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TELEPHONE INSTALLATIONS, LOCAL LINE
NETWORKS

Objective electro-acoustical measurements

Determination of sensitivity/frequency characteristics of local telephone systems

Recommendation ITU-T P.64

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Recommendation ITU-T P.64

Determination of sensitivity/frequency characteristics of local telephone systems

Summary

Recommendation ITU-T P.64 is mainly concerned with the electro-acoustical measurements required for supplying sensitivity/frequency characteristics suitable for use in calculating loudness ratings, or estimating other subjectivity-determined quantities. For this purpose, measurements under real conditions must form the basis. Artificial mouths and artificial ears must be used with due regard to obtaining good agreement between these measurements and those from real mouth and ear determinations. Measurements under real conditions are complicated, time-consuming and not reproducible with great precision.

This Recommendation describes measurement methods using recommended forms of artificial mouths and artificial ears (see Recommendations ITU-T P.51 and P.57).

This Recommendation applies mainly to local telephone systems (LTSs) with handset telephones; however, the principles also apply to other types of telephones.

Annexes D and E define handset positions to be used with the head and torso simulator (HATS) according to ITU-T P.58 and P.57 type 3.2, 3.3 and 3.4 artificial ears. Allowance is given to placing the handset in a way which best represents its intended use.

Annex F describes the correspondence between measurements using the loudness rating guard-ring position (LRGP) and the HATS position.

History

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FOREWORD

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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.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at <http://www.itu.int/ITU-T/ipr/>.

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Recommendation ITU-T P.64

Determination of sensitivity/frequency characteristics of local telephone systems

1 Scope

The sending, receiving or side-tone sensitivity/frequency characteristic of a local telephone system (LTS) is usually measured directly.

NOTE 1 – The sending, receiving or side-tone sensitivity/frequency characteristic can also be calculated provided that the relevant information of the telephone line and feeding bridge is known. Some of the information required for side tone is outside the scope of existing Recommendations.

NOTE 2 – The same principles also apply to the measurement of microphones and earphones.

Since electro-acoustical measurements of the type being considered may be required for different purposes, it is important to distinguish the following:

- a) supplying the designer of a transducer with information concerning the success he has achieved in aiming at a given sensitivity/frequency response;
- b) checking that the manufactured product meets the specified requirements;
- c) supplying sensitivity/frequency characteristics suitable for use in calculating loudness ratings or estimating other subjectivity-determined quantities.

This Recommendation is mainly concerned with c), but the principle is also applicable to a) and b). For these purposes, especially for c), measurements under real conditions must form the basis. Artificial mouths and artificial ears must be used with due regard to obtaining good agreement between these measurements and those from real mouth and ear determinations. Measurements under real conditions are complicated, time-consuming and not reproducible with great precision. This Recommendation describes measurement methods using recommended forms of artificial mouths and artificial ears (see [ITU-T P.51] and [ITU-T P.57]).

This Recommendation applies mainly to LTSs with handset telephones. However, the principles also apply to other types of telephones. Specific considerations for headsets are described in [ITU-T P.380] and, for loudspeaker telephones, [ITU-T P.340].

See [ITU-T P.76] for general principles concerning the determination of loudness ratings.

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.

[ITU-T G.111] Recommendation ITU-T G.111 (1993), *Loudness ratings (LRs) in an international connection*.

[ITU-T P.10] Recommendation ITU-T P.10/G.100 (2017), *Vocabulary for performance and quality of service*.

[ITU-T P.50] Recommendation ITU-T P.50 (1999), *Artificial voices*.

[ITU-T P.51] Recommendation ITU-T P.51 (1996), *Artificial mouth*.

[ITU-T P.57]	Recommendation ITU-T P.57 (2011), <i>Artificial ears</i> .
[ITU-T P.58]	Recommendation ITU-T P.58 (2013), <i>Head and torso simulator for telephonometry</i> .
[ITU-T P.76]	Recommendation ITU-T P.76 (1988), <i>Determination of loudness ratings; fundamental principles</i> .
[ITU-T P.78]	Recommendation ITU-T P.78 (1996), <i>Subjective testing method for determination of loudness ratings in accordance with Recommendation P.76</i> .
[ITU-T P.79]	Recommendation ITU-T P.79 (2007), <i>Calculation of loudness ratings for telephone sets</i> .
[ITU-T P.340]	Recommendation ITU-T P.340 (2000), <i>Transmission characteristics and speech quality parameters of hands-free terminals</i> .
[ITU-T P.380]	Recommendation ITU-T P.380 (2003), <i>Electro-acoustic measurements on headsets</i> .
[ITU-T Q.552]	Recommendation ITU-T Q.552 (2001), <i>Transmission characteristics at 2-wire analogue interfaces of digital exchanges</i> .

3 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CL	Centre of Lips
DRP	Drum Reference Point
ECRP	Ear Cap Reference Point
EEP	Ear canal Entrance Point
ERP	Ear Reference Point
FFT	Fast Fourier Transform
HATS	Head and Torso Simulator
LRGP	Loudness Rating Guard-ring Position
LSTR	Listener Side-Tone Rating
LTS	Local Telephone System
MECRP	Manufacturer-defined Ear Cap Reference Point
MRP	Mouth Reference Point
RLR	Receive Loudness Rating
SLR	Send Loudness Rating
STMR	Side-Tone Masking Rating

4 Sending sensitivities of the LTS

For the present purposes, the sending sensitivity of a local telephone system is specified in terms of the free-field sound pressure at a reference point in front of the mouth¹, and the electrical output from the local telephone system or the microphone as the case may be. The input sound pressure cannot be

¹ The mouth reference point used in this Recommendation is defined in Annex A.

measured simultaneously with the electrical output and therefore the measurement must be made in an indirect manner. The sound pressure at the reference point is measured in the absence of the handset and, with the artificial mouth source unchanged, the handset is placed in the defined position in front of the mouth and the output measured. When a human mouth and voice are used, the source cannot be relied upon to maintain its output constant between the measurement of free-field sound pressure and that of the electrical output from the microphone. Artificial mouths suffer from imperfect representation of the source impedance and field distribution that applies to real mouths.

In addition to providing the proper source conditions, it is necessary to ensure that the mouthpiece is located for every design of telephone handset at the position that would be used in the real situation. This can be achieved by locating the mouthpiece properly with respect to an ear reference point; this ensures that longer handsets are measured with a greater mouth-to-microphone distance than is the case for shorter handsets. The success of using a given handset measuring position for measurement of sensitivity/frequency characteristics can be judged only by making comparisons for handsets of different lengths, between real conversation test results using the artificial mouth and real mouths under suitably controlled measuring conditions. For this Recommendation, the telephone handset shall be located as defined in Annex C. The handset positions to be used with HATS according to [ITU-T P.58] and type 3.3 and 3.4 pinna simulators are defined in annexes D and E.

Special problems are encountered when making measurements with real mouths and real voices, even under controlled talking conditions. Under such circumstances, the sound pressure cannot be measured directly at the required mouth reference point and therefore it has to be measured at some other point and referred indirectly to the mouth reference point. Some previous determinations have made use of a measuring microphone 1 metre from the mouth but this requires anechoic surroundings and is affected by obstruction from the handset under test. Other methods have been also tried and none seem satisfactory so far.

5 Receiving sensitivities of the LTS

The type 1 artificial ear (see [ITU-T P.57] to be specified in [b-IEC 60318-1]) provides the means for precise measurements of the receiving sensitivities of the LTS. However, the sound pressures measured with it do not always agree well with those existing at the ear reference point in real ears under the test conditions used when subjective determinations of loudness ratings are being made. This can be attributed partly to the presence of appreciable acoustical leakage (L_E) between the earphone and the real ear (such leakage is not represented in available recommended forms of the artificial ear) and partly to an increase in enclosed volume between the forms of earphones and the forms of real ears. Therefore, to use the results of measurements made according to this Recommendation, if a type 1 [b-IEC 60318-1] artificial ear is used, it is necessary to make a correction (see clause 9 below).

[ITU-T P.57] describes the different existing ear simulators and their relevant domain of applicability.

In the case of the type 1 artificial ear, proper values of L_E should be used since this device does not include acoustic leak.

In the case of other devices, built-in or naturally-induced leaks exist. Consequently, for receiving loudness rating calculation according to [ITU-T P.79], the leakage term L_E shall be set to zero.

For these devices as well, the sound pressure is measured at the drum reference point (DRP). The correction functions given in [ITU-T P.57] for the different ears shall be used for converting data to the ear reference point (ERP).

For handsets with acoustic outlet(s) inside an ear cap, the ECRP is the same as the O point of Figure C.1.

6 Artificial mouth and voice

The following properties are required:

- a) The distribution in sound pressure around the orifice must be a good approximation to that around a human mouth.
- b) The acoustical impedance looking into the mouth must simulate that for human mouths, so that the pressure increase caused by the obstruction effect of telephone microphones will be representative.
- c) It must be possible to establish definite sound pressures at the mouth reference point as a function of frequency. A convenient feature to embody in a practical artificial mouth is the linearity, over a suitable range of sound pressures, of the ratio of sound pressure at the mouth reference point to the voltage input to the artificial mouth. The ratio must be independent of frequency at least over the range 200 to 4000 Hz but preferably 100 to 8000 Hz.

For the present purposes, the mouth reference point (MRP) is defined by the point on the axis of the artificial mouth located 25 mm in front of the equivalent lip position (see Annex A).

[ITU-T P.51] and [ITU-T P.58] define the requirements for artificial mouths.

7 Artificial ear

The following properties are required:

- a) The acoustical impedance presented to telephone earphones must simulate that presented by real ears under practical conditions of use of telephone handsets.
- b) The sensitivity of the artificial ear is defined as the pressure sensitivity of the ratio between the output of the artificial ear and the corresponding sound pressure level at the ERP measured under open ear conditions, see [ITU-T P.57].

For a human ear, the ear reference point (ERP) is defined in Annex A. The corresponding point when the ear cap is fitted to an artificial ear will usually differ from the place at which the sound pressure is measured and for this and other reasons, certain corrections are necessary when the results are used for calculating loudness ratings (see clause 5 above).

8 Definition of sending sensitivity of an LTS

The sending sensitivity of an LTS depends upon the location of the handset relative to the equivalent lip position of the artificial mouth. For the present purposes, the speaking position defined in Annex C shall be used.

Annex D defines the handset positions to be used with HATS according to [ITU-T P.58] and [ITU-T P.57] type 3.4 pinna simulator. Pressure forces to be used in conjunction with a type 3.4 artificial ear are typically in the range of 2 N to 13 N. 2 N corresponds to a loosely held handset. 13 N corresponds to a situation when the handset is pressed tight against the ear.

Similarly, Annex E defines the handset positions to be used with HATS according to [ITU-T P.58] and [ITU-T P.57] ear simulators type 3.2 and 3.3. With the type 3.2 ear simulator, which has a well-defined contact rim, the handset is applied towards the nominal ERP position.

With the type 3.3 anatomically shaped pinna simulator, the default position is the nominal ERP position. This position corresponds to a loosely held handset (high leak). Application forces in the range of 10 to 20 N may be applied to decrease the acoustic leak.

NOTE – The results measured with Annex D and Annex E set-ups should always clearly indicate the test conditions.

Usually, the sending sensitivity is a function of frequency.

The sending sensitivity of a local telephone system at a specified frequency or in a narrow frequency band is expressed as follows:

$$S_{mJ} = 20 \log_{10} \frac{V_J}{P_m} \text{ dB rel 1V/Pa}$$

where V_J is the voltage across a 600 ohm termination and p_m is the sound pressure at the mouth reference point. Note that p_m must be measured in the absence of the "unknown" handset of the test item.

Administrations who wish to use complex impedance termination for the measurement are referred to the method given in Annex B. The use of complex impedance terminations may change the SLR and RLR values slightly, in comparison to the values using 600 ohm termination. Furthermore, the break points for sending and receiving local telephone systems could change. The effect will be under study.

9 Definition of receiving sensitivity of an LTS

Usually, the receiving sensitivity is a function of frequency. The receiving sensitivity of a local telephone system at a specified frequency or in a narrow frequency band, as measured directly with an artificial ear complying with [ITU-T P.57], is expressed as follows:

$$S_{Je} = 20 \log_{10} \frac{P_e}{\frac{1}{2} E_J} \text{ dB rel 1Pa/V}$$

where p_e is the sound pressure at the ERP and $\frac{1}{2} E_J$ is half the emf in the 600 ohm source. See also clause 8 for complex impedance termination.

NOTE – The receiving sensitivity suitable for use in calculation of loudness is given by:

$$S_{Je} = S_{Je} - L_E$$

where L_E is a correction explained above in clause 5, and S_{JE} is the receiving sensitivity determined using a large number of real ears. Note that if type 3.2, 3.3 or 3.4 artificial ears are used for receiving loudness rating calculations according to [ITU-T P.79], the real ear loss correction L_E should be set to zero.

Further information on this topic is given in [ITU-T P.57] and [ITU-T P.79].

10 Definitions of talker and listener side-tone sensitivities of an LTS

The talker side-tone sensitivity of an LTS is a function of the sending and receiving sensitivities of the telephone set, but also depends on a number of factors including the local subscriber's line conditions, the effective terminating impedance at the local exchange and the side-tone balance circuit within the telephone set.

The side-tone sensitivity, as measured from an artificial mouth to the telephone earphone, is expressed as:

$$S_{meST} = 20 \log_{10} \left(\frac{P_e}{p_m} \right) \text{ dB}$$

where p_m is defined in clause 8, and p_e is the sound pressure developed at the ERP with the handset in the loudness rating guard-ring position (LRGP).

The listener side-tone sensitivity as measured in a diffuse room noise field is expressed as:

$$S_{RNST} = 20 \log_{10} \left(\frac{P_e}{p_{RN}} \right) \text{ dB}$$

where p_e is the sound pressure developed at the ERP with the handset held at LRGP in front of an unenergized artificial mouth, for a diffuse room noise sound pressure p_{RN} measured at the MRP, but in the absence of all obstacles (e.g., test head, handset, etc.).

11 Methods for determining S_{mJ} , S_{Je} , S_{meST} , S_{RNST} and Δ_{SM}

When the sending, receiving and side-tone sensitivities of an actual local telephone system are required, the measurements according to the definitions given in clauses 8, 9 and 10 above can be made as illustrated in Figures 1, 2, 3, 4 and 5. These methods have been used by many laboratories successfully.

When using fast Fourier transform (FFT) techniques for measuring the characteristics of non-linear LTS, the measurement principle used, i.e., ratio of r.m.s. variables, or cross-spectrum (coherent) method, should be specified.

More detail may be found in Section 3 of the [b-ITU-T Handbook].

Figure 1 shows the method of setting up the artificial mouth so that the sound pressure p_m at the mouth reference point is known at each test frequency or frequency band. It is recommended to provide equalization in the artificial mouth drive circuit to maintain the free-field sound pressure constant at the MRP to within ± 1 dB over the frequency range 100 to 8000 Hz. In no case should the deviation exceed ± 2 dB over the frequency range 200 to 4000 Hz and $+2/-5$ dB over the frequency range 100 to 8000 Hz. It is recommended that any deviations from the desired sound pressure level be taken into account when determining the sending or side-tone sensitivity of a local telephone system. This is particularly true if the deviation exceeds ± 1 dB.

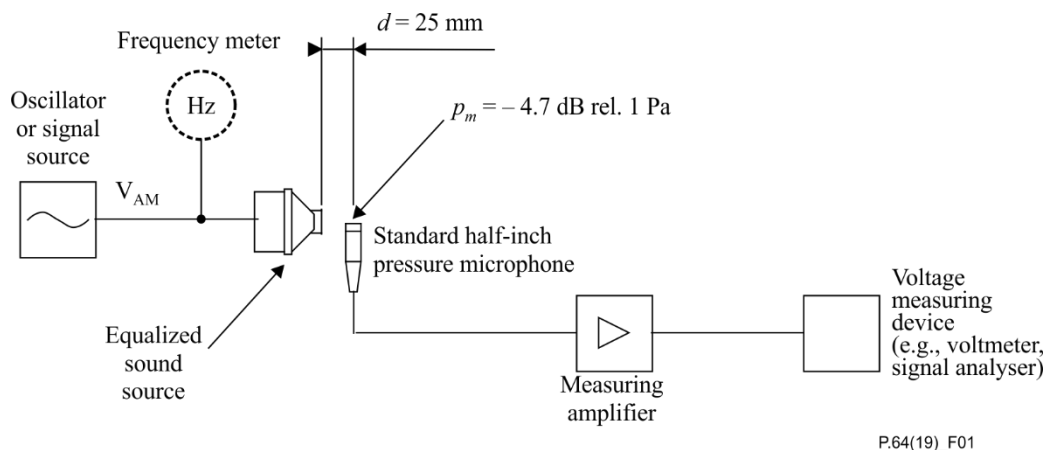


Figure 1 – Measurement of acoustic pressure p_m at the mouth reference point 25 mm from the artificial lip plane of the sound source

For any test signal, p_m of -4.7 dBPa is recommended (see clause 3.6.3 of [b-ITU-T Handbook]).

When sine waves are used as the test signal, the test frequency points should be those of ISO 1/3 octave frequencies from 200 Hz to 4000 Hz for the purpose of calculating sending and receiving loudness ratings. However, for the purpose of frequency response measurement, the interval of 1/3 octave only gives a rough estimation of the system under test. In this case, more frequency