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Recommendation G.961

DIGITAL TRANSMISSION SYSTEM ON METALLIC LOCAL

LINES FOR ISDN BASIC RATE ACCESS

(Melbourne, 1988)

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 digital section for the ISDN basic rate access.

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 digital section defined in Recommendation I.603 for operation and maintenance.

The terminology used in this Recommendation is very specific and not contained in the relevant terminology Recommendations. Therefore Annex B to Recommendation G.960 provides a number of terms and definitions used in this Recommendation.

1.2 *Definition*

Figure 1/G.961 shows the boundaries of the digital transmission system in relation to the digital section.

Figure 1/G.961, p.

The concept of the 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 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 digital section.

1.3 *Objectives*

Considering that the 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 last one is given in the following:

BER bit error ratio

BT bridged tap

CISPR Comité international spécial de perturbation radioélectrique (now part of IEC)

CL 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/G.961 shows the functions of the digital transmission system on metallic local lines.

Figure 2/G.961, p.

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 Digital Transmission system (DTS) between the LT and NT1 to its normal operational status. Procedures required to implement this function are described in § 6 of this Recommendation.

Activation from the LT could apply to the DTS only or to the DTS plus the customer equipment. In case the customer equipment is not connected, the DTS can still be activated.

Note — The functions required for operation and maintenance of the NT1 and one regenerator (if required) and for some activationB/Fdeactivation procedures are combined in one transport capability to be transmitted along with the 2B + D-channels. This transport capability is named the CL-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 of this Recommendation. This deactivation should be initiated only by the exchange (ET). See Note in § 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.

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 in § 2.6.

3 Transmission medium

3.1 *Description*

The transmission medium over which the digital transmission system 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 digital transmission system 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/G.961.

Figure 3/G.961, p.

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/G.961.

Figure 4/G.961, p.

3.4.2 *Group delay*

Typical ranges of values of DLL group delay as a function of frequency are shown in Figure 5/G.961.

Figure 5/G.961, p.

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/G.961.

Figure 6/G.961, p.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/G.961 to define the combined range of operation.

Figure 7/G.961, p.

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/G.961.

Figure 8/G.961, p.

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 digital section are specified in § 4 of Recommendation G.960. The digital transmission system performance must be such that these performance limits are met. For that purpose, a digital transmission system is required to pass specific laboratory performance tests that are defined in the next sections.

4.2 *Performance measurements*

Laboratory performance measurement of a particular digital transmission system 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 digital transmission system 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/G.961.

Figure 9.G.961, p.

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 interfering with each other in a cable carry the same digital transmission system. Intersystem NEXT results when pairs carrying different digital transmission systems 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/G.961. 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, p.

4.2.2.2 *Measurement arrangement*

Simulation of intrasystem NEXT noise is necessary for performance testing of digital transmission systems. 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/G.961.

The measurement arrangement of Figure 11/G.961 can be used for testing of performance with intrasystem crosstalk noise.

Figure 11/G.961, p.

The measurement arrangement in Figure 11/G.961 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/G.961.

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 k?73 in the frequency range 0 to 1000 kHz is recommended.

Boxes 3, 4 and 5 in Figure 11/G.961 are conceptual. Dependent on the particular realization, they could possibly be combined into one circuit. The measurement arrangement in Figure 11/G.961 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:

— ± | dB for values within 0 dB to 10 dB down from the theoretical peak;

— ± | 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.

4.2.3.2 *Measurement arrangement*

Figure 12/G.961 shows a possible arrangement for impulse noise testing.

Figure 12/G.961, p.

The impulse noise source in Figure 12/G.961 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 µV/ $\sqrt{z}$ and a bandwidth > | times the Nyquist frequency of the particular system. The peak factor of the noise must be > | ;

— a particular waveform, as represented in Figure 13/G.961.

Figure 13/G.961, p.

4.2.4 *Performance tests*

Five types of tests are required to describe the overall performance of a particular digital transmission system 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 digital transmission system to operate with received signals varying in level over a wide range. DLL models 1 and 2 in Figure 9/G.961 have a loss varying from very low (0 dB) to very high (37-50 dB at 80 kHz).

When testing with DLL models 1 and 2 in Figure 9/G.961, 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/G.961 are used to test performance of digital transmission systems 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/G.961 the observed bit error ratio (BER) should be 10^{D}lF261^{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.

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/G.961, the echo canceller 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.

With the TCM or ‘‘burst mode’’ method, illustrated in Figure 15/G.961, 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 the transmission delay and transmitter/receiver turn-around (switching of Sn and Se in Figure 15/G.961).

Figure 14/G.961, p.

Figure 15/G.961, p.

6 ActivationB/Fdeactivation

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 digital transmission system are system dependent and can be found in Annex A and in the Appendices to this Recommendation.

7 Operation and maintenance

7.1 *Operation and maintenance functions*

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

7.2 *CL channel*

7.2.1 **CL channel** *definition*

This channel is conveyed by the digital transmission system in both directions between LT and NT1. It is used to transfer information concerning operation, maintenance and activation/deactivation of the digital transmission system and of the digital section.

7.2.2 *CL channel requirements*

For further study.

The minimum number of functions (optional or mandatory) the CL 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 section 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/G.961.

Figure 16/G.961, p.

When no regenerator is present on the DLL connecting the LT and the NT1, for each case in Figure 16/G.961 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/G.961 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/G.961.

Figure 17/G.961, p.

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.

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.

Short-term overload 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: to be defined;

b) active state including restricted powering of the user-network interface as defined in Recommendation I.430: to be defined;

c) active state including normal powering of user-network interface as defined in Recommendation I.430: to be defined;

d) power down mode: to be defined.

8.7.2 *Power requirements of regenerator*

For further study.

8.8 *Current transient limitation*

The rate of change of current drawn by the NT1 or regenerator from the network shall not exceed *X* mA/µs. The value of *X* is to be defined.

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 of 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.

ANNEX A

(to Recommendation G.961)

General structure for an Appendix on electrical characteristics

A.0 *Electrical characteristics*

Short general characterization of the digital transmission system.

Note — The content of this Annex is a guideline for the presentation of the description of the digital transmission systems and is not intended to constrain any of the systems which will be included.

A.1 *Line code*

For both directions of the transmission the line code is . | | And the coding scheme will be . | |

A.2 *Symbol rate*

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

A.2.1 *Clock requirements*

A.2.1.1 *NT1 free running clock accuracy*

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

A.2.1.2 *LT clock tolerance*

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

A.3 *Frame structure*

The frame structure contains a frame word, *N* times (2B + D) and a CL channel.

H.T. [T1.961]

Frame word	*N* times (2B + D)	CL channel

Table [T1.961], p.

A.3.1 *Frame length*

The number *N* of (2B + D) slots in one frame is . | |

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

In Figure A-1/G.931 the bit allocation is given.

H.T. [T2.961]

TO BE PREPARED FOR EVERY SPECIFIC CASE

FIGURE A-1/G.961

Bit allocation in direction LT-NT1

H.T. [T3.961]

TO BE PREPARED FOR EVERY SPECIFIC CASE

FIGURE A-2/G.961

Bit allocation in direction NT1-LT

H.T. [T4.961]

	S1	S2	S3	S4
0001	|| || (em | |	|| || (em | |	|| || (em | |	|| || (em | |
0111	— || || |	— || || |	— || || |	— || || |
0100	— | || ||	— | || ||	— | || ||	— | || ||
0010	+ | (em || ||	+ | (em || ||	+ | (em || ||	+ | (em || ||
1011	+ || || (em |	+ || || (em |	+ || || (em |	+ || || (em |
1110	|| || | (em |	|| || | (em |	|| || | (em |	|| || | (em |
1001	+ | (em | |	+ | (em | |	+ | (em | |	— | (em | (em |
0011	| ||| || |	| ||| || |	| ||| || |	— | (em || ||
1101	|| || || ||	|| || || ||	|| || || ||	— || || (em |
1000	+ ||| || ||	+ ||| || ||	+ ||| || ||	|| || (em | (em |
0110	— | | |	— | | |	— | | |	— | (em | |
1010	+ | | (em |	+ | | (em |	+ | (em | (em |	+ | (em | (em |
1111	+ | || ||	| ||| || (em |	| ||| || (em |	| ||| || (em |
0000	+ || || |	|| || (em || ||	|| || (em || ||	|| || (em || ||
0101	|| || | |	— ||| || ||	— ||| || ||	— ||| || ||
1100	+ | | |	— | | (em |	— | | (em |	— | | (em |

Note — A received ternary block 000 is decoded as binary 0000.

FIGURE I-1/G.961 **MMS43-Code**
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Table [T2.961], p.

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

In Figure A-2/G.961 the bit allocation is given.

H.T. [T3.961]

TO BE PREPARED FOR EVERY SPECIFIC CASE

FIGURE A-2/G.961

Bit allocation in direction NT1-LT

H.T. [T4.961]

	S1	S2	S3	S4
0001	|| || (em | |	|| || (em | |	|| || (em | |	|| || (em | |
0111	— || || |	— || || |	— || || |	— || || |
0100	— | || ||	— | || ||	— | || ||	— | || ||
0010	+ | (em || ||	+ | (em || ||	+ | (em || ||	+ | (em || ||
1011	+ || || (em |	+ || || (em |	+ || || (em |	+ || || (em |
1110	|| || | (em |	|| || | (em |	|| || | (em |	|| || | (em |
1001	+ | (em | |	+ | (em | |	+ | (em | |	— | (em | (em |
0011	| ||| || |	| ||| || |	| ||| || |	— | (em || ||
1101	|| || || ||	|| || || ||	|| || || ||	— || || (em |
1000	+ ||| || ||	+ ||| || ||	+ ||| || ||	|| || (em | (em |
0110	— | | |	— | | |	— | | |	— | (em | |
1010	+ | | (em |	+ | | (em |	+ | (em | (em |	+ | (em | (em |
1111	+ | || ||	| ||| || (em |	| ||| || (em |	| ||| || (em |
0000	+ || || |	|| || (em || ||	|| || (em || ||	|| || (em || ||
0101	|| || | |	— ||| || ||	— ||| || ||	— ||| || ||
1100	+ | | |	— | | (em |	— | | (em |	— | | (em |

Note — A received ternary block 000 is decoded as binary 0000.

FIGURE I-1/G.961 **MMS43-Code**

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Table [T3.961], p.

A.4 *Frame word*

The frame word is used to allocate bit positions to the 2B + D + CL channels. It may, however, also be used for other functions.

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

The code for the frame word will be . | |

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

The code for the frame word will be . | |

A.5 *Frame alignment procedure*

A.6 *Multiframe*

To enable bit allocation of the CL channel in more frames next to each other a multiframe structure may be used. The start of the multiframe is determined by the frame word. The total number of frames in a multiframe is . | |

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

The multiframe will be identified by . | |

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

The multiframe will be identified by . | |

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

The NT1 shall synchronize its frame on the frame received in the direction LT to NT1 and will transmit its frame with an offset.

A.8 *CL channel*

A.8.1 *Bit rate*

A.8.2 *Structure*

A.8.3 *Protocols and procedures*

A.9 *Scrambling*

Scrambling will be applied on 2B+D channels and the scrambling algorithm shall be as follows:

— In direction LT to NT1

— In direction NT1 to LT.

A.10 *Activation/deactivation*

Description of system activation/deactivation procedure including options that are supported and options that are not supported.

See also Recommendation G.960, § 5.

A.10.1 *Signals used for activation*

A list and definition of the signals used for activation/deactivation (SIGs).

— signals used for start-up (CL not available);

— bits in CL channel in an already established frame.

A.10.2 *Definition of internal timers*

A.10.3 *Description of the activation procedure* (based on arrow sequence for the error-free case)

— activation from the network side;

— activation from the user side.

A.10.4 *State transition table NT1 as a function of INFOs, SIGs, internal timers*

The description of loop backs and options supported is given in such a way that the minimum implementation may be clearly identified.

A.10.5 *State transition table LT as a function of FEs, SIGs, internal timers*

The description of loop backs and options supported is given in such a way that the minimum implementation may be clearly identified.

A.10.6 *Activation times*

See Recommendation G.960, §§ 5.5.1 and 5.5.2.

A.11 *Jitter*

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

A.11.1 *NT1 input signal jitter tolerance*

The NT1 shall meet the performance objectives with wander/jitter at the maximum magnitudes (J_1, J_2) indicated in Figure A-3/G.961, for single jitter frequencies in the range of F_1 Hz to F_3 kHz (F_3 = 1/4 F_6, F_6 = symbol rate frequency), superimposed on the test signal source. The NT1 shall also meet the performance objectives with wander per day of up to phase is . | | UI/hour.

A.11.2 *NT1 output jitter limitations*

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

a) The jitter shall be equal to or less than . | | UI peak-to-peak and less than . | | UI r.m.s. when measured with a high-pass filter having a 20 dB/decade roll-off below M | (mu | $_2$ Hz (M ≥" 1).

b) The jitter in the phase of the output signal relative to the phase of the input signal (from the network) shall not exceed . | | UI peak-to-peak or . | | UI r.m.s. when measured with a band-pass filter having a 20 dB/decade roll-off above N | (mu | $_2$ Hz (N ≥" 2) and a 20 dB/decade roll-off below K | (mu | $_k$(F$_k$< < 1). This requirement applies with superimposed jitter in the phase of the input signal as specified in § A.11.1 for single frequencies up to F_2 Hz.

A.11.3 *Test conditions for jitter measurements*

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

Figure A-3/G.961, p.

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

The following specifications apply with a load impedance of . | |

A.12.1 *Pulse amplitude*

The zero to peak nominal amplitude of the largest pulse shall be

A.12.2 *Pulse shape*

The pulse shape shall meet the pulse mask of Figure . | |

A.12.3 *Signal power*

The average signal power shall be between . | | dBm and

A.12.4 *Power spectrum*

The upper bound of the power spectral density shall be within the template in Figure . | |

A.12.5 *Transmitter signal nonlinearity*

This is a measure of the deviations from ideal pulse heights and the individual pulse nonlinearity.

The measurement method is for further study.

A.13 *Transmitter/receiver termination*

A.13.1 *Impedance*

The nominal input/output impedance looking toward the NT1 or LT respectively shall be . | |

A.13.2 *Return loss*

The return loss of the impedance shall be greater than shown in the template Figure . | |

A.13.3 *Longitudinal conversion loss*

The minimum longitudinal conversion loss shall be as follows:

. | | kHz . | | dB

. | | kHz . | | dB

APPENDIX 1
(to Recommendation G.961)

Electrical characteristics of an MMS 43 transmission system

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/G.961. 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.

Figure I-1/G.961 [T4.961], p.

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 ± | 00 ppm.

I.2.1.2 *LT clock tolerance*

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

I.3 *Frame structure*

Each frame contains a frame word, 2B + D data and the CL-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: CL-channel;

— Symbols 110 to 120: frame word.

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 ± | symbols (0.5 ms) later than that received at the NT1 input, measured between the first symbols of each frame word.

I.8 *CL-channel*

I.8.1 *Bit rate*

The bit rate for the CL-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 CL-channel use ‘‘0’’ and ‘‘—’’ polarity of the CL-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 CL-channel may override these loopback commands.

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: $1 \oplus x^{-18} \oplus x^{-23}$.

where $\oplus$ 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 initated from both ends usig 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 CL channel. All other SIGs do not require the CL channel.

The CL 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/G.961 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 Recommendation G.960, § 5.4.1.3, and the primitives in Recommendation G.960, § 5.4.2.2 and § 5.4.2.3.

I.10.4 *NT1 state transition table*

The NT1 state transition table is described in Table I-1/G.961. INFOs on the interface at T reference point are related to SIGs on the line system and vice versa.

Figure I-2/G.961, p.23

H.T. [1T5.961]

TABLE I-1/G.961
{
NT1 state transition table
}

INFO 0	—	—	—	—	—	—	NT 1.9	NT 1.1
INFO 1	NT 1.2	—	—	—	—	—	/	—
INFO 3	/	/	/	/	NT 1.6	—	—	—
SIG 0	—	—	—	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	—	—	/	/
SIG 4H	/	/	/	/	/	NT 1.7	—	/
SIG 4	/	/	/	/	/	/	—	/
Exp. of T2 (Note 1)	—	—	—	—	—	—	—	NT 1.1
Lost framing T interface	/	/	/	/	/	—	NT 1.9	—
Lost framing line system NT 1.10 Exp. of internal timer Tn1 / / NT 1.4 / / / / / / / / / }	/	/	/	/	NT 1.10	NT 1.10	NT 1.10	/

Tableau I-1/G.961 [1T5.961] A L'ITALIENNE, p.24

{
TABLE I-1/G.961 *(cont.)*
}

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 — — No state change. }	/	/	/	/	/	/	NT 2.2	/	NT 2.2	NT 2.2	/	

/ 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.

Note 1 — Timer T2 as defined in Recommendation I.430.

Note 2 — INFO X: signal with no framing information i.e. binary ZERO’s.

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

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

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

Tableau I-1/G.961 (SUITE) [2T5.961] A L’ITALIENNE, p.24

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 NT1.1.

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/G.961. SIGs on the line sysem are related to Functional 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.

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.

H.T. [1T6.961]

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
{ Transmit signal Receive signal }	SIG 0	SIG 2W	SIG 2W	SIG 2	SIG 2	SIG 4H	SIG 4	SIG
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	—
SIG 0	—	—	—	—	FE 7; —	FE 7; —	FE 7; —	FE 6; L
SIG 1W	ST.Tl1, FE 2; LT 1.2	:	LT 1.4	/	/	/	/	—
SIG 1	/	/	/	FE 3; LT 1.5	—	/	/	—
SIG 3	/	/	/	ST.Tl2; LT 1.6	ST.Tl2; LT 1.6	—	—	—
Exp. of intern. timer T11	—	LT 1.4	—	—	—	—	—	—
Exp. of intern. timer T12 — Lost framing line system / / / / FE 7; — FE 7; — FE 7; — — / / / / }	—	—	—	—	—	FE 7; LT 1.4	—	—

Tableau I-1/G.961 [1T6.961] A L'ITALIENNE, p.24

H.T. [2T6.961]

TABLE I-2/G.961

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.
{ Transmit signal Receive signal }	SIG 0	SIG 2W	SIG 2W	SIG 2	SIG 2	SIG 4H	SIG 4	SIG 0	SIG 2V
FE 4	ST.Tl4; LT 2.1	—	LT 2.2 or —	LT 2.2 or —	LT 2.2 or —	—	—	LT 2.1	:
Exp. of itern. timer Tl4	—	—	—	—	—	—	—	—	LT 2.
Rec. synch. on looped b. sig. — — 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; LTx Perform action/issue message a and b; enter state LTx.

ST.Tlx Start Timer Tlx.

Tableau I-1/G.961 (SUITE) [2T6.961] A L'ITALIENNE, p.24

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 $C_{V\backslash d1}$ and CL.

I.10.6 *Activation times*

For definition of activation times see Recommendation G.960, § 5.5.

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

— without regenerator: 210 ms.

— with regenerator: 420 ms.

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

— without regenerator: 1.5 s.

— with regenerator: | 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 Recommendation G.823, § 4).

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/G.961.

Figure I-3/G.961, p.

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 ± | dB in the frequency range 3 Hz to 30 Hz.

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 2V ± | .2V 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/G.961.

Figure I-4/G.961, p.

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/G.961.

Figure I-5/G.961, p.

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 ohm.

I.13.2 *Return loss*

The return loss agains 150 ohm ± | % measured for NT1 or LT shall exceed the limits given in Figure I-6/G.961.

Figure I-6/G.961, p.

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/G.961.

Figure I-7/G.961, p.