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Voice-Grade Special Access Network Voiceband Data Transmission

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American National Standard
for Telecommunications –

Network Performance – Point-to-Point Voice-Grade Special Access Network Voiceband Data Transmission Objectives

Secretariat

Alliance for Telecommunications Industry Solutions

Approved May 23, 1994

American National Standards Institute, Inc.

Abstract

This standard provides performance objectives for the two-way transmission path between the access provider's network interface to an end-user and an interexchange carrier's point of termination. This set of objectives will enable the provision of quality end-to-end performance for voiceband data voice-grade special services. This standard sets objectives for analog performance-related transmission parameters based on end-user needs and applications.

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Foreword (This foreword is not part of American National Standard T1.512-1994.)

The specification of performance standards for the voiceband data voice-grade special access network was initiated under the auspices of the Accredited Standards Committee on Telecommunications, T1 which is sponsored by the Alliance for Telecommunications Industry Solutions (formerly the Exchange Carriers Standards Association).

The use of this standard will allow the provision of high-quality service to end-users by the telecommunications industry and ensure the ability of a carrier (EC) to provide, operate, and maintain a voice-grade special access network for voiceband data applications. The standard was developed to accommodate the characteristics of the existing digital network, while recognizing the differing characteristics of the analog technology still deployed.

This standard is one part of a series on network performance. Other documents that are planned are:

– network interface (NI) to point of termination (POT) performance;
– end-to-end (NI-to-NI) performance;
– voiceband data application performance.

The objectives, guidelines, and discussion stated herein reflect the following considerations:

– end-user needs of end-to-end service;
– network architectures and equipment used in providing voice-grade special access services at the time of the development of this standard, as offered by many exchange carriers (ECs) as nonswitched private line or leased line access;
– normally occurring variations in parameter characteristics of facilities and equipment used in providing voice-grade special access services;
– operational and economic feasibility of providing the standard services;
– current performance and technical capabilities of terminal equipment as specified in TIA/EIA and ITU standards;
– the predominately digital network.

An informative annex on the relation of transmission performance to end-user application performance is provided. A bibliographic informative annex is also provided.

Suggestions for improvement of this standard are welcome. They should be sent to the Alliance for Telecommunications Industry Solutions (formerly the Exchange Carriers Standards Association), Suite 500, 1200 G Street, NW, Washington, DC 20005.

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American National Standard
for Telecommunications –

Network Performance – Point-to-Point Voice-Grade Special Access Network Voiceband Data Transmission Objectives

1 Scope, purpose, and application

1.1 Scope

This standard provides transmission performance objectives for point-to-point voiceband data (VBD), voice-grade special access (VGSA) services covering the bi-directional path between an exchange carrier's (EC) end-user network interface (NI) and an interexchange carrier's (IC) point of termination (POT) (see figure 1). Throughout the document, the term, VGSA, implies point-to-point VGSA. Moreover, throughout the document, for consistency with previous standards, the designation, exchange carrier (EC), is used, but is intended to include all providers of special access services.

Transmission performance objectives for multipoint services require further study and therefore are not covered. Within this document, the term, IC, refers to interexchange carriers and any other connecting entities. Both originating (access) and terminating (egress) special access services are covered, and are referred to in this standard simply as special exchange access. VGSA is an element of voice-grade special services similar to that provided in what has historically been referred to as private line, leased line, or private network services.

The transmission performance objectives specified in this standard are based on end-user needs and applications, characteristics of voiceband data modems, and capabilities of evolving telecommunications networks. A discussion of end-user application needs, and the relationship of these needs to voiceband channel transmission performance, can be found in annex A. The objectives are considered to be reasonable criteria for circuit acceptance and restoral[1)]. Actual in-service performance will depend on the initial values and variance of parameters, not the objectives alone. Therefore, the objectives may not be met on all circuits or on any particular circuit at all times. In such cases, the carriers and end-users should work cooperatively to achieve a level of performance within transmission maintenance limits specified by the EC. This standard does not preclude the possibility of separate negotiations between carriers to implement other levels of service.

1.2 Purpose

This standard is intended to be used by the telecommunications industry to cooperatively provide service quality appropriate for end-user application needs. The use of this standard helps to ensure the ICs about the quality of the VGSA services and enable ECs to implement and maintain VBD-VGSA network arrangements. This standard is a product of a number of considerations. Among them are customer service needs, network architectures, the technical capabilities of transmission and equipment systems, as well as operational and economic concerns. See annex B, Bibliography, for examples.

1.3 Application

1.3.1 Architecture

This document specifies transmission performance objectives that are based on end-user application needs. This standard assumes that the emerging ITU-T V.34 modem recommendation operating at signaling data rate of 19.2 kbit/s is the most demanding application need[2)]. Many network architectures and facility and equipment combinations can be used to achieve these objectives. Generally, circuits will be routed through one or more serving offices between the POT and the NI.

1.3.2 Facilities

The actual facilities and equipment used to provide VBD-VGSA will vary, depending on the service provider, the geographical location, the embedded plant, economic considerations, and many other factors. Circuits may utilize digital facilities, analog facilities, or combinations of the two. Although the vast majority of the facilities in modern telecommunication networks are digital, cable extensions are commonly used from the NI to the first carrier system channel bank and between tandemed carrier systems. It is recommended that if cases arise that have not been addressed in this standard, the EC and the IC cooperate to negotiate needed performance.

Low-bit-rate-encoding techniques such as described in *American National Standard for Telecommunications – Digital processing of voice-band signals – Algorithms for 24-, 32-, and 40-kbit/s adaptive differential pulse-code modulation (ADPCM)*, ANSI T1.303-1989, have a severe impact on the transmission of high data rate VBD. A separate standard, *American National Standard for Telecommunications – Network performance tandem encoding limits for 32 kbit/s adaptive differential pulse-code modulation (ADPCM)*, ANSI T1.501-1988, provides tandem encoding limits and guidelines for functional usage of 32 kbit/s ADPCM. Therefore, the performance effects of ADPCM are not covered in this document. In order to ensure satisfactory VBD transmission performance, the recommendations of ANSI T1.501 should be followed in addition to meeting the objectives specified in this standard.

NOTE – Existing standard measurement methods in *American National Standard for Standard methods and equipment for measuring the transmission characteristics of analog voice frequency circuits*, ANSI/IEEE 743-1984 (R1993), do not reflect the effects of ADPCM on VBD performance. As part of a project to revise that standard, new measurement methods are currently being developed to identify low bit-rate encoding and to provide better measures of signal-to-total distortion and intermodulation.

1.3.3 Specification groups

In order to accommodate a wide range of end-user needs and applications, three groups of specifications, referred to as Group 1, Group 2, and Group 3 are provided. Group 1 is intended to meet the needs of modern high data rate modems and the most critical applications (e.g. V.34 at 19.2 kbit/s),[2)] and has stringent objectives for signal-to-noise ratio and intermodulation distortion. Group 2 is intended for lower data rate modems and less critical applications, and is specified in two tiers. Tier 1 has more stringent objectives for attenuation distortion and envelope delay distortion than Tier 2 and is intended for modems having compromise linear equalization. Tier 2, on the other hand, is intended for modems having adaptive equalizers. Group 3 objectives are the least stringent but are still adequate for many less demanding end-user applications. The Group 3 specifications are intended to be the minimal objectives for point-to-point VBD-VGSA.

1.3.4 Measurements

This document provides objectives for a set of analog parameters that relate to VBD-VGSA transmission performance between the POT and the NI. 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. The numerical values, however, do not include the contributions of impairments caused when digital loss is placed in the measurement path to test terminations of digital equipment. For further information on the effect of digital loss pads, see annex B of *American National Standard for Telecommunications – Network performance transmission specifications for switched exchange access network*, ANSI T1.506-1990. As discussed below, measurements can be made using analog or digital methods. Furthermore, under specific conditions, measurements can be made at other interfaces.

1.3.4.1 Measurement method – Analog

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

1.3.4.2 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 objectives in this document can be used as bounds or guidelines for digital measurements. This standard does not provide guidelines for discounting the effects of D/A conversions on the analog objectives. Note that the digital measurement method is not covered in ANSI/IEEE 743, but is commonly used.

1.3.4.3 Measurement interfaces

The objective values contained in tables 1, 2, and 3 apply between the NI and the POT. However, for practical reasons, measurements are sometimes made at other interfaces. Such measurements must be corrected to compensate for the contribution between the actual measurement interface and the POT or NI.

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 T1.501-1988, *Telecommunications – Network performance – Tandem encoding limits for 32 kbit/s adaptive differential pulse-code modulation (ADPCM)* [3)]

ANSI T1.506-1990, *Telecommunications – Network performance – Transmission specifications for switched exchange access network*

ANSI/IEEE 743-1984 (R1993), *Standard methods and equipment for measuring the transmission characteristics of analog voice frequency circuits* [3)]

3 Definitions and acronyms

3.1 Definitions

The following definitions apply in this standard.

3.1.1 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 bidirectional path.

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

3.1.3 customer premises equipment (CPE): Equipment at the end of a communication circuit, such as telephone sets, PBXs, voiceband data modems, and teletypewriters.

3.1.4 echo return loss (ERL): The echo return loss at any point in a channel is a frequency-weighted average, over the middle of the voiceband (3-dB bandwidth from 560 Hz to 1965 Hz), of the return losses, $RL(f)$, at that point, with the output of the channel terminated in a standard impedance. The precise weighting is provided in ANSI/IEEE 743.

3.1.5 end-user (EU): A customer involved with a telecommunication connection who uses (rather than provides) telecommunication services.

3.1.6 equal-level echo return loss (ELERL): The equal-level echo return loss 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 transmission level points (TLPs) at the interface. That is:

$$ELERL = (\text{4-wire } ERL) - (TLP_T - TLP_R),$$

where TLP_T is the transmitting TLP from the point of measurement toward the far end, and TLP_R is the receiving TLP at the point of measurement from the far end. Some return loss measuring sets make the adjustment for TLPs internally in the measuring set, thereby producing the result automatically. The term, equal-level echo path loss (ELEPL), is used to refer to ELERL or ELSRL measurements made at a 4-wire interface.

3.1.7 equal-level singing return loss (ELSRL): Equal-level singing return loss 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. That is:

$$ELSRL = (\text{4-wire } SRL) - (TLP_T - TLP_R)).$$

Some return loss measuring sets make the adjustment for TLPs internally in the measuring set, thereby producing the result automatically. The term, equal-level echo path loss (ELEPL), is used to refer to ELERL or ELSRL measurements made at a 4-wire interface.

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

3.1.9 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 an access network at a POT.

3.1.10 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 telecommunication services.

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

3.1.12 objective: A transmission performance parameter value (or range of values) that network providers should strive to achieve, for circuit acceptance or restoral, to satisfactorily support an intended customer application.

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

3.1.14 point-to-point voice-grade special access (VGSA): A nominal 300 Hz to 3000 Hz channel between an end-user network interface (NI) and an interexchange carrier point of termination (POT) used to provide point-to-point, nonswitched access to (or egress from) a LATA.

3.1.15 return loss (RL): The basic measure of echo power reflected back toward the originating end of a channel as a result of impedance mismatches throughout the channel. The 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 (f), with the channel terminated in a specified impedance. Mathematically, return loss is:

$$RL(f) = 10 \log_{10} \left(\right) = -20 \log_{10} |\rho|,$$

where p_t is the transmitted power, p_r is the reflected or returned power, and ρ is the reflection coefficient. $RL(f)$ is a single frequency measure of echo. To more realistically address the customer perception of echo and singing, echo return loss and singing return loss typically are specified. The term, *return loss,* is used colloquially to refer to ERL or SRL measurements made with a return loss measuring set at either a 2-wire or 4-wire interface.

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

3.2 Acronyms

ADPCM	adaptive differential pulse-code modulation
A/D	analog-to-digital conversion
ANSI	American National Standards Institute
BER	bit error ratio
BLER	block error ratio
CPE	customer premises equipment
CXR	carrier transmission system
D/A	digital-to-analog conversion
DCS	digital cross-connect system
EC	exchange carrier
ELEPL	equal level echo path loss
ELERL	equal level echo return loss
ELSRL	equal level singing return loss
ERL	echo return loss
EU	end user
IC	interexchange carrier
ITU-T	International Telecommunications Union-Telephony
IEEE	Institute of Electrical and Electronics Engineers
LATA	local access and transport area
NI	network interface
POT	point of termination
R2	test tone signal to second order intermodulation distortion power ratio
R3	test tone signal to third order intermodulation distortion power ratio
RL	return loss
SRL	singing return loss
TLP	transmission level point
VBD	voiceband data
VGSA	voice-grade special access

4 Objectives for point-to-point VGSA

4.1 Transmission objectives

The transmission objectives for point-to-point VGSA are given in tables 1, 2, and 3.

Table 1 lists a set of parameters, defined in ANSI T1.506, that can affect the performance of voiceband data communications. Tables 2 and 3 contain objectives for echo control parameters. The objectives for the parameters fall into three groups and one of the groups (Group 2) is further divided into two tiers. Group 1 defines objectives needed for higher data rate modems and more critical applications (e.g., V.34 at 19.2 kbit/s)[2]. This group has the most stringent objectives for noise and intermodulation distortion. Group 2 contains objectives useful for lower data rate modems and less critical applications than Group 1. Tier 1 has tight objective values for the linear impairments of attenuation distortion and envelope delay distortion and is meant for modems without adaptive linear equalization. Tier 2, on the other hand, is meant for modems that use modern adaptive equalization methods. Finally, Group 3 contains the least stringent objective values. Note that loss deviation objectives are set at ±1 dB for all groups in order to ease maintenance. Furthermore, the objectives table has no specification for phase jitter and frequency offset in Groups 1 and 2. This is because digital facilities do not generate incidental phase modulation impairments to any significant degree. A phase jitter measurement performed on a digital channel has contributions predominately from quantization noise for which there is already an objective.

Precise measurements of gain hits, phase hits, and dropouts are difficult to make and must be done with care because many standard measurement devices are inconsistent in their readings. Accordingly, Gain hit, Phase hit, and Dropout objectives are not included in the table. Although these parameters are not often perceived by voice users, they can have a significant effect on VBD performance. It is understood that the root causes of many transients are digital timing slips, protection switching, maintenance alarms, etc. Communication providers should work with the customer to solve transmission transient problems that degrade application performance.

Finally, the parameters in the table are those currently defined. The group currently revising ANSI/IEEE 743 is investigating the use of a D-filter rather than C-weighting for noise measurements appropriate for data transmission. Also, the use of multiple test tones over the voice band are under consideration for measuring low-frequency nonlinear distortion and the presence of ADPCM. These new methods and parameters are expected to better reflect the effects of certain impairments on high data rate modems. However, further study will be needed to establish objectives for these parameters and to correlate them with traditional parameters.

4.2 Echo control objectives

This subclause provides return loss (RL) and echo path loss (EPL) objectives for VBD-VGSA. Because the RL and EPL performance of these services depend on the channel configuration, various generic channel configurations are described. Objectives are provided for return loss at 2-wire interfaces and for equal-level echo path loss (ELEPL) at 4-wire interfaces. The objectives for RL and ELEPL are summarized in tables 2 and 3, respectively.

4.2.1 Channel configurations

Voiceband data special access may be provided over either “Effective 2-wire,” “Effective 4-wire,” or “4-wire” channels. The physical make-up of the channel may consist of either metallic cable, carrier transmission systems (CXR), or a combination of both.

4.2.1.1 Effective 2-wire channel

An effective 2-wire channel is terminated in a 2-wire interface at the end-user NI and may have either a 2-wire or 4-wire interface at the IC-POT. Effective 2-wire channels may be entirely 2-wire or may contain a 4-wire facility section such as a carrier with a 2-wire metallic extension. An effective 2-wire channel must contain at least one 2-wire segment and its expected transmission performance will be that of a 2-wire channel. The two directions of transmission are not physically separated and echo (signal energy reflected from points of impedance mismatch) must be a consideration in system operation. With an effective 2-wire channel configuration, it is not possible to ensure simultaneous independent transmission in both directions without special applications such as frequency-division multiplexing, split-band filtering or the use of modems employing echo-cancellation techniques. Figure 2 provides examples of typical 2-wire and effective 2-wire configurations.

4.2.1.2 Effective 4-wire channel

An effective 4-wire channel is terminated in a 2-wire interface at the end-user NI and a 4-wire interface at the IC-POT. An effective 4-wire channel consists of 4-wire facilities with no intermediate 2-wire segments. The expected transmission performance of the effective 4-wire channel is better than that of the effective 2-wire channel. Because there is a point of conversion from 4-wire to 2-wire transmission (at the end-user NI), echo must be considered and, as in the 2-wire and effective 2-wire cases, simultaneous independent transmission of information in both directions cannot be ensured. Figure 3 is an example of an effective 4-wire configuration.

4.2.1.3 4-wire channel

A 4-wire channel is terminated in 4-wire interfaces at both the end-user NI and the IC-POT, and consists of entirely 4-wire facilities. The 4-wire channel overcomes the limitations on simultaneous independent 2-way transmission inherent in 2-wire, effective 2-wire, and effective 4-wire channels. Figure 4 is an example of a 4-wire configuration.

4.2.2 Echo control

Signal reflections at impedance mismatch points on a voiceband channel are manifested as echoes. Power circulating in the transmission path of the channel is manifested as an oscillation or “singing.” Proper impedance balance at 2-wire to 4-wire junctions resulting in high return loss in the channel is used to control echo and singing.

4.2.3 Echo control measurements

4.2.3.1 Standard terminations

ERL and SRL measurements are made using a return loss measuring set (RLMS). Measurements are made at both 2-wire and 4-wire interfaces. In either case, the ERL and SRL measurements require a standard termination at the far end of the channel. If the far-end interface is a 2-wire NI, the standard termination is 600 Ω in series with 2.16 µF of capacitance; if the far-end interface is a 2-wire POT, the standard termination is 900 Ω in series with 2.16 µF of capacitance. At a 4-wire far-end interface, the standard termination is 600 Ω (with no series capacitance).

4.2.3.2 Return loss measurements

When measuring return loss at a 2-wire NI, a hybrid in conjunction with a balancing network comprising 600 Ω of resistance in series with 2.16 µF of capacitance is a necessary part of the measuring system to permit application of the test transmit signal and measurement of the reflected power. Measurements at a 4-wire interface do not require the use of a hybrid in the measuring system, but the return loss measuring set readings may require adjustment for the TLPs at the point of measurement. Specifications for return loss measuring sets can be found in ANSI/IEEE 743.

Annex A
(informative)

Relation of transmission performance to end-user application performance

Public and private voice-grade telecommunication services are important vehicles for VBD customers. These customers employ applications such as facsimile, bulk data transmission, and terminal/host systems, to name a few. In cases where the services are provided using VGSA arrangements for access to dedicated or switched POT-POT facilities, it is important that the end-to-end services be designed so they will meet customer application needs. These end-to-end needs are satisfied by designing the segments to a sufficiently high level of transmission performance such that the concatenated end-to-end impairment levels can be tolerated by the application. The objectives and discussions in this standard are based on the evolution of telecommunication transmission to predominately digital carrier systems. Voice-grade channels that use digital technology end-to-end, exhibit characteristics somewhat different from analog transmission arrangements. Digital facilities tend to have a smaller statistical spread of impairment values than analog facilities. Furthermore, some measurable parameters do not occur on digital circuits while other parameters need more careful control. In addition to network evolution, Customer Premises Equipment (CPE) technological development has also progressed to affect application performance. The trend in VBD CPE is to higher data rate, performance monitoring, and built-in protocols. CPE has evolved to take almost full advantage of channel capabilities.

For a network to be useful, it must satisfy the performance needs of the customer applications. It is possible to classify most applications into a few comprehensive categories, depending on their accuracy performance needs. For voiceband data applications, a digital channel is derived from the voiceband channel by using modems. Accuracy metrics often used for the digital channel are Bit Error Ratio (BER) and Block Error Ratio (BLER). Required modem performance as a function of application maps into related network transmission performance. Table A.1 gives classifications by accuracy performance metric and corresponding limits.

If the channels are engineered to overly stringent requirements, from the point of view of the application, the customer may ultimately pay an economic price for this inefficiency. There is, however, according to table A.1, a range of application needs depending on various end-user functions. To approach the optimum on a per-application basis, it is therefore reasonable to offer a spectrum of possible services. Each service meets the needs of a subset of applications with similar performance requirements, while at the same time offering appropriate economical treatment.

Given the above considerations, the application is realized through the following process. The customer initially defines the application and its performance needs. In theory, these needs dictate the choices to be made regarding the communication components. The customer chooses modems that have the required features such as data rate, error correction, protocols, ruggedness, etc. These modems are connected to the NIs of the communication channel. The customer should choose network channel segments that, when concatenated, have appropriate noise levels, linear impairments, nonlinear distortion, incidental modulation, etc. The modem characteristics dictate which of these parameters need to be tightly or loosely controlled. Contributions to the end-to-end parameters come from access, long haul, and egress segments. The modems interface to the access and egress segments that contain analog cable segments, the first and final A/D and D/A conversions, equalization equipment, Digital cross-connect systems (DCS), add/drop multiplexers, etc. The number and types of this equipment affect performance of the application. Finally, the customer chooses the connecting long-haul segment of the connection. Impairments on a digital POT-to-POT segment arise predominately from DCS, propagation delay, and digital errors. For the customer to make these complex/compound choices requires an understanding of the application needs and network capabilities as well as communication vendor assistance.

In order to formulate realistic objectives, it is worthwhile to discuss what is theoretically possible in a digital environment. Figure A.1 shows an (NI-NI) architecture that consists of a single pair of A/D – D/A conversions terminated with cable facilities.

In this example, the cable facilities contribute mainly to the loss, attenuation distortion, and impulse noise. To a lesser extent, envelope delay distortion and other impairments can occur. Loss, attenuation distortion, and envelope delay distortion can be equalized in the access/egress segments or by modems. Furthermore, the access and egress segments (NI-POT and POT-NI) contain the A/D and D/A equipment, respectively. This and associated equipment generate quantization noise, nonlinear distortion, and transients. Higher data rate modems tend to be more sensitive to these impairments than lower data rate devices.

Some examples of modem susceptibility to transients are given in table A.2. The “Impulse noise level” column labeled “None” refers to the level below which no errors occur; “All” refers to the level above which errors occur for every impulse. Also “Minimum phase hits” are estimated levels of phase hits that begin to cause modem errors. The levels in table A.2 are only guidelines. Different modem implementations may have different performance characteristics. Also, when multiple impairments are present, one impairment (e.g., noise) will cause the susceptibility to other impairments to be increased.

Finally, the long-haul portion of the channel is connected digitally to access and egress at the POTs. Except perhaps for additional quantization noise generated by bit robbing in DCS, no new steady state impairments should be added to the connection. However, this segment usually introduces the major component of throughput-affecting propagation delay. Furthermore, digital transmission errors can be reflected as analog impairments, particularly impulse noise[4)].

Under the best possible conditions this hypothetical end-to-end connection could be designed to have 3200-Hz bandwidth, no linear impairments, signal-to-C-notched-noise ratio of 39 dB (the theoretical maximum), second, and third, order intermodulation distortion better than 60 dB, no incidental modulation, and no transient impairments. Although this architecture can technically be achieved, the impairment levels may not always meet the above numbers due to statistical and temporal performance variation in the channel segments. Furthermore, digital access/egress segments with only one A/D conversion in each may not be available at all locations at all times. Access/egress with multiple A/D conversions or DCS may be more readily available with corresponding economic advantage to the customer. Finally, in many cases, an application may operate satisfactorily with lower levels of channel performance than this hypothetical connection delivers. Thus, it may be possible to use segments with additional A/D conversions (more quantization noise), or less control of linear impairments for the customer's purposes.

Annex B
(informative)

Bibliography

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1) Parameters measured for circuit acceptance and restoral will depend on the network provider's service offerings and may not include all the parameters specified in this standard.

2) Note that V.34 might be specified to have a maximum data rate as high as 28.8 kbit/s.

3) This standard is undergoing revision. Please contact the secretariat for more recent information.

4) For example, determination of the quantity of impulse noise generated per unit distance of digital facility requires further study.

5) This standard is currently undergoing the withdrawal process. It is expected to be replaced by ITU-T Recommendation G.726. Contact the secretariat for more recent information.

[6] Available from AT&T Customer Information Center, P.O. Box 19901, Indianapolis, IN 46219.

[7] Available from Bellcore Customer Service, 8 Corporate Place, Rm. 3C-183, Piscataway, NJ 08854-4156.