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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Electroacoustics – Audio-frequency induction loop systems for assisted hearing –
Part 2: Methods of calculating and measuring the low-frequency magnetic field emissions from the loop for assessing conformity with guidelines on limits for human exposure

Electroacoustique – Systèmes de boucles d'induction audiofréquences pour améliorer l'audition –
Partie 2: Méthodes de calcul et de mesure des émissions de champ magnétique basse fréquence à partir de la boucle pour l'évaluation de la conformité aux instructions sur les limites d'exposition humaine

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**ELECTROACOUSTICS –
AUDIO-FREQUENCY INDUCTION LOOP SYSTEMS
FOR ASSISTED HEARING –**

Part 2: Methods of calculating and measuring the low-frequency magnetic field emissions from the loop for assessing conformity with guidelines on limits for human exposure

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International Standard IEC 62489-2 has been prepared by IEC technical committee 29: Electroacoustics.

The text of this standard is based on the following documents:

FDIS	Report on voting
29/728/FDIS	29/736/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 62489 series, published under the general title *Electroacoustics – Audio-frequency induction loop systems for assisted hearing*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

ELECTROACOUSTICS – AUDIO-FREQUENCY INDUCTION LOOP SYSTEMS FOR ASSISTED HEARING –

Part 2: Methods of calculating and measuring the low-frequency magnetic field emissions from the loop for assessing conformity with guidelines on limits for human exposure

1 Scope

This part of IEC 62489 applies to audio-frequency induction-loop systems for assisted hearing. It may also be applied to such systems used for other purposes, as far as it is applicable. The standard is intended for assessment of human exposure to low-frequency magnetic fields produced by the system, by calculation and by in-situ testing.

This standard does not deal with other aspects of safety, for which IEC 60065 applies, or with EMC.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60118-4, *Electroacoustics – Hearing aids – Part 4: Induction loop systems for hearing aid purposes – Magnetic field strength*

IEC 60268-1, *Sound system equipment – Part 1: General*

IEC 60268-2, *Sound system equipment – Part 2: Explanation of general terms and calculation methods*

IEC 60268-10:1991, *Sound system equipment – Part 10: Peak programme level meters*

IEC 61786, *Measurement of low-frequency magnetic and electric fields with regard to exposure of human beings – Special requirements for instruments and guidance for measurements*

IEC 62226-2-1:2004, *Exposure to electric or magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body – Part 2-1: Exposure to magnetic fields – 2D models*

IEC 62311:2007, *Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz – 300 GHz)*

3 Rated values

The term rated means 'the value stated by the manufacturer'. Rated values are of two kinds: rated conditions, fundamental values that cannot be verified by measurement, and others that can be so verified. For a full explanation, see IEC 60268-2.

4 Situation regarding current standards

Current published and draft IEC standards on EMF exposure do not give unambiguous guidance on the approach that should be taken by product committees. The differences between the signals that we are concerned with and those considered in depth in EMF exposure standards are the following:

- wide relative bandwidth (ratio of highest to lowest frequency present, 100 Hz to 5 kHz);
- no predominant frequency within the band;
- rapidly-varying amplitude;
- high ratio of peak amplitude to average r.m.s. amplitude (at least 4).

5 Configurations of loops

5.1 Main types of configuration

There are four main types of configuration:

a) large area loops, with the smallest dimension larger than 1 m, usually installed at floor level in a room;

b) medium-area loops, with dimensions of the order of 1 m, often oriented in a vertical plane, installed at service desks and similar positions;

c) small area loops, with the largest dimension less than 1 m;

d) solenoid antennas, including the ear-hook.

NOTE Examples of small-area loops are portable systems, clipboards, neck loops, cushion loops (including those for use in vehicles) and chair loops.

5.2 General considerations

All loops produce strong fields close to the loop conductor(s). This is shown by the relationship between current I in a long, straight wire and the magnetic field strength H produced at a distance R from the centre of the wire, where R is greater than the radius r of the wire:

$$H = I/2\pi R \quad (1)$$

NOTE 1 Within the wire, the field strength decreases linearly from $I/2\pi r$ at the surface to zero at the centre.

NOTE 2 For n parallel conductors very close together (i.e. a multi-turn loop), the magnetic field strength is n times that produced by a single conductor.

For calculations of field strengths in the high field strength regions, very close to the conductor(s), the 'long, straight wire' approximation is almost always sufficiently accurate, except for solenoids, which need a completely different treatment (see 6.2).

5.3 Large-area loops

The occupants of the room are likely to come close to the loop conductor only by stepping on the floor at a point below which the conductor is installed. Such proximity is normally transient. However, in places of worship, devotional postures may bring parts of the body other than the feet into proximity. This may also apply in hospitals, treatment rooms and gymnasia.

Maintenance staff might come into closer contact and for longer periods, but it is unlikely that the system would then be operating.

5.4 Medium-area loops

For these, there are three considerations:

a) The hearing-aid user is normally at a distance from the loop comparable to its dimensions. Thus the loop current required to produce a maximum r.m.s. field strength of 400 mA/m (in compliance with IEC 60118-4) at the hearing-aid is much larger than the current required to produce it at the centre of the plane of the loop.

b) Nevertheless, the separation ensures that the hearing-aid user is not exposed to the high fields strengths near the loop conductor.

c) However, staff may come into close proximity of the loop conductor while the system is working unless steps are taken to maintain a minimum separation.

NOTE These loops often have more than one turn, so that the loop current can be kept reasonably small.

5.5 Small-area loops

For these, again, there are three considerations:

a) The separation for portable loops is very much greater than the loop dimensions, but for other types, the separation distance may be small or very small unless steps are taken to maintain a minimum separation.

b) The current apparently required is quite large, because of the large separation.

c) Both users and staff may come into close proximity of the loop, even that of a portable system.

NOTE These loops usually have many turns, so that the actual current is not so large.

5.6 Solenoid antennas

One example that is commercially available is the ear-hook. This device is typically as shown in Figure 1. A very small solenoid is incorporated in the stem of the device.

IEC 050/11

Figure 1 – An earhook induction transducer, with a BTE (behind the ear) hearing aid body for scale

6 Calculations

6.1 General

Calculation of the field strength can be reliably made using Equation (1) in almost all cases, except where the loop is very small or is a solenoid of length which is not very small compared with its plan dimensions, such as for the ear-hook device. It is necessary to calculate the current required in the loop to produce a field strength of 400 mA/m at the hearing-aid position, taking into account the orientation of the pick-up coil in the hearing-aid relative to the plane of the loop. In general, this calculation is not easy, but simple approximate methods give sufficiently accurate results when used with insight. Proprietary calculation software, based on published mathematical analyses, exists. General-purpose mathematics software can also be used.

Translating the calculated field strengths into a form comparable with exposure guidelines or limits is again, not simple. See Clause 8.

6.2 Solenoid antennas

There is no simple expression for the field strength at a point outside a solenoid. A solenoid may be treated as a stack of loops, or as a magnetic dipole, or the field strength can be calculated by means of a rather complex equation (See Bibliography).

7 Measurements

7.1 General

In the audio-frequency range, exposure time is irrelevant, because the predominant physiological effect, if it occurs, is nerve stimulation, which operates over a time-scale of a few milliseconds. It is therefore appropriate to use a quasi-peak measurement of field strength. Furthermore, exposure limits and guidelines are given in r.m.s. values, so the quasi-peak meter should be scaled to read r.m.s. values with a sinusoidal signal. This type of meter, the peak programme meter (PPM), is further described in IEC 60118-4 and IEC 60268-10 (type II).

It is also necessary to consider the type of magnetic field pick-up coil or sensor. Sensors may be single-axis, with just one coil, or three-axis, with three orthogonal coils. For use with a PPM, the single-axis sensor is most convenient, and if it is properly constructed, it is not difficult to orient it for maximum reading, especially as the likely direction of the field can usually be predicted from text-book field patterns.

The first measurement to be made shall determine that the field strength is correct at the point or points where it is intended to be 400 mA/m (or the agreed lower value if adjusted to reduce loudness, as specified in IEC 60118-4).

NOTE IEC 60118-4 specifies the use of either a PPM or an r.m.s. meter with a 125 ms integration time for the measurement of magnetic field strength. However, for the purpose of this standard, the 125 ms integration time is incompatible with the requirement to measure field strengths over times of the order of a few milliseconds.

The instrument specified for measurements on other equipment and systems, such as in IEC 62233, has an averaging time specified only as an upper limit of 1 s, which is also too slow for the assessment of fields due to audio-frequency signals.

7.2 Input signal

The input signal for the amplifier shall be the simulated programme signal described in IEC 60268-1, with additional filtering, -3 dB at 100 Hz and 5 kHz relative to the 1 kHz level, with ultimate attenuation slopes of at least 12 dB/octave.

7.3 Measuring instrument

It is unlikely that a suitable complete instrument is commercially available at present, since the application is extremely specialized. However, the design of an adapter for use with widely-available audio test equipment, or that itself provides the PPM function, is not very difficult. The elements are the following:

- the pick-up coil, which, because the field strengths of interest are high, needs few turns and no magnetic core material. Because the fields are highly inhomogeneous, the coil should be of small dimensions, to minimise averaging. A coil covering four faces of a 1 cm cube of insulating material is convenient;
- a frequency-response correction circuit, which produces a constant output from a magnetic field that varies with frequency in the same way as the guidelines or limits, with bandwidth control so as to discard out-of band interference signals;
- amplification of the signal such that the maximum permissible field strength produces an output voltage of 0,775 V for connection to the audio test equipment;
- optionally, a quasi-peak detector substantially as specified in IEC 60268-10 (type II) and means to display its output with a resolution of 1 dB.

8 Comparison of calculated or measured results with guidelines or limits

IEC 62226-2-1 uses the approach specified in IEC 62226-1, whereby a coupling factor, K, is used to determine the allowance to be made for non-uniformity of the induced current density in a thin disc, caused by an inhomogeneous magnetic field:

$$\mathrm{K} = J_n / J_u \qquad (2)$$

where J_n is the actual maximum current density and J_u is the maximum current density due to a homogeneous field:

$$J_u = \sigma \pi R f B \qquad (3)$$

where

σ is the conductivity of the disc;

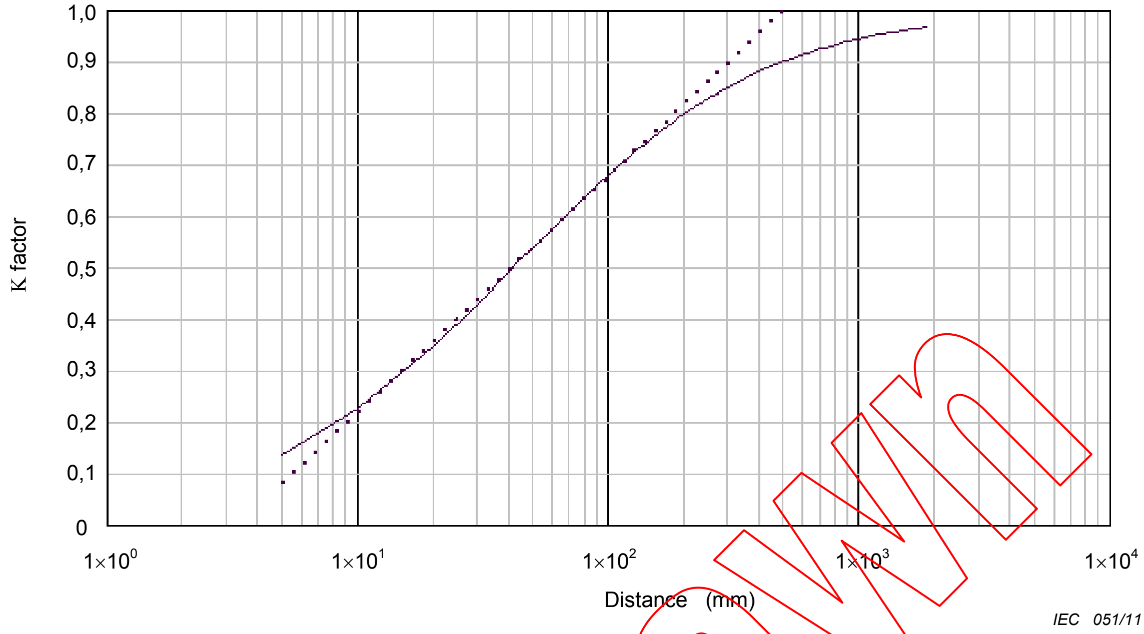
R is the radius of the disc;

f is the frequency; and

B is the magnetic induction (flux density) at the edge of the disc nearest to the source of the magnetic field.

For most purposes, σ may be taken as 0,2 S/m, but for particular cases, the values in Table C.1 of IEC 62311:2007 should be used. For the majority of cases, Equation (1) applies and thus Annex B of IEC 62226-2-1:2004 is relevant. Since the values of K are larger for the 100 mm radius disc, this radius is adopted for this standard.

Using the data from Tables B.1 and B.2 of IEC 62226-2-1:2004, a convenient presentation of the value of K as a function of the distance between the source and the nearest point of the disc is given in Figure A.1.



NOTE The dotted line represents the equation K = 0,2ln(r) – 0,24, where r is the distance. An example of a calculation using K is given in Annex B.

Figure 2 – K factor as a function of least distance between wire and disc

9 Meeting limits or guidelines

The field strength near the loop conductor is fixed by the current, which in turn is fixed by the field strength required at the hearing-aid position. It is clearly not possible to meet exposure requirements by reducing the current. It is also obvious that any form of shielding is unlikely to be practicable in most cases.

However, what can be done is to insert a physical barrier between the loop conductor and the person who might otherwise come too close to it. This barrier can be of any non-magnetic, non-electrically conducting material.

10 Measurement uncertainty

The total measurement uncertainty includes sensor position and orientation, operating conditions and, for in-situ measurements, magnetic background noise (although if the system complies with IEC 60118-4, the effect of noise is negligible). Guidance on uncertainty is provided in IEC 61786.