INTERNATIONAL TELECOMMUNICATION UNION

ITU-T G.116

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TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

International telephone connections and circuits – General Recommendations on the transmission quality for an entire international telephone connection

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Transmission performance objectives applicable to end-to-end international connections

ITU-T Recommendation G.116

(Previously CCITT Recommendation)

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ITU-T RECOMMENDATION G.116

TRANSMISSION PERFORMANCE OBJECTIVES APPLICABLE TO END-TO-END INTERNATIONAL CONNECTIONS

Summary

This Recommendation is intended to provide guidance to network and service planners who are concerned with the performance of international connections, and to network element designers who are responsible for the equipment specification. Information relating to analogue, digital, and analogue/digital terminal and network elements is provided. Additionally, this information is provided in the context of hybrid networks, i.e. networks built using analogue and digital network elements; integrated digital networks, i.e. networks with digital core network elements and analogue accesses; and integrated services digital networks, i.e. networks which have only digital network, digital access and digital terminal elements. The transmission systems used to create these connections may operate as analogue or digital systems. Digital switches and transport systems may operate as ATM, frame relay, plesiochronous digital hierarchy (PDH), synchronous digital hierarchy (SDH), systems.

The current regulatory operating environment in certain countries has made allowance for other networks to interconnect with the PSTN, e.g. private networks and digital cellular networks, and for customers to provision their own terminal equipment. The information in this Recommendation will provide guidance for all parties that wish to operate in this changing environment.

Source

ITU-T Recommendation G.116 was prepared by ITU-T Study Group 12 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on 30 September 1999.

FOREWORD

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

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 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 term *recognized operating agency (ROA)* includes any individual, company, corporation or governmental organization that operates a public correspondence service. The terms *Administration, ROA* and *public correspondence* are defined in the *Constitution of the ITU (Geneva, 1992)*.

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As of the date of approval of this Recommendation, the ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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Recommendation G.116

TRANSMISSION PERFORMANCE OBJECTIVES APPLICABLE TO END-TO-END INTERNATIONAL CONNECTIONS

(Geneva, 1999)

1 Preamble

This Recommendation is intended to provide guidance to network and service planners who are concerned with the performance of international connections, and to network element designers who are responsible for the equipment specification. Information relating to analogue, digital, and analogue/digital terminal and network elements is provided. Additionally, this information is provided in the context of hybrid networks, i.e. networks built using analogue and digital network elements; integrated digital networks, i.e. networks with digital core network elements and analogue accesses; and integrated services digital networks, i.e. networks which have only digital network, digital access and digital terminal elements. The transmission systems used to create these connections may operate as analogue or digital systems. Digital switches and transport systems may operate as ATM, frame relay, plesiochronous digital hierarchy (PDH), synchronous digital hierarchy (SDH), systems.

The current regulatory operating environment in certain countries has made allowance for other networks to interconnect with the PSTN, e.g. private networks and digital cellular networks, and for customers to provision their own terminal equipment. The information in this Recommendation will provide guidance for all parties that wish to operate in this changing environment.

Digital technology has matured and it is recommended that all new switches, i.e. those used for national and international switching, should be of digital design. Additionally, it is recommended that all new large private automatic branch exchanges (PBXs) should be digital and that interconnection with the PSTN should be digital, if practical, especially in those cases where the PBX performs a tandem function. It is also recommended that all new international circuits be implemented on digital transmission systems, e.g. SDH. It is recognized that while it is desirable that national transmission systems should trend to digital operation, there may be a need to increment existing analogue systems and guidance in this regard has been provided. It is also recognized that private networks may operate using PDH/SDH, ATM, frame relay, or other digital types of transport systems and may incorporate use of digital circuit multiplication equipment.

Recommendation G.107 presents the E-model, which is a computational model, that can be used for transmission planning. This Recommendation provides a model which can be used to determine the collective impact of impairments on overall connection performance.

2 Introduction

Networks are in various stages of evolution towards being all-digital. Thus, there will be instances where: connections will be routed utilizing all-digital components (end-to-end including the terminals); other connections will use all-digital network components and analogue access facilities; and still other connections will use portions of the network which are analogue while other network components may be digital. This Recommendation is intended to address each of these scenarios. Because the trend is towards digital, the masking benefits of significant channel noise for certain impairments found in analogue networks can no longer be assumed. As a result, the guidance provided in this Recommendation will reflect this new environment.

3 Approach

This Recommendation is intended to serve as the basis for all the transmission guidance available for end-to-end international connections. In this regard the hypothetical reference connections presented in Recommendation G.103 are used as a basis of this Recommendation. As digital technology continues to be implemented, the number of network connections over digital connections will increase while the number of connections over analogue systems will decrease. Thus, this Recommendation will tend to focus on connections similar to those shown in Figures 1/G.103, 2/G.103 and 3/G.103. The end-to-end international connections can be considered to be comprised of: two access facilities, two national extensions, and an international link composed of one or more international circuits. Additionally, this Recommendation makes the assumption that only digital exchanges and digital transport systems will be used in future international network segments. In the national extensions it is recognized that analogue elements will exist for years.

4 Normative 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; all 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.

– ITU-T Recommendation G.101 (1996), *The transmission plan*.

– ITU-T Recommendation G.103 (1998), *Hypothetical reference connections*.

– ITU-T Recommendation G.107 (1998), *The E-Model, a computational model for use in transmission planning*.

– ITU-T Recommendation G.113 (1996), *Transmission impairments*.

– ITU-T Recommendation G.114 (1996), *One-way transmission time*.

– ITU-T Recommendation G.120 (1998), *Transmission characteristics of national networks*.

– ITU-T Recommendation G.121 (1993), *Loudness ratings (LRs) of national systems*.

– ITU-T Recommendation G.122 (1993), *Influence of national systems on stability and talker echo in international connections*.

– ITU-T Recommendation G.126 (1993), *Listener echo in telephone networks*.

– ITU-T Recommendation G.131 (1996), *Control of talker echo*.

– ITU-T Recommendation G.142 (1998), *Transmission characteristics of exchanges*.

– ITU-T Recommendation G.165 (1993), *Echo cancellers*.

– ITU-T Recommendation G.168 (1997), *Digital network echo cancellers*.

– ITU-T Recommendation G.173 (1993), *Transmission planning aspects of the speech service in digital public land mobile networks*.

– ITU-T Recommendation G.174 (1994), *Transmission performance objectives for terrestrial digital wireless systems using portable terminals to access the PSTN*.

– ITU-T Recommendation G.175 (1997), *Transmission planning for private/public network interconnection of voice traffic*.

– ITU-T Recommendation G.176 (1997), *Planning guidelines for the integration of ATM technology into networks supporting voiceband services*.

– ITU-T Recommendation G.711 (1988), *Pulse code modulation (PCM) of voice frequencies*.

– ITU-T Recommendation G.722 (1988), *7 kHz audio-coding within 64 kbit/s*.

– ITU-T Recommendation G.723.1 (1996), *Speech coders: Dual rate speech coder for multimedia communications transmitting at 5.3 and 6.3 kbit/s*.

– ITU-T Recommendation G.726 (1990), *40, 32, 24, 16 kbit/s adaptive differential pulse code modulation (ADPCM)*.

– ITU-T Recommendation G.727 (1990), *5-, 4-, 3- and 2-bits/sample embedded adaptive differential pulse code modulation (ADPCM)*.

– ITU-T Recommendation G.728 (1992), *Coding of speech at 16 kbit/s using low-delay code excited linear prediction*.

– ITU-T Recommendation G.729 (1996), *Coding of speech at 8 kbit/s using Conjugate-Structure Algebraic-Code-Excited Linear-Prediction (CS-ACELP)*.

– ITU-T Recommendation P.11 (1993), *Effect of transmission impairments*.

– ITU-T Recommendation P.16 (1988), *Subjective effects of direct crosstalk; thresholds of audibility and intelligibility*.

– ITU-T Recommendation P.310 (1996), *Transmission characteristics for telephone band (300-3400 Hz) digital telephones*.

– ITU-T Recommendation P.311 (1998), *Transmission characteristics for wideband (150-7000 Hz) digital handset telephones*.

– ITU-T Recommendation P.340 (1996), *Transmission characteristics of hands-free telephones*.

– ITU-T Recommendation P.341 (1998), *Transmission characteristics for wideband (150-7000 Hz) digital hands-free telephony terminals*.

– ITU-T Recommendation P.342 (1996), *Transmission characteristics for telephone band (300-3400 Hz) digital loudspeaking and hands-free telephony terminals*.

5 Attenuation (overall loudness rating)

The long-term objective for overall loudness rating is 8-12 dB. Additional guidance can be found in Recommendation P.11.

Apparatus associated with long-distance telephone circuits, e.g. network elements specified in the G.160-series of Recommendations, should operate in compliance with Recommendations G.101, G.121 and G.122.

6 Attenuation distortion

6.1 General

The following Recommendations give guidance about attenuation distortion for connections using specific operating arrangements:

– Recommendation G.120: for circuits;

– Recommendation P.310: for voiceband (300-3400 Hz) digital telephones;

– Recommendation P.311: for wideband handset telephones;

– Recommendation P.340: for voiceband hands-free telephones;

– Recommendation P.341: for wideband hands-free telephones; and

– Recommendation P.342: for voiceband digital loudspeaking and hands-free telephony terminals.

In general, the intention of the ITU-T Recommendations for normal telephony, is to result in international connections, between electrical interfaces on an end-to-end concatenation of circuits[1], whose effectively transmitted frequency band (i.e. the band in which the attenuation distortion does not exceed 9 dB compared with the value for 1020 Hz), will be a little wider than the 300-3400 Hz band.

Although the ITU-T has produced Recommendations that deal with the send and receive loudness ratings of national systems (i.e. access facilities in tandem with national extension circuits), specific attenuation distortion limits applicable to analogue access systems have not been developed. Additionally, the ITU-T has not formulated specific recommendations regarding analogue telephone sets as this has been determined to be a national matter. Rather, the ITU-T has concentrated on developing Recommendations associated with digital switches, digital transport systems and digital telephone set characteristics.

The circuit performance objectives for attenuation distortion of international circuits and national extension circuits were originally selected so that acceptable performance would be obtained on 4-wire chains of up to 12 circuits. The ITU-T recommends that the individual equipment network performance objectives previously developed to meet this operating configuration, both for transmission systems and digital switches, should not be relaxed even though the network continues to evolve towards an all-digital network and the number of analogue baseband signal appearances is tending to decrease with time.

6.2 Circuits

Recommendation G.120 provides guidance regarding attenuation distortion for circuits in national networks. As it is assumed the international switches and international circuits are digital, guidance for attenuation distortion on international circuits is not required.

Apparatus associated with long-distance telephone circuits, e.g. network elements specified in the G.160-series of Recommendations, should operate in compliance with Recommendation G.120.

6.3 Digital terminals

The ITU-T has published Recommendations for both narrow-band, e.g. Recommendation P.310 (300-3400 Hz) 64 kbit/s digital sets based on Recommendation G.711 coding, and wideband, e.g. Recommendation P.311 (150-7000 Hz) 64 kbit/s digital sets based on Recommendation G.722 coding, digital terminals. The ITU-T recommends that these attenuation distortion curves (acoustic to acoustic) should not be relaxed as the network continues its evolution. Should other digital sets be designed to operate at differing bit rates, they should strive to achieve performance similar to the existing narrow-band or wideband digital telephone sets, as appropriate.

7 Clipping

Clipping can refer to two different types of situations. One is associated with the instantaneous power level of the signal while the other refers to the loss of small portions of the signal due to signal loss, e.g. discarded frames in low bit rate systems due to excessive line errors, lost cells in ATM systems resulting from contention of a shared resource (blocking and buffer overflow).

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[1] This objective purposely excluded consideration of the access facility from the customer premises to the local exchange.

7.1 Power level clipping

Clipping will be held to within acceptable constraints if the SLR of the terminal and the national system is maintained within the recommended level, see Recommendation G.121.

7.2 Temporal clipping

Systems that are designed such that temporal clipping (information loss) can occur should be designed such that:

clipping ≥ 64 ms should be avoided[2]; and

clipping < 64 ms should be kept below 0.2 per cent of active speech (per cent of clipped speech is 100 times the product of the frequency of speech clipping times clipping duration, divided by the speech activity factor).

Temporal clipping on all connections should be constrained so that the average speech loss, including the peak busy hour, is less than 0.5%. Thus, the number of tandemed systems which can perform temporal clipping should be constrained. Reduction in channel coding rate on an instantaneous basis to avoid clipping is preferred over temporal clipping.

8 Companders

Companders are no longer recommended for use on international connections.

9 Echo

9.1 General

A number of general principles have been adopted by the ITU-T with respect to echo. These follow:

1) Echo signals generated within the PSTN should be controlled by PSTN transmission plans or by network based equipment.
2) In all-digital networks, e.g. ISDNs, the digital terminals are responsible for echo control.
3) The PSTN operator is not responsible to control echo signals that are generated outside the PSTN, e.g. in private networks[3] or in digital public land mobile networks. It is recognized that in some instances the inherent ability of the PSTN to control echo may be sufficient to control echo in some specific implementations. However, for those instances where it is not, the party that generates the echo condition must control the echo condition.

The adoption of these principles has resulted in the creation of a number of Recommendations which are intended to provide guidance for specific situations, viz.:

Recommendation G.131 – For network control of talker echo.

Recommendation G.173 – For transmission planning aspects associated with the interconnection of digital public land mobile networks to the PSTN.

Recommendation G.174 – For transmission planning associated with terrestrial digital wireless systems using portable terminals to access the PSTN.

Recommendation G.175 – For transmission planning for private/public network interconnection of voice traffic.

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[2] This number should be reviewed in the context of a coder's ability to operate with temporal clipping.

[3] The term private network is intended to be broad enough to be applicable to single digital terminals as well as networks comprising a number of PBXs.

Recommendation G.176 – For planning guidelines associated with the integration of ATM technology into networks supporting voiceband services.

Recommendation P.11 – For guidance in regard to the effect of transmission impairments.

Recommendation P.310 – For voiceband (300-3400 Hz) digital telephones.

Recommendation P.311 – For wideband handset telephones.

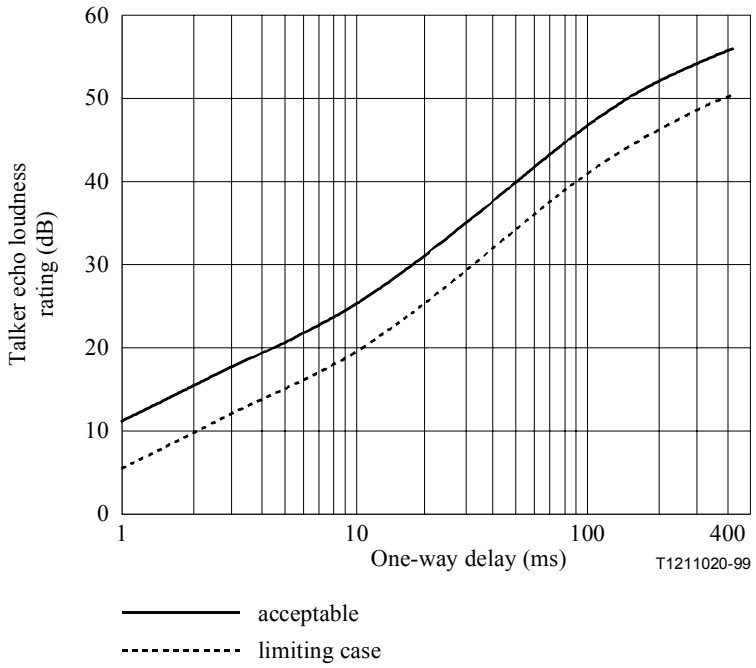
Recommendation P.340 – For voiceband (300-3400 Hz) hands-free telephones.

Recommendation P.341 – For wideband hands-free telephones.

Recommendation P.342 – For voiceband digital loudspeaking and hands-free telephony terminals.

In those instances where Recommendations are directly applicable, they should be used. In those cases where Recommendations are not directly applicable, the amount of echo path loss required to provide acceptable performance, as a function of the connection talker echo path delay, is shown in Figure 1 below. As this is intended to be the minimum echo path loss, it means that the figure should be used with the following assumptions:

- The loudness ratings of the telephone system are assumed to be at their minimum values of loudness rating (this means that if a volume control is provided on the telephone, it should be set at maximum volume).
- If a hybrid is used at the listener's end of the connection, the mean value of the echo balance return loss at the listener's end should be used.



Acceptable: Equivalent to the curve with "1%" probability of encountering objectionable echo in Recommendation G.131.
Limiting case: Equivalent to the curve with "10%" probability of encountering objectionable echo in Recommendation G.131.

Figure 1/G.116 – Echo tolerance curve

9.2 Circuits

Guidance regarding echo control on circuits is provided in Recommendation G.131. If active echo control must be used, then echo cancellers that comply with Recommendation G.168 are recommended.

9.3 Digital terminals

The ITU-T recommends that all-digital terminals, e.g. telephony and multimedia terminals, be designed with sufficient echo control capability to provide acceptable performance on any connection, e.g. national or international. In this regard, Figure 1 shows the echo path loudness rating required to provide acceptable echo performance as a function of connection delay.

It should be noted that Recommendations for specific digital terminals already exist. However, some of the requirements in those Recommendations are not as stringent as the requirement specified in Figure 1 above due to either the inability to meet these objectives with current vintages of technology or the inability to perform test methods by which compliance can be determined. However, it is expected as this technology matures the existing Recommendations will be reissued to provide more stringent echo control limits.

9.4 Private networks

Echo originated in private networks should be controlled. Guidance can be found in Recommendation G.175. If active echo control is implemented it should be compatible with Recommendation G.165 and new implementations should be compatible with Recommendation G.168.

10 Error on the reconstituted frequency

Recommendation G.120 provides guidance regarding national circuits. As these circuits may continue on into private networks, and echo control may be required to be placed within the private network, all circuits including private network circuits should comply with Recommendation G.120.

11 Group delay

Delay is a shared resource and although it is not practical to provide an allocation in all instances, as an objective it should be minimized. Guidance can be found in Recommendation G.114.

12 Linear crosstalk[4]

Guidance for circuits can be found in Recommendation G.120.

Guidance for linear crosstalk associated with terminals, local equipment and subscribers lines is provided in Recommendations P.11 and P.16. It is recommended that the objective of 0.1 per cent probability of intelligible crosstalk be used where parties may know each other, and below 1 per cent where the parties do not know each other. If Recommendation P.16 is used to calculate the probability of crosstalk, the calculations should be performed using configurations equivalent to Figures 1/G.103, 2/G.103 or 3/G.103.

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[4] With the introduction of new technology systems such as the digital transmission system on metallic local lines (ADSL) for high bit-rate asymmetric services, the opportunity for non-linear cross exists. The requirements applicable to the interference from these systems, i.e. non-linear crosstalk in the form of signal interference, into PSTN services is addressed in clause 15.

13 Non-linear distortion

Non-linear distortions can occur in analogue and digital systems.

13.1 Analogue non-linear distortion

Guidance for analogue circuits can be found in Recommendation G.120.

13.2 Quantization distortion

The ITU-T has agreed on a number of principles associated with non-linear digital distortions as follows. Guidance on transmission impairments is provided in Recommendation G.113.

- The transmission level point at the digital local exchange is 0 dBr, per Recommendation G.101.
- If a signal level adjustment must be made to national signals entering the digital domain, they should be made in the analogue domain and should be made prior to the A/D conversion. That is, in general there should be no level adjustments made to signals after they exit the originating local exchange and before they enter the international switch.
- Whenever possible signal level adjustments on terminating circuits should be made in the analogue domain, i.e. digital pads are not recommended and should not be used unless there are significant reasons for their use.
- The number of transcoding instances encountered by a signal on an international connection should be minimized whenever possible.
- When ATM signals are routed across international boundaries that would normally require that an A-law or μ-law transformation occur, the A-law or μ-law transformation need not occur until a G.711 compliant signal is generated at the interworking location between the ATM and PDH/SDH domains.
- The signal should be coded as A-law or μ-law by the originating terminal depending on the geographic location of the serving local exchange. In all-digital networks the terminal must be capable of decoding both G.711 signals, should they be presented.
- All signals should be coded initially into a G.711 signal and then transcoding should occur between the G.711 format and the other coding format[5].

13.3 Distortion from low bit rate codecs

The ITU-T has generated a number of Recommendations on low bit rate codecs, e.g. G.723.1, G.726, G.727, G.728, and G.729. These codecs whose main purpose is to improve channel efficiencies also introduce non-linear distortions. Guidance with regard to the degree of impairment that can be expected from various codecs is provided in Recommendation G.113, transmission impairments. The collective impact of impairments on end-to-end connections can be determined using the E-model, see Recommendation G.107.

14 Noise

Guidance for noise in national networks and on circuits can be found in Recommendation G.120.

Connections provided by digital systems using standard ITU-T codings will have acceptable noise performance which is substantially independent of length. See also non-linear distortion.

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[5] This condition should continue to apply until the ITU-T develops codecs that do not operate in this fashion.

15 Noise interference

15.1 Single tone or narrow-band noise interference

Guidance for linear single tone or narrow-band noise interference is provided in Recommendation P.11. It is recommended that the single tone noise or narrow-band noise be 10 dB less than the psophometric noise power in the circuit. To avoid audibility, an additional 5 dB of margin is recommended where practical. Configurations equivalent to Figures 1/G.103, 2/G.103 or 3/G.103 should be used to determine the expected psophometric noise levels.

15.2 Wideband noise interference

In FDM systems the wideband noise interference is considered as channel noise and is addressed in clause 14.

Wideband noise interference into connections provided over digital systems is addressed in clause 14.

The wideband noise introduced by technology systems, such as the digital transmission system on metallic local lines (ADSL) for high bit-rate asymmetric services, on telephony connections that use these same local lines can be significant. If these systems do not shield the telephony terminals from interference signals outside the speech band, i.e. from signals above 4 kHz by use of properly designed splitters/filters, the non-linearity of the circuits in the terminal can fold these interfering signals into noise in the telephony band. Thus, as the resultant noise on the connection can be higher than just the electrical noise measured on the loop, the connection noise must be measured acoustically at the output of the receiver. A provisional limit of 400 pWp equivalent noise[6] has been established as the maximum allowable interference limit.

16 Variation of transmission loss with time

Guidance for circuits can be found in Recommendation G.120.

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[6] As it is impossible to separate the regular loop noise from the interfering noise the total noise limit is equivalent to 500 pWp of noise. In acoustic terms this equates to an acoustic measurement of about 43 dB SPL (−51 dBPa).

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