RECOMMENDATION ITU-R BS.708*,**

Determination of the electro-acoustical properties of studio monitor headphones

(1990)

The ITU Radiocommunication Assembly,

considering

a) that unified and closely specified reference listening conditions are an essential prerequisite for subjective assessment and quality control;

b) that there are great difficulties in harmonizing the acoustical characteristics of existing control rooms and listening rooms;

c) that some aspects of the audio signal are more clearly perceptible by using headphones than by using loudspeakers;

d) that the frequency response of studio monitor headphones should provide the same sound-colour neutrality as required for loudspeaker monitoring in control rooms and high-quality listening rooms,

recommends

1 that the frequency response curve measured in accordance with Annex 2 should be flat within the limits specified in Annex 1;

2 that the frequency response of studio monitor headphones should be measured in accordance with Annex 2;

3 that the difference of frequency response between left and right earphone should not exceed 1 dB in the frequency range 100 Hz-8 kHz and 2 dB in the frequency range 10 kHz-16 kHz.

ANNEX 1

Specification of tolerances

The frequency response requirement for studio monitor headphones is defined by Fig. 1. The tolerance mask for the diffuse-field frequency response shown in Fig. 1 is based on measuring accuracy achievable by means of 16 test subjects.

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* This Recommendation should be brought to the attention of the IEC and the Audio Engineering Society (AES).

** Radiocommunication Study Group 6 made editorial amendments to this Recommendation in 2002 in accordance with Resolution ITU-R 44.

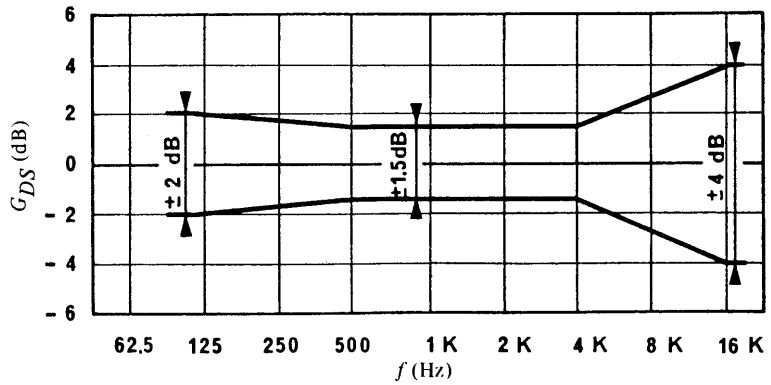

FIGURE 1 – *Tolerance mask for the diffuse-field frequency response of studio monitor headphones*

G_{DS}: diffuse-field earphone response (dB(Pa/V))

D01-sc

ANNEX 2

Diffuse-field frequency response of studio monitor headphones

Measurement specification

1 General

The measurement procedure is used to determine the frequency response of the individual earphones of a headphone as a function of the frequency by means of sound-pressure measurements in the auditory canals of test subjects. In the direct measurement procedure the sound pressure in the auditory canal caused by the headphone is compared with that caused by the reference sound field. In the indirect procedure, the sound field is replaced by a reference headphone calibrated by means of the direct method. The reference sound field is the diffuse sound field.

The measuring set-up consists of signal source and signal receiving equipment. The source comprises a noise generator, third-octave filters, at least one loudspeaker or a reference headphone and the headphone to be tested. It is also possible to use a real-time third-octave analyser to which a suitable wideband noise signal is applied. The receiving equipment contains a miniature or probe-mounted microphone to measure the sound pressure in the outer auditory canals of the test subjects and, if the direct procedure is used, a calibrated microphone with a known diffuse-field frequency response to measure the unweighted sound-pressure level in the reverberation chamber. The signal voltages of the microphones and loudspeakers should be determined by means of an r.m.s.-reading voltmeter with a sufficient integration time.

2 Probe microphone

The following requirements apply to the probe-mounted microphone, which is called “probe” in this text:

– the sound pickup should take place within the auditory canal at least 4 mm away from its beginning;

– in the area of the auricle and the outer 4 mm of the auditory canal the probe should not have a cross-section of more than 5 mm^2;

– in the following part of the auditory canal the ratio between the probe cross-section and the auditory canal section should be less than 0.6. (The average auditory canal cross section of an adult is approximately 45 mm^2.) The probe volume including fixing elements should be smaller than 130 mm^3;

– no special requirements are made for the transfer function of the probe. However, the response of the probe should be free of resonances. It is sufficient that the response of neighbouring third octaves does not differ by more than 3 dB;

– it should be guaranteed that, with an occluded ear, the probe output level is at least 15 dB below that obtained with an open ear;

– fixing elements are necessary to keep the probe at a central position in the auditory canal. The spring suspension of these elements should be dimensioned such that the probe fits sufficiently well into auditory canals with different cross-sections and can still be inserted and removed easily;

– the probe should be inspected and certified for use with regard to medical aspects by a physician.

3 Direct method of measurement

This method is based on a comparison of output voltage levels of a probe placed in the outer auditory canal of a test subject when a noise signal is produced by alternating sources, namely the headphone under test and a diffuse sound field of a reverberation chamber.

3.1 Test signals

The preferred sound signals are filtered noise signals that are obtained from pink noise by means of third-octave filters, specified in IEC Publication 225 (type b). The probe output has to be measured selectively in third octave steps. This can be done successively or at the same time with a real-time third octave analyser. The sound pressure levels of the test signals should be such that the input signals at the microphone amplifier are at least 10 dB above the inherent electric noise level and the noise level ensuing from body noise in the auditory canal. The sound pressure level at the reference point must not exceed 85 dB. The headphone voltage should be adjusted such that, at a third octave centre frequency of 500 Hz, the output level of the probe matches the output for the diffuse sound field within 3 dB.

3.2 Diffuse sound field

The sound field in the reverberation chamber is considered sufficiently diffuse if the following requirements are satisfied:*

– In the absence of the test subject the sound pressure level measured by means of an omnidirectional microphone at a distance of 15 cm before, behind, right and left of, above and below the reference point (entrance of the auditory canal of the test subject) must not deviate from the sound pressure level at the reference point by more than 2 dB;

– in the absence of the test subject the sound pressure level should be measured at the reference point using a directional microphone which has a directivity index of at least 8 dB above 500 Hz. The sound pressure level in each third-octave band ≥ 500 Hz must not deviate by more than 3 dB independent of the direction of the microphone.

3.3 Test subjects

The measurements in the auditory canal have to be done with at least 16 persons. Spectacles and earrings, etc., have to be taken off, and the ear should not be covered by hair. There are no special requirements on the hearing ability of test subjects, but the measured outer ear should not show abnormalities. If the probe does not fit sufficiently well into the auditory canal due to its dimensions, the person concerned cannot be employed as a test subject.

The test subjects should move as little as possible during measurements. The headphone has to be worn as intended by the mechanical construction especially regarding right and left hand earphones. The test subject should take care that the headphone fits as comfortably and at the same time as tightly as possible, and should carefully put the headphone on and off himself.

3.4 Measurement procedure

Before the measurement the probe is inserted into the test subject's auditory canal. The position in the auditory canal is uncritical provided that it lies at least 4 mm inwards. The microphone cable or the probe tube is fixed below the auricle, e.g. by a strip of plaster. The probe in the auditory canal should not change position perceptibly when the headphone is put on and off.

The probe output voltage is measured for each frequency band when the test subject is exposed to sound waves in the sound field (first sound-field measurement). Immediately afterwards the test subject carefully puts on the headphone, and the voltage received from the probe is then measured for each frequency band (first earphone measurement). After the test subject has put off the headphone and put it on again, the second earphone measurement is carried out. Then measurements on a different type of headphone may follow. Finally, the measurement in the sound field is repeated (second sound-field measurement).

In order to make sure that the probe has not moved during the whole measurement cycle – which is an indispensable prerequisite for a correct result – the probe voltage levels of the first and second sound-field measurement are compared. If the value measured in one of the frequency bands

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* These requirements are met in reverberation chambers intended for acoustical measurements. If such a chamber is not available, the diffuse-field frequency response of studio monitor headphones should be determined by means of the indirect measurement procedure (see § 4).

deviates by more than 2.5 dB, the whole measurement cycle must be repeated. If the repeated measurements also show differences of more than 2.5 dB, the test subject should be replaced by another one.

3.5 Determination of individual diffuse-field frequency responses

The arithmetic mean value of the probe voltage levels of the first and second sound-field measurement is calculated for each frequency band. The same applies to the voltage levels of the two earphone measurements. These mean values are then used to determine the individual diffuse-field frequency response of the tested earphone by means of:

$$G_{DSi}\,(\text{re 1 Pa/V}) = 20 \log \frac{U_{SK}}{U_{SD}}\ \text{dB} + L_D - 94\ \text{dB} - 20 \log \frac{U_K}{U_0} \qquad \text{dB}$$

where:

G_{DSi}: individual diffuse-field earphone response per frequency band,

U_{SK}: r.m.s. probe output voltage with earphone as sound source,

U_{SD}: r.m.s. probe output voltage in the diffuse field,

U_K: r.m.s. input voltage in the earphone,

U_0: reference voltage 1 V,

L_D: diffuse-field sound pressure level at reference point.

3.6 Determination of the diffuse-field frequency response

The diffuse-field frequency response of the earphone G_{DS} is determined by arithmetically averaging the results G_{DSi} of the test persons in each frequency band. Also the standard deviation should be calculated.

4 Indirect method of measurement

If the diffuse-field frequency response of a headphone was determined by means of the direct procedure, this headphone can be used as a reference instead of the diffuse sound field. The methods of direct measurements then apply correspondingly. The individual diffuse-field frequency response of the tested earphone is determined by:

$$G_{DSi}\,(\text{re 1 Pa/V}) = G_{DSr} + 20 \log \frac{U_B}{U_K}\ \text{dB} - 20 \log \frac{U_{SB}}{U_{SK}} \qquad \text{dB}$$

where:

G_{DSr}: individual diffuse-field response per frequency band of the reference earphone,

U_{SB}: r.m.s. probe output voltage with reference earphone as sound source,

U_B: r.m.s. input voltage at the reference-earphone.

If the indirect method of measurements has been chosen, the type and diffuse-field frequency response of the reference headphone has to be indicated.