American National Standard
for Telecommunications –

Network Performance – Switched Exchange Access Network Transmission Specifications

1 Scope, purpose, and application

1.1 Scope

This standard provides performance specifications for the analog transmission parameters of a switched exchange access network covering the bi-directional transmission path between an exchange carrier's (EC) end office (EO) and an interexchange carrier's (IC) point of termination (POT) (see figure 1). Within this document the term, IC, refers to interexchange carriers and any other connecting entities. The transmission parameters included are specified in clauses 4 and 5. (Absolute round trip delay guidelines are offered for the transmission path between the NI and the POT.) At this time, transient impairments affecting voiceband data are not included. Both originating (access) and terminating (egress) switched services are covered, and are referred to in this standard simply as exchange access services. For the purposes of this standard, originating (access) refers to the bi-directional transmission channel between the calling party’s serving end office and an interexchange carrier POT; terminating (egress) refers to the bi-directional transmission channel between an interexchange carrier POT and the called party’s serving end office.

The performance specifications are given in terms of acceptance limits, restoral limits, and immediate action limits. In-service parameter performance will be distributed statistically. The actual parameter performance is characterized by the parameter distributions and not by the limits alone. On this basis, although the parameter distributions are not requirements of this standard, network providers and equipment vendors should take into account the parameter distributions as well as the individual trunk limits in their plans and designs. The statistics in annex A reflect an estimate of the characteristics of the statistical distributions that are expected for a large number of channels.

1.2 Purpose

This standard is intended to be used by the telecommunications industry to provide high-quality service to end users. The use of this standard helps to assure the ICs about the quality of exchange access services and to provide exchange carriers with the ability to implement and maintain the exchange access network. This standard is a product of a number of considerations. Among them are customer service perception, network architectures (see SR-TSV-002275 and GR-334-CORE. See annex C), the technical capabilities of transmission and switching systems (see TR-NPL-000037 and *Analog voice and voiceband data transmission performance characterization of exchange access plant*) and terminal equipment (as described in ANSI/EIA 470-A-1987), as well as operational and economic concerns. Some of these considerations are discussed in annex B.

1.3 Application

1.3.1 Architecture

This standard applies to switched exchange access provided by an EC to an IC between an EC end office and a POT. Switched exchange access service is an element of voicegrade service similar to that provided in what has historically been referred to as the "public switched network."

This network allows for direct and tandem switched connections between an end office and a POT. The standard provides one set of requirements between the end office and the POT that apply independent of routing of the call through the exchange carrier's network. Guidelines are provided between the POT and the EC access tandem (AT).

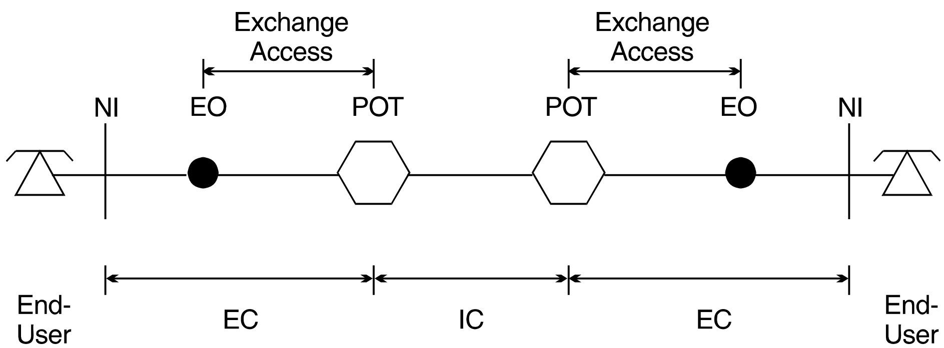

Figure 1 – Illustration of the various portions of a typical end-to-end connection, showing the relationship of exchange access portions to service providers

When the standard was developed, the arrangement was modeled after the capabilities of a service offering provided by many ECs and identified as Feature Group D. However, the standard is intended to be completely generic and may apply to future EC service offerings. For arrangements that differ from the original Feature Group model used to develop this standard, values for absolute delay and other performance parameters, such as post-dialing delay, need to be considered. Moreover, arrangements involving more than one EC between a POT and an end office were not evaluated in developing this standard. Such arrangements require further study.

1.3.2 Facilities

This standard applies generally to digital facilities and limited-mileage cable facilities. (In all cases, guidelines are not part of ANSI T1.506.) Specifically, it covers channels provided by the following facilities and combinations:

a) 64-kbit/s pulse code modulation (PCM) systems using 8-bit encoding, with or without Robbed-Bit signaling, and a μ-law characteristic with μ=255. Examples are channels using newer-design digital systems (D2, D3, D4, D5 channel banks, or their equivalent) on wire, radio, or fiber media;

b) Digital facilities of any length with cable extensions that are 1 mile or less in length;

c) Cable that is 1 mile or less in length;

d) Any combination of the above facility types, with or without intermediate switching (total cable not to exceed 1 mile in length).

The limits reflect the transmission performance capabilities of newer-design digital facilities (D2, D3, D4, D5 channel banks or their equivalent). Excluded are the early-design 7-bit PCM systems (such as D1 or the equivalent) and low-bit-rate-encoding systems such as 32-kbit/s adaptive differential pulse code modulation (ADPCM) systems. Cable facilities and cable extensions of 1 mile or less are included since they are sufficiently short to allow the combined facility to approximate the performance of a digital facility alone.

The development of this standard did not include the effects of systems such as digital cross-connect systems (DCS). Deployment of such systems may increase impairments such that exchange access service may not meet requirements.

This document specifies performance limits and allows for numerous architecture configurations and facility and switch combinations applicable to exchange access services. The actual facilities and switches used to provide service are a function of the existing telephone plant and may be influenced by the location of the POT. The existing telephone plant may vary by geographical area and between any pair of points within a geographical area (i.e., both analog and digital facilities may coexist between the same two points). Therefore, not all the specific facilities and combinations described in this standard might be offered or available between all point pairs within an EC area. It is recommended that if cases arise that have not been addressed in this standard, the EC and the IC cooperate to negotiate needed requirements.

This standard does not include the effects of low-bit-rate encoding techniques such as those employed in 32-kbit/s ADPCM as specified in ANSI T1.302-1989, and ITU-T Recommendation G.726. A separate standard, ANSI T1.501, deals with the performance impact and deployment guidelines for ADPCM. This exchange access standard is independent of ADPCM deployment. In addition to the requirements of this standard, the deployment guidelines contained in ANSI T1.501 are needed to control service performance.

1.3.3 Measurements

This document provides specifications for a set of analog parameters that relate to voice and voiceband data network performance between an end office and a POT. The numerical values contained in this standard include the contributions of digital-to-analog (D/A) conversion at a digital POT as found in commonly used channel banks. These numerical values, however, do not include the contribution of impairments caused when digital loss is placed in the measurement path to the test terminations of a digital AT or digital IC switch. For further information on the effect of digital loss pads, see annex B. As discussed in 1.3.3.1 and 1.3.3.2, measurements can be made using analog or digital methods. Further, under specific conditions, measurements can be made switch-to-switch.

1.3.3.1 Measurement method – analog

At an analog test access point, the parameters may be measured directly, using methodologies defined in ANSI/IEEE 743. At a digital POT, using analog measurement methods, specifications in this standard apply to measurements that include encoding or decoding with a 4-wire D4 channel bank, or equivalent, except that its contribution to the loss measurement error shall be less than 0.1 dB. (See Digital Channel Bank Requirements and Objectives. See annex C.)

1.3.3.2 Measurement method – digital

Measurements of analog parameters that are performed directly on a digital bit stream at the DS0 rate (64 kbit/s) may use a technology that does not contribute significant degradations that are associated with the D/A conversion process. It follows that the results of such measurements should generally be better than, or at least equal to, those that would be obtained after such a conversion. Therefore, the specifications in this document can be used as bounds or guidelines for digital measurements. This standard does not provide guidelines for discounting the effects of digital-to-analog conversion on the analog specifications. Note that the digital measurement method is not covered in ANSI/IEEE 743, but is commonly used in remote measuring systems.

1.3.3.3 Switch-to-switch testing

The specific recommended numeric values contained in the requirements clauses 4 and 5 in the standard apply between the end office and the POT. However, testing is usually most conveniently done switch-to-switch. If the IC switch is co-located with the POT, the standard may be used as the basis for switch-to-switch testing after accounting for the effect of the IC switch and office wiring, if any. If the switch and POT are not co-located, the switch-to-switch analog test results may need to be corrected by compensating for the contribution of the IC transmission facilities between the POT and the test position at the IC switch.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this American National Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

ANSI T1.302-1989 (R1996), *Telecommunications – Digital processing of voice-band signals – Line format for 32-kbit/s adaptive differential pulse-code modulation (ADPCM)*

ANSI T1.501-1994, *Telecommunications – Network performance – Tandem encoding limits for 32-kbit/s adaptive differential pulse-code modulation (ADPCM)*

ANSI/IEEE 743-1995, *Standard equipment requirements and measurement techniques for analog transmission parameters for telecommunications*

ITU-T Recommendation G.726, *Telecommunications – Digital processing of voice-band signals – Algorithms for 24-, 32-, and 40-kbit/s adaptive differential pulse-code modulation (ADPCM)* [1)]

3 Definitions

The following definitions apply in this standard:

3.1 acceptance limit (AL): The bound on performance that is allowed at service turn-up or acceptance of a circuit or connection by the IC, or when corrective action is taken to restore a parameter after a failure of the immediate action limit (IAL). Performance as measured by a parameter is satisfactory if the value of the parameter is equal to or better than the limit.

3.2 access line (loop): A channel between an end user's network interface and local end office.

3.3 access tandem (AT): An exchange carrier switching system that provides a traffic concentration and distribution function for inter-LATA traffic originating or terminating within a LATA.

3.4 channel: A transmission path between two points (one or both points may be a POT or NI). The term *channel* may refer to a unidirectional path or a bi-directional path.

3.5 connection: A temporary concatenation of transmission channels or telecommunication circuits, switching, and other functional units set up to provide for a transfer of information between two or more points in a telecommunication network.

3.6 end office (EO): An exchange carrier switching system where access lines (loops) are terminated for purposes of interconnection to each other and to trunks.

3.7 end user (EU): The calling party, or the called party, or both involved with a switched telecommunications connection. Customers who use (rather than provide) telecommunication services are end users.

3.8 exchange carrier (EC): The telecommunications common carrier franchised to provide service in specific geographic areas.

[1)] Available from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

3.9 immediate action limit (IAL): The bound on performance allowed for a circuit or connection that is in service. When any parameter value exceeds the IAL, the circuit or connection is considered defective and corrective action is necessary.

3.10 interexchange carrier (IC): A carrier that provides telecommunication services between LATAs. In this standard, the term, IC, is also used to refer to any other entity that connects to the exchange access network at a POT.

3.11 local access and transport area (LATA): A geographic area within each EC's franchised area, where an EC may offer local access and transport telecommunications services as well as local telecommunications services.

3.12 loop: See *access line (loop).*

3.13 network interface (NI): The point of demarcation between the carrier's facilities and the end-user installation that establishes the technical interface and division of operational responsibility.

3 14 point of termination (POT): The point of demarcation between exchange carriers and interexchange carriers that establishes the technical interface and division of operational responsibility.

3.15 restoral limit (RL): The bound on performance that is allowed when corrective action is taken to restore a parameter after an IAL failure. Performance as measured by a parameter is satisfactory if the value of the parameter is equal to or better than the limit.

3.16 switched exchange access network: The network of switching systems, interconnecting facilities, and equipment provided by an EC to provide telecommunications services between the EO and POT. Also referred to in this document as *exchange network.*

3.17 terminal equipment: Equipment at the end of a communication circuit, such as telephone sets, PBXs, voiceband data modems, and teletypewriters.

3.18 trunk: The channel between switching points.

4 Requirements and guidelines for voice transmission parameters

The requirements and guidelines for voice parameters are organized on a parameter-by-parameter basis. The parameters specified are:

a) loss and level;

b) loss deviation;

c) three-tone slope (attenuation distortion);

d) echo return loss;

e) singing return loss;

f) C-message noise;

g) C-notched noise;

h) absolute delay.

From a service performance perspective, the most important specifications are those between the POT and the EO. Thus, requirements are given for acceptance limits (AL) and immediate action limits (IAL) for the transmission path between the POT and the EO. As the path between the POT and the EO in a tandem arrangement will contain more than one link, parameter guidelines are given for the segment between the POT and the AT. These parameter guidelines are intended to assist the EC in providing specifications for particular service offerings where configurations between the POT and the AT are provided, and to ensure that the requirements between the POT and the EO are met.

4.1 Loss and level

4.1.1 Definitions

The 1004-Hz loss is the loss at 1004 Hz. In this clause, 1004-Hz loss is simply called "loss," except when referring to loss at other frequencies.

The loss of a channel or connection between two interfaces is the difference between the level at one point and the level at the other point, i.e., the input level minus the output level.

NOTE – As discussed in this subclause, the levels in this loss definition can both be analog, both digital, or one analog and one digital.

The level (analog level, absolute transmission level, power level, or simply power) at any point is the power in dBm of the signal into a resistive load equal to the designated impedance at the point of measurement, i.e., level is the ratio in dBm, of the received power at the point (power dissipated in a specified impedance at that point) to 1 milliwatt. Thus, 1 milliwatt corresponds to 0 dBm.

The transmission level (TL) at any point on a transmission system is the ratio in dB of the power of a signal at that point to the power of the same signal at a reference point, i.e., the design loss or gain, expressed in dB, between that point and some other point in the same circuit chosen as a reference.

The transmission level point (TLP) is a point in a transmission system at which is specified the ratio in dB of the power of a test signal at that point to the power of the test signal at a reference point. The reference point, called the *zero transmission level point (0 TLP)*, is an arbitrarily established point (which may be a hypothetical point unavailable for actual measurement) relative to which transmission levels at all other points are specified. A signal level of X dBm at the 0 TLP is designated X dBm0.

The digital milliwatt (DMW) is a defined digital representation of a 0-dBm 1000-Hz sine wave applied at the 0 TLP. The digit sequence for a µ255 representation of the DMW is defined in ITU-T Recommendation G.711.

The digital reference signal (DRS) is a digital representation of a 0-dBm0 1004-Hz analog sinusoid, such that it will be decoded into an analog signal equal in level to the analog signal obtained by decoding a digital milliwatt using the same decoder.

The encode level point (ELP), or e-dB encode level point (e-dB ELP), is a point at which an analog 1004-Hz sinusoid of e dBm would be encoded into a DRS.

The decode level point (DLP), or d-dB decode level point (d-dB DLP), is a point at which a DRS would be decoded into an analog 1004-Hz sinusoid of d dBm.

The digital level is the analog level that would result from decoding the digital stream at 0 DLP. Thus, DRS + P is the digital level of the bit stream that represents P dBm.

The switch reference point, or center, of a digital switch is any point at which a DRS appears in response to either a DRS on a digital facility or an encoding that would result from a 0-dBm0 analog test signal from the test position. (The test position is assumed to be 0-dB TLP.)

The switch reference point, or center, of an analog switch is any point at which the level is equal to the designated TLP of the switch when a 0-dBm test signal is applied at the test position. By convention, this point is taken to be the outgoing trunk appearance.

4.1.2 Measurement

The loss (loss, level, and loss deviation) specifications and measurements are applicable in both directions from POT to EO and from EO to POT. Also, for the case of tandem access, an additional specification is applicable in both directions from POT to AT and from AT to POT.

Although loss is specified in this standard, actual loss is not directly measured. The quantity actually measured is level. Loss is administered by level specifications. Control of level and loss is accomplished via the loss deviation parameter.

Loss at frequency f is determined by applying a tone of known level in dBm at one end of a channel or connection, measuring the received signal level in dBm at the other end of the channel or connection, and subtracting the received signal level from the source signal level. The source and the detector should have the nominal (resistive) impedances specified for their corresponding end of the channel or connection.

Requirements that shall be met by the source and the detector, and the detailed measurement technique, shall be as specified in ANSI/IEEE 743-1995. The applied signal should be within the dynamic range of the channels included in the connection, and the received signal should be at a level sufficiently higher than the noise.

4.1.3 General information

Loss is introduced into the transmission path of a telephone connection to control echo performance. The goal of the connection design loss is to provide sufficient loss to control echo performance while ensuring adequate received signal levels. This specification of loss is compatible with the recommended U.S./ North American Transmission Loss/Level Plan for interexchange service using the public switched telephone network. (See ITU-T Recommendation G.121.) This ITU-T Recommendation specifies that loss be inserted at the end office for an analog NI. Loss recommendations for services using a digital NI are specified in ANSI T1.508.

The loss of a channel or connection between two analog points is expressed in decibels as

$$\text{Loss} = 10\log\left(\frac{p_1}{p_2}\right),$$

where p_1 is the input power and p_2 is the output power and both powers are expressed in watts. The loss in decibels can also be expressed as

$$\text{Loss} = P_1 - P_2,$$

where P_1 and P_2 are the input and output power levels, i.e., the input and output powers expressed in dBm, i.e.

$$P_1 = 10\log\left(\frac{p_1}{10^{-3}}\right), \text{and}$$

$$P_2 = 10\log\left(\frac{p_2}{10^{-3}}\right).$$

Also, the nominal loss between the two points can be expressed in terms of the nominal TLPs as

$$\text{Loss} = X_1 - X_2,$$

where the input point is nominally an X_1 TLP and the output point is nominally an X_2 TLP.

Loss can be defined in several ways, depending on the various ways of defining the input and output powers. The definition of loss used in telephony is based on the definition of loss known in transmission engineering as transducer loss. The transducer loss of a channel or connection between two specified points is the ratio expressed in dB of the maximum power available from a source applied at one end of the channel or connection, and the actual power received (dissipated) in a specified impedance at the other end of the channel or connection. Maximum available power from a source is the power that would be dissipated in a load impedance conjugate to the source impedance. In telephony, the source impedance is, by design, always resistive and the specified standard impedance at the receiving end of the channel is, by convention, also resistive. Then the definition of transducer loss can be expressed as the difference in levels measured by instrumentation, as specified in ANSI/IEEE 743.

The loss of a channel or connection is a function of frequency. The loss at a nominal frequency of 1004 Hz is the quantity most often used to specify the loss of a channel or connection. For various purposes, loss is often measured at frequencies other than 1004 Hz. For example, frequency response (attenuation distortion) is specified in terms of the loss at a given frequency or over a specified frequency range, relative to the loss at a reference frequency, which is usually 1004 Hz (see 4.3).

It is useful to extend the definition of loss to apply to two points where one or both of the points is in a digital bit stream. This is done by providing a definition for digital level (i.e., level at a digital point) that is consistent with conventional analog level. Digital level is defined as the analog level that would result from decoding the digital bit stream at 0 DLP. Thus, (DRS+P) is the digital level of the bit stream that represents P dBm. This definition of digital level in terms of 0 DLP, which relates the digital bit stream to an equivalent analog level, permits defining loss between any two points in the path of an end-user call whether the points are analog or digital. Thus, loss between two digital points having digital levels (DRS+P_1) and (DRS+P_2) is {P_1–P_2}. Similarly, the loss between an analog point having level P_1 and a digital point having level (DRS+P_2) is {P_1–P_2}.

4.1.4 Requirements for loss

The requirements for loss apply between the EO and the IC switch, for both direct trunks and connections via access tandem. This goes beyond exchange access, which is only the segment between the EO and the POT. Achievement of the desired loss requires EC/IC cooperation. Compliance with the loss requirements by the exchange carrier is achieved by provision of the proper levels at the EO and POT. The design loss is given in table 1, except as stated in table 13. The requirements in table 1 are independent of whether access is direct or via access tandem. It is assumed that access tandems are designated as digital or as analog TP2 (i.e., –2 TLP at the switch center).

Table 1 – Design loss in dB between EO access line (loop) interface (analog) and center of IC switch

IC Switch Type	EO to IC	IC to EO	Notes*
Digital	0	6	1,2
Analog (TP0)	0	6	1,2
Analog (TP2)	3	3	1,2

* Text for the notes listed in this table appear in table 13.

For tandem access, there is an alternate design loss (IC option) for arrangements in which the trunks between the access tandem and the IC switch have a digital POT and interface with the switches as follows:

a) Digitally with a digital IC switch and at VF with an analog TP2 access tandem;

b) At VF with an analog TP0 IC switch and at VF with an analog TP2 access tandem;

c) At VF with an analog TP2 IC switch and digitally with a digital access tandem.

The alternate design loss for these arrangements is given in table 2, except as stated in table 13.

Table 2 – Alternate design loss in dB between EO access line (loop) interface (analog) and center of IC switch for tandem access using the applicable arrangements

IC Switch Type	EO to IC	IC to EO	Notes*
Digital	1	7	1,2
Analog (TP0)	1	7	1,2
Analog (TP2)	4	4	1

* Text for the notes listed in this table appear in table 13.

The result of the exceptions described in table 13 and the alternate designs in the tables is a range of acceptable loss values for exchange access. The plan embodied in these requirements achieves a total loss for the combined access and egress links (EO to IC switch + IC switch to EO) of nominally 6 dB, ranging from a low of 4 dB for the case of an analog combined AT/EO at each end or the case of cable with 2-dB loss at each end, to a high of 10 dB for the case of an alternate-design trunk at each end and cable with 4-dB loss at each end.

For each design case of tables 1 and 2, the access line (loop) interface is assumed to be analog. If the EO is a digital switch, the specified loss includes the effects of encode/decode operations.

For a digital IC switch, the level at the center of the switch is digital level relative to DRS. Loss is the difference between the analog level at the EO and the digital level at the center of the IC switch. The loss that may be introduced by ELP/DLP of other then 0/0 and by test pads at a digital IC switch are not included in the loss requirements in tables 1 and 2. Examples of loss associated with commonly used ELP/DLP and test pad values are given in tables 3 and 4.

Table 3 – Examples of loss associated with commonly used encode/decode levels

ELP/DLP at digital IC switch	Loss in dB between EO and IC encode/decode point	IC test pad value	Loss in dB between EO and IC test position
0/0	6/0	0	6/0
0/-6	6/6	0	6/6
-3/-3	3/3	3	6/6

NOTE – In each example, the loss in dB is 6/0 between the analog loop interface at the EO and the center of the digital switch, as stated in table 1.

Table 4 – Examples of loss associated with commonly used encode/decode levels for tandem access using the alternate design loss of table 2

ELP/DLP at digital IC switch	Loss in dB between EO and IC encode/decode point	IC test pad value	Loss in dB between EO and IC test position
0/0	7/1	0	7/1
0/-6	7/7	0	7/7
-3/-3	4/4	3	7/7

NOTE – In each example, the loss in dB is 7/1 between the analog loop interface at the EO and the center of the digital switch, as stated in table 2.

4.1.5 Requirements for levels at the EO and POT

The requirements for levels apply between the EO and the POT for both direct access and connections via access tandem. For direct access, the level entries in the tables can be interpreted as either levels in dBm or as TLP transmission levels in dB, and can be used as line-up values. For tandem access, the level entries should be interpreted as levels in dBm, but not as TLP transmission levels and not necessarily as line-up values since the line-up values could be different on the individual trunks. The levels at the end office are measured at the switch test position or analog access line (loop) interface.

The levels corresponding to the design losses of table 1 are given in tables 5 and 6. The levels corresponding to the alternate design losses of table 2 are given in tables 7 and 8.

Notes that qualify the requirements in tables 5 through 8 are given in table 13.

Table 5 – Requirements for power in dBm at the end office

IC switch type	EO to IC (Trans)	IC to EO (Rec)	Notes*
Digital	0	-6	3,4
Analog (TP0)	0	-6	3,4
Analog (TP2)	0	-5	3,4

* Text for the notes listed in this table appear in table 13.

Table 6 – Requirements for power in dBm at the POT

IC switch type	AT switch type	EO to IC (Rec)	IC to EO (Trans)	Notes*
Digital POT (Direct Access)	–	DRS	DRS	–
Digital POT (Tandem Access)				
Digital	Digital	DRS	DRS	–
Digital	Analog (TP2)	DRS	DRS	7
Analog (TP0)	Digital	DRS	DRS	–
Analog (TP0)	Analog (TP2)	DRS-1	DRS	7
Analog (TP2)	Digital	DRS	DRS+1	7
Analog (TP2)	Analog (TP2)	DRS-1	DRS	–
Analog POT (4-wire)		-16 to +7	-16 to +7	3,5
Analog POT (2-wire)		-3	-3	3,6

* Text for the notes listed in this table appear in table 13.

Table 7 – Alternate requirements for power in dBm at the end office for tandem access using the alternate design loss of table 2

IC switch type	EO to IC (Trans)	IC to EO (Rec)	Notes*
Digital	0	-7	3,4
Analog (TP0)	0	-7	3,4
Analog (TP2)	0	-6	3,4

* Text for the notes listed in this table appear in table 13.

Table 8 – Alternate requirements for power in dBm at the POT for tandem access using the alternate design loss of table 2

IC switch type	AT switch type	EO to IC (Rec)	IC to EO (Trans)	Notes*
Digital POT				
Digital	Analog (TP2)	DRS-1	DRS	–
Analog (TP0)	Analog (TP2)	DRS-1	DRS	–
Analog (TP2)	Digital	DRS	DRS	–
Analog POT (4-wire)		-16 to +7	-16 to +7	3,5

* Text for the notes listed in this table appear in table 13.

4.1.6 Guidelines for levels at the access tandem[2]

The following guidelines apply only to tandem access and, in particular, only to channels between the AT and the IC. The level entries in these guideline tables can be interpreted as either levels in dBm or as TLP transmission levels in dB, and can be used as line-up levels. The levels at the access tandem are measured at the switch test position. It is assumed that analog access tandems are designated as TP2 (i.e., -2 TLP). It is assumed that digital access tandems equivalently encode such that the combination of the ELP and any test pads results in a DRS when 0 dBm is applied and equivalently decode such that the combination of the DLP and the test pads results in a -6 dBm signal level when a DRS is applied.

The levels corresponding to the design losses of table 1 are given in tables 9 and 10. The levels corresponding to the alternate design losses of table 2 are given in tables 11 and 12.

Notes that qualify the guidelines in tables 9 through 12 are given in table 13.

Table 9 – Guidelines for power in dBm at the access tandem

IC switch type	AT switch type	EO to IC (Rec)	IC to EO (Trans)	Notes*
Digital	Digital	0	-6	–
Digital	Analog (TP2)	0	-5	7
Analog (TP0)	Digital	0	-6	–
Analog (TP0)	Analog (TP2)	0	-5	7
Analog (TP2)	Digital	0	-5	7
Analog (TP2)	Analog (TP2)	0	-4	–

* Text for the notes listed in this table appear in table 13.

Table 10 – Guidelines for power in dBm at the POT

IC switch type	AT switch type	AT to IC (Rec)	IC to AT (Trans)	Notes*
Digital POT				
Digital	Digital	DRS	DRS	–
Digital	Analog (TP2)	DRS+1	DRS	7
Analog (TP0)	Digital	DRS	DRS	–
Analog (TP0)	Analog (TP2)	DRS	DRS	7
Analog (TP2)	Digital	DRS	DRS+1	7
Analog (TP2)	Analog (TP2)	DRS	DRS	–
Analog POT (4-wire)		-16 to +7	-16 to +7	5

* Text for the notes listed in this table appear in table 13.

2) These guidelines are not a part of American National Standard T1.506.

Table 11 – Alternate guidelines for power in dBm at the access tandem for tandem access using the alternate design loss of table 2

IC switch type	AT switch type	AT to IC (Trans)	IC to AT (Rec)	Notes*
Digital	Analog (TP2)	0	-6	–
Analog (TP0)	Analog (TP2)	0	-6	–
Analog (TP2)	Digital	0	-6	–

* Text for the notes listed in this table appear in table 13.

Table 12 – Alternate guidelines for power in dBm at the POT for tandem access using the alternate design loss of table 2

IC switch type	AT switch type	EO to IC (Rec)	IC to EO (Trans)	Notes*
Digital POT				
Digital	Analog (TP2)	DRS	DRS	–
Analog (TP0)	Analog (TP2)	DRS	DRS	–
Analog (TP2)	Digital	DRS	DRS	–
Analog POT (4-wire)		-16 to +7	-16 to +7	5

* Text for the notes listed in this table appear in table 13.

Table 13 – Notes to tables 1 through 12

(1)	If a cable facility without gain is used in the access connection, the loss can vary by ± 1 dB.
(2)	If the EO is at an analog co-located AT/EO, the loss in each direction is 1 dB less. The 4-wire interface at the analog AT should consist of a 4-wire trunk circuit with interprocessor trunk, 2.0 dB switched pad, or the equivalent.
(3)	When a cable facility without gain is used in the access connection, the receive level can vary by ± 1 dB.
(4)	When the EO is at an analog co-located AT/EO, the receive (Rec) level is 1 dB higher. (This corresponds to 1 dB less loss.)
(5)	The levels at the POT depend on the specific hardware arrangement and corresponding interface code. For details, see GR-334.
(6)	When the IC switch has a 2-dB test pad (TP2, or -2 TLP at the switch reference point), the IC to EO (transmit) level can be -2 dBm rather than -3 dBm.
(7)	Alternate design loss can occur for these cases.

4.2 Loss deviation

4.2.1 Definition

Loss deviation (LD) is the difference between the measured level and the specified level of a received 1004-Hz tone.

4.2.2 Measurement

Loss deviation is specified at the end office and at the POT.

Loss deviation is measured in terms of analog levels in dBm and digital levels relative to a DRS. The measured level is subtracted from the specified level to obtain the loss deviation in dB. A positive loss deviation results when the measured level is lower than the specified level.

The discussion of loss, level, and loss and level measurement in 4.1 applies also to the loss deviation parameter. Measuring equipment specifications shall be as described in ANSI/IEEE 743-1995.

4.2.3 General information

The purpose of the loss deviation parameter is to control the departure of the actual line-up value of the 1004-Hz loss or level from the design value. Historically, loss was specified. Currently, level is specified for exchange access.

Loss deviation is a two-sided parameter. Limits are therefore specified by two values, one for high loss (+) and one for low loss (-). High loss corresponds to a level that is lower than specified.

In the case where the test tone traverses a complete trunk and test pads at each end, loss deviation can be stated in terms of either loss or level. In terms of loss, it is the difference between the actual measured loss (AML) and the expected measured loss (EML), LD = AML – EML. Also, if the test tone is transmitted at 0 dBm0 (i.e., 0 dBm at a 0 TLP), then the loss deviation is the difference between the measured level and the TLP value at point of measurement**.**

4.2.4 Requirements

Tables 14 and 15 provide requirements for the limits between the POT and the EO.

Table 14 – Requirements for loss deviation in dB between POT and EO (4-Wire POT)

IAL	±2.0
AL	±0.7*

* The AL is ±1.2 dB for channels using cable without gain.

Table 15 – Requirements for loss deviation in dB between POT and EO (2-Wire POT)

IAL	±2.0
AL	±0.7*

* The AL is ±1.2 dB for channels using cable without gain.

4.2.5 Guidelines[2)]

Table 16 provides guidelines for the limits between the POT and the AT.

Table 16 – Guidelines for loss deviation in dB between POT and AT (4-Wire POT)

IAL	±1.5
AL	±0.7

4.3 Three-tone slope

4.3.1 Definition

Three-tone slope (TTS) is a measure of frequency response consisting of the values of the frequency response at 404 Hz and 2804 Hz relative to the value at 1004 Hz.

Frequency response at frequency f is the difference in dB between the level at a reference frequency and the level at frequency, f, i.e., the level in dBm at the reference frequency minus the level in dBm at frequency, f.

4.3.2 Measurement

The general definition of frequency response applies at any frequency. Frequency response specifications in this standard are made in terms of three-tone slope. The measurements usually are made at a transmit level of -16 dBm0 for each of three tones. The slope for 404 Hz is obtained by subtracting the received level at 404 Hz from the received level at 1004 Hz,

$$TTS_{404\text{-}} = L_{1004} - l_{404}$$

The slope for 2804 Hz is obtained by subtracting the received level at 2804 Hz from the received level at 1004 Hz,

$$TTS_{2804\text{-}} = L_{1004} - l_{2804}$$

L signifies the level. TTS signifies the three-tone slope and its value is defined as a loss.

Measuring equipment specifications are contained in ANSI/IEEE 743.

4.3.3 General information

Frequency response of a channel is one of the characteristics that define the linear properties of a channel. Frequency response is the gain or loss versus frequency. In telephony, it is customary to use the loss versus frequency, where loss is as defined in 4.1.

The purpose of controlling the frequency response is to preserve harmonic relationships for speech and the waveform for voiceband data. For this purpose, it is sufficient to work with the frequency-dependent loss relative to the minimum loss in the band. The minimum loss typically occurs near 1000 Hz. The reference frequency is defined to be a fixed value of 1004 Hz. In this standard, the working definition is stated in terms of levels that are the actually measured quantities.

It is desirable from a service viewpoint to control the entire frequency response. However, it has been found by experience that control at one low frequency and one high frequency is usually adequate to control the complete frequency response.[3)] In this standard, the specifications relative to 1004 Hz are at the frequencies of 404 Hz and 2804 Hz. Two values are given, in the format -x/+y, one for low loss or high level (-), and one for high loss or low level (+). The values at frequencies between 404 and 2804 Hz are rarely worse than the values at 404 and 2804 Hz. The frequency response values at 404 and 2804 Hz relative to that at 1004 Hz are commonly called low- and high-frequency slope, respectively. It should be recognized that this is a specific terminology in telephony since the three-tone slope parameter is not a slope in the widely understood mathematical sense. Frequency response and three-tone slope have units of dB, not dB/Hz. Also, to avoid sign confusion, the commonly-used term *gain slope*, is not recommended since the three-tone slope parameter is defined as loss not gain. The three-tone slope requirements are sometimes referred to as attenuation distortion requirements.

4.3.4 Requirements

Tables 17 and 18 provide requirements for the limits between the POT and the EO.

Table 17 – Requirements for three-tone slope in dB at 404 Hz and 2804 Hz between POT and EO (4-Wire POT)

IAL	-1.5/+2.5
AL	-1.0/+2.0

3) These requirements will not necessarily control frequency response ripple which may be service limiting.

Table 18 – Requirements for three-tone slope in dB at 404 Hz and 2804 Hz between POT and EO (2-Wire POT)

IAL	-1.5/+2.5
AL	-1.0/+2.0

4.3.5 Guidelines[2)]

Table 19 provides guidelines for limits between the POT and the AT.

Table 19 – Guidelines for three-tone slope in dB at 404 Hz and 2804 Hz between POT and AT (4-Wire POT)

IAL	-1.0/+2.0
AL	-0.5/+1.5

4.4 Echo return loss and singing return loss

4.4.1 Definition

Echo return loss (ERL) at any point in a channel or connection is a frequency-weighted average, over the middle of the voiceband, of the return losses RL(f) at that point, with the output of the channel terminated with a specified standard impedance. The weighting is given in ANSI/IEEE 743. The 3-dB bandwidth of the weighting is 560 Hz to 1965 Hz.

Singing return loss (SRL) is the minimum of SRL-low and SRL-high. SRL-low is the frequency-weighted average of return losses in a low-frequency band (with 3-dB bandwidth from 260 Hz to 500 Hz). SRL-high is the frequency-weighted average of return losses RL(f) in a high-frequency band (with 3-dB bandwidth from 2200 Hz to 3400 Hz). The weightings are given in ANSI/IEEE 743.

Return loss RL(f) at any interface in a transmission path is the ratio, expressed in dB, of the transmitted power to the reflected or returned power at a single frequency, with the channel terminated in a standard impedance at a specified point.

Equal-level echo return loss (ELERL) at any 4-wire interface is the 4-wire ERL measured by a return loss measuring set at the interface, adjusted by the difference in TLPs at the interface,

$$\text{ELERL} = (4 - \text{wire ERL}) - (\text{TLP}_T - \text{TLP}_R),$$

where TLP_T is the transmitting TLP from the POT in the direction toward the EO, and TLP_R is the receiving TLP at the POT in the direction from the EO.

Equal-level singing return loss (ELSRL) at any 4-wire interface is the 4-wire SRL measured by a return loss measuring set at the interface, adjusted by the difference in TLPs at the interface,

$$\text{ELSRL} = (4 - \text{wire SRL}) - (\text{TLP}_T - \text{TLP}_R),$$

NOTE – The 4-wire performance specifications are limits on ELERL and ELSRL, at the POT. The 2-wire performance specifications are limits on the 2-wire ERL or SRL at the POT.

4.4.2 Measurement

The ERL and SRL specifications and measurements apply in the direction toward the EO. Incident power is transmitted toward the EO and reflected power is received in the direction from the EO.

The ERL and SRL specifications and measurements apply from the POT to the EO whether routing is direct or tandem. For the case of tandem access, additional ERL and SRL guidelines apply from the POT to the AT. For testing to the EO of a combined AT/EO switch, the POT-to-EO requirements apply. In either case, the ERL and SRL measurements require a nominal termination at the distant end of the channel (EO or AT). Nominal terminations shall be as defined in ANSI/IEEE 743.

For direct access the POT can be a 4-wire or 2-wire interface. For tandem access the interface at the POT is always a 4-wire interface.

The ERL and SRL measurements are made using a return loss measuring set (RLMS). The measurements are made at both 2-wire and 4-wire interfaces. At 2-wire interfaces, a hybrid is a necessary part of the measuring system to permit application of the transmit signal and measurement of the reflected power. Measurements at 4-wire interfaces do not require the use of a hybrid in the measuring system.[4)] The term, *return loss*, is also used colloquially to refer generically to either an ERL or SRL measurement made by a return loss measuring set at either a 2-wire or 4-wire interface. The term, *echo path loss (EPL*), is also used in the same way, but usually only at a 4-wire interface.

The raw ERL and SRL measurements need to be corrected using the TLPs at the measurement interface, as discussed below.

Measurement equipment specifications for RLMSs are contained in ANSI/IEEE 743.

4.4.3 General information

Echo is power that has been reflected from the primary signal path. (In digital networks which use digital terminals, acoustic coupling may produce an echo signal.) Talker echo is the echo that reaches the ear of the talker or the transmitting data set. Listener echo is the echo that reaches the ear of the listener or the receiving data set. For exchange access, the main control of echo is required in the direction looking from IC toward the EO, i.e., in the terminating exchange access channel. The subjective effect of the echo is governed by both the magnitude and delay of the echo. In the originating exchange access, delay is sufficiently short that any echo is perceived as sidetone. Echo control looking into the egress exchange access channel from the IC is necessary and sufficient (assuming proper IC echo control) to control both talker and listener echo.

Return loss (RL) is the basic measure of echo power reflected back to the originating end of a channel because of impedance mismatches throughout the channel. Return loss (RL) at any interface in a transmission path is the ratio, expressed in dB, of the transmitted power to the reflected or returned power at a single frequency, with the channel terminated in a specified standard impedance. Mathematically, return loss is equal to

$$\begin{aligned} RL(f) &= 10\log\left(\frac{p_t}{p_r}\right) \\ &= -20\log_{10}|\rho| \end{aligned}$$

where p_t is the transmitted power and p_r is the reflected or returned power, and ρ is the reflection coefficient. This is the fundamental definition.

RL(f) is a single-frequency measure of the echo. To cover both customer perception of the echo and singing more realistically, echo return loss and singing return loss are actually specified.

Echo return loss (ERL) is a frequency-weighted average of return losses, RL(f), over the middle of the voiceband (560 Hz to 1965 Hz), where talker echo is most annoying. The frequency weights are given in ANSI/IEEE 743.

Singing return loss (SRL) is the frequency-weighted average of return losses *RL*(f) at the edges of the voiceband (260 Hz to 500 Hz and 2200 Hz to 3400 Hz), where singing (instability) problems are most likely to occur. The frequency weights for SRL-low and SRL-high are given in tables 10 and 11 respectively of ANSI/IEEE 743.

[4)] A typical RLMS has selector knobs on the panel. The interface selector knob can be set for a 2-wire 600-Ω, 2-wire 900-Ω, or 4-wire interface. The 2-wire positions insert the appropriate hybrid. For a given interface selection, the other selector knob can be set to read either ERL, SRL-low, or SRL-high, and the appropriate frequency weighting is applied. Thus, 2-wire ERL or SRL is the ERL or SRL measured at a 2-wire interface by a RLMS, and 4-wire ERL or SRL is the ERL or SRL measured at a 4-wire interface by a RLMS.

The intent of the ELERL, ELSRL, and 2-wire specifications is to provide the same performance that the predivestiture terminal balance ERL and SRL specifications provided. In fact, the numerical values are the same. However, when the POT is located at a point that is different from the traditional terminal balance point, it is necessary to correct the ERL and SRL values measured at the POT by referring them to the traditional terminal balance point. The appropriate correction would be the sum of the losses in each direction (L_1 and L_2) between the traditional terminal balance point and the POT. For convenience, however, the correction has been defined in terms of the TLPs at the POT rather than these losses. The results are exact for direct access and within 1 dB for typical designs for the EO-to-AT-to-POT case. Thus,

$$\begin{aligned} ELERL &= ERL - TLP_T - TLP_R \\ &= ERL - (L_1 + L_2), \end{aligned}$$

$$\begin{aligned} ELSRL &= SRL - TLP_T - TLP_R \\ &= ERL - (L_1 + L_2) \end{aligned}$$

This relationship has been commonly stated elsewhere as equal level echo path loss,

$$\begin{aligned} ELEPL &= EPL - TLP_T - TLP_R \\ &= EPL - (L_1 + L_2) \end{aligned}$$

where the echo path loss (EPL) is either the ERL or SRL measured at the POT. The term, *EPL*, has also been used for several other concepts, including analytic modeling and engineering of specific circuit designs.

4.4.4 Requirements

Tables 20 and 21 provide requirements for the POT-to-EO limits.

Table 20 – Requirements for ELERL and ELSRL in dB — POT to EO (4-Wire POT)

	ELERL	ELSRL
IAL	16	11
AL	21	14

Note – For testing to the EO of a combined AT/EO switch, the POT-to-EO requirements apply.

Table 21 – Requirements for ERL and SRL in dB — POT to EO (2-wire POT)

	ERL	SRL
IAL	13	6
AL	18	10

4.4.5 Guidelines[2)]

Table 22 provides guidelines for the POT-to-AT limits.

Table 22 – Guidelines for ELERL and ELSRL in dB — POT to AT (4-Wire POT)

	ELERL	ELSRL
IAL	25	18
AL	27	20

4.5 C-message noise

4.5.1 Definition

C-message noise (CMN) is the C-message frequency-weighted, short-term-average noise power on an idle channel, i.e., a channel with a termination and no signal at the transmitting end.

CMN is expressed in dBrnC.

The CMN performance specifications in this document are expressed in dBrnC0.

4.5.2 Measurement

The measurement of C-message noise consists of a short-term average of the noise within a voicegrade channel, as measured by a standard noise measuring set equipped with C-message frequency weighting. C-message noise is measured at the receiving end of a channel or connection with a measuring set incorporating C-message weighting. The sending end of the channel or connection is terminated in its nominal impedance, i.e., in a quiet termination. The C-message noise measuring set is also terminated in the nominal impedance. The C-message noise is measured in dBrnC, which is the C-message weighted noise power in dB relative to 1 picowatt (10^{-12} watts or -90 dBm). In ANSI/IEEE 743, the standard measurement methods and equipment characteristics, including the C-message weighting, are defined.

The C-message noise performance specifications are expressed in terms of dBrnC0, which is the level in dBrnC referred to the channel 0 TLP (zero transmission level point). See 4.1 regarding TLP.

4.5.3 General information

Idle-circuit noise of a channel or connection is the weighted average noise power during the quiescent state, i.e., with no signal on the channel or connection. Idle-circuit noise is the total effect of various noise sources such as white noise, crosstalk, and other interferences. In speech transmission, the quantity of interest is the interfering effect of noise rather than the absolute noise power. To reflect the detection characteristics of the human ear, idle-circuit noise measurements are frequency weighted. The most common weightings used to reflect interfering effect of noise on speech transmission are the C-message weighting used in this standard and the psophometric weighting used in international applications and in ITU-T Recommendations.

The performance specifications in this subsection are for the C-message frequency weighting. This weighting is used to account for the frequency characteristics of 500-type, or similar, telephone set transducer efficiency as well as end-user annoyance to tones as a function of frequency.

Digital switches using digital loss pads to provide loss introduce additional CMN compared with digital switches using analog loss pads. An allowance of 1 dB is provided as a correction to the CMN requirements for acceptance limits. The allowance of 1 dB may not fully represent the potential impact of digital loss on CMN. (See annex B for more details). The correction should be applied only in the POT-to-EO direction when digital loss is used. The more stringent limit for offices that do not use digital loss is used in the EO-to-POT direction.

4.5.4 Requirements

Table 23 provides the requirements for the limits between the POT and the EO.

Table 23 – Requirements for C-message noise in dBrnC0 (between POT and EO*)

IAL	30
AL	28

* For a digital EO using digital loss, add 1 dB to the acceptance limits, for the terminating (POT-to-EO) direction.

4.5.5 Guidelines[2)]

Table 24 provides guidelines for limits between the POT and the AT.

Table 24 – Guidelines for C-message noise in dBrnC0 (between POT and AT)

IAL	28
AL	26

4.6 C-Notched noise

4.6.1 Definition

C-notched noise (CNN) is the C-notched (C-message with a notch) frequency-weighted, short-term-average noise power on a channel with an applied 1004-Hz holding tone. The notch filter of the C-notched weighting eliminates the holding tone.

CNN is expressed in dBrnC.

The CNN performance specifications in this document are expressed in dBrnC0.

4.6.2 Measurement

CNN is measured in a manner similar to CMN, but the sending end of the channel or connection transmits a 1004-Hz holding tone from a source terminated in the nominal impedance. The level of the holding tone should be either -13 dBm0 or -16 dBm0, as discussed below. C-notched noise is measured at the receiving end of a channel or connection with a measuring set terminated in the nominal impedance, incorporating notched C-message weighting. The filter has the C message contour and a notch in the 995- to 1025-Hz band, which notches out (attenuates) the holding tone. For measurements to be significant, the attenuation of the holding tone should be large enough so that its residual power is small compared to the remaining "noise" power. Harmonic distortion, quantizing noise, and phase and amplitude jitter components contribute to the CNN measurement value. The CNN is measured in dBrnC, which is the C-notched weighted noise power in dB relative to 1 picowatt (10–12 watts or -90 dBm). In ANSI/IEEE 743, the standard measurement methods and equipment characteristics, including the C-message weighting and the requirements on the holding tone and the notch, are defined.

The CNN performance specifications are expressed in terms of dBrnC0, which is the level in dBrnC referred to the channel 0 TLP (zero transmission level point). See 4.1 for a definition of TLP.

4.6.3 General information

CNN is measured and specified to characterize the performance of digital carrier systems, which use quantizers. In systems using quantizers, the noise increases in the presence of a signal. To measure this noise, a test tone (holding tone) is transmitted from the sending end of the channel or connection under test to activate signal-dependent equipment on the channel or connection. The level of the holding tone used for measurement of CNN in the Exchange Access Study (see TR-NPL-000037) was approximately -13 dBm0 (data level). Some automatic measuring systems use a -16-dBm0 holding tone. The tone is then filtered out ahead of the noise measuring set. The filter used to remove the tone is a narrow-notched filter centered at the frequency of the tone; hence, the name C-notched noise.

The 1004-Hz holding tone is usually transmitted at -16 dBm0 (voice holding-tone level) or at -13 dBm0 (data holding-tone level). Specifications are given below for both levels. The specifications are equivalent. The specifications were converted assuming that on digital-carrier systems, C-notched noise increases dB for dB with the increase in holding-tone level for input signals in the approximate range between -30 dBm0 and 0 dBm0. Therefore, an increase in holding-tone level from -16 dBm0 to -13 dBm0 results in a 3-dB increase in CNN.

Digital switches using digital loss pads to provide loss introduce additional CNN compared with digital switches using analog loss pads. Separate tables are provided for the case when digital loss is used at a digital end office. The amount of degradation is roughly comparable to that of a pair of digital channel banks. The CNN values for this case were obtained by power summing the CNN requirement for offices that do not use digital loss with 39 dBrnC0 (using a -16-dBm0 holding tone) or 42 dBrnC0 (for a -13-dBm0 holding tone). The resulting requirement for the case of digital loss should be applied only in the terminating (POT-to-EO) direction. The more stringent requirement for offices that do not use digital loss is used in the originating (EO-to-POT) direction.

The CNN specifications in this subclause correspond exactly to the S/CNN specifications in 5.1. The relationship is given in 5.1.

4.6.4 Requirements

Tables 25 through 28 provide the requirements for the limits between the POT and the EO. For exchange access made through a digital end office using digital loss, Tables 28 and 29 provide the requirements in the terminating (POT-to-EO) direction.

Table 25 – Requirements for C-Notched noise in dBrnC0 using a -16-dBm0 holding tone (between POT and EO)

IAL	42
AL	41

Table 26 – Requirements for C-notched noise in dBrnC0 using a -13-dBm0 holding tone (between POT and EO)

IAL	45
AL	44

Table 27 – Requirements for C-notched noise in dBrnC0 using a -16-dBm0 holding tone (for digital EO employing digital loss) (POT to EO)

IAL	44
AL	43

Table 28 – Requirements for C-notched noise in dBrnC0 using a -13-dBm0 holding tone (for Digital EO employing digital loss) (POT to EO)

IAL	47
AL	46

4.6.5 Guidelines[2)]

Tables 29 and 30 provide guidelines for the limits between the POT and the AT.

Table 29 – Guidelines for C-notched noise in dBrnC0 using a -16-dBm0 holding tone (between POT and AT)

IAL	40
AL	39

Table 30 – Guidelines for C-notched noise in dBrnC0 using a -13-dBm0 holding tone (between POT and AT)

IAL	43
AL	42

4.7 Absolute round-trip delay

4.7.1 Definitions

NI-to-POT(POT-to-NI) one-way delay is the period of time that starts when the signal event occurs at the NI (POT), and ends when the corresponding signal detection occurs at the POT (NI). This delay refers to any conventional method of determining one-way delay on the NI-POT (POT-to-NI) directed segment. This one-way delay applies to telecommunication segments that originate at an NI(POT) and terminate at a POT(NI).

NI-POT round trip delay is the sum of the NI-to-POT one-way delay and the POT-to-NI one-way delay. This delay refers to any conventional method of determining round-trip delay on the NI-to-POT segment. This round-trip delay applies to telecommunication segments that are bounded by an NI and a POT.

4.7.2 Guidelines[2)]

The evolving exchange access network is changing, in both technology (digital) and architecture (robust, self-healing networks). The introduction of these changes increases the round-trip delay of the access network relative to its analog equivalent. This increase is due to digital processing in fixed elements and the larger propagation delay of fiber routes. Guidance on the round-trip delay between the NI and POT is provided to allow planning of the connection provider's respective networks. The guidance is aimed at allowing flexible evolution of digital networks, while maintaining good quality.

The estimated round-trip delays presented in this section are based on a reference model reflecting the expected changes. The approach used in developing these delays is provided in subclause B.2.3.11 of annex B. The total round-trip delay was calculated using the value for fiber facilities (0.0168 ms/mile), but the estimate is also applicable to T1 facilities in general. The total NI-POT round-trip delay is given by:

NI–POT Round-trip Delay (ms) = Round-trip Processing Delay (ms) +

NI–POT Propagation Delay (ms/mile) × NI–POT Route Distance (one-way miles),

where:

	Round-trip Processing Delay (ms)	**Round-trip Propagation Delay (ms/mile)**
Minimum	4.0	0.0168
Typical	6.1	0.0168
Maximum	10.0	0.0168

The total estimated NI–POT round-trip "Minimum", "Typical" and "Maximum" delays are given in figure 2.

While the delay guidelines provided here are intended for network planning purposes, it should be emphasized that delay is an important performance parameter that should be increased only when the network benefit outweighs the impact on user applications. Network providers should cooperate to seek solutions in those cases where delay is anticipated to be a problem. Examples are increased echo impairment on connections without cancelers, exceeding the operational limits of cancelers, and degraded throughput or response time of some voiceband data applications.

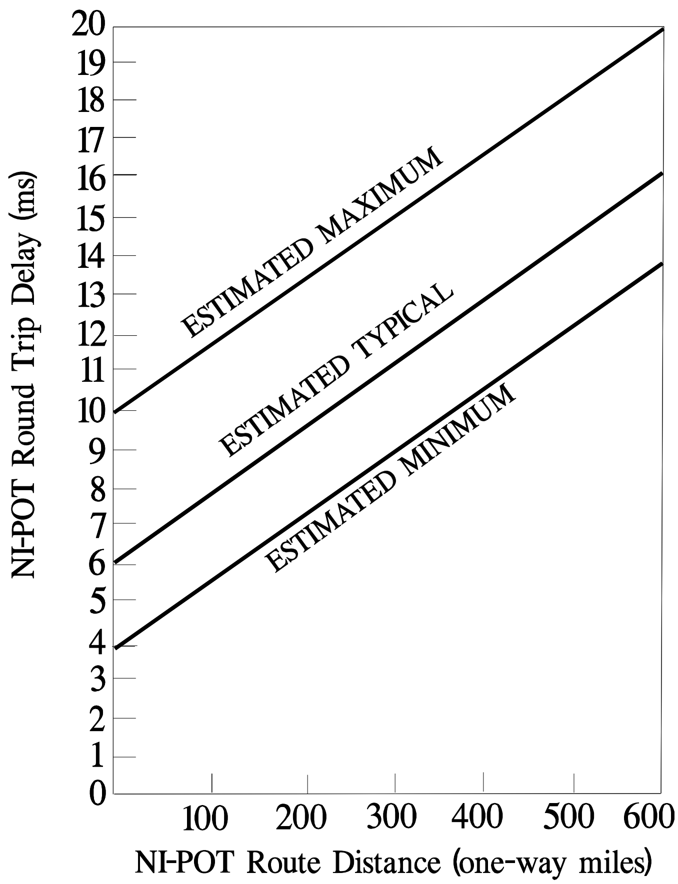

Figure 2 – Guidelines for NI-POT delay (based on reference model of access)

5 Requirements and guidelines for voiceband data transmission parameters

The requirements and guidelines for voiceband data parameters are specified for most cases of:

a) signal-to-C-notched-noise ratio,

b) signal-to-intermodulation-distortion ratios,

c) envelope delay distortion,

d) amplitude jitter, and

e) phase jitter.

Specifications are not currently supplied for:

a) impulse noise,

b) gain hits,

c) phase hits, and

d) dropouts.

These voiceband data parameters are recognized as being significant for quality voiceband data transmission; however, the voice transmission parameters of clause 4 are also important.

The requirements and guidelines are given by restoral limits (RLs) and immediate action limits (IALs).

Voiceband data restoral limits and immediate action limits represent the limiting values of facility performance. The limits are based on the 95th (or 5th) and 99th (or 1st) percentiles, respectively, of the parameter statistical distributions (see annex A). The limits are provided in 5.1 and subsequent sections. Requirements are given for restoral limits and immediate action limits for the transmission path between the POT and the EO. Performance guidelines are given for RLs and IALs for the segment between the POT and the AT.

5.1 Signal-to-C-Notched-Noise Ratio

5.1.1 Definition

Signal-to-C-notched noise ratio (S/CNN) is the ratio in decibels of a received 1004-Hz holding tone signal power to the corresponding C-notched noise power.

This definition may be expressed as:

$$S/CNN\ (dB) = S_{1004}\ (dBm) - CNN\ (dBrnC) + 90$$

S_{1004} (dBm) is the received level of a 1004-Hz holding tone expressed in dBm.

CNN (dBrnC) is the received noise measured through a C-notch filter and expressed in dBrnC.

A conversion factor of 90 is added to compensate for the different units of the noise and tone power. This conversion factor is part of the definition of S/CNN and its use assumes that the noise will be measured through a C-notch filter (dBrnC).

5.1.2 Measurement

The measurement of S/CNN is made in a manner similar to CNN but the signal is measured as well as the noise. The channel is terminated in its nominal impedance. A 1004-Hz holding tone is transmitted from the sending end from a source terminated in the nominal impedance. The level of the holding tone is usually -13 dBm0 or -16 dBm0. A level of -13 dBm0 more closely relates to data signal levels. However, because of existing automated test equipment and testing procedures, measurements may also be made at -16 dBm0. Two components are measured: signal and noise. When the 1004-Hz signal component is measured, the notch filter is not used. When the noise component of the measurement is performed, a filter is inserted that has the C-message contour and a notch in the 995- to 1025-Hz band, which attenuates (notches out) the holding tone. For measurements to be significant, the attenuation of the holding tone should be large enough so that its residual power is small compared to the remaining "noise" power. Harmonic distortion, quantizing noise, and phase and amplitude jitter components contribute to the CNN measurement value and therefore to the S/CNN measurement value. In ANSI/IEEE 743, the standard measurement methods and equipment characteristics, including the C-message weighting and the requirements on the holding tone and the notch, are defined.

5.1.3 General information

Probably the most important steady-state parameter that affects voiceband data communication performance is S/CNN. Proper modem operation requires low noise relative to received power level. Since data communication systems use modulated carriers, the noise measurements need to be performed with power on the connection to activate equipment having signal-level-dependent noise sources. For 4-kHz channels, a 1004-Hz holding tone is used to activate signal-dependent equipment on the channel or connection.

The 1004-Hz holding tone usually is transmitted at -16 dBm0 (voice holding tone level) or at -13 dBm0 (data holding tone level). Specifications are given below for both levels. The specifications are equivalent. The specifications were converted using the following rules:

a) On digital-carrier systems, S/CNN remains roughly constant or, equivalently, C-notched noise increases dB-for-dB with the increase in holding-tone level for input signals in the approximate range between -30 dBm0 and 0 dBm0.

b) On cable systems the holding tone should have no effect on C-notched noise values, and therefore, S/CNN should improve dB-for-dB with increases in the holding-tone level.

c) Digital carrier S/CNN values are mostly due to the quantizers associated with these facilities. However, digital carrier shows a tight S/CNN distribution about its mean value, which is a recognized property of the digital carrier D-channel bank.

d) Digital switches using digital loss pads to provide loss introduce additional CNN, and thereby degrade the S/CNN ratio, compared with digital switches using analog loss pads. Separate tables are provided for the case when digital loss is used at a digital end office. The amount of degradation is roughly comparable to that of a pair of digital channel banks. The CNN values for this case were obtained by power summing the CNN requirement for offices that do not use digital loss with 39 dBrnC0 (for a -16-dBm0 holding tone) or 42 dBrnC0 (for a -13-dBm0 holding tone). The S/CNN requirement corresponds directly to the CNN requirement. The resulting requirement for the case of digital loss should be applied only in the POT-to-EO direction. The more stringent requirement for offices that do not use digital loss is used in the EO-to-POT direction.

The S/CNN specifications in this section correspond exactly to the CNN specifications in 4.6. The relationship is given in 5.1.1.

5.1.4 Requirements.

Tables 31 through 34 provide requirements for the limits between the POT and the EO.

For exchange access made through a digital end office using digital loss, Tables 35 and 36 provide the requirements in the terminating (POT-to-EO) direction.

Table 31 – Requirements for S/CNN in dB using a -16-dBm0 holding tone (between POT and EO)

IAL	32
RL	33

Table 32 – Requirements for S/CNN in dB using a -13-dBm0 holding tone (between POT and EO)

IAL	32
RL	33

Table 33 – Requirements for S/CNN in dB using a -16-dBm0 Holding Tone (for digital EO employing digital loss) (POT to EO)

IAL	30
RL	31

Table 34 – Requirements for S/CNN in dB using a -13-dBm0 holding tone (for digital EO employing digital loss) (POT to EO)

IAL	30
RL	31

5.1.5 Guidelines[2)]

Tables 35 and 36 provide guidelines for limits between the POT and the AT.

Table 35 – Guidelines for S/CNN in dB using a -16-dBm0 holding tone (between POT and AT)

IAL	34
RL	35

Table 36 – Guidelines for S/CNN in dB using a -13-dBm0 holding tone (between POT and AT)

IAL	34
RL	35

5.2 Signal-to-intermodulation-distortion ratios

5.2.1 Definitions

Signal-to-second-order-intermodulation-distortion ratio (R2) is the ratio in decibels of the composite power of four received test tones to the total power of the measured second-order intermodulation products.

Signal-to-third-order-intermodulation-distortion ratio (R3) is the ratio in decibels of the composite power of four received test tones to the total power of the measured third-order intermodulation products.

Intermodulation distortion is the power generated at extraneous frequencies (intermodulation products) when a multi-tone signal is applied.

5.2.2 Measurement

Nonlinearities in 4-kHz circuits are presently evaluated by an intermodulation-distortion measurement using the four-tone method. Four equal-level tones are transmitted at a composite signal level of -13 dBm0. The transmitted multi-tone signal consists of four equal-level test tones at 860 Hz ± 3 Hz (called A) and 1380 Hz ± 8 Hz (called B). A selective detector is used in the test equipment to measure the appropriate second-order intermodulation-distortion products at B - A and B + A and the third-order intermodulation-distortion products at 2B - A. The result is reported as the ratio of the received four-tone level to the second- or third-order distortion products. R2 and R3 are signal-to-distortion ratios. Therefore, higher values mean better performance.

Measured values of R2 and R3 may contain extraneous components caused by background or quantizing noise. The performance specifications given in 5.2.4 and 5.2.5 assume that these components have been removed and only the nonlinear distortion products are present. The procedure for removing these extraneous components is to perform an associated signal-to-noise-ratio check in which R2 and R3 are measured when only two of the four tones are transmitted. The level of the two tones is increased by 3 dB to maintain the same composite signal level so that codecs are excited by the same power. The corrected R2 or R3 is obtained by power subtraction of the 2-tone R2 or R3 from the 4-tone R2 or R3.

Instruments intended to measure signal-to-intermodulation-distortion ratio shall be as described in ANSI/ IEEE 743.

5.2.3 General information

The purpose of controlling R2 and R3 is to control channel nonlinearity. Modem error performance can be affected by channel nonlinearities, such as compression and clipping, which cause harmonic and intermodulation distortion in a voiceband signal.

Linearity of a channel or connection is the property in which the output level is directly (linearly) proportional to the applied input level, i.e., the output power is a constant multiple of the input power.

For a signal consisting of a single sinusoidal tone, nonlinearity generates harmonics, i.e., harmonic distortion of the signal. For a multi-tone signal, nonlinearity also generates spurious cross-products at other frequencies, i.e., intermodulation distortion.

5.2.4 Requirements

Tables 37 and 38 provide the requirements for limits between the POT and the EO. (See annex B for a discussion of the effects of digital loss pads).

Table 37 – Requirements for R2 in dB (between POT and EO)

IAL	NA
RL	42

NOTE – NA = Not Available.

Table 38 – Requirements for R3 in dB (between POT and EO)

IAL	NA
RL	42

NOTE – NA = Not Available.

5.2.5 Guidelines[2)]

Tables 39 and 40 provide guidelines for limits between the POT and the AT.

Table 39 – Guidelines for R2 in dB (between POT and AT)

IAL	46
RL	52

Table 40 – Guidelines for R3 in dB (between POT and AT)

IAL	50
RL	52

5.3 Envelope delay distortion

5.3.1 Definition

Envelope delay (ED) is the derivative with respect to frequency of the phase-versus-frequency characteristic $\phi(f)$ of a transmission channel.

$$ED(f) = \frac{d\phi(f)}{df}$$

Envelope delay distortion (EDD) is the envelope delay at frequency f relative to the value of the envelope delay at a reference frequency, usually 1704 Hz.

$$EDD(f) = \frac{d\varphi\varphi(f}{df} - \left[\frac{\Delta\varphi(f)}{\Delta f}\right]_{f=1704Hz}$$

Requirements and guidelines for envelope delay distortion are expressed in microseconds (µs).

5.3.2 Measurement

Envelope delay distortion measurements are based on estimating the phase shift of the envelope of low-frequency modulation at 83-1/3 Hz of a carrier relative to modulation of a reference-frequency carrier or relative to the original modulation. The North American method uses a separate reference path except for the special case of loop-around measurements where the original modulation source itself serves as a reference. Standards for instruments intended to measure EDD are contained in ANSI/IEEE 743. The resulting implementation provides the following estimate of the above formula:

$$EDD(f) = \left[\frac{\Delta\phi(f)}{\Delta f}\right] - \left[\frac{\Delta\phi(f)}{\Delta f}\right]_{f=1704Hz}$$

where Δf=166-2/3 Hz.

5.3.3 General Information

Envelope delay distortion (EDD) is a measure of the linearity of the phase-versus-frequency characteristic of a channel. Phase is somewhat difficult to measure. Its derivative, $d\phi(f)/df$, called the envelope delay (ED), is more practical and is used instead as a measure of channel phase linearity.

The phase-versus-frequency characteristic of a channel is one of the characteristics that define the linear properties of a channel. Distortionless transmission requires a linear phase-versus-frequency characteristic or, equivalently, a flat ED-versus-frequency characteristic. A nonlinear phase-versus-frequency characteristic on a connection causes different frequency components of a signal to have different transit times, which in turn leads to distortion in the received signal. Phase linearity is controlled to limit waveform distortion of the speech or data signal. For controlling waveform distortion, the absolute value of phase slope or the absolute value of ED is not relevant. Only the departure of phase from linear or the ED from flat is relevant. Therefore, it would be appropriate to use the ED relative to the minimum ED as in ITU-T documents, for example, ITU-T Recommendation P.11. However, for consistency, simplicity, and ease of operation, it has been conventional in North America to define instead the envelope delay distortion (EDD) as the ED relative to the ED at 1704 Hz. A negative value can occur if the frequency of minimum ED differs from 1704 Hz.

Envelope delay distortion, like attenuation distortion, is specified at two frequencies (relative to the value at the reference frequency). Independent specifications are given at the two frequencies to reflect differing facility characteristics at low and high frequencies. It has been found by experience that control at one low and one high frequency is usually adequate to control the complete envelope delay distortion characteristic.[5)]

5.3.4 Requirements

Tables 41 and 42 provide the requirements for the limits between the POT and the EO.

Table 41 – Requirements for EDD in microseconds at 604 Hz relative to ED at 1704 Hz (between POT and EO)

IAL	720
RL	600

Table 42 – Requirements for EDD in microseconds at 2804 Hz relative to ED at 1704 Hz (between POT and EO)

IAL	400
RL	350

5) These requirements will not necessarily control EDD ripple, which may be service affecting.

5.3.5 Guidelines[2)]

Tables 43 and 44 provide guidelines for the limits between the POT and the AT.

Table 43 – Guidelines for EDD in microseconds at 604 Hz relative to ED at 1704 Hz (between POT and AT)

IAL	400
RL	350

Table 44 – Guidelines for EDD in microseconds at 2804 Hz relative to ED at 1704 Hz (between POT and AT)

IAL	210
RL	195

5.4 Amplitude jitter

5.4.1 Definition

Amplitude jitter (AJ) is any deviation or fluctuation of the peak value of a 1004-Hz tone from its nominal value, as measured by a standard amplitude-jitter measuring set having demodulated amplitude jitter bands of 20 to 300 Hz and 2 to 300 Hz.

Amplitude jitter is expressed in peak percent (%) amplitude modulation.

5.4.2 Measurement

Amplitude jitter is measured by an instrument that indicates the amount of jitter in the amplitude of a received holding tone (usually 1004 Hz) in a specified amplitude band. The amplitude jitter band is the frequency band of the demodulated amplitude jitter. Two demodulated amplitude jitter bands are usually measured: the 20- to 300-Hz band and either the 4- to 300-Hz or the 2- to 300-Hz band.

The instrument is calibrated in peak percent modulation. This value corresponds to the quasi-maximum value of the demodulated amplitude jitter during the measurement interval.

In ANSI/IEEE 743, standards for instruments intended to measure amplitude jitter in the 20- to 300-Hz band and in the 4- to 300-Hz band are provided, but not in the 2- to 300-Hz band.

5.4.3 General information

Amplitude modulation can affect the error performance of voiceband data modems. The 4- to 300-Hz or 2- to 300-Hz band is important for many modern modems, including those that use echo canceling techniques. Measurement in the 20- to 300-Hz band is usually sufficient for modems that do not use echo cancelers. Test sets with the 20- to 300-Hz and 4- to 300-Hz bands are widely available. However, the Exchange Access Study (EAS) data are in the 20- to 300-Hz and 2- to 300-Hz bands. (See TR NPL 000037)

The measurement of amplitude jitter indicates the total effect on the amplitude of the holding tone of incidental amplitude modulation and other sources including quantizing and message noise, impulse noise, gain hits, phase jitter, and additive tones such as single-frequency interference. Caution should be exercised to ensure that an amplitude jitter measurement is not driven by quantizing noise or impulse noise. Digital loss may also introduce amplitude jitter in an amount roughly equal to that of an encode/decode process. The effect of digital loss on this and other parameters is under study.

Normally performing facilities may generate some amplitude modulation. The quantities generated could adversely affect service if many of these facilities are present in tandem, or if any one or more of these facilities have large amplitude modulation, or both. This standard provides amplitude-jitter limits that reflect the capability of facilities as measured in the EAS. The amplitude jitter performance of facilities should be within these limits. However, when measuring voiceband data parameters, it is not usually necessary to measure amplitude jitter to verify compliance with the amplitude-jitter limits. Amplitude jitter usually can be adequately controlled by measuring and controlling S/CNN and impulse noise.

5.4.4 Requirements

Tables 45 and 46 provide the requirements for the limits between the POT and the EO. The effect of digital loss pads needs further study (see annex B). Table 47 provides a placeholder for requirements that are not available at this time.

Table 45 – Requirements for 20- to 300-Hz amplitude jitter in % (between POT and EO)

IAL	4.7
RL	3.4

Table 46 – Requirements for 2- to 300-Hz amplitude jitter in % (between POT and EO)

IAL	5.8
RL	3.8

Table 47 – Requirements* for 4- to 300-Hz amplitude jitter in % (between POT and EO)

IAL	NA
RL	NA

NOTE – NA = Not Available.

* The actual limits for the 4- to 300-Hz band would be equal to or tighter than the 2- to 300-Hz limits. However, until requirement limits are derived for the 4- to 300-Hz range, the 2- to 300-Hz limits should be met for 4- to 300-Hz measurements.

5.4.5 Guidelines[2)]

Tables 48 and 49 provide guidelines for the limits between the POT and the AT. Table 50 provides a placeholder for guidelines that are not available at this time.

Table 48 – Guidelines for 20- to 300-Hz amplitude jitter in % (between POT and AT)

IAL	3.3
RL	2.7

Table 49 – Guidelines for 2- to 300-Hz amplitude jitter in % (between POT and AT)

IAL	3.9
RL	2.9

Table 50 – Guidelines* for 4- to 300-Hz amplitude jitter in % (between POT and AT)

IAL	NA
RL	NA

NOTE – NA = Not Available.

* The actual limits for the 4- to 300-Hz band would be equal to or tighter than the 2- to 300-Hz limits. However, until guideline limits are derived for the 4- to 300-Hz range, the 2- to 300-Hz limits should be met for 4- to 300-Hz measurements.

5.5 Phase jitter

5.5.1 Definition

Phase jitter (PJ) is any deviation or fluctuation of the zero crossings of a 1004-Hz tone from their nominal position in time, as measured by a standard phase-jitter measuring set having demodulated phase jitter bands of 20-to-300 Hz and 2-to-300 Hz.

Phase jitter is expressed in degrees peak-to-peak (°p-p).

5.5.2 Measurement

Phase jitter is measured by an instrument that indicates the amount of jitter in the zero crossings of a received holding tone (usually 1004 Hz), in a specified phase jitter band, of the demodulated phase jitter. Two demodulated phase jitter bands are usually measured: the 20- to 300-Hz band and either the 4- to 300-Hz or the 2- to 300-Hz band.

The instrument is calibrated in degrees peak-to-peak (°p-p). This value corresponds to the quasi-maximum value of the demodulated phase jitter during the measurement interval.

In ANSI/IEEE 743, standards for instruments intended to measure phase jitter in the 20- to 300-Hz band and the 4- to 300-Hz band are provided, but not in the 2- to 300-Hz band.

5.5.3 General Information

Phase jitter is an important impairment parameter that can affect the error performance of voiceband data receivers that use phase detection techniques. There are two significant bands of demodulated phase jitter frequencies. The 20- to 300-Hz band is important to all phase-detecting modems. The wider 4- to 300-Hz or 2- to 300-Hz band is important for many modern modems that use echo-canceling methods. Test equipment with the 20- to 300-Hz and 4- to 300-Hz bands are widely available. However, the EAS data are in the 20- to 300-Hz and 2- to 300-Hz bands.

The measurement of phase jitter indicates the total effect on the holding tone of incidental phase modulation and other sources including quantizing and message noise, impulse noise, phase hits, additive tones such as single-frequency interference, and digital timing jitter. Caution should be exercised to ensure that a phase-jitter measurement is not driven by impulse noise. In addition, phase jitter can be created in the channel from amplitude-jitter and vice versa. Therefore, signal-to-noise ratio and amplitude jitter measurements may need to be performed in conjunction with phase jitter tests. Digital loss may also introduce phase jitter in an amount roughly equal to that of an encode/decode process. The effect of digital loss on this and other parameters is under study.

Normally performing digital facilities do not typically generate phase modulation in significant amounts. Nevertheless, this standard provides phase-jitter limits for these facilities that reflect the capability of digital facilities as measured in the EAS. The phase-jitter performance of digital facilities should be within these limits. However, when measuring voiceband data parameters, it is not usually necessary to measure phase jitter to verify compliance with the phase-jitter limits specifications. Phase jitter usually can be adequately controlled by measuring and controlling S/CNN, impulse noise, and DS1 (or higher) digital timing jitter.

5.5.4 Requirements

Tables 51 and 52 provide the requirements for the limits between the POT and the EO. The effect of digital loss pads needs further study (see annex B). Table 53 provides a placeholder for requirements that are not available at this time.

Table 51 – Requirements for 20- to 300-Hz phase jitter in °p-p (between POT and EO)

IAL	3.4
RL	2.5

Table 52 – Requirements for 2- to 300-Hz phase jitter in °p-p (between POT and EO)

IAL	4.4
RL	3.0

Table 53 – Requirements* for 4- to 300-Hz phase jitter in °p-p (between POT and EO)

IAL	NA
RL	NA

NOTE – NA = Not Available.

* The actual limits for the 4- to 300-Hz band would be equal to or tighter than the 2- to 300-Hz limits. However, until requirement limits are derived for the 4- to 300-Hz range, the 2- to 300-Hz limits should be met for 4- to 300-Hz measurements.

5.5.5 Guidelines[2)]

Tables 54 and 55 provide guidelines for the limits between the POT and the AT. Table 56 provides a placeholder for guidelines that are not available at this time.

Table 54 – Guidelines for 20- to 300-Hz phase jitter in °p-p (between POT and AT)

IAL	2.5
RL	1.5

Table 55 – Guidelines for 2- to 300-Hz phase jitter in °p-p (between POT and AT)

IAL	2.7
RL	1.8

Table 56 – Guidelines* for 4- to 300-Hz phase jitter in °p-p (between POT and AT)

IAL	NA
RL	NA

NOTE – NA = Not Available.

* The actual limits for the 4- to 300-Hz band would be equal to or tighter than the 2- to 300-Hz limits. However, until guideline limits are derived for the 4- to 300-Hz range, the 2- to 300-Hz limits should be met for 4- to 300-Hz measurements.

5.6 Impulse noise

5.6.1 Definition

Impulse noise (IN) is any large excursion of the total noise waveform that is much higher than the normal peaks of message circuit noise.

5.6.2 Measurement

(not available at this time)

5.6.3 General information

(not available at this time)

5.6.4 Requirements

Table 57 provides a placeholder for requirements that are not available at this time.

Table 57 – Requirements for impulse noise in counts per minute (between POT and EO)

IAL	NA
RL	NA

NOTE – NA = Not Available.

5.6.5 Guidelines[2)]

Table 58 provides a placeholder for guidelines that are not available at this time.

Table 58 – Guidelines for impulse noise in counts per minute (between POT and AT)

IAL	NA
RL	NA

NOTE – NA = Not Available.

5.7 Gain hits

5.7.1 Definition

A gain hit (GH) is a sudden increase or decrease in the level of a received 1004-Hz holding tone that lasts at least 4 milliseconds.

5.7.2 Measurement

(not available at this time)

5.7.3 General information

(not available at this time)

5.7.4 Requirements

Table 59 provides a placeholder for requirements that are not available at this time.

Table 59 – Requirements for gain hits (between POT and EO)

IAL	NA
RL	NA

NOTE – NA = Not Available.

5.7.5 Guidelines[2)]

Table 60 provides a placeholder for guidelines that are not available at this time.

Table 60 – Guidelines for gain hits (between POT and AT)

IAL	NA
RL	NA

NOTE – NA = Not Available.

5.8 Phase hits

5.8.1 Definition

A phase hit (PH) is a sudden change in the phase of a received 1004-Hz holding tone that lasts at least 4 milliseconds.

5.8.2 Measurement

(not available at this time)

5.8.3 General information

(not available at this time)

5.8.4 Requirements

Table 61 provides a placeholder for requirements that are not available at this time.

Table 61 – Requirements for phase hits (between POT and EO)

IAL	NA
RL	NA

NOTE – NA = Not Available.

5.8.5 Guidelines[2)]

Table 62 provides a placeholder for guidelines that are not available at this time.

Table 62 – Guidelines for phase hits (between POT and AT)

IAL	NA
RL	NA

NOTE – NA = Not Available.

5.9 Dropouts

5.9.1 Definition

A dropout (DO) is a decrease in the level of a received 1004-Hz holding tone, relative to the level at the start of the measuring interval, that exceeds 12 dB and lasts for at least 4 milliseconds.

5.9.2 Measurement

(not available at this time)

5.9.3 General information

(not available at this time)

5.9.4 Requirements

Table 63 provides a placeholder for requirements that are not available at this time.

Table 63 – Requirements for dropouts (between POT and EO)

IAL	NA
RL	NA

NOTE – NA = Not Available.

5.9.5 Guidelines[2)]

Table 64 provides a placeholder for guidelines that are not available at this time.

Table 64 – Guidelines for dropouts (between POT and AT)

IAL	NA
RL	NA

NOTE – NA = Not Available.

Annex A
(Informative)

Guidelines for parameter statistical distributions

A.1 General

The previous clauses provide requirements and guidelines on impairment parameter limits that apply to individual trunks. The IALs are extreme-value limits that nominally correspond to the 99th or 1st percentiles, as appropriate, of the statistical distributions of the impairment parameters. Except for loss deviation and return loss, the ALs and RLs nominally correspond to the 95th or 5th percentile, as appropriate. Such limits are very useful for maintenance purposes.

To do network planning and service performance evaluations, it is necessary to have knowledge of the entire distributions and not just extreme values. This annex contains the mean, standard deviation, and selected order statistics describing the impairment parameter statistical distributions for each access arrangement. This information on the parameter distributions was derived from the Exchange Access Study (EAS) (TR-NPL-000037), which was one basis for establishing the limits, as discussed in annex B. The statistical distribution characteristics were determined by trimming the data until 1% of the distribution exceeded the IAL, and then calculating the mean, standard deviation and other statistics.[6)] It is important to emphasize that the performance of an end-to-end connection or segment is best characterized by the parameter distributions and not the limits alone. On this basis, although the parameter distributions are not requirements of the standard, network providers and equipment vendors should take into account the parameter distributions as well as the individual trunk limits in their plans and designs.

The statistics in this annex reflect the characteristics of the statistical distribution that is expected for a large number of channels. These estimates are based on a finite national survey of BOC facilities made in 1983. Generally these distributions are not described by a classical Gaussian distribution. Improvements in technologies in providing access facilities could change these distributions. Also, distributions of measured characteristics on a small number of channels, such as occurring between a POT and any one access tandem or end office, may differ from those shown.

The guidelines in this annex are organized on a parameter-by-parameter basis. The facility combinations for which the statistical distributions were derived for each impairment parameter and for each arrangement are shown at the top of each table. These particular chosen combinations are in many cases worse than would be usually expected or "typical" but not necessarily the worst combination that could be used. These combinations are equal to or similar to the combinations on which the limits were based. The facility codes used in the tables are:

a) T Digital facility;

b) C Voice-frequency cable facility.

These codes denote a single facility. Thus, for example, T + T denotes two digital facilities in tandem, i.e., two pairs of digital channel banks.

The statistical distribution guidelines do not include the effect of digital loss pads. Digital switches using digital loss pads to provide the loss specifications of 4.1 introduce additional impairments compared with digital switches using analog loss pads. The parameters that are affected are C-message noise, C-notched noise and signal-to-C-notched-noise ratio, signal-to-intermodulation-distortion ratios R2 and R3, amplitude jitter, and phase jitter. The effect of digital loss on the statistical distributions of these parameters has not been included in this annex.

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6) For parameters with an upper and lower limit (i.e., loss deviation and three-tone slope), the data were trimmed such that the upper limit corresponded to the 99.5th percentile and the lower limit to the 0.5th percentile.

A.2 Definitions

Means, standard deviations, medians, and 85th (or 15th) percentiles that are presented in this annex have their standard statistical meanings and they are computed from the estimated discrete probability density functions.

A.3 Guidelines

A.3.1 Loss and level

Guidelines for the statistical distributions of loss and level can be obtained from the requirements and guidelines for nominal loss and level given in 4.1, together with the guidelines for statistical distributions for loss deviation given in A.3.2.

A.3.2 Loss deviation

Table A.1 provides guidelines for the statistical distribution characteristics between the POT and the EO.

Table A.1 – Guidelines for statistical distribution of loss deviation in dB (between POT and EO)

	T+T
Mean *	0.14
Standard Deviation	0.93
Median *	0.01
85th Percentile	0.67

* The nominal value for this statistic that should be used for planning purposes is 0.0 dB.

Table A.2 provides guidelines for the statistical distribution characteristics between the POT and the AT.

Table A.2 – Guidelines for statistical distribution of loss deviation in dB (between POT and AT)

	T
Mean *	0.05
Standard Deviation	0.68
Median *	-0.01
85th Percentile	0.41

* The nominal value for this statistic that should be used for planning purposes is 0.0 dB.

A.3.3 Three-tone slope

Tables A.3 and A.4 provide guidelines for the statistical distribution characteristics between the POT and the EO.

Table A.3 – Guidelines for statistical distribution of three-tone slope in dB at 404 Hz (between POT and EO)

	T+T
Mean	1.19
Standard Deviation	0.41
Median	1.15
85th Percentile	1.49

Table A.4 – Guidelines for statistical distribution of three-tone slope in dB at 2804 Hz (between POT and EO)

	T+T
Mean	0.49
Standard Deviation	0.58
Median	0.34
85th Percentile	1.06

Tables A.5 and A.6 provide guidelines for the statistical distribution characteristics between the POT and the AT.

Table A.65 – Guidelines for statistical distribution of three-tone slope in dB at 404 Hz (between POT and AT)

	T
Mean	0.59
Standard Deviation	0.29
Median	0.56
85th Percentile	0.78

Table A.6 – Guidelines for statistical distribution of three-tone slope in dB at 2804 Hz (between POT and AT)

	T
Mean	0.23
Standard Deviation	0.43
Median	0.05
85th Percentile	0.72

A.3.4 Echo return loss and singing return loss

Tables A.7 and A.8 provide guidelines for the POT-to-EO statistical distribution characteristics.

Table A.7 – Guidelines for statistical distribution of ELERL and ELSRL in dB (POT to EO) (4-Wire POT)

	T	
	ELERL	ELSRL
Mean	28.3	24.0
Standard Deviation	4.7	4.0
Median	27.4	23.5
15th Percentile	23.6	19.3

Table A.8 – Guidelines for statistical distribution of ERL and SRL in dB (POT to EO) (2-Wire POT)

	C	
	ERL	SRL
Mean	21.2	15.1
Standard Deviation	5.2	5.1
Median	20.5	13.7
15th Percentile	16.5	9.9

A.3.5 C-message noise

Table A.9 provides guidelines for the statistical distribution characteristics between the POT and the EO.

Table A.9 – Guidelines for statistical distribution of C-message noise in dBrnC0* (between POT and EO)

	T+T
Mean	22.6
Standard Deviation	2.5
Median	22.0
85th Percentile	24.5

* The lower limit (threshold) of the test set used to collect the EAS measurements for which these statistics were obtained was 10 dBrnC. Noise readings below this threshold were assumed to be 9 dBrnC. When converting to dBrnC0, these values may be as high as 18 dBrnC0. (See TR-NPL-000037). Measurements made using test sets with different thresholds may give different statistics.

Table A.10 provides guidelines for the statistical distribution characteristics between the POT and the AT.

Table A.10 – Guidelines for statistical distribution of C-message noise in dBrnC0* (between POT and AT)

	T
Mean	19.2
Standard Deviation	2.8
Median	18.4
85th Percentile	20.7

* The lower limit (threshold) of the test set used to collect the EAS measurements for which these statistics were obtained was 10 dBrnC. Noise readings below this threshold were assumed to be 9 dBrnC. When converting to dBrnC0, these values may be as high as 18 dBrnC0 (see TR-NPL-000037). Measurements made using test sets with different thresholds may give different statistics.

A.3.6 C-notched noise

Table A.11 provides guidelines for the statistical distribution characteristics between the POT and the EO.

Table A.11 – Guidelines for statistical distribution of C-notched noise in dBrnC0 using a -13-dBm0 holding tone* (between POT and EO)

	T+T
Mean	41.4
Standard Deviation	1.2
Median	41.4
85th Percentile	42.4

* The lower limit (threshold) of the test set used to collect the EAS measurements for which these statistics were obtained was 10 dBrnC. Measurements made using test sets with different thresholds may give different statistics.

Table A.12 provides guidelines for the statistical distribution characteristics between the POT and the AT.

Table A.12 – Guidelines for statistical distribution of C-notched noise in dBrnC0 using a -13-dBm0 holding tone* (between POT and AT)

	T
Mean	38.2
Standard Deviation	1.8
Median	38.0
85th Percentile	39.2

* The lower limit (threshold) of the test set used to collect the EAS measurements for which these statistics were obtained was 10 dBrnC. Measurements made using test sets with different thresholds may give different statistics.

A.3.7 Signal-to-C-notched-noise ratio

Table A.13 provides guidelines for the statistical distribution characteristics between the POT and the EO.

Table A.13 – Guidelines for statistical distribution of S/CNN in dB using a -13-dBm0 holding tone (between POT and EO)

	T+T
Mean	35.6
Standard Deviation	1.2
Median	35.3
15th Percentile	34.2

Table A.14 provides guidelines for the statistical distribution characteristics between the POT and the AT.

Table A.14 – Guidelines for statistical distribution of S/CNN in dB using a -13-dBm0 holding tone (between POT and AT)

	T
Mean	38.9
Standard Deviation	1.4
Median	38.5
15th Percentile	37.4

A.3.8 Signal-to-intermodulation-distortion ratios

Tables A.15 and A.16 provide guidelines for the statistical distribution characteristics between the POT and the EO.

Table A.15 – Guidelines for statistical distribution of R2 in dB* (between POT and EO)

	T1+T2
Mean	55.0
Standard Deviation	5.9
Median	56.0
15th Percentile	49.0

* The designation T denotes all T-carrier data. The designations T1 and T2 are used to differentiate the direction in which the EAS measurements were made. T1 measurements were taken at the toll office, tone sent from the End Office location. T2 measurements were taken at the End Office, tone sent from the Toll Office location. The statistics are computed using measurements at analog offices only.

Table A.16 – Guidelines for statistical distribution of R3 in dB* (between POT and EO)

	T1+T2
Mean	53.0
Standard Deviation	5.6
Median	54.0
15th Percentile	49.0

* The designation T denotes all T-carrier data. The designations T1 and T2 are used to differentiate the direction in which the EAS measurements were made. T1 measurements were taken at the toll office, tone sent from the End Office location. T2 measurements were taken at the End Office, tone sent from the Toll Office location. The statistics are computed using measurements at analog offices only.

Tables A.17 and A.18 provide guidelines for the statistical distribution characteristics between the POT and the AT

Table A.17 – Guidelines for statistical distribution of R2 in dB* (between POT and AT)

	T1/T2
Mean	59.0/59.0
Standard Deviation	3.9/7.2
Median	60/62
15th Percentile	55.0/51.0

* The designation T denotes all T-carrier data. The designations T1 and T2 are used to differentiate the direction in which the EAS measurements were made. T1 measurements were taken at the toll office, tone sent from the End Office location. T2 measurements were taken at the End Office, tone sent from the Toll Office location. The statistics are computed using measurements at analog offices only.

Table A.18 – Guidelines for statistical distribution of R3 in dB* (between POT and AT)

	T1/T2
Mean	59.0/58.0
Standard Deviation	3.4/7.2
Median	60.0/60.0
15th Percentile	55.0/53.0

* The designation T denotes all T-carrier data. The designations T1 and T2 are used to differentiate the direction in which the EAS measurements were made. T1 measurements were taken at the toll office, tone sent from the End Office location. T2 measurements were taken at the End Office, tone sent from the Toll Office location. The statistics are computed using measurements at analog offices only.

A.3.9 Envelope delay distortion

Tables A.19 and A.20 provide guidelines for the statistical distribution characteristics between the POT and the EO.

Table A.19 – Guidelines for statistical distribution of EDD in µs at 604 Hz (between POT and EO)

	T+T
Mean	435
Standard Deviation	99
Median	426
85th Percentile	539

Table A.20 – Guidelines for statistical distribution of EDD in µs at 2804 Hz (between POT and EO)

	T+T
Mean	312
Standard Deviation	74
Median	310
85th Percentile	333

Table A.21 and A.22 provide guidelines for the statistical distribution characteristics between the POT and the AT.

Table A.21 – Guidelines for statistical distribution of EDD in µs at 604 Hz (between POT and AT)

	T
Mean	218
Standard Deviation	70
Median	194
85th Percentile	314

Table A.22 – Guidelines for statistical distribution of EDD in µs at 2804 Hz (between POT and AT)

	T
Mean	156
Standard Deviation	53
Median	157
85th Percentile	169

A.3.10 Amplitude jitter

Tables A.23 and A.24 provide guidelines for the statistical distribution characteristics between the POT and the EO.

Table A.23 – Guidelines for statistical distribution of 20-to-300 Hz amplitude jitter in % (between POT and EO)

	T+T
Mean	2.9
Standard Deviation	0.6
Median	2.8
85th Percentile	3.4

Table A.24 – Guidelines for statistical distribution of 2-to-300 Hz amplitude jitter in % (between POT and EO)

	T+T
Mean	3.1
Standard Deviation	0.6
Median	3.0
85th Percentile	3.5

Table A.25 provides a placeholder for specifications that are not available at this time.

Table A.25 – Guidelines for statistical distribution of 4-to-300 Hz amplitude jitter in % (between POT and EO)

	T+T
Mean	NA
Standard Deviation	NA
Median	NA
85th Percentile	NA

NOTE – NA = Not Available.

Tables A.26 and A.27 provide guidelines for the statistical distribution characteristics between the POT and the AT.

Table A.26 – Guidelines for statistical distribution of 20-to-300 Hz amplitude jitter in % (between POT and AT)

	T
Mean	1.8
Standard Deviation	0.5
Median	1.6
85th Percentile	2.2

Table A.27 – Guidelines for statistical distribution for 2-to-300 Hz amplitude jitter in % (between POT and AT)

	T
Mean	1.8
Standard Deviation	0.5
Median	1.7
85th Percentile	2.1

Table A.28 provides a placeholder for specifications that are not available at this time.

Table A.28 – Guidelines for statistical distribution of 4-to-300 Hz amplitude jitter in % (between POT and AT)

	T
Mean	NA
Standard Deviation	NA
Median	NA
85th Percentile	NA

NOTE – NA = Not Available.

A.3.11 Phase jitter

Tables A.29 and A.30 provide guidelines for the statistical distribution characteristics between the POT and the EO.

Table A.29 – Guidelines for statistical distribution of 20-to-300 Hz phase jitter in °p-p (between POT and EO)

	T+T
Mean	2.1
Standard Deviation	0.7
Median	2.0
85th Percentile	2.2

Table A.30 – Guidelines for statistical distribution of 2-to-300 Hz phase jitter in °p-p (between POT and EO)

	T+T
Mean	2.5
Standard Deviation	0.6
Median	2.4
85th Percentile	2.7

Table A.31 provides a placeholder for specifications that are not available at this time.

Table A.31 – Guidelines for statistical distribution of 4-to-300 Hz phase jitter in °p-p (between POT and EO)

	T+T
Mean	NA
Standard Deviation	NA
Median	NA
85th Percentile	NA

NOTE – NA = Not Available.

Tables A.32 and A.33 provide guidelines for the statistical distribution characteristics between the POT and the AT.

Table A.32 – Guidelines for statistical distribution of 20-to-300 Hz phase jitter in °p-p (between POT and AT)

	T
Mean	1.3
Standard Deviation	0.6
Median	1.2
85th Percentile	1.3

Table A.33 – Guidelines for statistical distribution of 2-to-300 Hz phase jitter in °p-p (between POT and AT)

	T
Mean	1.5
Standard Deviation	0.5
Median	1.4
85th Percentile	1.6

Table A.35 provides a placeholder for specifications that are not available at this time.

Table A.34 – Guidelines for statistical distribution of 4-to-300 Hz phase jitter in °p-p (between POT and AT)

	T
Mean	NA
Standard Deviation	NA
Median	NA
85th Percentile	NA

NOTE – NA = Not Available.

Annex B
(Informative)

Methodology used in developing limit values

B.1 General

This annex provides a guide to the methodologies and rationale used in developing the limits specified in the standard. The limits were derived primarily on the basis of the capabilities of the existing network, although several other considerations, summarized in the Foreword, were used. The annex summarizes the approach used to derive the IALs, ALs, and RLs for voice and voiceband data, reflecting the capabilities of the existing networks; the facilities, network architecture and switches. The definitions of IAL, AL, and RL are given in clause 3 of the standard.

B.2 Capabilities of the exchange access network

B.2.1 Capabilities of exchange facilities

The major factor in developing the limits was the actual performance of a sample distribution of current access facilities and arrangements. This approach was taken to avoid the need for fundamental design changes. At the time of the development of this standard, measured data for the postdivestiture exchange access network were not available. Considerable changes in the architecture of the access network had occurred. Consensus of the committee was that the best available data were the facility information obtained in the EAS. This field study, conducted in 1983 by Bell Communications Research, characterized the analog voice and voiceband data transmission performance of facilities of the then access network (see TR-NPL-000037). This study was supplemented by other information where appropriate.

Performance estimates of the basic arrangements of the postdivestiture access network were obtained by using mathematical models and the measured information. The arrangements included direct and tandem-switched connections between the POT and the EO. The arrangements were derived based on the service architecture of the offering identified as Feature Group D. The performance of the connection between the POT and the AT generally was considered to involve one facility and was estimated directly from the EAS. The performance of the direct and tandem switched connections between the POT and the EO was estimated from that of two tandem facilities. The values contained in this standard are derived on the basis of reference connections using the number of facilities in table B.1. Actual service connections covered by this standard may contain a different number of facilities. The performance of each facility in these arrangements was based on measured information from the EAS. Performance was based on information on newer design digital carrier systems. Estimates of some parameters were obtained by methods similar to those used in exchange access performance modeling studies (see TR-NPL-000002).

Table B.1 – Assumed number of facilities in each arrangement

Routing	No. of Facilities
Between POT and EO, direct or via AT	2
Between POT and AT	1

The following summing laws were used for each parameter.

a) For loss, loss deviation, attenuation distortion, and envelope delay, the summing law used was linear algebraic addition, that is, ordinary arithmetic.

b) For C-message noise, C-notched noise and second-order intermodulation distortion the summing law used was power summing, that is,

$$A"+"B = 10\log_{10}\left(10^{\frac{A}{10}} + 10^{\frac{B}{10}}\right).$$

c) For echo return loss, singing return loss, signal-to-C-notched-noise ratio and signal-to-second-order-intermodulation-distortion ratio R2, the summing law used was

$$A"+"B = -10\log_{10}\left(10^{-\frac{A}{10}} + 10^{-\frac{B}{10}}\right).$$

d) For third-order intermodulation distortion, the summing law used was power summing modulo 16 (modified voltage addition), that is,

$$A"+"B = 16\log_{10}\left(10^{\frac{A}{16}} + 10^{\frac{B}{16}}\right).$$

e) For signal to third-order intermodulation distortion ratio R3, the summing law used was

$$A"+"B = -16\log_{10}\left(10^{-\frac{A}{16}} + 10^{-\frac{B}{16}}\right).$$

f) For phase jitter and amplitude jitter, the summing law used was

$$A"+"B = \left(A^{n} + B^{n}\right)^{\frac{1}{n}},$$

with n=1.33 for the 2-to-300 Hz band and n=1.45 for the 20-to-300 Hz band.

B.2.2 Methodology for developing the limits

The determination of the performance limits is analogous to a quality assurance process in a manufacturing plant. Items falling within a specified set of limits are satisfactory, those outside are rejected. For access network performance, the performance limits are based largely on the worst-performing tail of the estimated distribution for the segment between the POT and the EO or between the POT and the AT. The 99% level or 1% level, or both, depending on the parameter, is taken to be the nominal starting point for the immediate action limit. The 95% value or 5% value, or both, depending on the parameter, is typically used as a nominal starting point for the acceptance limit or restoral limit.

Differing methodologies were used in arriving at an estimate of a "satisfactory" performance distribution from the measured performance distribution, which usually has some percentage of "unsatisfactory" performing circuits. Several approaches were used in the submittals. For example, one approach was to use the properties of idealized distributions such as the Gaussian distribution. Another approach was to estimate the 99%, 95%, 5%, or 1% level by smoothly extrapolating the distribution from the region of regularity. In many cases, either of these estimates of the levels were highly influenced because of a sparse sample of data, or the disproportionate effect of outliers, or both. Approaches included discarding data from nontypical offices, or removing (trimming) outliers that far exceeded reasonable performance.

The values obtained by the above processes were adjusted to accommodate differing views including factors such as interpretation of measurements, parameter stability, measurement accuracy, measurement precision, operations procedures, and standard channel-design considerations. The total process is iterative and reflects the numerous and sometimes conflicting considerations involved.

B.2.3 Specific rationale variations for each parameter

Special considerations associated with each particular parameter are discussed in this subclause.

B.2.3.1 Loss and level

The loss and level specifications were determined by fixed-loss-plan design considerations rather than from measured data. A loss specification depends on the two points chosen. The loss specifications in 4.1 are stated for the loss between the analog loop interface at the EO and the center (switch reference point) of the IC switch. This definition permits a simple loss specification that is consistent with the classical analog plan and the fixed loss plan, and that reflects the loss experienced by an end-user call.

B.2.3.2 Loss deviation

Loss deviation is specified by a two-valued limit having a negative (less-loss) and a positive (more-loss) specification. Both tails of the measured distributions of loss deviation were examined in the 1% and 5% region and the 95% and 99% region. Although there are slight nonsymmetries in the 1% and 99% regions, symmetric limits appear justified. The worst case of the less-loss and more-loss cases was chosen. The IAL values were rounded to the nearest 0.5 dB. For loss deviation, the ALs were not derived from a nominal starting point of 5% and 95% values. Since loss can be adjusted, established practices were followed and the ALs were set at 0.7 dB for direct trunks. Additional allowance was made for cable facilities without gain.

B.2.3.3 Three-tone slope

Attenuation distortion is specified by a two-valued limit having a negative (less-loss) and a positive (more-loss) specification. Both tails of the measured slope distribution were examined. This was done at both 404 Hz and 2804 Hz. The distributions of slope are very non-symmetric about zero dB. (Slope is basically a more-loss impairment.) Hence, the negative- and positive-slope limits are stated separately. The worst-case value of either 404 or 2804 Hz was chosen for the common limit to apply at both frequencies. The AL and IAL values were rounded to the nearest 0.5 dB.

B.2.3.4 Echo return loss and singing return loss

Echo return loss and singing return loss values were based on long-standing historic standards for terminal balance and not the measured data. Values were suitably adjusted numerically to apply at the POT rather than at a traditional terminal-balance measuring point of the IC switch.

The limits depend on whether 4-wire or 2-wire facilities are used. For tandem access, in which the link between the POT and the AT is always 4-wire, the limits depend on whether 4-wire or 2-wire facilities are used between the access tandem and the end office. The 4-wire limit applies to both the 4-wire and 2-wire cases.

B.2.3.5 C-message noise

The C-message-noise limits are based on EAS data for digital carriers. Digital-carrier C-message noise is not mileage dependent. Based on the measured data, cable facilities of 15 miles or less have the same limit as digital carrier.

Digital switches using digital loss pads to provide loss introduce additional CMN compared with digital switches using analog loss pads. There is little in-service data on this effect, none in the noise range of the limits values. Based on extensive laboratory measurements and analytical studies, it is known that for low-input CMN levels, the nominal output CMN is asymptotic to a value equal to the digital loss plus a noise value of up to 23 dBrnC0, and for high-input CMN levels, the nominal output CMN is asymptotic to the input CMN. This nominal behavior of CMN in the presence of digital loss was modeled by the algorithm of power summing the limit for offices that do not use digital loss with a noise value of 21 dBrnC0. This nominal model results (after rounding to the nearest dB) in a 1-dB increase for any limits between 26 and 30 dBrnC0 and 0 dB for limits above 30 dBrnC0. An allowance of 1 dB was added to the

CMN requirements for acceptance limits. The correction should be applied only in the POT-to-EO direction when digital loss is used. The more stringent limit for offices that do not use digital loss should be used in the EO-to-POT direction.

B.2.3.6 C-notched noise

The C-notched noise limits are specified for both a -16 dBm0 holding tone and a -13 dBm0 holding tone. The EAS data were measured with a -13 dBm0 holding tone, the approximate power of voiceband data modems. Currently, some automatic trunk-measuring systems measure at -16 dBm0. The EAS data were adjusted according to the following rules to estimate the C-notched Noise at -16 dBm0:

a) C-notched noise on digital carrier increases 1 dB for each 1-dB increase in holding-tone level (i.e., digital carrier has constant signal-to-C-notched-noise ratio over the signal levels of interest);

b) C-notched noise on cable is essentially independent of holding-tone level.

Mileage effects are found to be insignificant.

Digital switches using digital loss pads to provide loss introduce additional CNN compared with digital switches using analog loss pads. Separate tables are provided for the case when digital loss is used at a digital end office. The amount of degradation is roughly comparable to that of a pair of digital channel banks. The CNN values for this case were obtained by the algorithm of power summing the CNN requirement for offices that do not use digital loss with 39 dBrnC0 (for a -16-dBm0 holding tone) or 42 dBrnC0 (for a -13-dBm0 holding tone). The resulting requirement for the case of digital loss should be applied only in the POT-to-EO direction. The more stringent requirement for offices that do not use digital loss should be used in the EO-to-POT direction.

B.2.3.7 Signal-to-C-notched-noise ratio

Signal-to-C-notched-noise ratio (S/CNN) and C-notched noise (CNN) are directly related. (See 5.1.1.) The limits for signal-to-C-notched-noise ratio are designed to correspond exactly to the limits for C-notched noise.

Digital switches using digital loss pads to provide loss introduce additional CNN, and thereby degrade the S/CNN ratio, compared with digital switches using analog loss pads. Separate tables are provided for the case in which digital loss is used at a digital end office. The amount of degradation is roughly comparable to that of a pair of digital channel banks. The CNN values for this case were obtained by the algorithm of power summing the CNN requirement for offices that do not use digital loss with 39 dBrnC0 (for a -16-dBm0 holding tone) or 42 dBrnC0 (for a -13-dBm0 holding tone). The S/CNN requirement corresponds directly to the CNN requirement. The resulting requirement for the case of digital loss should be applied only in the terminating (POT-to-EO) direction. The more stringent requirement for offices that do not use digital loss should be used in the originating (EO-to-POT) direction.

B.2.3.8 Signal-to-intermodulation-distortion-ratios

The guidelines are based on the capabilities of digital carrier as measured in the EAS at a predivestiture toll switch. The requirements need further study, because of unexplained measured performance that is lower than would be expected from design.

Digital switches using digital loss pads to provide loss introduce additional intermodulation distortion, and thereby degrade R2 and R3, compared with digital switches using analog loss pads. When digital loss is used, low values of R2 and R3 are not significantly affected; however, the average performance could be affected. The effect of digital loss on IALs and RLs for R2 and R3 needs further study.

B.2.3.9 Envelope delay distortion

Separate specifications for envelope delay distortion are given at 604 Hz and 2804 Hz to reflect performance differences at the low and high frequencies. This allowed independent and tighter control at the higher frequencies. To permit a specification that reflects the EDD performance of digital carrier at high frequencies, only cable of 1 mile or less is included. The EAS data show that although cable performs about as well as digital carrier at the low frequencies, cable performs worse at the high frequencies.

B.2.3.10 Amplitude jitter and phase jitter

Amplitude jitter and phase jitter are specified in two frequency bands specified in ANSI/IEEE 661 as 20 to 300 Hz and 4 to 300 Hz. The band of 4 to 300 Hz described in ANSI/IEEE 661 was not measured in the EAS because of available instrumentation. Thus, values were specified in the 2- to 300-Hz and 20- to 300-Hz bands, which were measured in the EAS.

Digital switches using digital loss pads to provide loss introduce additional amplitude jitter and phase jitter compared with digital switches using analog loss pads. The amplitude jitter and phase jitter specifications should be adjusted when digital loss is used. The amount of jitter degradation is roughly the amount expected from the noise contribution of a pair of digital channel banks. However, the exact appropriate amount of adjustment, which needs study, is not provided.

B.2.3.11 Methodology used in developing delay guidelines

This subclause describes the approach used in developing the NI-POT round-trip delay guidelines of 4.7. The NI-to-POT round-trip delay consists of two components: the propagation delay and the processing delay. The propagation delay is a function of the route distance. It is assumed that all the facilities have the delay of fiber with a round-trip propagation delay (ms) equal to 0.0168 the one-way distance (in miles) between the NI and POT. The processing delay depends on how many network elements are included in the NI-to-POT path, and their types. The characteristics of processing delay of a network element are summarized by a typical value and a range as displayed in table B.2. The delay guidelines were derived using this information and the reference NI-POT architecture depicted in figure 3.

There are four representative NI-to-POT paths depicted in the reference architecture (see figure B.1). Three processing delay values are computed for each path using the low, the typical and the high network element values of table B.2, for a total of 12 values. For figure 2, the estimated minimum and maximum processing delay values are taken to be the smallest and largest values obtained. The value used as the typical processing delay is taken to be the value of the path using a direct line to an RSU evaluated with typical network element values.

Below are a list of abbreviations used.

DAT	digital access tandem
DCS	DS1 to DS0 digital cross-connect system
DEO	digital end office
DI	digital interface at DEO/RSU
EDSX	DS1 to DS1 digital cross-connect
LI	access line (loop) interface at DEO/RSU
M13 MUX	DS1 to DS3 multiplex
NI	network interface
POT	point of termination
RDT	remote digital terminal
RSU	remote switching unit

Table B.2 – Assumed range and typical round-trip delay values of network elements (ms)

Network Element	Typical Value	Low Value	High Value
DEO/HOST (DI-to-LI)	1.3	0.75	1.9
DEO/HOST (DI-to-DI)	1.0	0.9	1.4
RSU (DI-to-LI)	1.2	1.0	1.7
RSU (DI-to-DI)	0.8	0.7	1.0
RDT	0.6	0.5	1.3
DCS	0.8	0.6	1.5
DAT	1.0	0.9	1.3
M13 MUX	0.04	0.04	0.04
EDSX (1/1)	0.2	0.2	0.2

NOTE – The choice of the particular access arrangement is not meant to constrain delay values on access to those generated as estimates from the reference model. Deployment of systems with new capabilities and features in the access network is bound to increase delay in that network, since enhanced capabilities and expanded feature sets are associated, by necessity, with additional signal processing. For example, the typical delay given for the RDT applies only for basic service. Additional features such as Time Slot Interchange, concentration of IDLC channels would increase the typical round trip delay.

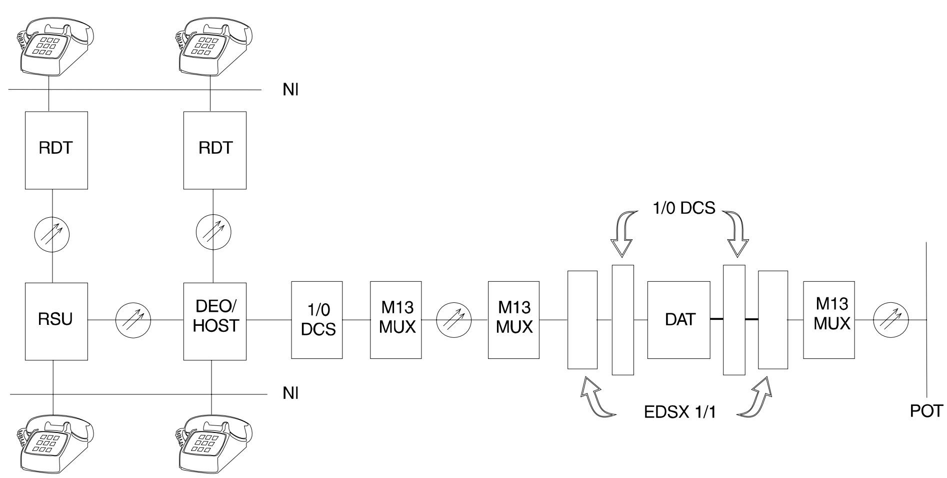

Figure B.1 – NI-POT digital reference architecture

Annex C
(informative)

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