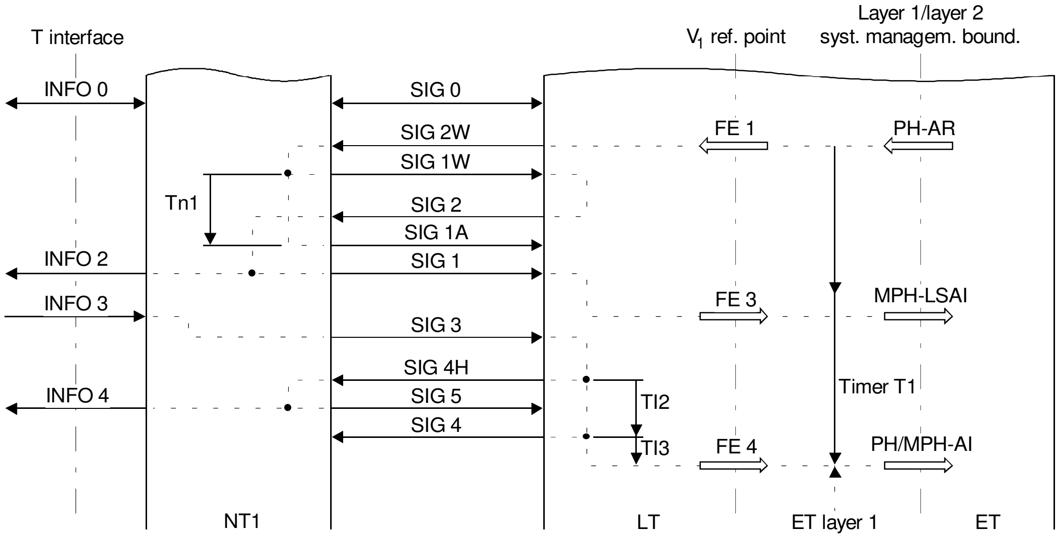
I.10.3 Description of the activation procedure

In Figure I.2 the activation/deactivation procedures are described for the non-failure situation.

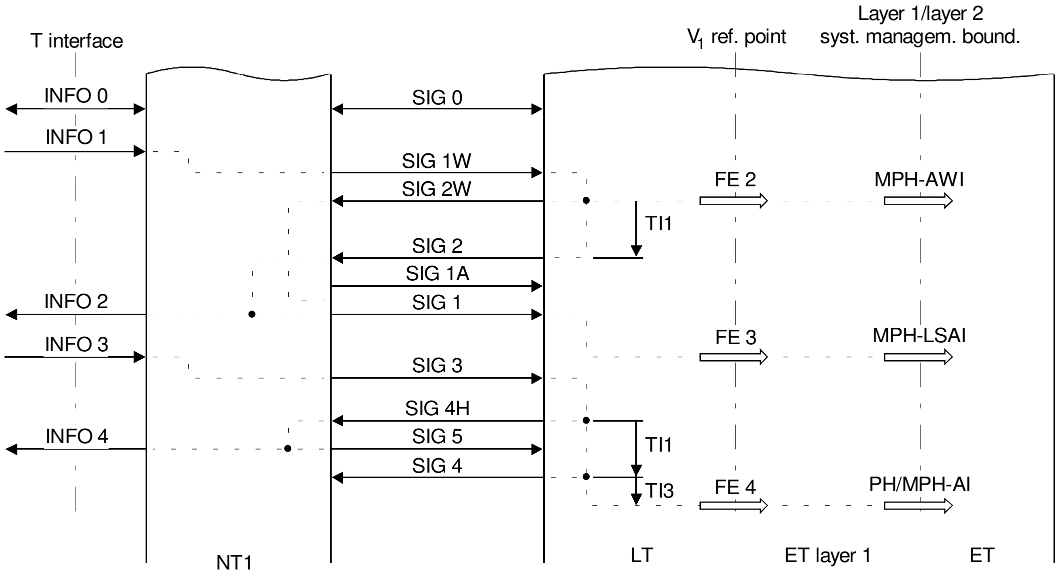
Timer T1 (located in ET layer 1) and Timer T2 (located in NT1) are as specified in Recommendation I.430; the functional elements (FE) are defined in 5.4.1.3/G.960, and the primitives in 5.4.2.2/G.960 and 5.4.2.3/G.960.

I.10.4 NT1 state transition table

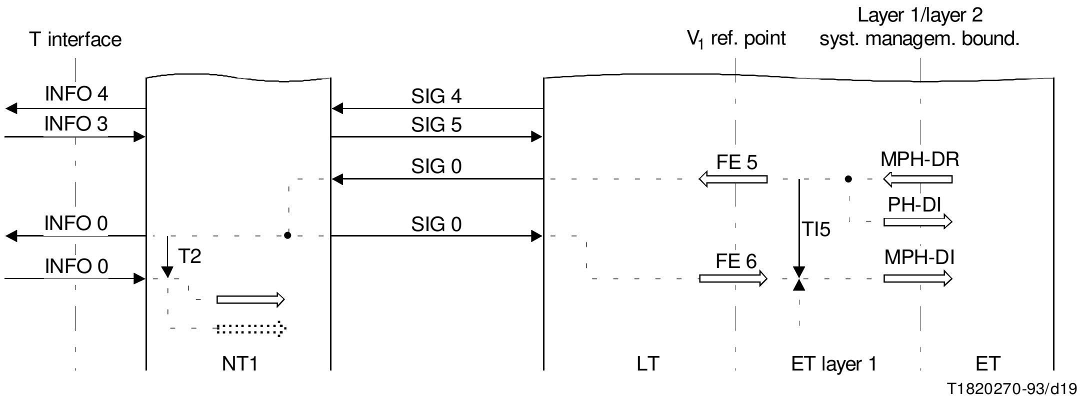
The NT1 state transition table is described in Table I.1. INFOs on the interface at T reference point are related to SIGs on the line system and vice versa.



a) Activation from network side



b) Activation from user side



c) Deactivation

FIGURE I.2/G.961

Activation/deactivation procedures: arrow diagrams (non-failure situations)

TABLE I.1/G.961

NT1 state transition table

State →	NT 1.1	NT 1.2	NT 1.3	NT 1.4	NT 1.5	NT 1.6	NT 1.7	NT 1.8	NT 1.9	NT 1.10	NT 2.1	NT 2.2
Transmit signal	INFO 0	INFO 0	INFO 0	INFO 0	INFO 2	INFO 2	INFO 4	INFO 0	INFO 2	INFO X (Note 2)	INFO 2	INFO 4 (Note 4)
Receive signal	SIG 0	SIG 1W	SIG 1W	SIG 1A	SIG 1	SIG 3	SIG 5	SIG 0	SIG 5	SIG 0 (Note 3)	SIG 3	SIG 5 (Note 5)
INFO 0	–	–	–	–	–	–	NT 1.9	NT 1.1	–	–	–	–
INFO 1	NT 1.2	–	–	–	–	–	/	–	–	/	–	/
INFO 3	/	/	/	/	NT 1.6	–	–	–	NT 1.7	/	–	–
SIG 0	–	–	–	ST.T2; NT 1.8	ST.T2; NT 1.8	ST.T2; NT 1.8	ST.T2; NT 1.8	–	ST.T2; NT 1.8	ST.T2; NT 1.8	ST.T2; NT 1.8	ST.T2; NT 1.8
SIG 2W	ST.Tn1; NT 1.3	NT 1.4	/	/	/	/	/	–	/	/	/	/
SIG 2	/	–	–	NT 1.5	–	–	/	/	/	/	NT 1.6 or –	/
SIG 4H	/	/	/	/	/	NT 1.7	–	/	/	/	NT 1.7	/
SIG 4	/	/	/	/	/	/	–	/	–	–	/	NT 1.7
Exp. of T2 (Note 1)	–	–	–	–	–	–	–	NT 1.1	–	–	–	–
Lost framing T interface	/	/	/	/	/	–	NT 1.9	–	–	–	/	/
Lost framing line system	/	/	/	/	NT 1.10	NT 1.10	NT 1.10	/	NT 1.10	–	NT 1.10	NT 1.10
Exp. of internal timer Tn1	/	/	NT 1.4	/	/	/	/	/	/	/	/	/

TABLE I.1/G.961 *(end)*

NT1 state transition table

State	NT 1.1	NT 1.2	NT 1.3	NT 1.4	NT 1.5	NT 1.6	NT 1.7	NT 1.8	NT 1.9	NT 1.10	NT 2.1	NT 2.2
Transmit signal	INFO 0	INFO 0	INFO 0	INFO 0	INFO 2	INFO 2	INFO 4	INFO 0	INFO 2	INFO X (Note 2)	INFO 2	INFO 4 (Note 4)
Receive signal	SIG 0	SIG 1W	SIG 1W	SIG 1A	SIG 1	SIG 3	SIG 5	SIG 0	SIG 5	SIG 0 (Note 3)	SIG 3	SIG 5 (Note 5)
SIG 2-L2	/	–	–	NT 2.1	NT 2.1 or –	NT 2.1 or –	/	/	/	/	–	/
SIG 4H-L2	/	/	/	/	/	NT 2.2	–	/	/	/	NT 2.2	–
SIG 4-L2	/	/	/	/	/	/	NT 2.2	/	NT 2.2	NT 2.2	/	–

– No state change.

/ Impossible by the definition of peer-to-peer physical layer procedures or system internal reasons.

ST.Tx; NTy Start Timer x; enter state NT y.

NOTES

1 Timer T2 as defined in Recommendation I.430.

2 INFO X: signal with no framing information i.e. binary ZERO's.

3 Any other signal which produces an error indication on the LT side is allowed, especially loss of framing or excessive error rate.

4 The D-Echo bit is set to binary ZERO.

5 The B- and D-channels are looped back to the network side.

The following states are used:

NT 1.1 Deactivated state (low power consumption mode). No signal is transmitted.

NT 1.2 The NT1 sends the awake signal SIG 1W to the LT, on the receipt of INFO 1 from the user side, and waits for the receipt of the awake acknowledge signal SIG 2W from the LT.

NT 1.3 On receipt of the awake signal SIG 2W, the NT1 responds with SIG 1W and starts transmission of SIG 1A on expiry of timer Tn1, unless a new awake signal SIG 2W from the LT is received.

NT 1.4 After completion of the awake procedure, the NT1 waits for SIG 2 to synchronize its receiver.

NT 1.5 The receiver on the network side is synchronized. The NT1 sends SIG 1 to the LT and INFO 2 to the user side to initiate the activation of the interface of reference point T. It waits for the receipt of INFO 3.

NT 1.6 The interface at T reference point is synchronized in both directions of transmission. The NT1 sends SIG 3 to the LT and waits for the receipt of SIG 4H.

NT 1.7 The NT1 is fully active and sends INFO 4 to the user side and SIG 5 to the LT. The B and D channels are operational.

NT 1.8 Pending deactivation state. The NT1 sends INFO 0 to the user side to deactivate the interface at reference point T and SIG 0 to the LT. It waits for the receipt of INFO 0 or expiry of timer T2 to enter state NT 1.1.

NT 1.9 This state is entered on loss of signal or loss of framing at the T interface. No indication is sent to the LT, in accordance with Note 3 to Table 4/I.430.

NT 1.10 This state is entered on loss of framing at the line side. An indication is forwarded to the user side (INFO X) and to the network side (SIG 0).

The following states support activation when loopback 2 is requested:

NT 2.1 The receiver on the network side is synchronized. The NT1 sends SIG 3 to the LT and INFO 2 to the user side (transparent loopback). It waits for the receipt of SIG 4H-L2 from the LT.

NT 2.2 The NT1 is fully active and sends INFO 4 to the user side (transparent loopback) and SIG 5 to the LT. Loopback 2 is operated and receive data 2B + D are sent to the LT.

I.10.5 LT state transition table

The LT state transition table is described in Table I.2. SIGs on the line system are related to function elements (FEs) on the V_1 reference point.

The following states are used:

LT 1.1 Deactivated state. No signal is transmitted.

LT 1.2 On receipt of the awake signal SIG 1W, the LT responds with SIG 2W and starts transmission of SIG 2 on expiry of timer Tl1, unless a new awake signal SIG 1W from the NT1 is received.

LT 1.3 The LT sends the awake signal SIG 2W to the NT1, on the receipt of FE 1, and waits for the awake acknowledge signal SIG 1W from the NT1.

LT 1.4 The LT sends SIG 2 to the NT1 and waits for SIG 1 or SIG 3 to synchronize its receiver. When the LT is synchronized and has detected SIG 1, it issues FE 3.

LT 1.5 The line transmission system is synchronized in both directions of transmission. The LT waits for the receipt of SIG 3.

TABLE I.2/G.961

LT state transition table

State →	LT 1.1	LT 1.2	LT 1.3	LT 1.4	LT 1.5	LT 1.6	LT 1.7	LT 1.8	LT 2.1	LT 2.2	LT 2.3	LT 2.4
Transmit signal Receive signal	SIG 0	SIG 2W	SIG 2W	SIG 2	SIG 2	SIG 4H	SIG 4	SIG 0	SIG 2W	SIG 2	SIG 4H	SIG 4
FE 1	LT 1.3	–	–	–	–	–	–	–	–	–	–	–
FE 5	:	LT 1.8	LT 1.8	LT 1.8	LT 1.8	LT 1.8	LT 1.8	–	LT 1.8	LT 1.8	LT 1.8	LT 1.8
SIG 0	–	–	–	–	FE 7; –	FE 7; –	FE 7; –	FE 6; LT 1.1	–	–	–	–
SIG 1W	ST.TI1, FE 2; LT 1.2	:	LT 1.4	/	/	/	/	–	–	/	/	/
SIG 1	/	/	/	FE 3; LT 1.5	–	/	/	–	/	–	–	–
SIG 3	/	/	/	ST.TI2; LT 1.6	ST.TI2; LT 1.6	–	–	–	/	–	–	–
Exp. of intern. timer TI1	–	LT 1.4	–	–	–	–	–	–	–	–	–	–
Exp. of intern. timer TI2	–	–	–	–	–	FE 7; LT 1.4	–	–	–	–	FE 4; LT 2.4	–
Lost framing line system	/	/	/	/	FE 7; –	FE 7; –	FE 7; –	–	/	/	/	/

TABLE I.2/G.961 *(end)*

LT state transition table

State →	LT 1.1	LT 1.2	LT 1.3	LT 1.4	LT 1.5	LT 1.6	LT 1.7	LT 1.8	LT 2.1	LT 2.2	LT 2.3	LT 2.4
Transmit signal / Receive signal	SIG 0	SIG 2W	SIG 2W	SIG 2	SIG 2	SIG 4H	SIG 4	SIG 0	SIG 2W	SIG 2	SIG 4H	SIG 4
FE 4	ST.Tl4; LT 2.1	–	LT 2.2 or –	LT 2.2 or –	LT 2.2 or –	–	–	LT 2.1	:	:	:	:
Exp. of intern. timer Tl4	–	–	–	–	–	–	–	–	LT 2.2	–	–	–
Rec. synch. on looped b. sig.	/	/	/	–	–	–	–	–	/	ST.T12; LT 2.3	–	–

– No state change.
/ Impossible by the definition of peer-to-peer physical layer procedures or system internal reasons.
: Impossible by the definition of the physical layer.
a, b; LT x Perform action/issue message a and b; enter state LTx.
ST.Tlx Start Timer Tlx.

LT 1.6 The line transmission system and the interface at T reference point are synchronized in both directions of transmission. The LT sends SIG 4H until the expiry of timer Tl2.

LT 1.7 Fully active state. The LT sends SIG 4 to the NT1 and issues FE 4. The B and D channels are fully operational.

LT 1.8 Pending deactivation state. The LT sends SIG 0 to the NT1 to deactivate the line system and the interface at T reference point. It waits for the receipt of SIG 0 to enter state LT 1.1 and to issue FE 6.

The following states support activation when loopback 1 is requested:

LT 2.1 The LT sends the awake signal SIG 2W to the NT1 (transparent loopback), on the receipt of FE 9, and starts transmission of SIG 2 on expiry of timer Tl4.

LT 2.2 The LT has operated loopback 1 and is synchronizing its receiver on the looped back signal.

LT 2.3 The LT sends SIG 4H until the expiry of timer Tl2.

LT 2.4 The LT is fully active and sends SIG 4 to the NT1 (transparent loopback). Loopback 1 is operated.

The LT state transition table is not affected by loopback 2 and 1A requests. The corresponding control signals are transferred across channels C_{v_1} and C_L.

I.10.6 Activation times

For definition of activation times see 5.5/G.960.

a) Maximum activation time for activation occurring immediately after a deactivation:

   – without regenerator: 210 ms

   – with regenerator: 420 ms.

b) Maximum time for activation occurring after the first powering of a line:

   – without regenerator: 1.5 s

   – with regenerator: 3 s.

I.11 Jitter

Jitter tolerances shall assure that the maximum network limit of jitter (see Recommendation G.823) is not exceeded.

Furthermore, the limits of Recommendation I.430 must be 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 local line and the inclusion of repeaters, provided that they are covered by the transmission media characteristic (see 3). The limits must be met regardless of the transmitted signal. A suitable test sequence is for further study (see 4/G.823).

I.11.1 Limits of maximum tolerable input jitter

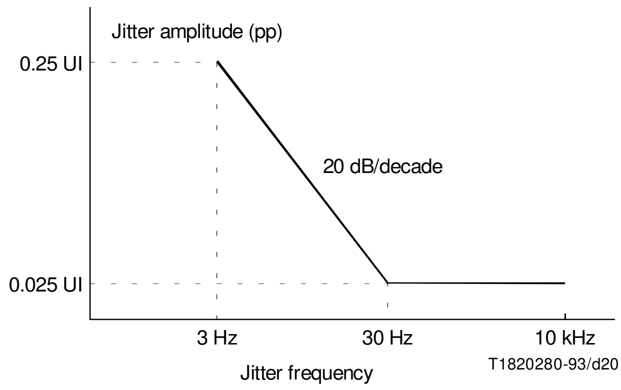
The amplitude of the jitter at the NT1 input shall be limited by the template given in Figure I.3.

I.11.2 Output jitter of NT1 in absence of input jitter

When measured with a highpass filter with a 30 Hz cut-off frequency, the jitter at the output of the NT1 shall not exceed 0.02 UIpp. Without a filter, the jitter shall not exceed 0.1 UIpp.

I.11.3 Timing extraction jitter

The jitter at the output of the NT1 shall closely follow the input jitter. Therefore, the jitter transfer function of the NT1 shall be less than ± 1 dB in the frequency range 3 Hz to 30 Hz.



1 UI = 1/120 kHz = 8.$\overline{3}$ μs

FIGURE I.3/G.961

Minimum tolerable sinusoidal input jitter

I.11.4 Test conditions for jitter measurements

For further study.

I.12 Transmitter output characteristics

I.12.1 Pulse amplitude

The amplitude of a transmitted single pulse shall be 2 V ± 0.2 V with a load impedance of 150 ohm.

I.12.2 Pulse shape

The shape of a transmitted single pulse shall fit the mask given in Figure I.4.

I.12.3 Signal power

Not specified.

I.12.4 Power spectrum

The upper bound of the power spectral density shall be limited according to Figure I.5.

I.12.5 Transmitter signal nonlinearity

Not specified.

I.13 Transmitter/receiver termination

I.13.1 Impedance

The nominal output/input impedance of the NT1 and LT shall be 150 ohms.

I.13.2 Return loss

The return loss against 150 ohms ± 1% measured for NT1 or LT shall exceed the limits given in Figure I.6.

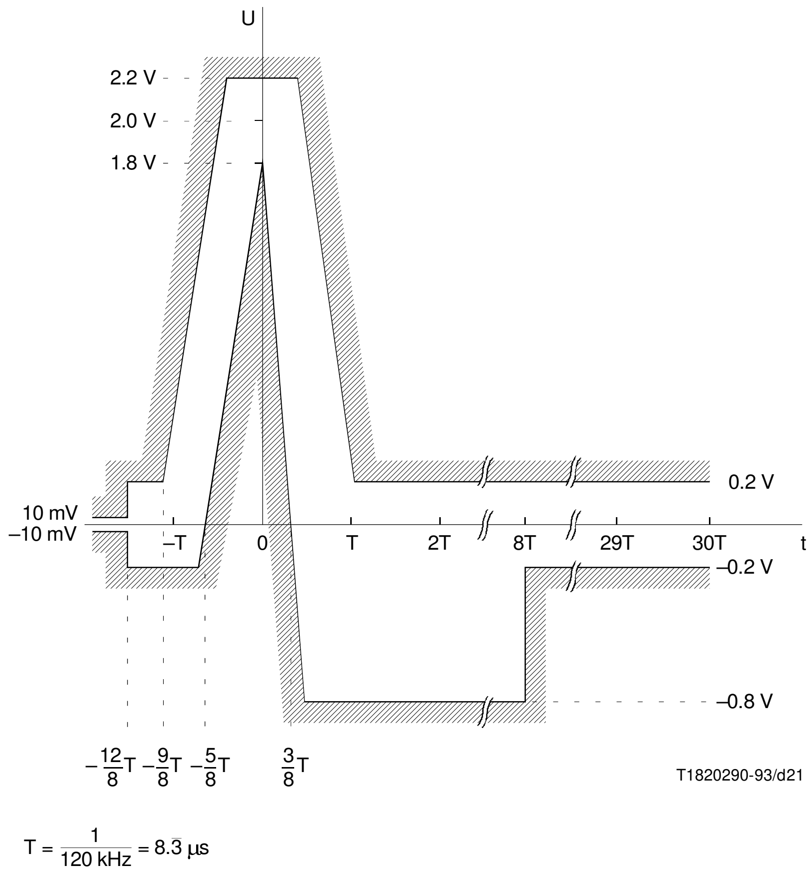


FIGURE I.4/G.961

Pulse mask for transmitted single pulse

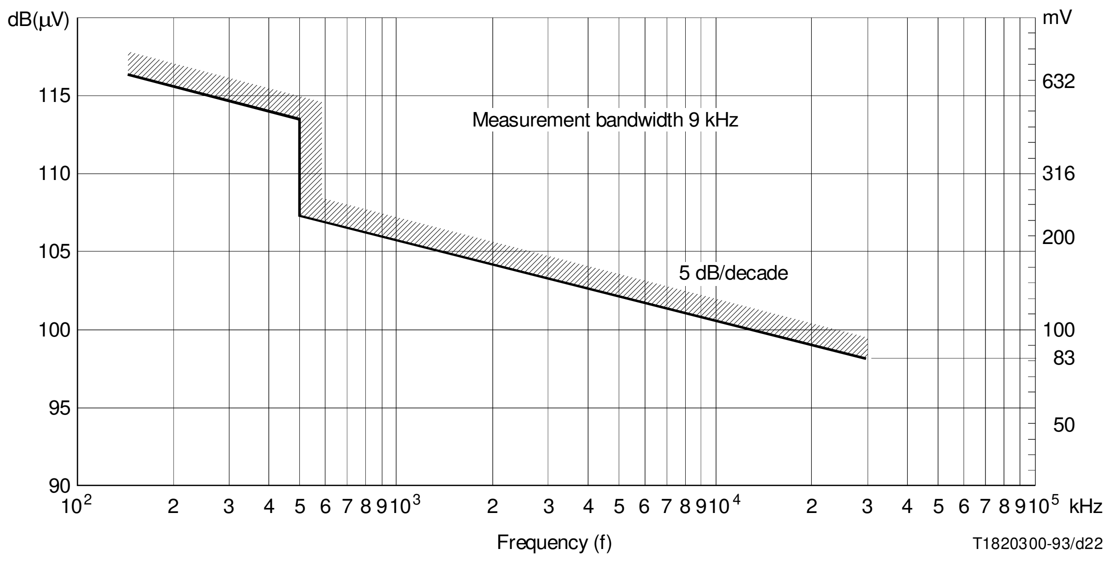


FIGURE I.5/G.961

Limits of transmit power spectrum

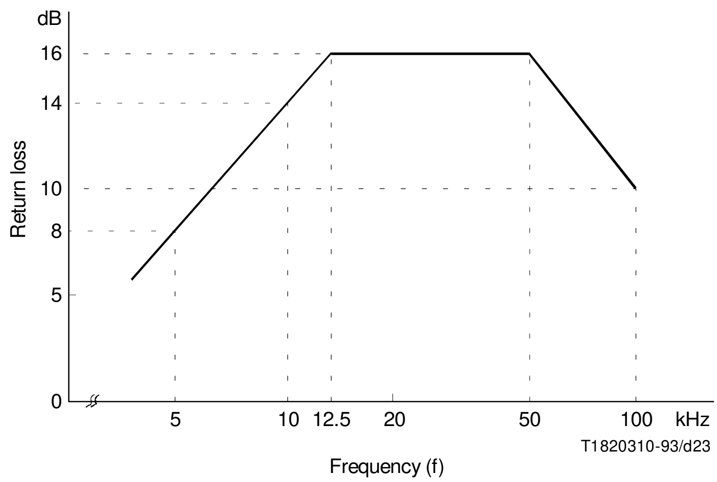


FIGURE I.6/G.961

NT1 and LT return loss

I.13.3 Longitudinal conversion loss

The longitudinal conversion loss at the line interface for LT and NT1 shall exceed the limits given in Figure I.7.

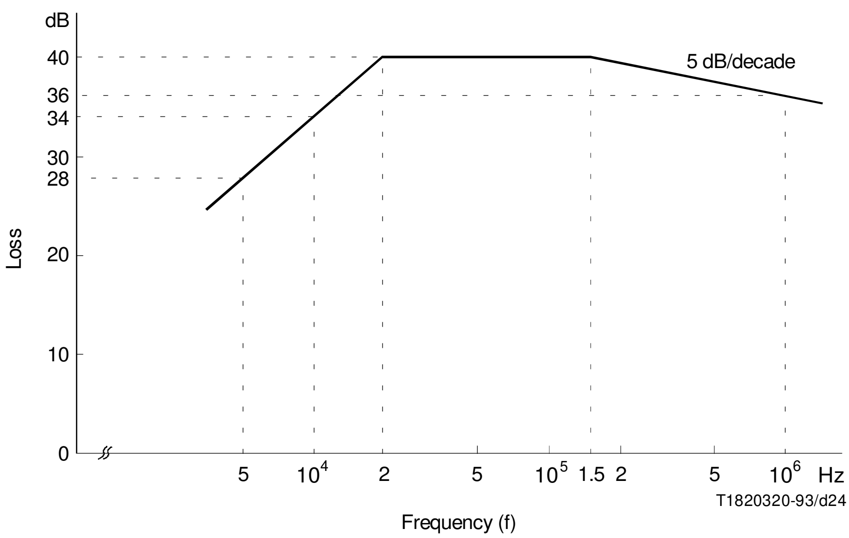


FIGURE I.7/G.961

Longitudinal conversion loss

Annex A

Extension functions and requirements for a line system with MMS 43 line code

(This annex does not form an integral part of this Recommendation)

No extension functions and requirements have been defined yet.

Appendix II

Core requirements for a system using 2B1Q line code

(This appendix does not form an integral part of this Recommendation)

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 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 C_L-channel are also paired, coded and scrambled in the same way.

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:

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

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 C_L-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.

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 ± 100 ppm.

II.2.1.2 LT clock tolerance

The tolerance of the clock provided at the LT is ± 5 ppm.

Time ⟶

Data	B_1				B_2				D
Bit Pairs	b_{11} b_{12}	b_{13} b_{14}	b_{15} b_{16}	b_{17} b_{18}	b_{21} b_{22}	b_{23} b_{24}	b_{25} b_{26}	b_{27} b_{28}	d_1 d_2
Quat # (relative)	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9
# Bits # Quats	8 4				8 4				2 1

T1814300-92/d25

b_{11} First bit of B_1 octet as received at reference point T
b_{18} Last bit of B_1 octet as received at reference point T
b_{21} First bit of B_2 octet as received at reference point T
b_{28} Last bit of B_2 octet as received at reference point T
d_1 d_2 Consecutive D-channel bits (d_1 is first bit of pair as received at reference point T)
q_i ith quat relative to start of given 18-bit 2B + D data field

NOTE – There are 12 2B + D 18-bit fields per 1.5 ms basic frame.

FIGURE II.1/G.961

2B1Q encoding of 2B + D bit fields

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 C_L-channel bits shown in Figure II.2.

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 is shown in Figures II.1 and II.2.

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 C_L-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:

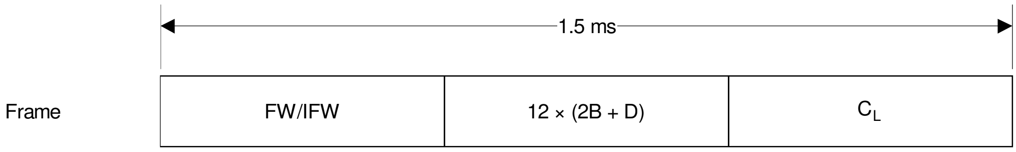
$$FW = +3\ +3\ -3\ -3\ -3\ +3\ -3\ +3\ +3$$

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.



Function	Frame word	2B + D	Overhead
# Quats	9	108	3
Quat positions	1-9	10-117	118-120
# Bits	18	216	6
Bit positions	1-18	19-234	235-240

T1814310-92/d26

Symbols and abbreviations:

quat	Quaternary symbol = 1 baud
–3, –1, +1, +3	Symbol names
2B + D	Customer data channels B_1 , B_2 and D
FW	Frame Word (9-Symbol Code) = +3 +3 –3 –3 –3 +3 –3 +3 +3
IFW	Inverted (or complementary) frame word = –3 –3 +3 +3 +3 –3 +3 –3 –3
C_L	M-channel bits, M_1 to M_6

NOTE – Frames in the NT1-to -Network direction are offset from frames in the Network-to -NT1 direction by 60 ± 2 quats.

FIGURE II.2/G.961

Frame structure of 2B1Q transmission system

II.5 Frame alignment procedure

A unique frame alignment procedure is not specified. However, the time limits specified in II.10 shall be met.

II.6 Multiframe

To enable the allocation of the C_L-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 eight.

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 ± 2 quaternary symbols (i.e. about 0.75 ms).

II.8 C_L-channel

The C_L-channel consists of the last three symbols (6 bits) in each basic frame of the multiframe.

II.8.1 Bit rate

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

II.8.2 Structure

Forty-eight bits of a multiframe are used for the C_L-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.

		Framing	2B + D	C_L (overhead) bits M_1-M_6					
	Quat positions	1-9	10-117	118 s	118 m	119 s	119 m	120 s	120 m
	Bits positions	1-18	19-234	235	236	237	238	239	240
Multiframe No.	Basic frame No.	Frame word	2B + D	M_1	M_2	M_3	M_4	M_5	M_6
		LT to NT1							
A	1	IFW	2B + D	EOC_{a1}	EOC_{a2}	EOC_{a3}	ACT	1	1
	2	FW	2B + D	EOC_{dm}	EOC_{i1}	EOC_{i2}	DEA	1	FEBE
	3	FW	2B + D	EOC_{i3}	EOC_{i4}	EOC_{i5}	1	CRC_1	CRC_2
	4	FW	2B + D	EOC_{i6}	EOC_{i7}	EOC_{i8}	1	CRC_3	CRC_4
	5	FW	2B + D	EOC_{a1}	EOC_{a2}	EOC_{a3}	1	CRC_5	CRC_6
	6	FW	2B + D	EOC_{dm}	EOC_{i1}	EOC_{i2}	1	CRC_7	CRC_8
	7	FW	2B + D	EOC_{i3}	EOC_{i4}	EOC_{i5}	UOA	CRC_9	CRC_{10}
	8	FW	2B + D	EOC_{i6}	EOC_{i7}	EOC_{i8}	AIB	CRC_{11}	CRC_{12}
B, C, …									
		NT1 to LT							
1	1	IFW	2B + D	EOC_{a1}	EOC_{a2}	EOC_{a3}	ACT	1	1
	2	FW	2B + D	EOC_{dm}	EOC_{i1}	EOC_{i2}	PS_1	1	FEBE
	3	FW	2B + D	EOC_{i3}	EOC_{i4}	EOC_{i5}	PS_2	CRC_1	CRC_2
	4	FW	2B + D	EOC_{i6}	EOC_{i7}	EOC_{i8}	NTM	CRC_3	CRC_4
	5	FW	2B + D	EOC_{a1}	EOC_{a2}	EOC_{a3}	CSO	CRC_5	CRC_6
	6	FW	2B + D	EOC_{dm}	EOC_{i1}	EOC_{i2}	1	CRC_7	CRC_8
	7	FW	2B + D	EOC_{i3}	EOC_{i4}	EOC_{i5}	SAI	CRC_9	CRC_{10}
	8	FW	2B + D	EOC_{i6}	EOC_{i7}	EOC_{i8}	1*	CRC_{11}	CRC_{12}
2, 3, …									

ACT Activation bit (set to ONE during activation)

AIB Alarm indication bit (ZERO indicates interruption)

CRC Cyclic redundancy check: covers 2B + D and M4

1 Most significant bit
2 Next most significant bit
etc.

CSO Cold-start-only bit (ONE indicates cold-start-only)

DEA Deactivation bit (set to ZERO to announce deactivation)

EOC Embedded operations channel

a Address bit
dm Data/message indicator
i information (data/message)

FEBE Far end block error bit (ZERO for errored multiframe)

NTM NT1 in test mode bit (ZERO indicates test mode)

PS_1, PS_2 Power status bits (ZERO indicates power problems)

quat Pair of bits forming quaternary symbol

s Sign bit (first) in quat
m Magnitude bit (second) in quat

SAI S-activation indicator bit (optional, set = 1 for S/T activity)

UOA DLL-only-bit (optional, set = 1 to activate S/T

1 Reserve bit for future standard; set = ONE

1* Network indicator bit; reserved for network use, set = ONE

2B + D User data, bits 19-234 in basic frame

M C_L-channel, bits 235-240 in basic frame

FW/IFW Frame word/inverted frame word, bits 1-18 in frame

NOTES

1 8 × 1.5 ms. Basic frames → 12 ms. Multiframe.

2 NT1-to-Network multiframe delay offset from Network-to-NT1 multiframe by 60 ± 2 quats (about 0.75 ms).

3 All bits other than the frame work are scrambled.

FIGURE II.3/G.961

2B1Q multiframe technique and overhead bit assignments

II.8.3 Protocol and procedures

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

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:

$$P(x) = x^{12} \oplus x^{11} \oplus x^3 \oplus x^2 \oplus x \oplus 1$$

where

$\oplus$ = modulo 2 summation.

One method of generating the CRC code for a given multiframe is illustrated in Figure II.4. 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 multiframe 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 C_L-channel 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 subclauses. To reflect a change in status, a new value for M_4 bits shall be repeated in at least three consecutively transmitted multiframes.

II.8.3.2.1 Far end block error (FEBE) bit, mandatory

The FEBE bits shall be the M_6 bits in the second basic frame of the multiframes transmitted by either transceiver. 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, mandatory

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). If a Loopback 2 (2B + D) is requested, the ACT bit (from NT to LT) is set to binary ONE after time T7 (see Figure II.6) as part of the loopback start-up sequence to communicate readiness to loopback data. This use of the ACT bit for Loopback 2 is recommended. However, some existing implementations may not set ACT = 1 for Loopback 2.

II.8.3.2.3 The DEA bit, mandatory

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). 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 at least three successive multiframes before terminating transmission of signal.

II.8.3.2.4 NT1 power status bits

The M_4 bits in the second and third basic frames of multiframes transmitted by the NT1 (Figure II.3) are reserved for NT1 power status indication; their use is optional. When not used, these bits shall be set to ONE in SN3. See Annex A to Appendix II.

II.8.3.2.5 NT1 test mode indicator (NTM) bit

The M_4 bit in the fourth basic frame of multiframes transmitted by the NT1 to the network (Figure II.3) is reserved for NT1 test mode indication; its use is optional. If this function is not used, the bit shall be set to ONE in SN3. See Annex A to Appendix II.

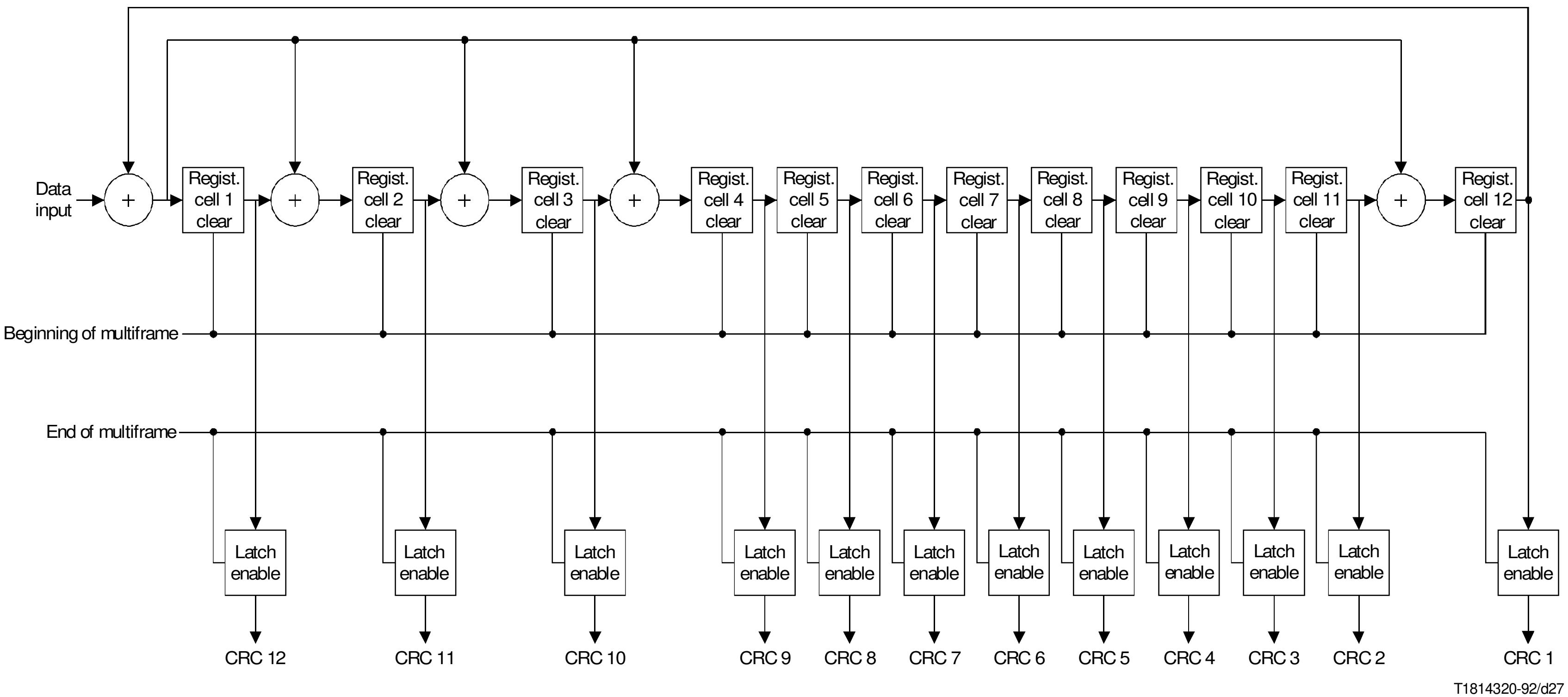


FIGURE II.4/G.961

CRC-12 generator

II.8.3.2.6 Cold-start-only (CSO) bit

The M_4 bit in the fifth frame of the multiframe transmitted by an NT1 is reserved for cold-start-only indication; its use is optional. If this function is not used, this bit shall be set to ZERO in SN3. See Annex A to Appendix II.

II.8.3.2.7 DLL-only-activation (UOA) bit

The M_4 bit in the seventh basic frame of multiframes transmitted by an LT is reserved for DLL-only-activation; its use is optional. If this function is not used, this bit shall be set to ONE in SL2 and SL3. See Annex A to Appendix II.

II.8.3.2.8 S/T-interface-activity-indicator (SAI) bit

The M_4 bit in the seventh basic frame of the multiframes transmitted by an NT1 is reserved for S/T-interface-activity-indication; its use is optional. If this function is not used, this bit shall be set to ONE in SN3. See Annex A to Appendix II.

II.8.3.2.9 Alarm indicator bit (AIB)

The M_4 bit in the eighth basic frame of the multiframes transmitted by the network toward the NT1 is reserved for the alarm indicator bit; its use is optional. If this function is not used, the AIB bit shall be set to ONE in SN3. See Annex A to Appendix II.

II.8.3.2.10 Network indicator bit (NIB) for network use

The NIB bit shall be the M_4 bit in the eighth basic frame of multiframes transmitted by the NT1 toward the network. The NT1 shall always set this bit to binary ONE in SN3.

NOTE – The use of NIB at the LT or in the REG is beyond the scope of this Recommendation.

II.8.3.2.11 Reserved bits

All bits in M_4, M_5, and M_6 not 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 kbit/s) are allocated to an embedded operations channel (EOC) which supports operations communications needs between the network and the NT1.

NOTE – The use of the EOC functions for REG mode and the necessary messages is beyond the scope of this Recommendation.

II.8.3.3.1 EOC frame

The EOC frame shall be composed of 12 bits synchronized to the multiframe (see Table II.1).

TABLE II.1/G.961

The EOC frame layout

Bits	3	1	8
Function provided	Address field	Data/msg indicator	Info field

The three-bit address field may be used to address up to seven 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).

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 (data/message bit set to binary ONE) 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).

If an NT1, not implementing EOC data transfer functions, receives a data byte (Data/message bit set to binary ZERO) in a properly-addressed EOC frame, rather than echo on the third and subsequent receipts of that same correctly-addressed EOC frame, it shall return the Unable to Comply message in the next available EOC frame.

The protocol specification 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:

	Node	Address
	NT1	000
Broadcast	(all nodes)	111

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**: This function directs the NT1 to loop back the user-data (2B + D) bit stream toward the network. This loopback 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 B_1-channel (or B_2-channel) loopback**: This function directs the NT1 to loop back 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. The implementation and operation of the individual B-channel loopbacks is optional.

3) **return to normal**: The 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**: This 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**: This message requests the sending of corrupt CRCs toward the network, until cancelled with return to normal.

6) **notify of corrupted CRC**: This 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**: This 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 shows the codes for each of the EOC functions defined in II.8.3.3.4.

TABLE II.2/G.961

Messages required for command/response EOC mode

Message	Origin (o) & destination (d)		
	Message code	Network	NT1
Operate 2B + D loopback	0101 0000	o	d
Operate B_1-channel loopback[a)]	0101 0001	o	d
Operate B_2-channel loopback[a)]	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

a) The use of B_1- and B_2-channel loopbacks is optional. However, the loopback codes are reserved for these functions.

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. Another 64 EOC message codes have been reserved for internal network use in the following four blocks of 16 codes each (x is ONE or ZERO): 0110 xxxx, 0111 xxxx, 1000 xxxx, 1001 xxxx. All remaining codes not defined in Table II.2 and not reserved for non-standard applications or for internal network use are reserved for future standardization. Thus, 120 codes associated with the NT1 (000) and broadcast (111) addresses, are available for future standardization, i.e. 256 total codes, minus eight defined codes from the table, minus 64 codes for non-standard applications, minus 64 codes for internal network use.

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) prior to the insertion of FW.

In the LT-NT1 direction the polynomial shall be:

$$1 \oplus x^{-5} \oplus x^{-23}$$

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 ONEs.)

II.10 Start-up and control

This subclause gives requirements for the start-up and turn-off processes, including examples of 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. A specification of a procedure enabling the transmission system to be activated without activating the interface at reference point T is given in Annex A to Appendix II on extension functions.

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

1) **total activation**: The word activation is used here to describe a process that includes the start-up process as given in 2) below and activation as given in Recommendation I.430.

2) **start-up**: A 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 cancellers to the point that two-way transmission requirements are met.

3) **warm-start**: The 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.

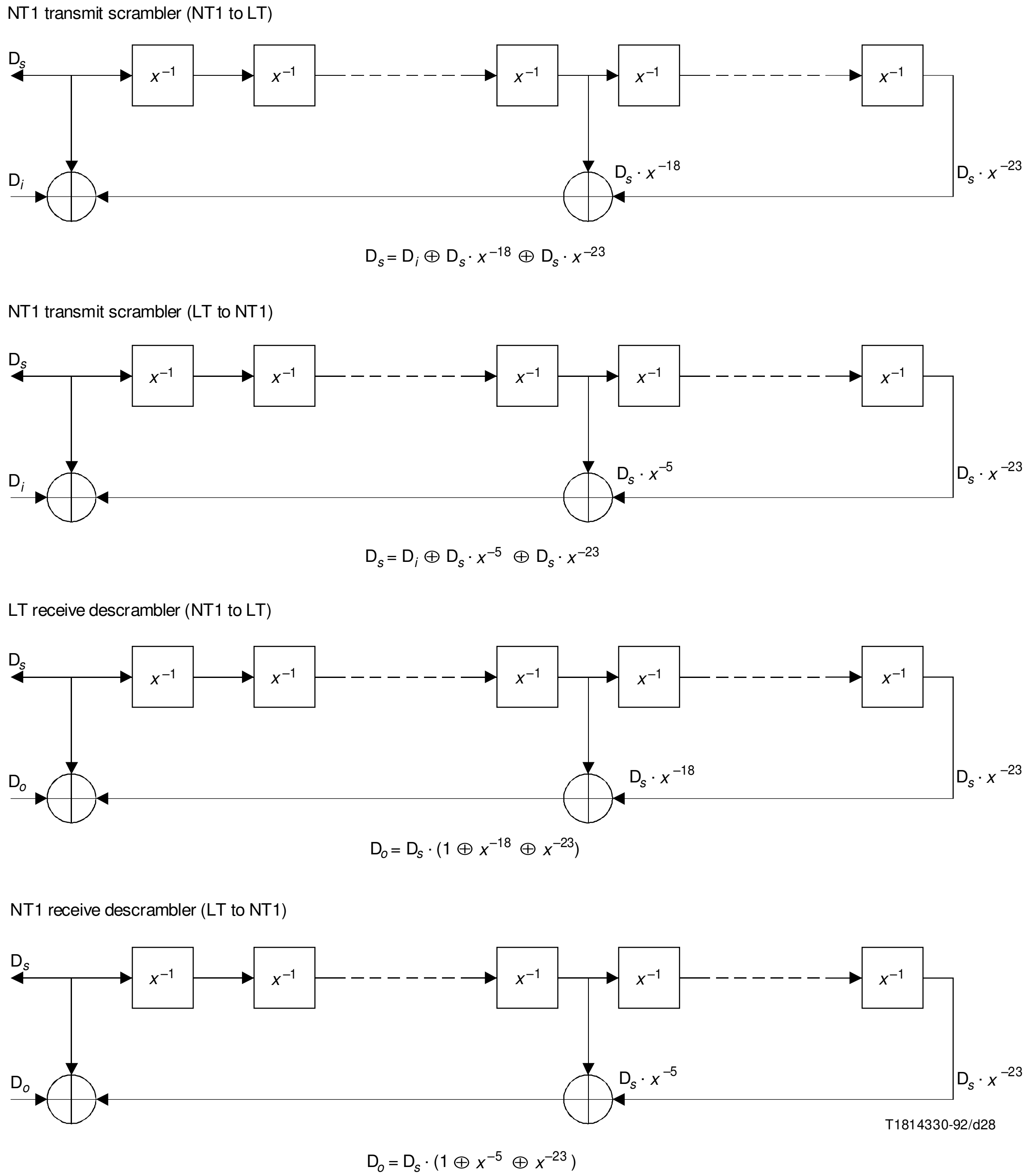


FIGURE II.5/G.961

Scrambler and descrambler

4) **cold-start**: The 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.

5) **cold-start-only**: NT1 transceivers that do not meet optional warm-start activation-time requirements (see II.10.6) are called cold-start-only transceivers. The use of cold-start-only transceivers is optional.

6) **full operational status**: Full operational status of a transceiver means that it has:

   a) acquired bit timing (for NT1); bit timing phase (for LT), and frame synchronization from the incoming signal from the other transceiver;

   b) recognized the incoming multiframe marker; and

   c) fully converged both echo canceller and equalizer coefficients.

7) **deactivation**: The word deactivation is used here to describe a process that includes the turn-off process as given in 8) below and deactivation of the S/T interface as given in Recommendation I.430.

8) **turn-off**: The process by which a pair of fully operational transceivers transition to the RESET state.

9) **RESET**: The RESET state consists of two sub-states: the RECEIVE RESET and the FULL RESET states. In other subclauses 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 canceller coefficients of the transceiver.

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

10) **FULL RESET**: The 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 DLL).

   The FULL RESET state shall also be entered following power up.

   While in FULL RESET, NT1s may initiate transmission only if responding to a new power off/on cycle or to a new request for service from the customer terminal (TE). Under all other conditions, where the transceivers have been turned off (see II.10.1.5.2), the NT1s shall remain quiet, i.e. they shall not start transmitting any signal until they have received the TL signal (start-up tone) from the network.

11) **RECEIVE RESET**: The 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 DLL). In addition, the transceiver 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). Unless it responds to a 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.

12) **power down state**: While in RESET state, an NT1 may be in this condition. The NT1 consumes less power but is capable of detecting TL from the network side and/or INFO 1 from the user side.

13) **transparency**: The word transparency is used in this Recommendation to mean that the B_1-, B_2-, D-channel (2B + D) bits received by the transceiver on the interface are passed to the TE at the NT and to the network at the LT. Likewise, when a transceiver is transparent, 2B + D bits sent to the transceiver at the LT from within the network or at the NT from the TE are transmitted on the interface. Conversely, when a transceiver is not transparent, 2B + D bits received on the interface are not passed along to the

TE at the NT or to the network at the LT. Likewise, when a transceiver is not transparent, 2B + D bits from within the network at the LT or from the TE at the NT are not transmitted on the interface. Transparency applies separately to each transceiver. Conditions for transparency are discussed in II.10.3.4.

II.10.1 Signals used for start-up and control

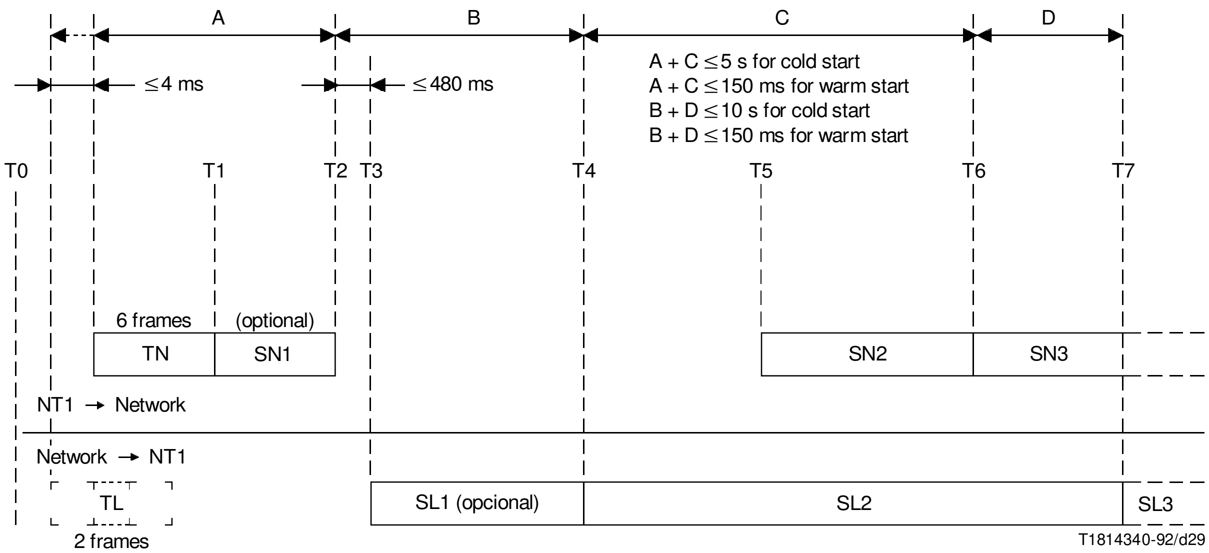
II.10.1.1 Signals during start-up

Figure II.6 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.

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 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, all the pulse sequences are framed and multiframed in accordance with the normal frame structure shown in Figures II.1, II.2 and II.3, 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:

. . . +3 +3 +3 +3 –3 –3 –3 –3 . . .



Time: Description of event or state:

T0 RESET state.
T1 Network and NT1 are awake.
T2 NT1 discontinues transmission, indicating that the NT1 is ready to receive signal.
T3 Network responds to termination of signal and begins transmitting signal toward the NT1.
T4 Network begins transmitting SL2 toward the NT1, indicating that the network is ready to receive SN2.
T5 NT1 begins transmitting SN2 toward the network, indicating that NT1 has acquired FW frame and detected SL2.
T6 NT1 has acquired multiframe marker, and fully operational.
T7 Network has acquired multiframe marker, and is fully operational.

FIGURE II.6/G.961

State sequence for transceiver start-up

Signal	Frame word (FW)	Multiframe (IFW)	2B + D	M	Start	Stop	Times (frames)
TN	± 3 ϒ	± 3 ϒ	± 3 ϒ	± 3 ϒ	♦	♦	6
SN1	Present	Absent	1	1	T1	T2	–
SN2	Present	Absent	1	1	T5	T6	–
SN3	Present	Present	Normal+	Normal	T6	*	–
TL	± 3 ϒ	± 3 ϒ	± 3 ϒ	± 3 ϒ	♦	♦	2
SL1	Present	Absent	1	1	T3	T4	–
SL2	Present	Present	0	Normal	T4	T7	–
SL3	Present	Present	Normal+	Normal	T7	*	–

ϒ Tones have alternating pattern of four +3 symbols followed by four –3 symbols, and no FW.

♦ See Figures II.6 and II.10.1.3 for start and/or stop time of this signal.

TN, TL Tones produced by NT1 or LT, respectively (see II.10.1.1).

SNx, SLx Pulse patterns produced by NT1 or LT, respectively.

Tx Notation refers to transition instants defined in Figure II.6.

Absent Under multiframe this notation means only that FW is transmitted instead of IFW.

Normal Normal means that the M bits are transmitted onto the 2-wire line as required during normal operation; e.g. valid CRC bits, EOC bits, and indicator bits are transmitted.

Normal+ Except to perform a loopback, 2B + D bits shall remain in the previous state (SN2 or SL2) until both ACT bits indicate full transparency of the B- and D-channels (i.e. the 2B + D bits of SN3 and SL3 shall remain set to ONE and ZERO, respectively, until transparency is achieved at both ends of the DLL).

* Signals SN3 and SL3 continue indefinitely (or until turn-off).

FIGURE II.7/G.961

Definitions of signal during start-up

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 ± 100 ppm.

II.10.1.3 Start-up sequence

Figure II.6 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. 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 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.

II.10.1.5 Progress indicators

II.10.1.5.1 Start-up

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 INFO 3. To communicate this progress indication, ACT from the NT1 is set to ONE. Assuming INFO 3 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) 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

All transceivers shall cease transmission following loss of received signal. There are different turn-off procedures for transceivers that have achieved full operational status than for tranceivers that have not (see II.10.2).

The network may take advantage of the capabilities of warm-start NT1s by announcing turn-off. In announcing turn-off, the network shall change DEA from binary ONE to ZERO in at least three consecutive multiframes before ceasing transmission. It shall cease transmission before sending the DEA bit in the multiframe following the multiframe in which DEA = ZERO is sent for the last time.

During multiframes with DEA = ZERO, the NT1 has time to prepare for turn-off.

After the warm-start NT1 has prepared itself for turn-off, it shall upon detection of loss of signal from the network, cease transmission and enter the RECEIVE RESET state within 40 ms of the occurrence of the transition to no signal at its interface. As specified in II.10.2, unless it responds to a TL signal from the network, 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 network side transceiver, after announcing turn-off and ceasing transmission, shall enter the FULL RESET state upon detection of loss of received signal from the NT1.

Although NT1s are not permitted to initiate turn-off, the LT shall respond to loss of signal as stated above.

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 cease transmission and, as specified in II.10.2, shall enter the RECEIVE RESET state and remain for at least 40 ms (unless it responds to a wake-up tone), after which it shall enter the FULL RESET state. The manner of entering the RECEIVE RESET state is different for the different conditions listed above.

For 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 3) 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.

For condition 2), the transceiver shall immediately enter the RECEIVE RESET state.

For conditions 2) and 3), these requirements apply to transceivers after multiframe synchronization is achieved (see T6 and T7 in Figure II.6).

In addition, an NT1 shall enter the FULL RESET state if the 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 and II.7).

II.10.3 Description of the start-up procedure

II.10.3.1 Start-up 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 and II.7. If the LT happens to try to activate at the same time, it may send a TL tone during the TN tone without harm.

For cold-start-only NT1s, start-up shall be attempted upon NT1 power-up. After an unsuccessful start-up attempt, the NT1 DLL transceiver may enter FULL RESET.

While in the RESET state, NT1 may initiate transmission only if responding to a new power off/on cycle or a new service request. Under all other conditions where the system 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 LT.

II.10.3.2 Start-up 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 and II.7.

II.10.3.3 Sequence charts

Examples of sequence charts for start-up by both terminal and ET equipment are given in Figures II.8 and II.9.

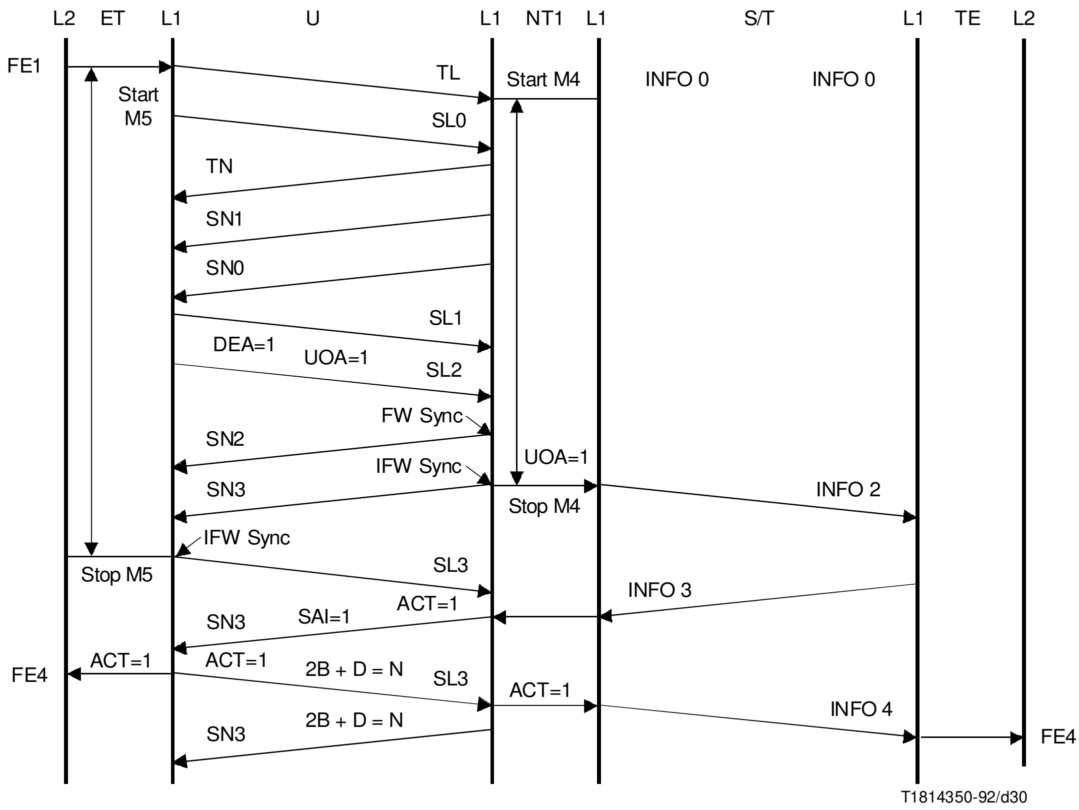
II.10.3.4 Transparency

Transparency of the transmission in both directions by the NT1 shall be provided after the NT1 achieves full operational status (T6), and both ACT = ONE from 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; and

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



NOTES

1 Receipt of INFO3 and SL3 at the NT1 can theoretically occur in either order.

2 For symbols and abbreviations see Table II.5.

3 The reading of the UOA bit is necessary only when the option “DLL-only turn-on” is implemented.

FIGURE II.8/G.961

Total activation initiated by the exchange

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; and

3) receives ACT = ONE from the NT1.

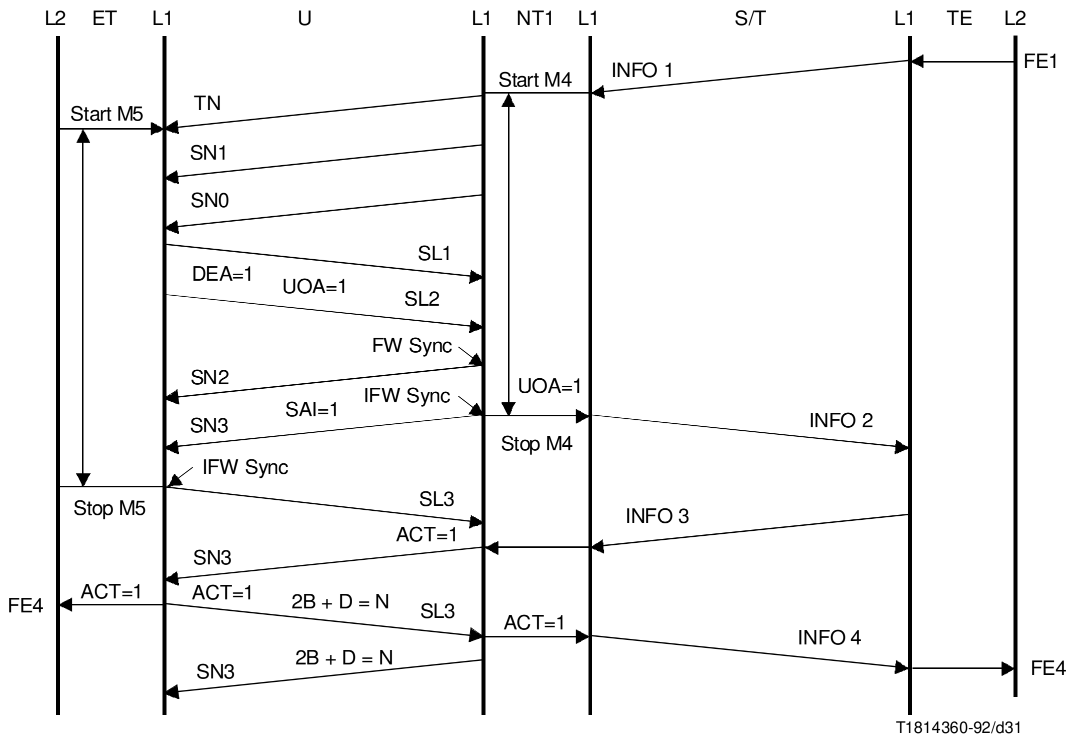
Full operational status at the LT means that the LT has:

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 canceller and equalizer coefficients.

At the LT, transparency of the B- and D-channels shall occur at any time during either the first LT transmitted superframe with ACT = ONE or during the last LT transmitted superframe with ACT = ZERO. Transparency occurs at the transition from all zeros to “normal” in the B- and D-channels in SL3. For example, referring to Figure II.1, suppose superframe A is the last transmit superframe with ACT = ZERO, superframe B is the first transmit superframe with ACT = ONE, and superframes C and D continue with ACT = ONE. The transition to transparency may occur not later than the first bit of superframe C. This means that all B- and D-channel bits in superframes C and D shall be transmitted transparently, provided that conditions for transparency have been maintained.



NOTES

1 Receipt of INFO3 and SL3 at the NT1 can theoretically occur in either order.

2 For symbols and abbreviations see Table II.5.

3 The reading of the UOA bit is necessary only when the option "DLL-only turn-on" is implemented.

FIGURE II.9/G.961

Total activation initiated by terminal equipment

At the LT, transparency of the B- and D-channels in the LT-to-network direction may occur at a different time than transparency in the LT-to-NT direction. However, in both directions the LT shall become transparent during the two transmit superframes A and B described in the example. The NT may not yet have achieved transparency during this interval.

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 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 provides an example of a state transition table for the NT1 as a function of INFOs, SIGs, and timers. For symbols, abbreviations and notes to this table, see Table II.5.

II.10.5 State transition table for the LT

Table II.4 provides an example of a state transition table for the LT as a function of FEs, SIGs, and timers. For symbols, abbreviations and notes to this table, see Table II.5.

TABLE II.3/G.961

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

Event ↓															
State name	Power off	Full reset	Alerting	EC training (optional)	EC converged	FW sync	IFW sync	Pending active	Active	Pending deacti-vation	Tear down	TE inactive	Receive reset	L2 operated TE active (Note 23)	L2 operated TE inactive (Note 23)
State code (Fig. II.6 event)	NT0	NT1 (T0)	NT2	NT3 (T1)	NT4 (T2)	NT5 (T5)	NT6 (T6)	NT7	NT8	NT9	NT10	NT11	NT12	NT7A	NT11A
Signal → LT	SN0	SN0	TN	SN1	SN0	SN2	SN3 ACT = 0	SN3 ACT = 1	SN3 ACT = 1	SN3 (Note 8)	SN0	SN3 ACT = 0	SN0	SN3 ACT = 1	SN3 ACT = 1
Signal → TE (Note 7)	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 2	INFO 2 (Note 22)	INFO 4		INFO 0	INFO 2	INFO 0	INFO 4 (Note 17)	INFO 2 (Note 17)
Power on	ST.M4 NT2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Loss of power (Note 1)	–	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0
Received new INFO 1 signal (Notes 2 and 3)	/	ST.M4 NT2 (Note 12)	–	–	–	–	–	/	/	–	–	/	–	/	–
Received INFO 3 signal (ACT = 0, DEA = 1) (Notes 2 and 4)	/	/	/	/	/	/	NT7	–	–	–	–	NT7	–	–	NT7A
Received INFO 0 or S/T loss of sync (Notes 2 and 5)	/	–	–	–	–	–	–	NT11	NT11	–	–	–	–	NT11A	–
End of tone TN (9 ms)	/	/	NT3 or NT4	/	/	/	/	/	/	/	/	/	/	/	/
Received tone TL	/	ST.M4 NT2	–	/	/	/	/	/	/	/	/	/	ST.M4 STP.M6 NT2	/	/

TABLE II.3/G.961 *(cont.)*

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

Event ↓ / State name	Power off	Full reset	Alerting	EC training (optional)	EC converged	FW sync	IFW sync	Pending active	Active	Pending deacti-vation	Tear down	TE inactive	Receive reset	L2 operated TE active (Note 23)	L2 operated TE inactive (Note 23)
State code (Fig. II.6 event)	NT0	NT1 (T0)	NT2	NT3 (T1)	NT4 (T2)	NT5 (T5)	NT6 (T6)	NT7	NT8	NT9	NT10	NT11	NT12	NT7A	NT11A
Signal → LT	SN0	SN0	TN	SN1	SN0	SN2	SN3 ACT = 0	SN3 ACT = 1	SN3 ACT = 1	SN3 (Note 8)	SN0	SN3 ACT = 0	SN0	SN3 ACT = 1	SN3 ACT = 1
Signal → TE (Note 7)	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 2	INFO 2 (Note 22)	INFO 4		INFO 0	INFO 2	INFO 0	INFO 4 (Note 17)	INFO 2 (Note 17)
Echo canceller converged	/	–	–	NT4	–	–	–	–	–	–	–	–	–	–	–
FW sync and detect SL2	/	/	/	/	NT5	–	–	–	–	–	–	–	/	–	–
IFW sync (SL2)	/	/	/	/	/	STP.M4 NT6	–	–	–	–	–	–	/	–	–
Received DEA = 0 (SL2 or SL3) (Note 6)	/	/	/	/	/	/	NT9	NT9	NT9	–	–	NT9	/	NT9	NT9
Received (SL2 or SL3) ACT = 0 and DEA = 1 (Note 1)	/	/	/	/	/	/	–	–	NT7	NT6, NT7, NT7A, NT11 or NT11A (Note 13)	–	–	/	–	–
Received (SL3) ACT = 1 and DEA = 1 (Note 1)	/	/	/	/	/	/	–	NT8	–	NT8 (Note 13)	–	–	/	–	–
Loss of synchronization (> 480 ms) (Note 1)	/	/	/	/	/	/	NT10	NT10	NT10	NT10	–	NT10	–	NT10	NT10

TABLE II.3/G.961 *(end)*

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

	State name	Power off	Full reset	Alerting	EC training (optional)	EC converged	FW sync	IFW sync	Pending active	Active	Pending deacti-vation	Tear down	TE inactive	Receive reset	L2 operated TE active (Note 23)	L2 operated TE inactive (Note 23)
	State code (Fig. II.6 event)	NT0	NT1 (T0)	NT2	NT3 (T1)	NT4 (T2)	NT5 (T5)	NT6 (T6)	NT7	NT8	NT9	NT10	NT11	NT12	NT7A	NT11A
	Signal → LT	SN0	SN0	TN	SN1	SN0	SN2	SN3 ACT = 0	SN3 ACT = 1	SN3 ACT = 1	SN3 (Note 8)	SN0	SN3 ACT = 0	SN0	SN3 ACT = 1	SN3 ACT = 1
Event ↓	Signal → TE (Note 7)	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 2	INFO 2 (Note 22)	INFO 4		INFO 0	INFO 2	INFO 0	INFO 4 (Note 17)	INFO 2 (Note 17)
Loss of signal (> 480 ms) (Notes 1 and 11)		/	/	/	/	STP.M4 NT1	–	ST.M6 NT12	ST.M6 NT12	ST.M6 NT12	/	/	ST.M6 NT12	–	ST.M6 NT12	ST.M6 NT12
Expiry of timer M4 (15 seconds) (Note 1)		/	/	/	NT10	NT10	NT10	/	/	/	/	/	/	–	/	/
Loss of signal (< 40 ms)		/	/	/	/	–	–	–	–	–	ST.M6 NT12	ST.M6 NT12	–	/	–	–
Expiry of timer M6 (40 ms) (Note 1)		/	/	/	/	/	/	/	/	/	/	/	/	NT1	/	/
Received EOC (SL3) Loopback 2 (L2) request (Notes 18 and 23)		/	/	/	/	/	/	NT11A	NT7A	NT7A	/	/	NT11A	/	–	–
Received EOC Return to normal request (Note 23)		/	/	/	/	/	/	/	/	–	–	–	–	/	NT7	NT11
NOTE – For symbols, abbreviations, and notes, see Table II.5.																

TABLE II.4/G.961

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

	State name	Power off	Full reset	Alerting	Awake	EC training (optional)	EC converged	FW sync	IFW sync	Active	Deacti vation alerting	Tear down	Pending deacti- vation	Receive reset	L2 set (Note 23)
	State code (Fig. II.6 event)	LT0	LT1 (T0)	LT2	LT3 (T1)	LT4 (T3)	LT5 (T4)	LT6	LT7 (T7)	LT8	LT9	LT10	LT11	LT12	LT8A
Event ↓	Signal → NT	SL0	SL0	TL	SL0	SL1	SL2 DEA = 1 ACT = 0	SL2 DEA = 1 ACT = 0	SL3 DEA = 1 ACT = 0 (Note 19)	SL3 DEA = 1 ACT = 1	SL3 DEA = 0 ACT = 0	SL0	SL0	SL0	SL3 DEA = 1 ACT = 1 (Note 18)
Power on		LT1	–	–		–	–	–	–	–	–	–	–	–	–
Loss of power (Note 1)		–	LT0 FE7	LT0 FE7	LT0 FE7	LT0 FE7	LT0 FE7	LT0 FE7	LT0 FE7	LT0 FE7	LT0 FE7	LT0 FE7	LT0 FE7	LT0 FE7	LT0 FE7
Activation request (FE1) or Loopback 2 request (FE8) (Note 1)		–	ST.M5 LT2 FE2	–	–	–	–	–	–	–	–	–	–	–	–
Deactivation request (FE5) (Notes 1 and 9)		–	–	–	–	–	–	–	LT9	LT9	–	–	–	–	LT9
End of tone (TL) (3 ms) Continue FE1 or FE8		/	/	LT3	/	/	/	/	/	/	/	/	/	/	/
Received tone TN Continue FE1 or FE8		/	ST.M5 LT3	–	–	/	/	/	/	/	/	/	/	ST.M5 STP.M7 LT3	/
Loss of signal energy (TN or SN1) Continue FE1 or FE8		/	/	–	LT4 or LT5	–	/	/	/	/	/	/	/	/	/

TABLE II.4/G.961 *(cont.)*

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

State name	Power off	Full reset	Alerting	Awake	EC training (optional)	EC converged	FW sync	IFW sync	Active	Deacti vation alerting	Tear down	Pending deacti-vation	Receive reset	L2 set (Note 23)
State code (Fig. II.6 event)	LT0	LT1 (T0)	LT2	LT3 (T1)	LT4 (T3)	LT5 (T4)	LT6	LT7 (T7)	LT8	LT9	LT10	LT11	LT12	LT8A
Event ↓ / Signal → NT	SL0	SL0	TL	SL0	SL1	SL2 DEA = 1 ACT = 0	SL2 DEA = 1 ACT = 0	SL3 DEA = 1 ACT = 0 (Note 19)	SL3 DEA = 1 ACT = 1	SL3 DEA = 0 ACT = 0	SL0	SL0	SL0	SL3 DEA = 1 ACT = 1 (Note 18)
Echo canceller converged Continue FE1 or FE8	/	–	–	–	LT5	–	–	–	–	–	–	–	–	–
FW sync (SN2 or SN3) Continue FE1 or FE8	/	/	/	/	/	LT6	–	–	–	–	–	–	/	–
IFW sync (SN3) Continue FE1 or FE8	/	/	/	/	/	/	STP.M5 LT7	–	–	–	–	–	/	–
Received ACT = 0 (SN3) (Note 1) (Note 21)	/	/	/	/	/	/	/	FE3	LT7	–	–	–	/	LT7
Received ACT = 1 (SN3) Continue FE1 (Note 1)	/	/	/	/	/	/	/	LT8 FE4	–	–	–	–	/	–
Loss of synchronization (> 480 ms) (Note 1)	/	/	/	/	/	/	/	LT10 FE7	LT10 FE7	LT10 FE7	–	–	–	LT10 FE7
Loss of signal (> 480 ms) Note 1)	/	/	/	LT1 (Note 16)	/	–	–	ST.M7 LT12 FE7	ST.M7 LT12 FE7	ST.M7 LT12 FE7	–	–	–	ST.M7 LT12 FE7

TABLE II.4/G.961 *(end)*

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

State name	Power off	Full reset	Alerting	Awake	EC training (optional)	EC converged	FW sync	IFW sync	Active	Deacti vation alerting	Tear down	Pending deacti- vation	Receive reset	L2 set (Note 23)
State code (Fig. II.6 event)	LT0	LT1 (T0)	LT2	LT3 (T1)	LT4 (T3)	LT5 (T4)	LT6	LT7 (T7)	LT8	LT9	LT10	LT11	LT12	LT8A
Signal → NT	SL0	SL0	TL	SL0	SL1	SL2 DEA = 1 ACT = 0	SL2 DEA = 1 ACT = 0	SL3 DEA = 1 ACT = 0 (Note 19)	SL3 DEA = 1 ACT = 1	SL3 DEA = 0 ACT = 0	SL0	SL0	SL0	SL3 DEA = 1 ACT = 1 (Note 18)
Event ↓														
End of last superframe with DEA = 0 (Note 10)	/	/	/	/	/	/	/	/	/	LT11	/	/	/	/
Expiry of timer M5 (15 seconds) (Note 1)	/	/	/	LT10 FE7	LT10 FE7	LT10 FE7	LT10 FE7	/	/	/	/	/	/	/
Absence of signal < 40 ms (Note 1)	/	–	/	/	/	–	–	–	–	–	ST.M7 LT12	LT1 FE6	–	–
Expiry of timer M7 (40 ms) (Note 1)	/	/	/	/	/	/	/	/	/	/	/	/	LT1 FE6	/
Loopback 2 request (FE8) Receiver ACT = 1 (SN3) (Notes 18 and 23)	/	/	/	/	/	/	/	LT8A FE4	–	–	–	–	–	–
Return to normal request (Note 23)	–	–	–	–	–	–	–	–	–	–	–	–	–	LT7 (Note 20)

NOTE – For symbols, abbreviations, and notes, see Table II.5.

TABLE II.5/G.961

Symbols, abbreviations and notes for Tables II.3 and II.4

Symbols and abbreviations

–	No change, no action
/	Impossible or prohibited situation under normal circumstances
FE1	Activate access (Note 1) – PH-AR
FE2	Access activation initiated (Note 1) – MPH-AWI
FE3	Access digital section activated (Note 1) – MPH-DSAI
FE4	Access activated or loopback operated (Note 1) – PH-MPH-AI
FE5	Deactivate access (Note 1) – PH/MPH-DR
FE6	Access deactivated (Note 1) – PH/MPH-DI
FE7	LOS/LFA in DS or loss of power at NT (Note 1) – PH/MPH-EI
FE8	Activate loopback 2 (Note 1) – MPH-L2AR
NTn	Go to state NTn
LTn	Go to state LTn
L2	Loopback 2
ST.Mn	Start timer Mn
STP.Mn	Stop timer Mn
SLn, SNn	Signals defined in Figures II.6 and II.7 (SL0, SN0 = no signal)
Tn	Events defined in Figures II.6 and II.7

NOTES

1 Primitives are the subject of continuing study and are significant only in combined LT/ET implementations.

2 These events are initiated at the T reference point (see Tables 6/I.430 and 4/I.430).

3 This condition represents an activation request event.

4 This condition indicates that the user data path (2B + D channels) in the TE-to-NT direction is transparent to user data.

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

6 This event takes priority over received ACT = ZERO for warm-start NTs. This event could be ignored for cold-start-only NTs.

7 S/T INFO signals are shown as transmit signals in Table II.3 which does not directly control these signals. They are included for information only.

8 The signals output in this state remain unchanged from signals output during the preceding state. (For example, ACT = ZERO if states NT6 or NT11 preceded, or ACT = ONE if states NT7 or NT8 preceded.)

9 This event will cause turn-off of the NT independent of whether the transmitter is cold-start-only or warm-start.

10 This event occurs after transmitting at least three superframes with DEA = ZERO. See II.10.1 5.2.

11 When in state NT4, absence of signal > 480 ms causes transition to state NT1.

12 When INFO 1 remains continuous after the NT fails to bring up the network side and returns to state NT1, the NT does not again go to state NT2 unless a new transition from INFO 0 to INFO 1 is received. See II.10.10 and Recommendation I.430.

13 The transceiver should return to the state from which it entered state NT9 unless the UOA or ACT bits have changed.

14 The text for this note has been removed.

TABLE II.5/G.961 *(end)*

Symbols, abbreviations and notes for Tables II.3 and II.4

NOTES

15 This note applies only for Table A.II.3, and the text is provided in Table A.II.4.

16 When in state LT3 absence of signal > 480 ms causes transition to state LTI.

17 The NT makes the transition from SN2 to SN3 transmitted toward the network upon confirmation of the loopback 2 request. In the same general time frame, the NT sends ACT = ONE toward the network, following the timing rules for transparency given in II.10.3.4. Subsequently, the NT sets loopback 2, upon confirmation of the transition of the signal from the network from SL2 to SL3.

Whether the LT should reply to the ACT = ONE signal from the NT with ACT = ONE toward the NT, and whether the NT should wait for confirmation of ACT = ONE from the network before setting the loopback are for further study.

During loopback 2, the B- and D-channels in SN3 contain the information from corresponding channels in SL3. M bits are not looped back. loopback 2 is a transparent loopback, meaning that the B-and D-channels in SL3 are also put into INFO 4 toward the TE. In state NT/A, transition to INFO 4 (from INFO 2) toward the TE is made at the same time as the transition to SN3 toward the network. However, when the TE is inactive (NT11A), INFO 2 is sent. It is not necessary to wake up the TE in this case, and indeed the purpose of the test may be to determine whether the NT is functioning properly even though communication with the TE is impossible (eg. when the TE has lost power or has become disconnected). Some existing implementations may not set ACT = ONE for loopback 2.

18 The EOC request shall not be sent before T7 (when the LT has achieved IFW sync). Before T7 EOC echoes are not received at the LT. Once T7 is reached the loopback 2 request may be sent by the network, using the EOC protocol defined in II.8.3.3.2. Once the LT confirms the receipt of SN3 and ACT = ONE from the NT, it should make the transition to SL3 (see Figure II.7). At that same time, the test signal to be used in the B-and D-channels may be sent th SL3. See Note 17 for further discussion.

19 The LT sends SL2 until transparency is achieved as described in II.10.3.4.

20 For warm-start transceivers, the return-to-normal request is usualy accompanied by a deactivation request (FE5), and when loopback 2 has been released, the LT transitions from LT8A to LT7 where, as shown in Table II.4, a number of additional transitions are available. For example, when the deactivation request has accompanied the return-to-normal request, the state quickly transitions to LT9 and eventually to LT1 or LT12 where an FE6 is sent to the ET after expiry of timer M7, and the access is deactivated.

Cold-start-only transceivers normally remain active when loopback 2 is released, and transparency depends on readiness for layer 2 communication at both ends, and the consequent setting of ACT bits in both directions. For example, the LT may move quickly from LT8A to LT7 (as shown) and then to LT8 if both ends are ready.

21 On receiving ACT = ZERO in SN3 while in state LT8 (active) or in a state LT8A (loopback 2 set) the LT retuns to state LT7. The ET maintains either FE1 or FE8 depending of whether it came from LT8 or LT8A respectively. In state LT8. receipt of ACT = ZERO means loss of layer 2 communication with the TE.

22 In state NT7, SN3 is sent only when transparency for layer 2 communication or for a loopback is achieved. Otherwise SN2 is sent.

23 Aspects relating to loopback 2 are provisional.

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: transceivers shall synchronize within 300 ms on warm starts and within 15 s on cold starts. The 15 s 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 for details.

NOTE – The 300 ms requirement applies to laboratory tests only. No 300 ms timer is involved in actual in-service DLLs. See definitions in II.10 for warm and cold starts.

As indicated in Figure II.6, 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 15 s. This is a 95% value.

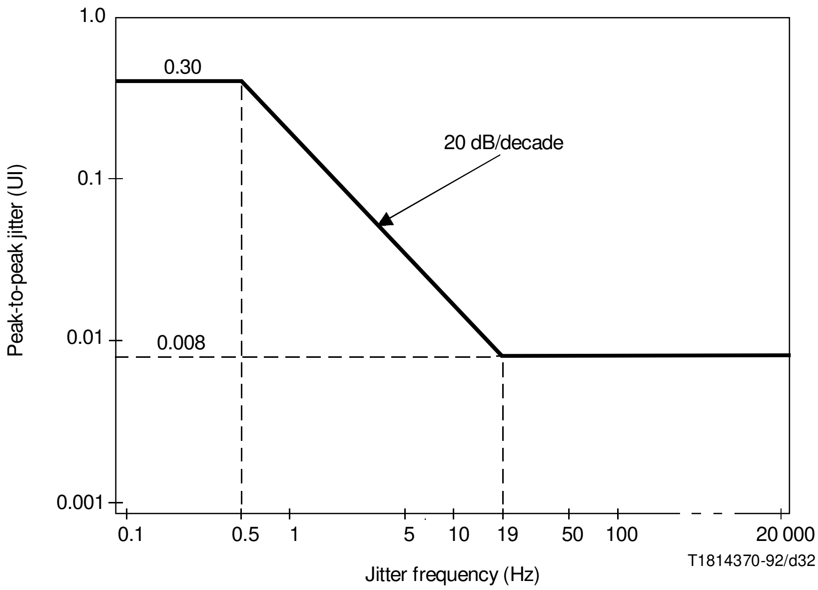
II.11 Jitter

Jitter tolerances are intended to ensure that the limits of Recommendation I.430 (Figure 9/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 local line and the inclusion of one regenerator, provided that they are covered by the transmission media characteristics (see 3). The limits shall be met regardless of the bit patterns in the B-, D- and C_L-channels.

Jitter is specified in terms of unit intervals (UI) of the nominal 80 kbaud 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, for single jitter frequencies in the range of 0.1 Hz to 20 kHz, on the LT output signal with the received signal baud rate in the range of 80 kbauds ± 5 ppm. The NT1 shall also meet the performance objectives with wander per day on the LT output of up to 1.44 UI peak-to-peak where the maximum rate of change of phase is 0.06 UI/hour.



NOTE – Unit interval (UI) = 12.5 µs.

FIGURE II.10/G.961

Permissible sinusoidal NT1 input signal jitter

II.11.2 NT1 output jitter limitations

With the wander/jitter as specified in II.11.1, superimposed on the NT1 input signal, the jitter on the transmitted signal of the NT1 towards the LT shall conform to the following, with the received signal baud rate in the range of 80 kbauds ± 5 ppm, as described in II.2.1.2.

1) The jitter shall be equal to or less than 0.04 UI peak-to-peak and less than 0.01 UI r.m.s. when measured with a high-pass filter having a 6 dB/octave roll-off below 80 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 r.m.s. when measured with a band-pass filter having a 6 dB per 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 subtracted.) 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 LT input signal jitter tolerance

The LT shall operate satisfactorily with input signal jitter equal to the worst case NT1 output signal jitter allowed by the limits set in II.11.2.

II.11.4 LT output jitter and synchronization

The output signals from the LT shall not exceed the NT1 input signal jitter tolerance limits stated in II.11.2. This requirement shall be met while maintaining data synchronization with the network.

II.11.5 Test conditions for jitter measurements

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

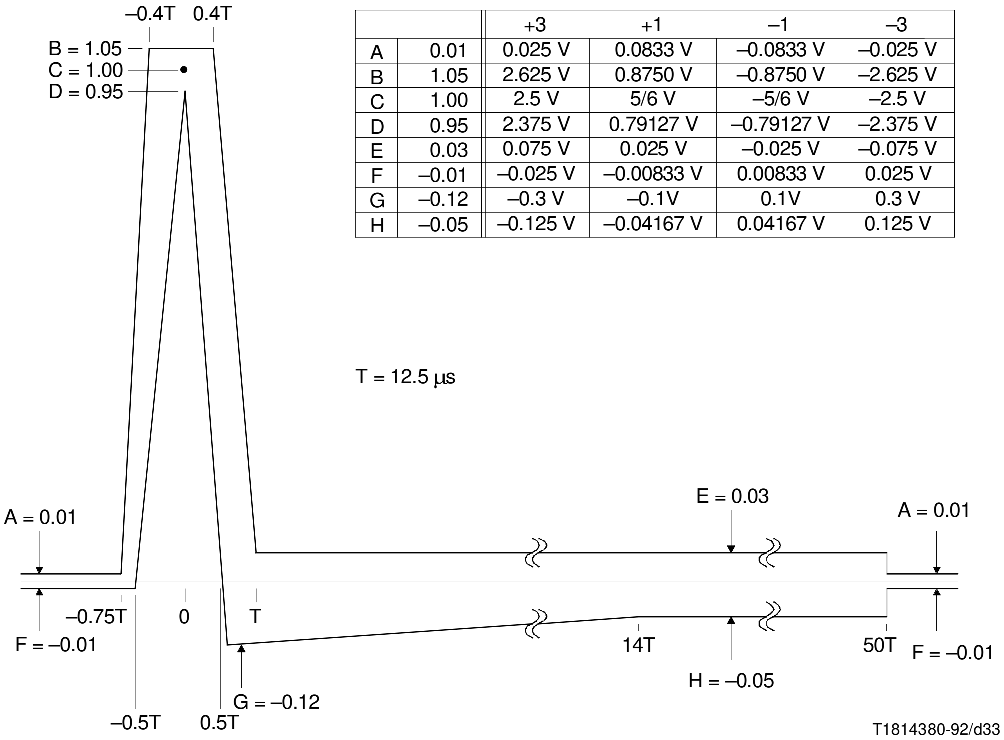
The nominal peak of the largest pulse shall be 2.5 volts (see Figure II.11).

II.12.2 Pulse shape

The transmitted pulse shall have the shape specified in Figure II.11. The pulse mask for the four quaternary symbols shall be obtained by multiplying the normalized pulse mask shown in Figure II.11 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.



		+3	+1	–1	–3
A	0.01	0.025 V	0.0833 V	–0.0833 V	–0.025 V
B	1.05	2.625 V	0.8750 V	–0.8750 V	–2.625 V
C	1.00	2.5 V	5/6 V	–5/6 V	–2.5 V
D	0.95	2.375 V	0.79127 V	–0.79127 V	–2.375 V
E	0.03	0.075 V	0.025 V	–0.025 V	–0.075 V
F	–0.01	–0.025 V	–0.00833 V	0.00833 V	0.025 V
G	–0.12	–0.3 V	–0.1V	0.1V	0.3 V
H	–0.05	–0.125 V	–0.04167 V	0.04167 V	0.125 V

NOTE – Compliance of transmitted pulses within boundaries of the pulse mask is not sufficient to assure compliance with the power spectral density requirement and the absolute power requirement. Compliance with the requirements in II.12.3 and II.12.4 is also required.

FIGURE II.11/G.961

Normalized output pulse from NT1 or LT

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. Measurements to verify compliance with this requirement are to use a noise power bandwidth of 1.0 kHz.

II.12.5 Transmitter 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 r.m.s. non-linearity is at least 36 dB below the r.m.s. signal at the interface.

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_{out}) with a precision of no less than 12 bits (see Figure II.13). 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 subtractor may both be in digital form, or they may both be in analogue form.

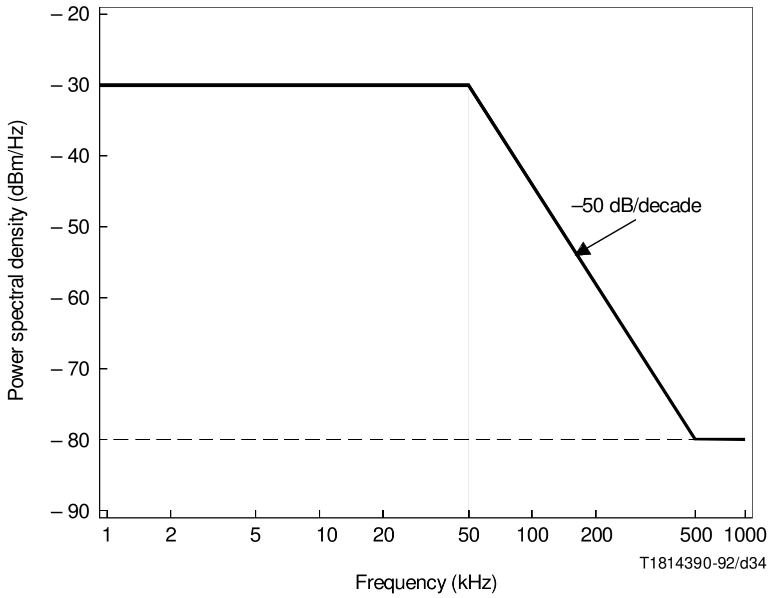


FIGURE II.12/G.961

Upper bound of power spectral density of signal from NT1 and LT

The linear digital filter input ("Quaternary Input Data" in Figure II.13) 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 analogue 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 r.m.s. 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 $< V_{out}^2 >$ at the filter output, as shown in Figure II.13, rather than the mean-squared value of the transmitter output itself.

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.

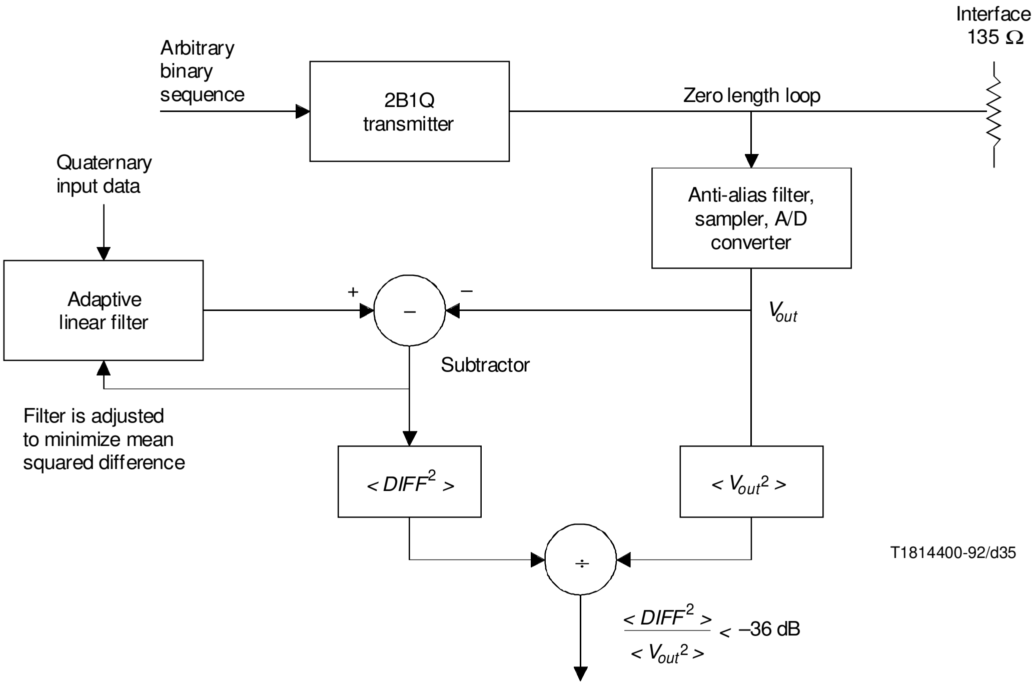


FIGURE II.13/G.961

Measurement of transmitter linearity

II.13.3 Longitudinal conversion loss

II.13.3.1 Longitudinal balance

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

$$\mathrm{LBal} = 20 \log \left(\frac{e_1}{e_m} \right) \mathrm{dB}$$

where

e_1 = the applied longitudinal voltage (referenced to the building or safety ground of the NT1);

e_m = the resultant metallic voltage appearing across a 135-ohm termination.

The balance shall be > 20 dB at frequencies up to 5 Hz. The minimum requirement increases above 5 Hz at 20 dB per decade to 55 dB at 281.2 Hz. The balance shall be > 55 dB between 281.2 Hz and 40 000 Hz. Above 40 000 Hz, the minimum requirement decreases at 20 dB per decade. See Figure II.15.

Figure II.16 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).

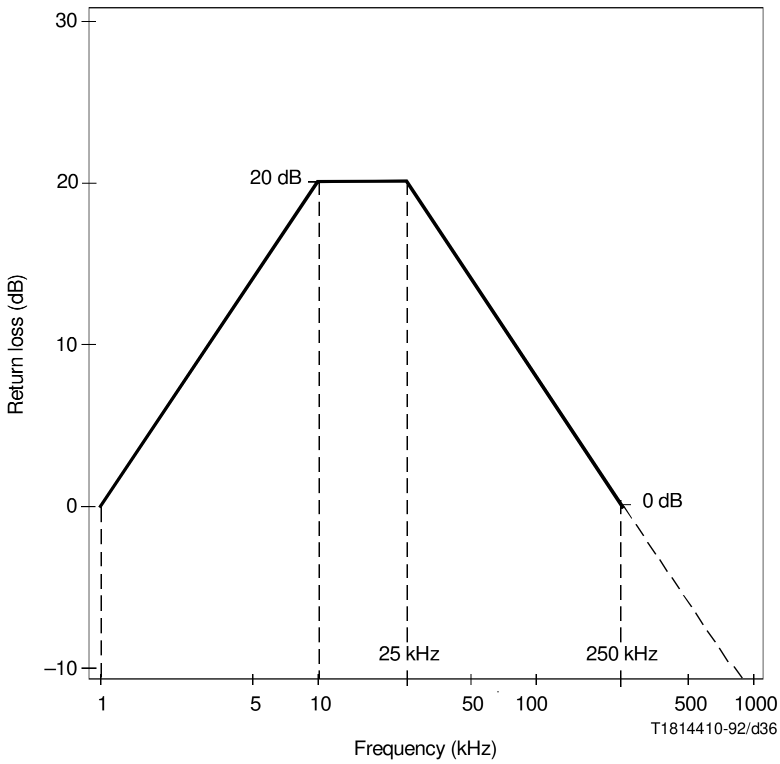


FIGURE II.14/G.961

Minimum return loss

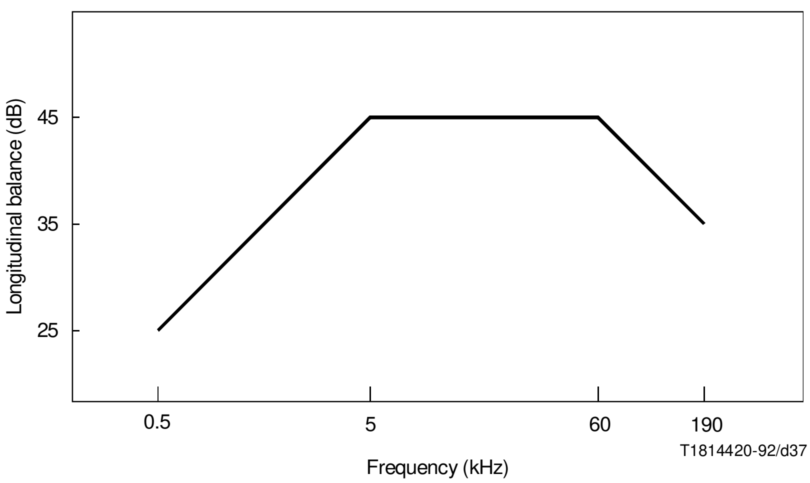
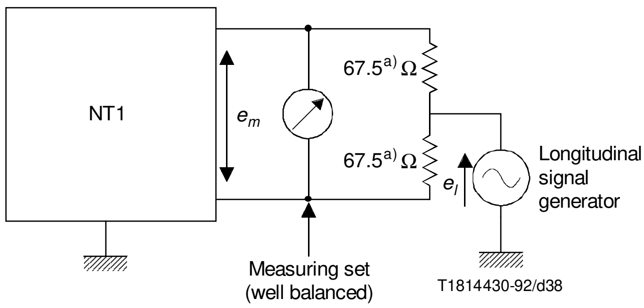


FIGURE II.15/G.961

Minimum longitudinal balance requirement



[a] These resistors should be matched to better than 0.03% tolerance.

FIGURE II.16/G.961

Measurement method for longitudinal balance

Annex A

(to Appendix II)

Extension functions of the system using 2B1Q line code

A.II.1 Introduction

The functions described in this annex are optional.

A.II.2 NT1 power status bits

The power status bits shall be the M_4 bits in the second and third basic frames of multiframes transmitted by the NT1 (Figure II.3). The use of this function is optional. When the PS_1 and PS_2 bits are used to convey the status of primary or secondary power sources, they shall be used as defined in Table A.II.1. See II.8.3.2.4. If these bits are not used, they shall be set to ONE in SN3.

A.II.3 NT1 test mode indicator (NTM) bit

The NT1 test mode indicator bit shall be the M_4 bit in the fourth basic frame of multiframes transmitted by the NT1 to the network (Figure II.3). The use of this function is optional. 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 EAC messages. If the function is used, the bit shall be a binary ONE to indicate normal operation and a ZERO to indicate test mode. If the function is not used, the bit shall be set to ONE in SN3. See II.8.3.2.5.

TABLE A.II.1/G.961

Power status bit assignments and definitions

NT1 status	PS_1 & PS_2 binary values	Definition
All power normal	11	Primary and back-up battery (if provided) power supplies are both normal. Normal power at T reference point, if provided.
Secondary power out	10	Primary power is normal, but the back-up battery (if provided) is marginal, unavailable, or has failed. Normal power at T reference point, if provided.
Primary power out	01	Primary power is marginal or has failed. Back-up battery (if provided) is normal. Voltage at T reference point (if provided) is less than 34 V or reversed.
Dying gasp	00	Both primary power and back-up battery (if provided) are marginal or have failed. Voltage at T reference point (if provided) is less than 34 V or reversed. The NT1 may shortly cease normal operation.

A.II.4 Cold-start-only (CSO) bit

The CSO bit is the M_4 bit in the fifth frame of the multiframe transmitted by an NT1. The use of this function is optional. It may be used to indicate the start-up capabilities of the NT1 transceiver. If the NT1 has a cold-start-only transceiver, as defined in II.10 5), this bit is set to ONE. Otherwise, this bit shall be set to ZERO in SN3. See II.8.3.2.6.

A.II.5 DLL-only-activation (UOA) bit

The UOA bit shall be the M_4 bit in the seventh basic frame of the multiframes transmitted by an LT. The use of this function is optional. It shall be used to request the NT1 to activate or deactivate the S/T interface (if present). If the S/T interface is to be activated, this bit may be set to binary ONE. Otherwise, this bit may be set to binary ZERO. If the function is not used, the bit shall be set to ONE in SL2 and SL3. See II.8.3.2.7.

A.II.6 S/T-interface-activity-indicator (SAI) bit

The SAI bit shall be the M_4 bit in the seventh basic frame of the multiframes transmitted by an NT1. The use of this function is optional. It may be used to indicate to the network when there is activity at the S/T reference point. If there is activity (INFO 1 or INFO 3) at the S/T reference point, this bit may be set to ONE. Otherwise it may be set to ZERO. If this function is not used, the bit shall be set to ONE in SN3. See II.8.3.2.8.

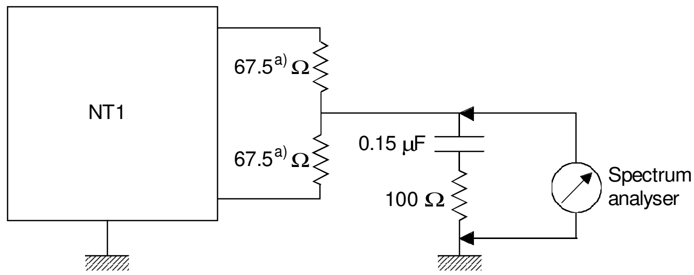
A.II.7 Alarm indicator bit (AIB)

The AIB bit shall be the M_4 bit in the eighth basic frame of the multiframes transmitted by the network toward the NT1. The use of this function is optional. When the transmission path for D-, B_1-, and B_2-channels has been established all the way to the local exchange, a binary ONE may be forwarded to the NT1. Failure or interruption of an intermediate transmission system which transports the D-, B_1-, and B_2-channels shall result in forwarding ZERO to the NT1. Such failures may include loss of signal, loss of frame synchronization/carrier link or basic access DLL, and transmission terminal failure. Intermediate transmission interruptions may include loopbacks at intermediate points or absence of provisioning of an intermediate transmission system. If this function is not used, the bit shall be set to ONE in SN3. See II.8.3.2.4.

A.II.8 Longitudinal output voltage

The longitudinal component of the NT1 output signal has an r.m.s. voltage, in any 4 kHz bandwidth averaged in any one 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 μF capacitor.

Figure A.II.1 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.



[a)] These resistors should be better than 0.1% tolerance.

FIGURE A.II.1/G.961

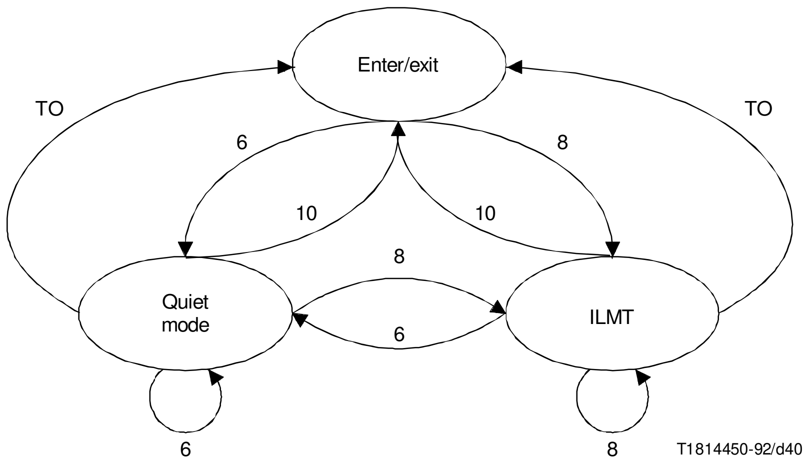
Measurement method for longitudinal output voltage

The ground reference for these measurements is the building ground.

A.II.9 NT1 maintenance modes

The NT1 Quiet Mode (QM) functionality within an NT1 (or customer equipment containing the NT1 functionality) will assure that an NT1 will not attempt a start-up or will not initiate transmission during metallic loop tests conducted by the network. The Insertion Loss Measurement Test (ILMT) will cause a known test signal to be generated by an NT1. This test will be used in network measurements of DLL transmission characteristics and may provide the ability to determine, from a single-ended test of the metallic loop, if the loop can support DLL transmission.

Figure A.II.2 NT1 loop testing states, illustrates the various NT1 states associated with both the NT1 Quiet Mode and the Insertion Loss Measurement Test.



ILMT	Insertion Loss Measurement Test
Insertion Loss Signal	Scrambled, framed 2B1Q
6, 8, 10	Number of pulses within trigger signal
Trigger Signal	dc or low frequency ac pulses
TO	Timeout = 75 seconds

NOTE – As a result of a power off/on cycle, the NT1 exits the maintenance mode and attempts start-up as described in II.10 10). All knowledge of previous maintenance modes is lost.

FIGURE A.II.2/G.961

NT1 loop testing states

A.II.9.1 NT1 Quiet Mode

The NT1 Quiet Mode implementation shall be as follows:

1) The NT1 shall unconditionally enter the Quiet Mode upon receipt of six consecutive pulses in the trigger signal. Once triggered, the function shall latch until either timeout or turnoff.

2) While in the Quiet Mode, the NT1 shall cease all transmission and not attempt start-up.

3) The NT1 Quiet Mode duration shall be 75 seconds. If no trigger signal is received to change the NT1 state during the 75-second QM duration, the NT1 shall exit the maintenance mode. Upon exiting the maintenance mode, the NT1 and the network shall be responsible for operation described in II.10.3.1 and II.10.3.2.

4) A receipt of six consecutive pulses in the trigger signal during Quiet Mode shall cause the NT1 to return to the start of the Quiet Mode state. (The Quiet Mode would then continue for another 75 seconds until either timeout or receipt of a new trigger signal that would alter the NT1 state.)

5) A receipt of eight consecutive pulses in the trigger signal during Quiet Mode shall cause the NT1 to enter the Insertion Loss Measurement Test state.

6) A receipt of ten consecutive pulses in the trigger signal during Quiet Mode shall cause the NT1 to exit the maintenance mode [see 3) above].

7) If the NT1 receives one through five, seven, nine or greater than ten consecutive pulses in the trigger signal, then the state change command is not valid and no action is taken by the NT1.

A.II.9.2 Insertion Loss Measurement Test

The Insertion Loss Measurement Test implementation shall be as follows:

1) The receipt by the NT1 of eight consecutive pulses in the trigger signal (see A.II.9.3, A.II.9.4 and A.II.9.5) shall unconditionally initiate the Insertion Loss Measurement Test. Once triggered, the function shall latch until either timeout or turnoff. The NT1 shall not attempt start-up during the Insertion Loss Measurement Test.

2) While in the Insertion Loss Measurement Test state, the NT1 shall generate a scrambled, framed, 2B1Q signal. SN1 and SN2 (see II.9) are examples of scrambled, framed, 2B1Q signals suitable for the Insertion Loss Measurement Test signal.

3) The Insertion Loss Measurement Test duration shall be 75 seconds. Upon exiting the maintenance mode the NT1 and the network shall be responsible for operation as described in II.10.3.1 and II.10.3.2.

4) Receipt of eight consecutive pulses in the trigger signal during the Insertion Loss Measurement Test duration shall cause the NT1 to return to the start of the Insertion Loss Measurement Test. (The ILMT would then continue for 75 seconds until timeout or receipt of a new trigger signal to alter the NT1 state.)

5) A receipt of six consecutive pulses in the trigger signal during Insertion Loss Measurement Test shall cause the NT1 to enter the Quiet Mode state.

6) A receipt of ten consecutive pulses in the trigger signal during Insertion Loss Measurement Test shall cause the NT1 to exit the maintenance mode [see 3) above].

7) If the NT1 receives one through five, seven, nine or greater than ten consecutive pulses in the trigger signal, then the state change command is not valid and no action is taken by the NT1.

A.II.9.3 NT1 Quiet Mode and Insertion Loss Measurement Test trigger signal

The NT1 shall be capable of detecting the following two types of signals: The NT1 shall respond to either

1) dc signalling that begins with a steady current flow (start interval) followed by six, eight or ten pulses sent as breaks in the current and ends with steady dc current flow (stop interval); or

2) ac signalling that begins with no current flow (start interval, less than 200 μA dc) followed by six, eight or ten half cycles or a 2 to 3 Hz sine wave, and ends with no current flow (stop interval). When receiving the ac signalling, the NT1 shall count each half cycle of the same wave as one pulse.

A valid test trigger signal shall consist of a valid start interval followed by either six, eight or ten consecutive pulses followed by a valid stop interval. Unless an entire trigger sequence consisting of a start interval, pulses and stop interval is received, the NT1 shall take no action.

A stop interval may be followed by a start interval without any intervening breaks. Signals on the loop before the start interval or after the stop interval shall not affect the NT1 trigger detection function.

The start and stop intervals shall be ≥ 500 ms. The NT1 shall be capable of detecting and validating the trigger signal and entering into the desired state required by the number of pulses transmitted.

A request for the same or a new state shall occur no sooner than one second after the beginning of the preceding stop interval. On receipt of a valid signal, the NT1 shall transit from one state to the requested state within 500 ms.

The pulse detector in the NT1 shall be implemented so that there is no aliasing for pulse rates up to 64 pulses per second.

A.II.9.4 dc signalling format

The dc signal shall begin with a steady current flow with pulses sent as breaks in the current. These pulses shall:

1) be applied to the NT1 by test equipment in the network at a pulse speed of 4 to 8 pps;

2) have a 40-60% break;

3) have source voltage of 43.5 to 56 volts; and

4) have source resistance of 200 to 4000 ohms (includes test system, test trunk, loop, and margin resistance).

A.II.9.5 Low frequency ac signalling format

The ac signal shall consist of six, eight or ten half cycles of 2 to 3 Hz sine wave. Each half cycle of the sine wave is equivalent to one pulse described in subclause I.9.4. This sine wave shall:

1) be applied to the NT1 by test equipment in the network at a frequency between 2 and 3 Hz;

2) have peak voltage between 60 and 62 volts; and

3) have a source resistance between 900 and 4500 ohms (ac source, test system, test trunk, loop, and margin resistance).

A.II.9.6 Tables A.II.2 and A.II.3 give examples of finite state matrices associated with activation/deactivation. Figures A.II.3 to A.II.7 give additional information on the activation/deactivation process and the turn-on process.

Table A.II.4 contains symbols, abbreviations and notes to Tables A.II.2 and A.II.3.

TABLE A.II.2/G.961

Activation/deactivation: NT ("H") finite state matrix (DLL-only turn-on option)

Event ↓	State name	Power off	Full reset	Alerting	EC training (optional)	EC conver-ged	SW sync	ISW sync	ISW sync CALL	Pending Active	Active	UOA active	S/T deacti-vation	UOA and TE CALL	Pending deacti-vation	Tear down	TE inactive	Receive reset
	State code (Fig. 17 event)	NT0	NT1 (T0)	NT2	NT3 (T1)	NT4 (T2)	NT5 (T3)	NT6(a) (T6)	NT6 (T6)	NT7	NT8	NT8(a)	NT8(b)	NT8(c)	NT9	NT10	NT11	NT12
	Signal→LT	SN0	SN0	TN	SN1	SN0	SN2	SN3 ACT = 0 SAI=1or 0	SN3 ACT = 0 SAI=1 or 0	SN3 ACT = 1 SAI = 1	SN3 ACT = 1 SAI = 1	SN3 ACT = 0 SAI = 0	SN3 ACT = 0 SAI = 0	SN3 ACT = 0 SAI = 1	SN3 (Note 8)	SN0	SN3 ACT = 0 SAI = 0	SN0
	Signal→TE (Note 7)	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 2	INFO 2	INFO 4	INFO 0	INFO 0	INFO 0		INFO 0	INFO 2	INFO 0
Power on		ST.M4 NT2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Loss of power (Note 1)		–	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0	NT0
Received new S/T INFO 1 signal (Notes 2 and 3)		/	ST.M4 NT2 (Note 12)	–	–	–	–	–	–	/	/	NT8(c)	NT8(c)	–	–	–	/	–
Received INFO 3 signal (UOA = 1, ACT = 0, DEA = 1) (Notes 2 and 4)		/	/	/	/	/	/	/	NT7	–	–	/	–	/	–	–	NT7	–
Received INFO 0 or S/T loss of sync (Notes 2 and 5)		/	–	–	–	–	–	–	–	NT11	NT11	/	NT8(a)	/	–	–	–	–
End of tone TN (9 ms)		/	/	NT8 or NT1	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Received tone TL		/	ST.M4 NT2	–	/	/	/	/	/	/	/	/	/	/	/	/	/	ST.M4 STP.M6 NT2

TABLE A.II.2/G.961 *(cont.)*

Activation/deactivation: NT (“H”) finite state matrix (DLL-only turn-on option)

Event ↓	State name	Power off	Full reset	Alerting	EC training (optional)	EC conver-ged	SW sync	ISW sync	ISW sync CALL	Pending Active	Active	UOA active	S/T deacti-vation	UOA and TE CALL	Pending deacti-vation	Tear down	TE inactive	Receive reset
	Code de l'état (événement Figure 17)	NT0	NT1 (T0)	NT2	NT3 (T1)	NT4 (T2)	NT5 (T3)	NT6(a) (T6)	NT6 (T6)	NT7	NT8	NT8(a)	NT8(b)	NT8(c)	NT9	NT10	NT11	NT12
	Signal→LT	SN0	SN0	TN	SN1	SN0	SN2	SN3 ACT = 0 SAI=1 or 0	SN3 ACT = 0 SAI=1 or 0	SN3 ACT = 1 SAI = 1	SN3 ACT = 1 SAI = 1	SN3 ACT = 0 SAI = 0	SN3 ACT = 0 SAI = 0	SN3 ACT = 0 SAI = 1	SN3 (Note 8)	SN0	SN3 ACT = 0 SAI = 0	SN0
	Signal→TE (Note 7)	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 2	INFO 2	INFO 4	INFO 0	INFO 0	INFO 0		INFO 0	INFO 2	INFO 0
Echo converged		/	–	–	NT4	–	–	–	–	–	–	–	–	–	–	–	–	–
SW and detect SL2		/	/	/	/	NT6	–	–	–	–	–	–	–	–	–	–	–	/
ISW sync (SL2)		/	/	/	/	/	STP.M4 NT6(a)	–	–	–	–	–	–	–	–	–	–	/
Received (SL2 or SL3) DEA = 0 (Note 6)		/	/	/	/	/	/	NT9	NT9	NT9	NT9	NT9	NT9	NT9	–	–	NT9	/
Received (SL2 or SL3) UOA = 0 and DEA = 1		/	/	/	/	/	/	NT8(a) or NT8(c)	NT8(a) or NT8(c)	NT8(b)	NT8(b)	–	–	–	Previous state (Note 13)	–	NT8(a)	–
Received (SL2 or SL3) UOA = 1, ACT = 0 and DEA = 1		/	/	/	/	/	/	NT6	–	–	NT7	NT6	–	NT6	Previous state (Note 13)	–	–	/
Received (SL3) UOA = 1, ACT = 1 and DEA = 1 (Note 1)		/	/	/	/	/	/	–	–	NT8 FEA	–	–	–	–	Previous state (Note 13)	–	–	/

TABLE A.II.2/G.961 *(end)*

Activation/deactivation: NT ("H") finite state matrix (DLL-only turn-on option)

Event ↓	State name	Power off	Full reset	Alerting	EC training (optional)	EC conver-ged	SW sync	ISW sync	ISW sync CALL	Pending Active	Active	UOA active	S/T deacti-vation	UOA and TE CALL	Pending deacti-vation	Tear down	TE inactive	Receive reset
	State code Fig. 17 event)	NT0	NT1 (T0)	NT2	NT3 (T1)	NT4 (T2)	NT5 (T3)	NT6(a) (T6)	NT6 (T6)	NT7	NT8	NT8(a)	NT8(b)	NT8(c)	NT9	NT10	NT11	NT12
	Signal→LT	SN0	SN0	TN	SN1	SN0	SN2	SN3 ACT = 0 SAI=1or 0	SN3 ACT = 0 SAI=1 or 0	SN3 ACT = 1 SAI = 1	SN3 ACT = 1 SAI = 1	SN3 ACT = 0 SAI = 0	SN3 ACT = 0 SAI = 0	SN3 ACT = 0 SAI = 1	SN3 (Note 8)	SN0	SN3 ACT = 0 SAI = 0	SN0
	Signal→TE (Note 7)	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 0	INFO 2	INFO 2	INFO 4	INFO 0	INFO 0	INFO 0		INFO 0	INFO 2	INFO 0
Loss of synchroni-zation.(> 480 ms) (Note 1)		/	/	/	/	/	/	NT10	NT10	NT10	NT10	NT10	NT10	NT10	NT10	–	NT10	–
Loss of signal (> 480 ms) (Notes 1 and 11)		/	/	/	/	STP.M4 NT1	–	ST.M6 NT12	ST.M6 NT12	ST.M6 NT12	ST.M6 NT12	ST.M6 NT12	ST.M6 NT12	ST.M6 NT12	/	/	ST.M6 NT12	–
Expiry of timer M4 (15 seconds) (Note 1)		/	/	/	NT10	NT10	NT10	/	/	/	/	/	/	/	/	/	/	–
Loss of signal < 40 ms		/	/	/	/	–	–	–	–	–	–	–	–	–	ST.M6 NT12	ST.M6 NT12	–	/
Expiry of timer M6 (40 ms) (Note 1)		/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	NT1
NOTE – For symbols, abbreviations and notes, see Table A.II.4.																		

TABLE A.II.3/G.961

Activation/deactivation: LT ("J") finite state matrix (DLL-only turn-on option)

Event ↓	Power off	Full reset	Alerting	Awake	EC training (optional)	EC converged CALL	SW sync CALL	ISW sync CALL	Active	EC converged UOA	SW sync UOA	DDL active	Desacti-vation S/T	Desacti-vation alerting	Tear down	Pending deacti-vation	Receive reset
State code (Fig. 17 event)	J0	J1 (T0)	J2	J3 (T1)	J4 (T3)	J5 (T4)	J6	J7 (T7)	J8	J5(a) (T4)	J6(a)	J8(a)	J7(a)	J9	J10	J11	J12
Signal→NT	SL0	SL0	TL	SL0	SL1	SL2 DEA = 1 ACT = 0 UOA = 1	SL2 DEA = 1 ACT = 0 UOA = 1	SL3 DEA = 1 ACT = 0 UOA = 1	SL3 DEA = 1 ACT = 1 UOA = 1	SL2 DEA = 1 ACT = 0 UOA = 0	SL2 DEA = 1 ACT = 0 UOA = 0	SL3 DEA = 1 ACT = 0 UOA = 0	SL3 DEA = 1 ACT = 0 UOA = 0	SL3 DEA = 0 ACT = 0	SL0	SL0	SL0
Power on	J1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Low of power (Note 1)	–	J0 FE7	J0 FE7	J0 FE7	J0 FE7	J0 FE7	J0 FE7	J0 FE7	J0 FE7	J0 FE7	J0 FE7	J0 FE7	J0 FE7	J0 FE7	J0 FE7	J0 FE7	J0 FE7
Activation request (FE1) (Note 1)	–	ST.M6 J2 FE2	–	–	–	–	–	–	–	J5	J6	J7	J7	–	–	–	–
U-only turn-on request (FE11) (Note 1)	/	ST.M6 J2 FE2	–	–	–	J5(a)	J6(a)	J7(a)	J7(a)	–	–	–	–	–	–	–	–
Deactivation request (FE5) (Notes 1 and 9)	–	–	–	–	–	–	–	J9	J9	–	–	J9	J9	–	–	–	–
End of tone TL (3 ms)	/	/	J3	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Received tone TN	/	ST.M6 J3	–	–	/	/	/	/	/	/	/	/	/	/	/	/	ST.M6 STP.M7 J3

Activation/deactivation: LT ("J") finite state matrix (DLL-only turn-on option)

Event ↓ / State name	Power off	Full reset	Alerting	Awake	EC training (optional)	EC converged CALL	SW sync CALL	ISW sync CALL	Active	EC converged UOA	SW sync UOA	DDL active	Desacti-vation S/T	Desacti-vation alerting	Tear down	Pending deacti-vation	Receive reset
State code (Fig. 17 event)	J0	J1 (T0)	J2	J3 (T1)	J4 (T3)	J5 (T4)	J6	J7 (T7)	J8	J5(a) (T4)	J6(a)	J8(a)	J7(a)	J9	J10	J11	J12
Signal→NT	SL0	SL0	TL	SL0	SL1	SL2 DEA = 1 ACT = 0 UOA = 1	SL2 DEA = 1 ACT = 0 UOA = 1	SL3 DEA = 1 ACT = 0 UOA = 1	SL3 DEA = 1 ACT = 1 UOA = 1	SL2 DEA = 1 ACT = 0 UOA = 0	SL2 DEA = 1 ACT = 0 UOA = 0	SL3 DEA = 1 ACT = 0 UOA = 0	SL3 DEA = 1 ACT = 0 UOA = 0	SL3 DEA = 0 ACT = 0	SL0	SL0	SL0
Loss of signal energy (TN or SN1)	/	–	–	J4, J6 or J6(a)	–	/	/	/	/	/	/	/	/	/	/	/	/
Echo canceller converged and FE11 (Note 1)	/	–	–	–	J5(a)	–	–	–	–	–	–	–	–	–	–	–	–
Echo canceller converged and FE1 (Note 1)	/	–	–	–	J6	–	–	–	–	–	–	–	–	–	–	–	–
SW sync (SN2 or SN3)	/	/	/	/	/	J6	–	–	–	J6(a)	–	–	–	–	–	–	–
ISW sync (SN3) (Note 1)	/	/	/	/	/	/	STP.M6 J7	–	–	/	STP.M6 J8(a) FE3	–	–	–	–	–	–
Received (SN3) ACT = 0 (Note 1)	/	/	/	/	/	/	/	FE3	J7 FE7	/	/	–	J8(a) FE3	–	–	–	–
Received (SN3) ACT = 1 (Note 1)	/	/	/	/	/	/	/	J8 FE4	–	/	/	/	–	–	–	–	–

TABLE A.II.3/G.961 *(end)*

Activation/deactivation: LT ("J") finite state matrix (DLL-only turn-on option)

Event ↓ / State name	Power off	Full reset	Alerting	Awake	EC training (optional)	EC converged CALL	SW sync CALL	ISW sync CALL	Active	EC converged UOA	SW sync UOA	DDL active	Desacti-vation S/T	Desacti-vation alerting	Tear down	Pending deacti-vation	Receive reset
State code (Fig. 17 event)	J0	J1 (T0)	J2	J3 (T1)	J4 (T3)	J5 (T4)	J6	J7 (T7)	J8	J5(a) (T4)	J6(a)	J8(a)	J7(a)	J9	J10	J11	J12
Signal→NT	SL0	SL0	TL	SL0	SL1	SL2 DEA = 1 ACT = 0 UOA = 1	SL2 DEA = 1 ACT = 0 UOA = 1	SL3 DEA = 1 ACT = 0 UOA = 1	SL3 DEA = 1 ACT = 1 UOA = 1	SL2 DEA = 1 ACT = 0 UOA = 0	SL2 DEA = 1 ACT = 0 UOA = 0	SL3 DEA = 1 ACT = 0 UOA = 0	SL3 DEA = 1 ACT = 0 UOA = 0	SL3 DEA = 0 ACT = 0	SL0	SL0	SL0
Received (SN3) SAI = 1 (Note 1)	/	/	/	/	/	/	/	–	–	/	/	J7 FE1 (Note 15)	–	–	–	–	–
Loss of synchroni-sation (> 480 ms) (Note 1)	/	/	/	/	/	/	/	J10 FE7	J10 FE7	/	/	J10 FE7	J10 FE7	J10 FE7	–	–	–
Loss of signal (> 480 ms) (Note 1)	/	/	/	J1 (Note 16)	/	–	–	ST.M7 J12 FE7	ST.M7 J12 FE7	–	–	ST.M7 J12 FE7	ST.M7 J12 FE7	ST.M7 J12 FE7	–	–	–
End of last superframe with DEA = 0 (Note 10)	/	/	/	/	/	/	/	/	/	/	/	/	/	J11	/	/	/
Expiry of timer M5 (15 seconds) (Note 1)	/	/	/	J10 FE7	J10 FE7	J10 FE7	J10 FE7	/	/	J10 FE7	J10 FE7	/	/	/	/	/	/
Absence of signal (< 40 ms) (Note 1)	/	–	/	/	/	–	–	–	–	–	–	–	–	–	ST.M7 J12	J1 FE6	–
Expiry of timer M7 (40 ms) (Note 1)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	J1 FE6

NOTE – For symbols, abbreviations, and notes, see Table A.II.4.