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SERIES P: TELEPHONE TRANSMISSION QUALITY,
TELEPHONE INSTALLATIONS, LOCAL LINE
NETWORKS

Objective measuring apparatus

In-service non-intrusive measurement device – Voice service measurements

ITU-T Recommendation P.561

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TELEPHONE TRANSMISSION QUALITY, TELEPHONE INSTALLATIONS, LOCAL LINE NETWORKS

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ITU-T Recommendation P.561

In-service non-intrusive measurement device – Voice service measurements

Summary

This Recommendation provides specifications for voice service transmission measurement devices that provide measurements on an in-service and non-intrusive basis. These In-Service, Non-intrusive Measurement Devices (INMDs) are utilised primarily for the measurement of voice-grade parameters such as speech level, noise level, echo loss and speech echo path delay.

INMDs may also be used to measure parameters associated with digital transmission systems, in both circuit switched and packet switched networks, that impact the performance of the voice-grade channels being transported. This Recommendation specifies interfaces, measurement ranges, and accuracy requirements for measuring voice-grade transmission parameters as well as descriptions of optional functions associated with these parameters.

Source

ITU-T Recommendation P.561 was revised by ITU-T Study Group 12 (2001-2004) and approved under the WTSA Resolution 1 procedure on 14 July 2002.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

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

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ITU-T Recommendation P.561

In-service non-intrusive measurement device – Voice service measurements

1 Scope, purpose, and application

1.1 Scope

This Recommendation provides specifications for voice service transmission measurement devices that provide measurements on an in-service and non-intrusive basis. These In-Service Non-intrusive Measurement Devices (INMDs) are utilized primarily for the measurement of voice-grade parameters such as speech level, noise level, echo loss and speech echo path delay. INMDs may also be used to measure parameters associated with digital transmission systems, in both circuit switched and packet switched networks, that impact the performance of the voice-grade channels being transported. This Recommendation specifies interfaces, measurement ranges, and accuracy requirements for measuring voice-grade transmission parameters, as well as descriptions of optional functions associated with these parameters. It does not specify the measurement algorithms to be used, nor the application of the resulting measurement.

1.2 Purpose

The INMD in this Recommendation is intended for in-service (maintenance) application, to detect network anomalies affecting transmission performance on voice services.

1.3 Application

The INMDs are used as stand-alone devices or can be used as parts of network elements. They may be deployed at selected switch and facility nodes in telecommunications networks to measure the in-service performance parameters of voice grade services, and to locate and analyze network anomalies. The analysis of network anomalies is made easier when the connection information such as calling and called address digits, circuit assignments involved, etc., are known, together with the measured performance. Recording of such information does not constitute intrusion of privacy, since speech intelligence is not monitored. Other optional functions may be added to make the INMD more useful.

The INMD can only be used at a four-wire point. In order to study conditions on the two-wire part of a subscriber line, the INMD must be connected via a four-wire trunk on the network element (that connects to the subscriber's line under study); thus, to isolate a problem to the particular subscriber's line, some means of conveying connection information from the network element to the INMD must be employed. The INMD measures transmission on the path including the customer-provided equipment to the point of INMD measurement access. In this way, the INMD can detect transmission anomalies on the built-up connection. These anomalies can be caused by the customer environment, subscriber line, switches and trunks, including anomalies at interfaces between these network elements. In particular, the INMD can, potentially, observe anomalies that are not detectable by traditional out-of-service tests. Examples of these difficult-to-detect anomalies are:

- intermittent fading;
- acoustical feedback;
- room noise;
- defective customer equipment;
- intermittent leakage on metallic circuits;

- intermittent noise;
- design violations;
- pair gain system problems;
- digital switch level and echo control problems;
- echo problems at the line-to-trunk interface;
- tones and announcement level control problems; and
- switch translation problems that cause violations in network loss plans.

Although the INMD is potentially able to detect such anomalies, it should be noted that the INMD cannot specifically separate combined signals, e.g. room noise and cable noise, or acoustical feedback and hybrid mismatch. Similarly, the INMD cannot distinguish between a trouble on a trunk, on a switch, on the terminating subscriber line, or on the terminal equipment. Network anomalies detected by the INMD may be subsequently isolated to the affecting network element, by applicable out-of-service tests, or facility performance monitoring. Alternatively, the use of advanced signal processing techniques, such as pattern recognition, may enable the INMD to infer the source of an anomaly, e.g. by recognizing particular types of noise.

As an alternative to routine testing of network elements, for the detection of network anomalies, the INMD is effective when used in call sampling mode. In this way, there is no need to maintain large routine testing databases. For post active detection, the INMD is most effective when used as a portable device for detecting intermittent problems. Stand-alone, facility access INMD systems, complete with proprietary interfaces to data collection and analysis software, currently exist and are being used by service providers.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [1] ITU-T Recommendation P.10 (1998), *Vocabulary of terms on telephone transmission quality and telephone sets*.
- [2] ITU-T Recommendation G.100 (2001), *Definitions used in Recommendations on general characteristics of international telephone connections and circuits*.
- [3] ITU-T Recommendation P.56 (1993), *Objective measurement of active speech level*.
- [4] ITU-T Recommendation G.122 (1993), *Influence of national systems on stability and talker echo in international connections*.
- [5] ITU-T Recommendation G.703 (2001), *Physical/electrical characteristics of hierarchical digital interfaces*.
- [6] ITU-T Recommendation G.772 (1993), *Protected monitoring points provided on digital transmission systems*.
- [7] ITU-T Recommendation M.3010 (2000), *Principles for a telecommunications management network*.
- [8] ITU-T Recommendation G.763 (1998), *Digital circuit multiplication equipment using G.726 ADPCM and digital speech interpolation*.

- [9] ITU-T Recommendation G.223 (1988), *Assumptions for the calculation of noise on hypothetical reference circuits for telephony.*
- [10] ITU-T Recommendation G.212 (1988), *Hypothetical reference circuits for analogue systems.*
- [11] ANSI/IEEE 743-1984: *Standard methods and equipment for measuring the transmission characteristics of analogue voice frequency circuits.*
- [12] ITU-T Recommendation G.131 (1996), *Control of talker echo.*
- [13] ITU-T Recommendation P.48 (1988), *Specification for an intermediate reference system.*
- [14] ITU-T Recommendation G.712 (2001), *Transmission performance characteristics of pulse code modulation channels.*
- [15] ITU-T Recommendation O.41 (1994), *Psophometer for use on telephone-type circuits.*
- [16] ITU-T Recommendation G.165 (1993), *Echo cancellers.*
- [17] ITU-T Recommendation G.711 (1988), *Pulse code modulation (PCM) of voice frequencies.*
- [18] ITU-T Recommendation G.191 (2000), *Software tools for speech and audio coding standardization.*
- [19] ITU-T Recommendation P.800 (1996), *Methods for subjective determination of transmission quality.*
- [20] ITU-T, Handbook on Telephonometry (1993).
- [21] ITU-T Recommendation P.830 (1996), *Subjective performance assessment of telephone-band and wideband digital codecs.*
- [22] ITU-T Recommendation P.310 (2000), *Transmission characteristics for telephone band (300-3400 Hz) digital telephones.*
- [23] ITU-T Recommendation Y.1540 (2002), *Internet protocol data communication service – IP packet transfer and availability performance parameters.*
- [24] ITU-T Recommendation E.164 (1997), *The international public telecommunication numbering plan.*

3 Abbreviations and definitions

3.1 Abbreviations

Relevant abbreviations in ITU-T Rec. P.10 [1] will apply.

ADPCM	Adaptive Differential Pulse Code Modulation
ATM	Asynchronous transfer mode
DCME	Digital Circuit Multiplexing Equipment
DSI	Digital Speech Interpolation
DTMF	Dual-Tone Multi Frequency
ENR(p)	Echo to Noise (psophometrically weighted) Ratio
IETF	Internet Engineering Task Force
INMD	In-service Non-intrusive Measurement Device
IP	Internet Protocol
IRS	Intermediate Reference System

LPC	Linear Predictive coding
LSTR	Listener Sidetone Rating
MF	Multi-Frequency
MOS	Mean Opinion Score
NLP	Non linear processing
OLR	Overall Loudness Rating
PCM	Pulse Code Modulation
PLC	Packet Loss Concealment
REL	Reference Echo Loss
REPL	Reference Echo Path Loss
RFC	Request for comment
RLR	Receiving Loudness Rating
r.m.s.	root mean square
RNL	Reference Noise Level
RR	Receiver Report
RSAF	Reference Speech Activity Factor
RSEPD	Reference Speech Echo Path Delay
RSEPL	Reference Speech Echo Path Loss
RSL	Reference Speech Level
RTCP	Real-time Transfer Control Protocol
RTP	Real-time Transfer Protocol
SLR	Sending Loudness Rating
SNR(p)	Active speech level to noise (psophometrically weighted) ratio
SR	Sender Report
STMR	Sidetone Masking Rating
TMN	Telecommunication Management Network
UDP	User Datagram Protocol
VAD	Voice Activity Detector
VoIP	Voice over Internet Protocol

3.2 Definition

This Recommendation defines the following terms:

3.2.1 double talk interval: The interval during which both directions of transmission are experiencing incident speech spurts.

At the INMD monitoring point, this will be different from the double talk experienced by both parties due to the delay between the termination points and the measurement equipment.

3.2.2 echo: Echo is defined in ITU-T Rec. G.100 [2] as unwanted signal delayed and insufficiently weakened to such a degree that, for instance, in telephony, it is perceived as distinct from the wanted signal (i.e. the signal directly transmitted).

3.2.3 echo Loss: The echo loss (ITU-T Rec. G.122 [4]) is derived from the integral of the power transfer characteristic weighted by a negative slope of 3 dB/octave starting at 300 Hz and extending to 3400 Hz. The echo loss should be calculated with the speech echo path delay removed. This echo loss figure has been found to give better agreement with subjective opinion for individual connections than an unweighted echo path loss.

For a flat echo path frequency response, echo loss is equal to speech echo path loss and echo path loss.

3.2.4 echo path: The round trip electrical path starting from the point of incident speech measurement and ending at the point where the correlated reflected speech is measured.

3.2.5 echo path loss: The echo path has a unique impulse response. The Echo Path Loss is the integral of the impulse response (in the frequency domain). Echo Path Loss is not dependent on the speaker.

3.2.6 far-to-near (FN) transmission direction: A distinctly specified direction of transmission with one end of a circuit labelled far (F) and the other end labelled near (N), where transmission is in the direction from far to near.

3.2.7 hangover time: A specified duration of time beginning with the end of a speech spurt and ending at the beginning of noise measurements, if no new speech spurts occur in the mean time.

3.2.8 incident speech: Speech whose source is talker energy.

3.2.9 near-to-far (NF) transmission direction: A distinctly specified direction of transmission with one end of a circuit labelled near (N) and the other end labelled far (F), where transmission is in the direction from near to far.

3.2.10 noise level: The electrical energy (measured in dBmp) caused by spurious signals.

Spurious signals, i.e. noise, can be generated internally to the circuit or may be the result of interference from external sources. These sources can be classified as environmental, circuit and impulse noise. Noise level measurements should only be applied to steady noise during speech pause intervals.

Measurements of impulsive noise signals is an area for further study.

3.2.11 reflected speech: Speech whose direction of transmission and level has been altered by network discontinuities such as four-to-two wire conversions.

This definition is consistent with the definition of Talker echo but includes any reflected speech which may not be classified as echo.

Talker echo is defined in ITU-T Rec. G.100 [2] as echo produced by reflection near the listener's end of a connection, and affecting the talker.

3.2.12 speech activity factor: The ratio of active speech to total measurement interval.

3.2.13 speech echo path delay: It is the period (in ms) between the detection of an incident signal at a zero reference point, on a four-wire point, to the detection of its corresponding reflected signal at the same four-wire point (on the opposite direction).

For multiple echo path reflections the speech echo path delay should be calculated for each detection of the corresponding reflected signal.

3.2.14 speech echo path loss: It is the ratio of the r.m.s. values of the incident to reflected speech signals with the speech echo path delay removed. The Speech Echo Path Loss is highly dependent on the speaker.

3.2.15 speech level: Active Speech level is defined in ITU-T Rec. P.56 [3]. In general, speech level is the electrical energy generated by the conversion of acoustical talker energy excluding any noise that is not part of the speech (such as impulses, reflected speech, and steady noise during periods of silence), but including inter syllabic pauses (brief periods of low or zero power that are not perceived as interruptions in the flow of speech).

3.2.16 speech pause interval (or quiet interval): A period of time during which speech levels are absent due to inter syllabic and conversational pauses.

Inter syllabic pauses are the gaps inherent in the articulation process. Such gaps are short approximately up to 350 ms and are not noticed as such by the listener. These pauses should be considered as part of the utterance and therefore included in a measurement of speech.

Conversational pauses are generally longer. They will be noticed by the listener, either consciously or subconsciously, and should be excluded from the a measurement of speech level since they do not contribute to the subjective loudness of the speech. When these pauses are excluded, the measurement is said to be made when the talker is "active".

3.2.17 speech present: It is a period of time where speech is considered present. Speech is not a continuous stream of sound, as it may seem when listening to it, but contains many pauses. Hence, the speech present contains speech spurt intervals and speech pause intervals.

3.2.18 speech spurt (or utterance) interval: A period of time during which speech is present due to syllabic emphasis.

4 Interface requirements

The INMDs of classes A, B and C (see clause 8) have two types of external interfaces, electrical and data transport. The electrical interface is at a protected monitor digital access point where the signal is measured. The data transport interfaces are at the data port to network elements (for transport of connection information) and operations systems (for remote processing of INMD data).

The INMDs of class D (see clause 8) have IP interfaces to access the signal to measure. As far as data transport is concerned, it will be used for remote control of the INMD (upload of measurement scenarios, download of measurement results, remote processing of data).

The major difference between the interfaces of classes A, B and C INMDs on one hand and of class D on the other hand, is that the signal is directly accessible in a PCM format on the first case, whereas it is encapsulated inside packets and must be reconstructed in the second case.

Other additional interfaces may be supplied with the INMD, such as interfaces to data analysis systems, which can be proprietary or use open standards.

4.1 Electrical interfaces for class A, B and C INMDs

The type of electrical interface is determined by the point of access, on a DS1 facility or at a digital switch. Analogue access is also possible but is not defined within this Recommendation.

4.1.1 DS1 digital interface

The DS1 signal format and facility protected monitor interface is described by ITU-T Recs. G.703 [5] (Physical/electrical characteristics of hierarchical digital interfaces) and G.772 [6] (digital protected monitoring points).

4.2 TMN data transport interfaces for class A, B and C INMDs

ITU-T Rec. M.3010 [7] specifies principles for telecommunications management networks, it may be desirable to provide interfaces that conform to it.

4.3 Interfaces for class D INMDs

The IP interfaces of class D INMDs can be of different kinds, including Ethernet (up to 1 Gbit/s) and ATM. An INMD can be inserted on an IP link and behave like an IP switch, but it is rather recommended (for security reasons) to use a mirroring of the traffic incoming and outgoing at a given data port of a given network element to access the information.

Data transport interfaces may be M.3010 – compliant to connect the INMD to a TMN. If it is not part of a TMN, the communication with a centralized management station can be done using any data transport technology.

4.4 Reconstruction of signal for class D INMDs

In order to correctly analyze the VoIP stream, or access the encapsulated audio signal, the received packet stream at the IP interface must be reconstructed. A faithful representation of this stream can only be generated with knowledge of the specific equipment (e.g. gateway) used to terminate the IP link.

That means that a class D INMD should implement the following functionalities :

- de-jitter buffer;
- voice decoder;
- comfort noise generator;
- error concealment process.

4.4.1 The de-jitter buffer

This feature must be implemented to simulate the behaviour of the termination of the IP link (a VoIP gateway or a native IP terminal) faced with the irregular arrival rate of the IP packets. It is recommended that at least the following characteristics of this buffer, as shown in Figure 1 below, could be configured in order to adapt to different types of terminations :

- minimum size;
- maximum size;
- the filling mechanism (static or dynamic, and which dynamic).

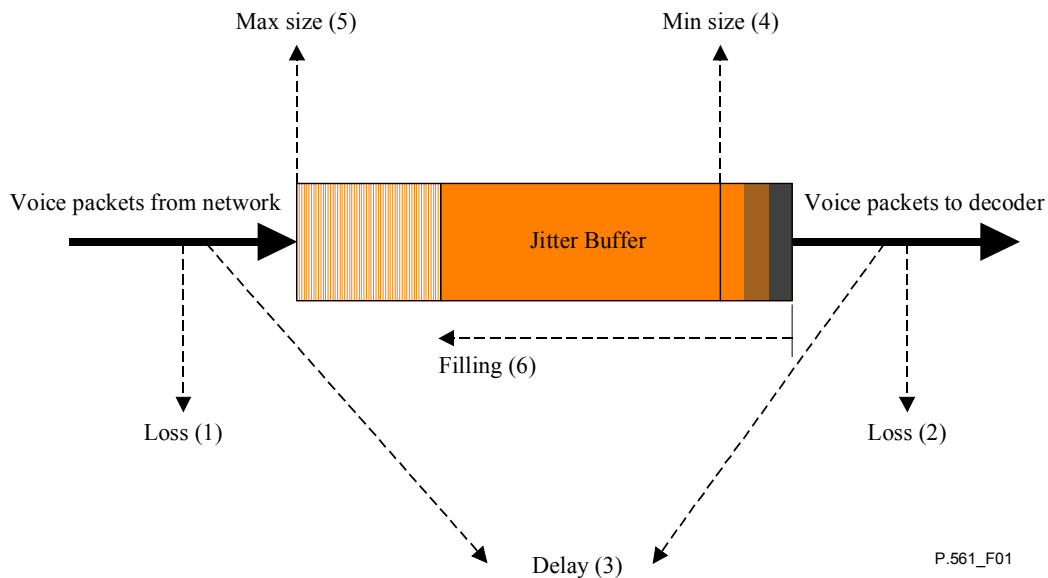


Figure 1/P.561 – Jitter buffer characteristics

4.4.2 The voice decoder

The identification of the coder used when building the packets, is contained inside the headers of RTP packets. The INMD should be able to implement a decoding process compliant with the international standards for the following types of coders :

- G.711 (A and μ law);
- G.723.1 (5.3 and 6.3 kbit/s);
- G.729 A and B;
- GSM 06-10, 06-20 and 06-60.

4.4.3 The comfort noise generation

Some voice activity detection schemes are associated with some of the standardized voice coders given in 4.4.2. The information on whether they are implemented or not is contained inside the headers of RTP packets. Therefore, the INMD should be able to implement a comfort noise generation associated to those VADs and compliant to the corresponding international standards.

4.4.4 The error concealment process

Some standardized codecs do not contain a built-in IP packet loss concealment (PLC) scheme, but some specific error concealment algorithms have been standardized, that can be implemented. Such is the case for G.711, for instance.

The information on whether or not they are implemented, is not contained inside the headers of RTP packets since it is a processing occurring at the decoding level. Nevertheless, since this information can be known by other means (internal information system, e.g.), the INMD should be able to implement all PLC algorithms compliant with the corresponding international standards.

5 Functional requirements

The functional interface requirements depend on whether access to connection information is at a facility access point, or at the switch network element, when measuring on switched connections. For facility access, the facility may be the only data source, whereas for switch access, connection information is more conveniently obtained from the network element rather than the INMD. In fact, the network elements may be the only convenient source of connection information for common channel signalling trunk connections performed by signalling system seven. For voice grade INMDs, there are recommended and optional functions. These functions are specified on a connection specific basis.

5.1 Required measurement functions

The required measurement functions for the INMDs of class A, B, C and D are:

Speech and noise characterization

- active speech level;
- noise level (psophometric weighted);
- speech activity factor.

Echo characterization

- speech echo path delay (single or multiple reflection measurements);

and at least one of the following echo measurements:

- echo loss (single or multiple reflection measurements);
- echo path loss (single or multiple reflection measurements);
- speech echo path loss (single or multiple reflection measurements).

The above required functions are for voice connections only, and do not apply to connections of short duration where there is insufficient time to make an accurate determination of the values, or where a connection is not completed. Measurement of these recommended functional values is described subsequently. These recommended functions are necessary for the in-service voice transmission application.

Three echo loss parameters are recommended as each gives different information concerning the connection. The echo loss conforms to ITU-T Rec. G.122 [4] and has been found to correlate better with subjective opinion than unweighted echo path loss measurements. The echo path loss provides an unweighted measurement of the echo power and can identify echo problems at high frequencies (>2000 Hz) which could impact voiceband data performance. The speech echo path loss reflects the actual amount of speech energy reflected and, because of this, could be strongly correlated with the subjective opinion of callers. Further work is needed to determine if this is true. On some connections it may not be possible to resolve all three measurements. When comparing results between INMDs, care should be taken that the correct echo measurement definition is used. For a thorough assessment of the echo path performance, it is recommended that all three echo loss parameters be measured.

For the INMDs of class D, extra measurement functions related to the analysis of the real time transfer protocol (RTP) are required :

- **1-point IP packet delay variation**
- **IP packet loss ratio**