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Code of practice for audio-frequency induction-loop systems (AFILS)

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 82, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI and came into effect on 30 September 2011. It was prepared by Technical Committee EPL/100, *Audio, video and multimedia systems and equipment*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 7594:1993, which is withdrawn.

Relationship with other publications

The performance of induction loop systems is specified in BS EN 60118-4:2006, whereas this standard gives recommendations and guidance for their design, planning, installation, testing, operation and maintenance. Provisions for components of a system are given in BS EN 62489-1. Methods of calculation and measurement of the magnetic field, in the context of human exposure, are given in BS EN 62489-2.

Information about this document

This is a full revision of the standard, updating all aspects.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Section 1: General

1 Scope

This British Standard gives recommendations for and guidance on the design, planning, installation, testing, operation and maintenance of an audio frequency induction loop system (AFILS) intended for communicating speech, music and/or other signals. It is mainly concerned with AFILS for hearing enhancement, in which the signals are communicated to users of hearing aids equipped with magnetic pick-up coils. However, most of the standard also applies to AFILS used for other purposes, and some additional information on these purposes is given in Section **3**.

This standard does not apply to induction-loop systems which use a carrier frequency, nor to other systems for hearing enhancement purposes which do not use magnetic induction.

2 Normative references

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

BS EN 60065, *Audio, video and similar electronic apparatus – Safety requirements*

BS EN 60118-4:2006/IEC 60118-4:2006, *Electroacoustics – Hearing aids – Part 4: Induction loop systems for hearing aid purposes – Magnetic field strength*

BS EN 61672-1:2003/IEC 61672-1:2003, *Electroacoustics – Sound level meters – Part 1: Specifications*

BS EN 62489-1/IEC 62489-1, *Electroacoustics – Audio-frequency induction loop systems for assisted hearing – Part 1: Methods of measuring and specifying the performance of system components*

BS 7671, *Requirements for Electrical Installations – IEE Wiring Regulations Seventeenth Edition* [1)]

3 Terms, definitions, signs and symbols

3.1 Terms and definitions

For the purposes of this standard, the following definitions apply.

3.1.1 audio-frequency induction-loop system (AFILS)
system including amplifier(s), microphones and/or other signal sources, in which magnetic fields are created by the flow of audio-frequency current in a conductor arranged in the form of a loop or coil

3.1.2 AFILS for hearing enhancement
AFILS in which the intended receivers are hearing aids or specially designed listening devices equipped with coils acting as magnetic antennas

1) Informative dated reference also made to BS 7671:2008+A1:2010.

3.1.3 direct-to-reverberant ratio
ratio at a given point in the sound field, of the sound pressure due to the wanted sound source to the sound pressure due to reverberation

3.1.4 hearing aid
personal amplification system, worn entirely on the listener, which is designed to enable a person with impaired hearing to hear more easily

3.1.5 induction-loop listener
listening device which is designed to give an audible output in response to signals transmitted by an AFILS

3.1.6 induction-loop monitor receiver
equipment designed to verify the performance of an AFILS by audio and visual means:

a) providing visible indication that it is powered and when the strength of the magnetic field produced by the loop falls within a specified range; and

b) providing an audio-frequency output by which the sound quality of the AFILS transmissions can be assessed

NOTE Other facilities may be included (see Annex A).

3.1.7 magnetic field strength
magnitude of the magnetic field, at a stated point in space and in a stated direction, generated by the flow of alternating current in an AFILS

3.1.8 listening plane
plane of the listeners' telecoils in their hearing aids

NOTE As most hearing aid users are standing or sitting, only the vertical component of the magnetic field of an area-coverage loop system is useful and the listening plane is horizontal. However, if the user is lying down, the horizontal component of the magnetic field is useful. The listening plane for seated listeners is conventionally taken as 1.2 m above floor level and that for standing listeners as 1.7 m above floor level. Where a single plane height is required for design purposes, it should be taken as being 1.45 m above floor level, and the resultant design checked for heights of 1.2 m and 1.7 m.

3.1.9 useful magnetic field volume
volume within which the system provides hearing-aid users with a signal of acceptable quality

[From BS EN 60118-4:2006.]

3.1.10 system designer
technically competent person who takes responsibility for the technical specification, design and performance of the system

3.1.11 simple installation
AFILS that is neither large nor complex and does not require specialist skills in order to achieve a satisfactory result

3.1.12 counter system
ticket office system
small area AFILS designed to assist communication between (usually) two persons, sometimes through a transparent screen

NOTE For example at a ticket office, bank, or a social security office.

3.1.13 large area installation
AFILS that has an approximate coverage area greater than 400 m^2

*NOTE Such installations are likely to require specialized design knowledge in order to obtain a satisfactory result (see **4.3**).*

3.1.14 complex installation
AFILS needed when:

- it is required to operate close to another AFILS, which could lead to co-interference;
- it is required that a certain area is not covered by the AFILS, in case it might interfere with sensitive electronic equipment, e.g. electric guitars or dynamic microphones;
- it is required that the system operates on a number of different listening planes;
- an unconventional layout of loop conductors is indicated;
- there is metal in the building's structure and this causes irregularity in the field strength when using a perimeter loop

*NOTE See Clause **10**.*

3.1.15 direction of magnetic field
resultant direction of the magnetic field at a point in three dimensional space, arising from the phasor sum of components of the field derived by integration over all elements of the induction-loop

NOTE See also Annex G.

3.1.16 reference magnetic field strength level
0 dB reference for magnetic field strength levels, which is 400 mA/m

*NOTE See BS EN 60118-4, **3.1**.*

3.1.17 overspill
magnetic field of usable strength that is present outside the volume in which is it required

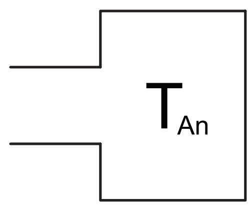
NOTE This volume is larger than the useful magnetic field volume because a field of usable strength can be weaker than the minimum specified in BS EN 60118-4 for the useful magnetic field volume.

3.2 Signs and symbols

3.2.1 Symbol for an induction-loop

The symbol shown in Figure 1 should be used on circuit diagrams to indicate an AFILS.

Figure 1 **Symbol for use on diagrams**

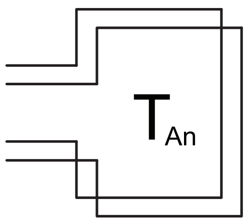


*NOTE n is the number or letter corresponding to the classification of loop. See Clause **10**.*

3.2.2 Symbol for multiple loops

The symbol shown in Figure 2 should be used on circuit diagrams to indicate a complex or low-spill AFILS.

Figure 2 **Symbol for multiple loops for use on diagrams**



*NOTE n is the number or letter corresponding to the classification of loop. See Clause **10**.*

3.2.3 Sign for display in premises where an AFILS is installed and for AFILS equipment identification

Signs for display should be produced on a durable material.

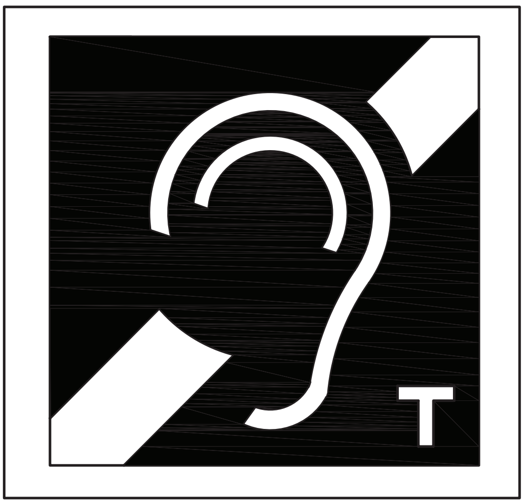
Areas where the reception of the AFILS is satisfactory should be clearly indicated at visible positions by means of the sign shown in Figure 3, which is based on the one originally adopted by the World Federation of the Deaf, should be used. The sign should indicate T as shown. The background colour should be Pantone reference 661 or 662 (blue) and the printing should be in white.

NOTE Signs of other colours are found in use.

Normally the dimensions of the display signs should be a minimum of 100 mm × 100 mm, when used on equipment they may be of any convenient size.

The sign should appear at a position visible in normal use on AFILS equipment, on loop cable junction boxes and adjacent to the loop cable itself where it would be helpful to maintenance personnel or help to prevent accidental disturbance.

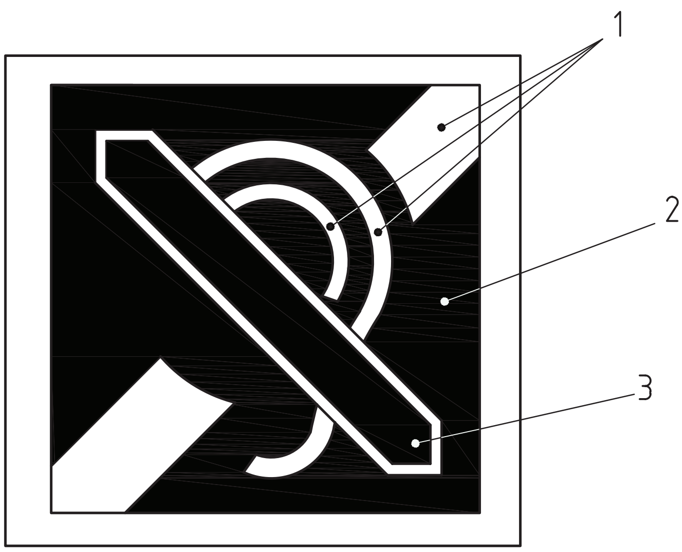
Figure 3 **Sign for display in premises to indicate that an AFILS is installed and for AFILS equipment identification**



3.2.4 Identification of areas where reception of the AFILS is not satisfactory

Areas where the reception of the AFILS is not satisfactory should be clearly indicated on a plan of the space by means of the sign shown in Figure 4. The plan should be placed where it can be seen by both hearing-aid users and staff. This sign should also be placed visibly in the unsatisfactory area and/or on all seats in that area.

Figure 4 **Sign to show seating areas where AFILS reception is not satisfactory**



Key

1 White

2 Blue background

3 Red cancelling line with white surround

4 General

4.1 Object

The recommendations of this standard are intended to lead to the following.

a) Prospective purchasers clearly understand the functions and limitations of an AFILS (see Annex B).

b) The design, installation and setting-up of the AFILS allows compliance with the appropriate requirements for safety and electromagnetic compatibility and all relevant regulations relating to electrical installations.

c) Users wearing hearing aids equipped with a magnetic pick-up coil receive signals transmitted by the AFILS that are intelligible and free from undue distortion and interference even when all non-AFILS equipment normally used in the environment is in operation.

d) The reception of such signals is possible in any part of the space; where, by force of circumstance, the reception in some parts is limited, this is clearly defined and identified (see **3.2.4**).

e) Visual indication is given to prospective users that an AFILS is installed.

f) Means are provided for the building management to easily verify that an AFILS is working satisfactorily (see Annex A).

g) The AFILS can be satisfactorily operated and maintained by properly trained and competent personnel.

h) Where necessary, the AFILS is arranged for minimum extraneous coverage. It should be understood, however, that even if an AFILS is designed to limit extraneous coverage, it might be possible for a determined person outside the intended area of coverage to receive what might be confidential information.

i) Guidance is given on means to reduce possible effects of the magnetic field produced by the loop on other nearby equipment.

4.2 How to use this code of practice

This standard is divided into sections, with recommendations intended primarily for:

a) purchasers of AFILS (Section **1** and Section **2**);

b) designers of AFILS and AFILS equipment (Section **3** and Section **5**);

c) installers of AFILS (Section **4** and Section **5**);

d) those responsible for commissioning, testing, operation and maintenance (see Section **5**, Section **6** and Section **7**);

e) those responsible for day-to-day operations, ensuring that the facilities are accessible to as many people as is reasonably possible.

4.3 Specialist advice

Except for home systems sold as a complete kit, the engagement of a skilled system designer is advisable and is considered to be essential whenever large or complex installations are involved. Professional bodies such as the Institute of Sound and Communications Engineers may be approached for lists of such specialists.

4.4 Safety aspects

It is essential that an AFILS, even if temporary, is installed in a safe manner and in accordance with safe work practices (see Clause **13**).

4.5 Conforming to existing performance standards

The performance standard for AFILS is BS EN 60118-4:2006, the requirements of which have been incorporated (where applicable) as recommendations in this standard.

Section 2: Purchasing an AFILS, placing a contract for its installation, or obtaining independent assessment of the performance of an installation

5 Technical advice

5.1 Complying with this standard

Significant problems can arise with poorly designed or installed AFILS. Purchasers should stipulate that the design and installation are to comply with this code of practice and that the system should conform to BS EN 60118-4:2006. Operation and maintenance procedures should also be in accordance with this code of practice.

NOTE For small self-install systems intended for home use, it is expected that the manufacturer has ensured that the basic requirements of this standard will be met if the user follows the installation instructions carefully.

It is recommended that contracts include a specific variation clause under which parties agree to the terms of the contract and document any agreed variations.

5.2 Seeking technical advice

NOTE While many successful AFILS have been installed to date, compliance with this standard should greatly increase the probability that satisfactory results will be obtained. Its provisions, however, cannot be properly applied without adequate technical knowledge and experience, and each design presents individual challenges.

Wherever possible, technical advice should be sought during the early planning stages of an AFILS. Such advice should cover:

a) the suitability of an AFILS for a particular venue and/or application (see Clause **10**);

b) factors that may adversely affect the performance of an AFILS;

c) factors that may add to the cost of installing an AFILS;

d) the need for, and scope of, an initial site assessment (see Clause **12**);

e) details of the audio source(s);

f) where microphones are to be used, their positioning to minimize extraneous noise and reverberation.

In all cases, the responsibility for the correct performance of the system at the time of commissioning should lie with the system designer, when one is involved (see Section **3**). It should be understood, however, that the system designer cannot be held responsible for the parts of the system outside their control.

Where the AFILS is to be installed as part of other electrical works, it is especially important that all aspects of the design are clearly specified, especially regarding microphones, required coverage and overspill (see **3.1.17** and **9.2**).

5.3 The nature of the advice

Advice sought will depend on the particular installation requirements for each AFILS, but should generally be covered by the following categories:

a) advice from the designer/installer direct to the client on all aspects, from initial quotations for the task in the planning stages through to installation, commissioning and maintenance of the AFILS;

b) advice from the designer to a technician who lacks experience with AFILS installations but who has the task of installing the system (e.g. systems in new buildings where installation is to be carried out by electrical contractors; systems installed by in-house staff);

c) advice from an appropriate organization or professional body such as the Institute of Sound and Communications Engineers.

5.4 Professional (consultancy) advice

Professional advice from a specialist consultant should be sought when installations are to be undertaken in extra-large buildings, prestigious buildings and those posing special difficulties.

The advice of an independent consultant may also be sought in the event of a dispute between the purchaser and supplier or manufacturer.

NOTE Such advice can often provide the most economical resolution of the dispute.

6 Objective of the system

Before approaching a supplier, it is important to write down, in non-technical terms, what the users of the system require it to do and the environment it is to be used in. Care should be taken that this is as comprehensive as possible: anything left out at this stage can result in extra expenditure later.

Factors that should be considered include:

- the room(s) and three dimensional space(s) to be covered;
- what sounds or audio signals are to be reproduced and where they are to come from (all the sources and places);
- whether the audio information needs to be confidential (e.g. a court);
- known/likely interference from other equipment (e.g. power transformers, air-conditioning equipment, other AFILS, and some fluorescent lighting);
- building construction, such as structural steel work and metal sheeting in walls, floors and ceilings, particularly close to the looped area;
- any metal construction within the space (e.g. tiered seating or metal suspended ceiling grids);
- architectural considerations or restrictions (e.g. listed building status); and
- how continuing satisfactory operation of the system can be ensured, for instance by regular testing by trained staff, or by the installation of a fixed monitor receiver (see Annex A).

7 Choosing the system supplier

7.1 General

Possible procedures for acquiring an AFILS are recommended in **7.2**, **7.3** and **7.4**. The choice of procedure should depend on the size of the space to be covered and any special complications which might be involved.

7.2 Approaching a contractor

Particularly for simple AFILS, a contractor may be asked to design, supply and install suitable equipment and all cabling, based on the objective of the system (see Clause **6**). Names of contractors who specialize in this work may be obtained from business directories and trade associations. Responsibility for choosing appropriate equipment (microphones, amplifier, etc.) and for installing and setting up the AFILS correctly, should rest with the contractor.

NOTE For a small AFILS, the cost of a formal initial survey might not be justified, but many contractors will conduct an informal survey as a matter of course.

7.3 Approaching a manufacturer of AFILS equipment

NOTE Some manufacturers of AFILS equipment are willing to produce the site survey for the proposed installation, design a system and, perhaps, recommend a competent installation contractor. Manufacturers who are unable to provide this service themselves may offer contact with appropriate designers/installers who can undertake such projects. Names of manufacturers can be obtained from business directories and trade associations such as the Institute of Sound and Communications Engineers.

Responsibility for choosing appropriate equipment (microphones, amplifier, etc.) and commissioning the system should rest with the selected manufacturer or designer/installer. The contractor should be responsible to the manufacturer for the correct installation of the AFILS and commissioning (where this is also undertaken).

For some AFILS, the installation contractor may call in a manufacturer to provide detailed technical advice on areas of uncertainty or particular difficulty. On these occasions the contractual obligations of the installation contractor and the manufacturer to the prospective purchaser should be clearly documented, preferably under a single contract.

7.4 Approaching a specialist consultant

When it is appropriate to engage a specialist consultant, this should be done at the earliest opportunity. The consultant should be responsible for the initial survey, design and commissioning of the AFILS, choice of equipment and for helping to assess installers' proposals. Where necessary, the consultant should also liaise with architects and construction contractors on matters affecting the AFILS. Names of consultants who specialize in this work may be obtained from business directories and trade associations.

NOTE Such a consultant might be independent or might be a competent person employed by a manufacturing or contracting organization.

8 Contractual provisions

8.1 Performance specification

The purchase contract should include an agreed performance specification, prepared by the system designer, to which the system is contractually required to conform at the commissioning stage. A guide to the preparation of a specification is given in Annex D. Where the choice of equipment to be used is not completely under the control of the system designer (for example, if some existing microphones are to be used), any reservation about the suitability of such equipment should be clearly explained to the purchaser in writing.

8.2 Verifying that the completed system delivers its intended performance

Tests of the completed installation to verify that the AFILS performs satisfactorily should be specified in the contract and should cover:

a) checks of the system using a calibrated meter designed to measure field strength in conformity with BS EN 60118-4:2006;

b) subjective tests using persons with normal hearing listening through suitable receiving units;

c) subjective tests by hearing aid users, with their hearing aids set to T;

d) provision of either field-strength meters for use by trained staff or a fixed monitor receiver.

If the subjective tests are conducted correctly and do not provide confirmation of positive instrumentation checks, the system designer should be held responsible for identifying measures necessary to achieve satisfactory results. The contract should, therefore, include adequate provisions for properly defining the system designer's responsibility with regard to the preparation of any required remedial proposals and their implementation.

*NOTE The emphasis is on satisfactory results, as determined by the users of the system, rather than achieving particular objective results from technical tests. See BS EN 60118-4:2006, **6.4.2**.*

The system designer should advise on methods of eliminating interference by the AFILS with other nearby electronic equipment, and modifications to the AFILS should be agreed with the system designer; it is advisable for the contract to specify how the costs of such remedial work are to be apportioned.

*COMMENTARY ON **8.2***
*The need for specific measures to eliminate interference by the AFILS with other nearby electronic systems (e.g. multiple grounding, legacy equipment with inadequate immunity, unforeseen proximity of loop cabling to other cabling, see Clause **9**) might be impossible to predict before the AFILS is installed and tested.*

Remedial work has to be carried out by the body having technical responsibility for the appropriate system (telephone systems, etc.).

*The tests in **17**b) are to determine the perceived sound quality of the system and its adequate freedom from noise, reverberation and distortion. They are not intended to demonstrate that the needs of any particular hearing-aid user are met.*

8.3 Arbitration

It is recommended that provision is made in the contract for arbitration in the event that problems arise.

Where possible, an arbitration body should be identified.

9 Factors to be considered at the design stage

9.1 External factors

9.1.1 Magnetic noise interference

*COMMENTARY ON **9.1.1***
*Magnetic fields radiated from mains cables and overhead and underground power lines or cables and equipment can be picked up in most buildings on a hearing aid switched for use with a loop system (T position). Where the field is at a low level of intensity it is not normally troublesome. However, under certain circumstances the field strength can be sufficiently high to interfere with the signal picked up from the induction-loop, causing annoyance to the listener and in some cases making it impossible to use the loop system. Examples of sources of magnetic interference are fluorescent and other types of discharge lamps, electronic lamp dimming systems and faulty or incorrectly routed wiring (see Clause **13**).*

For the limits on magnetic noise level, see BS EN 60118-4:2006.

Serious magnetic interference can be caused by the separation of live and neutral conductors (or of phase conductors) of mains circuits, which is particularly found in old buildings where numerous changes have been made to electrical installations. Magnetic interference is also a problem in newer buildings where loop circuits have been installed in rooms with suspended ceilings and the fluorescent lighting circuits have an interlinked neutral instead of each lighting circuit having an individual neutral.

*Such wiring is not in accordance with BS 7671:2008+A1, **444.4.2.1**(iii).*

9.1.2 Effect of metal in the building structure and within the coverage area

NOTE 1 The performance of the AFILS can be seriously degraded if there is metal (which might be concealed) in the building. Local degradation of the performance can also occur near large metal objects or constructions within the coverage area.

NOTE 2 For new builds, the building designers should provide detailed drawings and information regarding structural metal and sheet metal in the vicinity of all AFILS.

While these effects are difficult to predict, the customer should be made aware of their likely or potential impact. The outcome of site measurements of the effect of metal in the building structure on magnetic fields should be considered as part of the objectives and the design procedure, and any anticipated detrimental effects reported to the customer.

9.2 Magnetic field overspill

Care should be taken to ensure that confidential information is not fed into the AFILS as it can be possible to hear this information with a suitable receiver some distance outside the loop. Special designs of loop system may be considered, which can help to reduce the overspill field. (See also **3.1.17**)

While certain AFILS rely on magnetic fields extending beyond the loop for their correct operation, this extended field can potentially interfere with any other communication system, including another AFILS. For example, an AFILS installed in a theatre auditorium might interfere with the intelligibility of an AFILS installed at the box office (interference in the other direction is much less likely). Since the magnetic field produced by an induction loop is not confined to the area within the loop, signals can often be picked up on a suitably equipped hearing aid or receiver outside the room or the building in which the loop is installed, or even in an adjacent public road or area. This can cause difficulties when two or more loop systems in close proximity to each other are in operation simultaneously, as listeners to one of the loops may also hear overspill signals from the other.

It is not practicable to recommend limits on overspill field strength as the acceptable strength depends on many site-specific factors. It is recommended that the requirements for overspill be specified contractually in each case in which it is necessary.

Section 3: AFILS system design

10 Classification of systems

NOTE 1 Because of the diversity of use for AFILS the following classifications are intended to group similar applications, providing minimum performance characteristics for each group based on the intended use; for example the permissible magnetic noise and overspill with adjacent counter loops can be considerably higher than that of a theatre system as the user is only in contact with the counter system for a small period of time.

AFILS should be assessed by a competent person and assigned one of the following classifications for operation and performance.

NOTE 2 Classifications start A (AFILS) to prevent confusion with fire systems L classifications.

- A1: **Portable or hand held self contained equipment**. This equipment is designed for mobile/temporary use only to assist one-to-one communication. It is not intended to be used on counters or left permanently installed in a location. It is intended, for example, for use by travelling professionals such as doctors or lawyers.
- A2: **Small volume system for use in counters, signage, intercom, emergency voice communication system (EVCS).** Coverage is required within a small defined volume (generally not more than 2 m × 2 m × 0.5 m), where the user is in a fixed position and use is transitory, e.g. counter systems for a ticket office or GP surgery, help points. For counter systems where confidentiality is important the design of the AFILS may be required to attenuate the magnetic field outside a designated space (usually the useful magnetic field volume) to a level at which speech cannot be understood. But there is no requirement for the magnetic attenuation to exceed the acoustic attenuation.
- A3: **Perimeter loop for coverage of a single volume where other AFILS are not present in the vicinity and where security, overspill or overcoming significant metal losses is of no importance,** e.g. church/stone building remote from other buildings containing AFILS.
- A4: **Multi-loop systems**, specifically designed to control the horizontal and vertical field components for AFILS installed in close proximity and/or to overcome significant metal content, e.g. classrooms or cinemas with multiple AFILS, an auditorium with a box office AFILS in same building, reinforced concrete construction, or an office space with a raised steel computer floor. The techniques involved depend entirely on the individual application: from as simple as a figure 8 loop, to the use of two separate arrays of loops in conjunction with a phase shifter or similar device. Consultation of a specialist in AFILS antenna design is essential to ensure that the correct solution is applied. Professional bodies such as the Institute of Sound and Communications Engineers may be approached for lists of such specialists.
- A5: **Loop systems designed for purposes other than assistive listening** such as stage direction or observational counselling.

- A6: **Personal loops, hand held or worn on the body.**
- A7: **Specialist loops** which fall into none of the above categories, such as systems for lifts, which generally require detailed design work by a competent AFILS specialist.

NOTE 3 Table 1 gives the required features, performance and indications for different loop classes and covers the desired and minimum features of classes A1 to A4; by their nature the other classes have specific requirements beyond the scope of this standard.

Table 1 **Required features, performance and indications for different loop classes**

Type	**Allowable background noise** dB L A)	**Field variation in the useful magnetic field volume** dB	**Loop separation** B)	**User controls (minimum)**	**Indications**
A1: *Portable or hand held self contained equipment*	–32, –22 for short time periods	12	2 m		Power, loop current
A2: *Small volume system for use in counters, signage, emergency voice communication system (EVCS).*	–32, –22 for short time periods	12	Width of loop ×2 e.g. 2 m for counters using 1 m wide loop	Input gain, loop drive	Power, loop current, input signal present or automatic gain control active
A3: *Area coverage systems for a single volume where other AFILS are not present in the vicinity and where security or overspill or overcoming significant metal losses is of no importance*	–32, –22 for short time periods	6	Width of loop ×2 e.g. 10 m for 5 m wide loop	Input gain, loop drive.	Power, loop current, input signal present or automatic gain control active
A4: *Low overspill loop systems*	–32, –22 for short time periods	6	As recommended by designer, typically 2 m	Input gain, loop drive.	Power, loop current, input signal present or automatic gain control active

A) dB L is "decibels with respect to 400 mA/m".

B) Separation between two adjacent loops in the plane of the loops to minimize the pick up of signals from one loop by a hearing-aid user using the other loop. Where loops are installed one above the other the situation is more complex and requires specialist knowledge to minimize interference.

11 Signal sources

*COMMENTARY ON CLAUSE **11***
The prime objective of an AFILS is the improvement in the signal to noise ratio and direct-to-reverberant ratio, in order to improve the intelligibility for the hearing aid user. As such the choice of the audio source and the choice and positioning of microphones are of paramount importance.

For Type A1 systems the microphone is usually contained within the device.

*For Type A2 systems microphones are used for counter systems, with particular attention to counters where the server and customer are separated by glass and the need for the hearing aid user to hear a proportion of their own voice to help regulate their speech; for EVCS, help points and signage the audio source is usually taken directly from the loudspeaker or public address/voice alarm system (see **11.2**).*

Where several microphones are used in a space or the talkers move to set locations within a space (such as places of worship) the use of several open microphones increases the background noise lowering the intelligibility of the system.

For theatres, cinemas and places of worship, it is advisable to consider an audience-response microphone for ambience between events and to reassure users the AFILS is in operation. This ambient input may be passed through a "ducking circuit" to prevent the performance system audio being picked up by this ambient input and thus reducing the intelligibility.

11.1 Audio sources

Type A2, A3 and A4 AFILS may be required to reproduce voice alarm signals and messages whilst overriding other input signals.

Type A3 and A4 systems can have a variety of sources from microphones and line level systems. In these arrangements particular care has to be taken in the choice of source, particularly for multi-function venues. If there is no fixed position for a talker in the space, it is advisable to consider wireless microphones or multiple microphones and suitable audio processing such as manual switching, noise gates or automatic mixers to minimize noise.

For type A5 and type A6 systems the audio sources are application specific although the general recommendations still apply.

When positioning talkers and their associated microphones, it is essential to avoid mechanical noise entering the system from local sources such as air conditioning, AV projector fans and the suchlike.

11.2 Interconnection with sound reinforcement systems

*COMMENTARY ON **11.2***
Where the room configuration is constant, it may be satisfactory to derive the signal for the AFILS from a sound reinforcement system. If so, it should preferably be derived from a low-level output on the mixer or amplifier of the sound reinforcement system, but it is also possible to derive the signal from a loudspeaker distribution system.

If the input to the AFILS is to be taken from a low level output of a sound reinforcement system, then it should be confirmed that any adjustment of the output of the sound system itself does not affect the signal being fed to the AFILS, and that the AFILS signal is not subject to equalization for the room characteristic. It should be made difficult to switch off inadvertently, or to fade down the feed to the AFILS.

Makeshift methods, such as placing a microphone in front of a loudspeaker, should not be used in a permanent installation. This does not exclude the use of properly designed attachments, for example for television receivers, or use of the microphone and loudspeaker technique in a temporary installation provided that satisfactory operation can be achieved.

11.3 Interconnection with a voice alarm system

Where the AFILS is used as a supplementary alarm device to reproduce messages or signals from a voice alarm system, provision should be made to silence or override all other input signal inputs for the duration of the voice alarm message. Some AFILS amplifiers have this feature built-in while others require additional equipment for this purpose. A voice alarm system should provide both an audio signal connection and a control connection (usually a switched DC voltage) to the AFILS.

The AFILS should also provide an indication to the voice alarm system that the amplifier is working correctly and that current is flowing in the loop. This is usually provided by volts-free contacts that open when a fault is detected.

11.4 Use and siting of microphones

Where the talker position is predictable, the microphone should be securely fixed and maintained in position.

In other cases, and especially where the room configuration changes, it may be necessary to provide one or more microphones, and a mixer or mixing amplifier, specifically for the AFILS. Such microphones should be chosen and sited, in liaison with the occupier of the building, architect, etc., with a view to obtaining as much direct sound from the original sources as possible, and a uniform loudness balance if there are several sources.

NOTE 1 Directional microphones normally give the best results; highly directional microphones require considerable skill and experience in order to achieve consistent loudness, unless the signal levels are continuously monitored and adjusted. However, where a microphone has to be located at a distance from the source (on a balcony front in a theatre for example) a highly directional microphone is almost always required in order to achieve adequate intelligibility.

Microphones should be located so as to have a clear "view" of the source they are intended to cover, and should be located away from air conditioning grilles, fans, strong air currents or other potential sources of acoustic noise pick-up, for example fluorescent or theatre lighting, and video projectors.

It is not advisable to use very inexpensive microphones, such as those intended for household use. Microphones requiring batteries should not be used, because of the inconvenience of replacing them; an exception is made for wireless microphones. Microphones vary greatly in their susceptibility to picking up the magnetic field of the loop. Dynamic microphones should be tested for magnetic pick-up unless the manufacturer provides adequate assurance of immunity.

Where questions or comments from an audience are to be relayed via the AFILS, highly directional microphones may be used. These should be positioned so that in spite of the very restricted coverage provided by each microphone, uniform pick-up from all audience positions is achieved.

NOTE 2 It is usually necessary to provide a separate pre-amplification channel for each of these microphones, and for an operator to control the channel gains when the microphones are in use.

NOTE 3 Alternative positions may require evaluation with a trial loop and an induction-loop monitor receiver.

NOTE 4 The use of appropriate equalization on an individual microphone channel can considerably help to reduce unwanted room effects and low frequency acoustic noise transmission.

11.5 Microphone accessories

AFILS microphones should be mounted on surfaces or structures that are solid or not vulnerable to vibration, impact or similar disturbance (either accidental or deliberate), and not mounted on floor stands, because floor noise, kicks, clicks and handling noise can be very disturbing to a hearing aid user. Microphones are very susceptible to accidental damage and vandalism, so they should be secured against unauthorized access, especially when the AFILS is left unattended.

AFILS microphones should not normally be provided with a switch accessible to the microphone user, because of the likelihood of incorrect operation. An exception may be made if only properly trained persons use the microphones, and the switch is not built into or mounted directly on the microphone (as this often results in noise when the switch is operated).

11.6 Use of several microphones

Microphones which are not directly picking-up the wanted signal should be switched off.

NOTE 1 In general, the fewer the number of microphones in operation at any one time the better the clarity and intelligibility of the wanted signal becomes. Microphone mixers and preamplifiers which include voice switching or noise gating are extremely useful when more than one or two microphones are needed and a trained operator is not available.

*NOTE 2 In small to medium-sized meeting rooms, a boundary-layer microphone (see **11.6**) located centrally on the meeting table or on the ceiling immediately above it can often prove more effective than four or five simultaneously operating cardioid table microphones, as a more uniform and less "coloured" sound pick-up is possible. However, the maximum distance over which such a device operates effectively is likely to be less than approximately 3 m from the talker, who should not be located more than 45° off-axis of at least one microphone.*

In Type A2 counter systems, microphones should be provided on both the staff and customer sides where the parties are separated by a glass screen or other obstruction.

11.7 Distance between the microphone and the source of sound

It is essential that the signal delivered to hearing aid users is as free from reverberation and noise (as well as other forms of degradation) as possible; this is because the single-channel nature of the AFILS prevents the listener using the mechanisms of the ear-brain system to distinguish wanted sounds from unwanted.

Microphones should be positioned as close to the original source(s) of sound as possible, and the output signal of each microphone should be checked by listening for sufficiently low levels of reverberation and noise at an early stage, so that any unsatisfactory performance can be corrected.

Although it is not possible to give numerical design procedures for determining the maximum permissible distance between an AFILS microphone and the wanted source of sound; two primary factors should be jointly taken into account, i.e. general noise and room reverberation.

For talker-to-microphone distances larger than 3 m, use of a number of local microphones should be considered to improve the direct-to-reverberant sound-pressure level ratio, with the absolute minimum number of microphones being in operation at any given time.

To avoid introducing audibly delayed signals, the difference in path lengths between any source and the two nearest active microphones should not generally exceed 5 m for music or 8 m for speech. Adjacent microphones should not in general be closer together than three times the distance between the source of sound and the closest microphone.

NOTE 1 The further a microphone is located away from the sound source, the weaker the wanted signal becomes. This effectively reduces the signal-to-noise ratio and also reduces the direct-to-reverberant sound pressure level ratio.

In order to help maintain an acceptable signal to noise ratio, the maximum microphone distance should be limited to approximately 6 m to 10 m, even in quiet auditoriums with trained speakers and assuming a microphone having a cardioid directional response. The use of a highly directional "shotgun" microphone may be used to extend the range up to 15 m maximum.

NOTE 2 The effects of reverberation, however, are additive to noise, and tend to reduce the distance still further. For effective speech intelligibility, a direct-to-reverberant ratio greater than 0 dB is necessary (normal unimpaired listeners). For hearing impaired listeners, a direct-to-reverberant sound pressure level ratio of at least +4 dB to +6 dB is usually necessary but this is highly dependent upon a number of factors including size, shape, volume and reverberation time of the room, and the characteristics of any reflecting surfaces.

NOTE 3 For example in an auditorium with a volume of 3 000 m^3 and a reverberation time of 1.5 s, the maximum acceptable distance with two cardioid microphones operating may be as little as 4 m to 5 m.

The direct-to-reverberant sound pressure level ratio *K* may be calculated from the following equation, if only a single microphone is used:

$$K = 10\lg\left[\frac{QV}{314D^2\left(RT\right)}\right]$$

where

- Q is the directivity index of the microphone;
- V is the volume of the room (in m^3);
- D is the distance between sound source and the microphone (in m);
- RT is the reverberation time of the room (in s).

If more than one microphone is used, the subject becomes significantly more complicated and specialist advice should be sought.

NOTE 4 Except for large auditoriums and places of worship, RT for most medium to large rooms is likely to be between 1 s and 2 s. Small rooms generally have a shorter RT e.g. around 0.5 s for well furnished (domestic) rooms and up to around 1 s to 1.2 seconds for lecture theatres and similar sized rooms. (primary school classrooms should have an RT value of 0.6 s or less, 0.8 for secondary school classrooms and open plan areas/seminar rooms and 0.8s to 1.2 s for assembly halls. Lecture theatres should have RT values < 1.0 s and 0.8 s for small rooms (<50 people).

It should be realized that this equation assumes a diffuse, statistical sound field to exist and does not take into account the effects of local reflections, or non-exponential sound decay within the room. However, the equation may be used to obtain an initial estimate of the likely maximum usable microphone distances.

*COMMENTARY ON **11.7***
The ratio K decreases by a factor of 3 dB each time the number of active microphones in operation is doubled. For example, using two microphones instead of one reduces the direct-to-reverberant sound pressure level ratio by approximately 3 dB.

Since the equation for K includes the directivity index Q of the microphone, the directional characteristic of the microphone affects the distance from the source of sound at which a given direct-to-reverberant sound pressure level ratio is achieved. The directional characteristics (somewhat idealized) of some common types of microphone are shown in Figures 5 to 11. The hypercardioid characteristic gives the maximum rejection of reverberant sound of all simple microphones, while the supercardioid characteristic gives the maximum ratio of front to random energy efficiency. The directional characteristics of highly directional or shotgun interference-tube rifle microphones vary considerably with frequency (see Figures 9 to 11), and they might therefore pick up considerable low-frequency reverberation: this can be reduced by the careful use of equalization.

A type of microphone which has low sensitivity to reverberant sound is the boundary-layer (pressure-zone) microphone, in which the microphone capsule is mounted very close to a plane reflecting surface, supplied as part of the microphone. These microphones are designed to be placed in contact with a large flat surface, and owe their reduced sensitivity to reverberation to the confinement (by the large flat surface) of the directional response in three dimensions to half-space, instead of the full-space which applies to other types of microphone. The basic directional characteristic of the microphone capsule may be omni-directional, in which case the three-dimensional directional characteristic is a hemisphere, or a cardioid, giving a three-dimensional pattern in the form of a half-cardioid of revolution.

Figure 12 shows the relative distances from the source of sound at which different types of microphone can be operated, for a given direct-to-reverberant sound pressure level ratio. It is important to minimize the actual distance in all cases, but with a minimum distance of approximately 300 mm, below which breath noise, coloration and large variations in signal level with small changes in distance can lead to degradation of intelligibility.

NOTE 5 Figures 13 to 16 show typical examples of good and bad microphone positioning.

The sound wave reflected from a desk top can interfere with the direct sound (as shown in Figure 17) which should be taken into consideration. This effect can cause considerable unevenness in the frequency response above 1 kHz, which may be minimized by positioning the microphone at least 150 mm above the surface. It may be helpful to cover the part of the desk top around the microphone with a layer of soft material, preferably at least 25 mm thick.

Figure 5 **Horizontal directional response of an omni-directional microphone with its axis vertical: decibel scale**

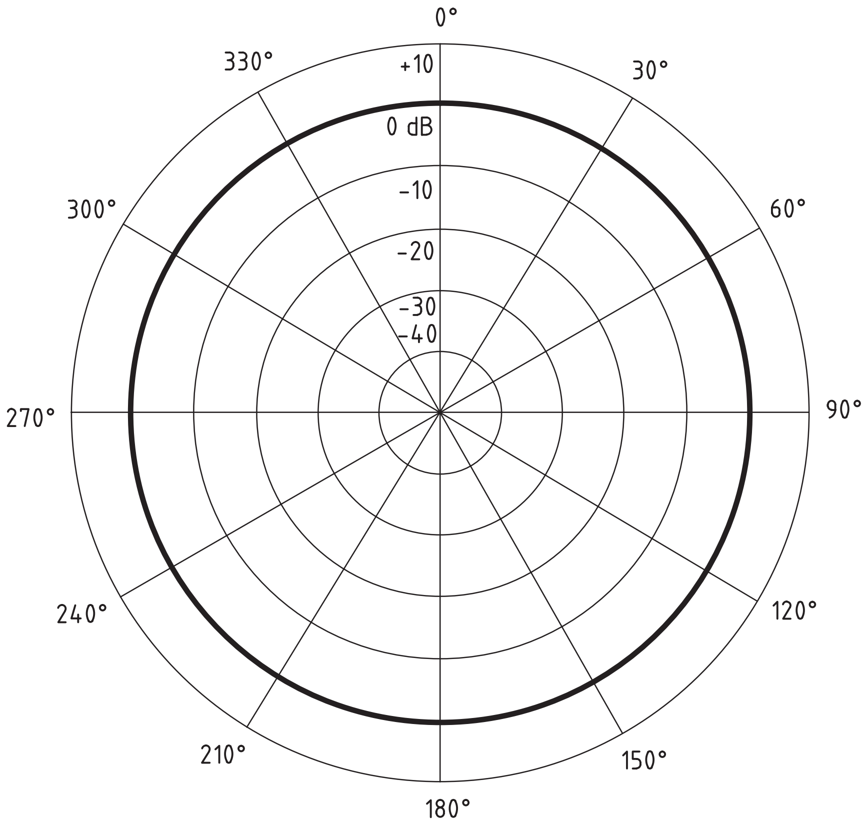


Figure 6 **Directional response of a cardioid microphone: decibel scale**

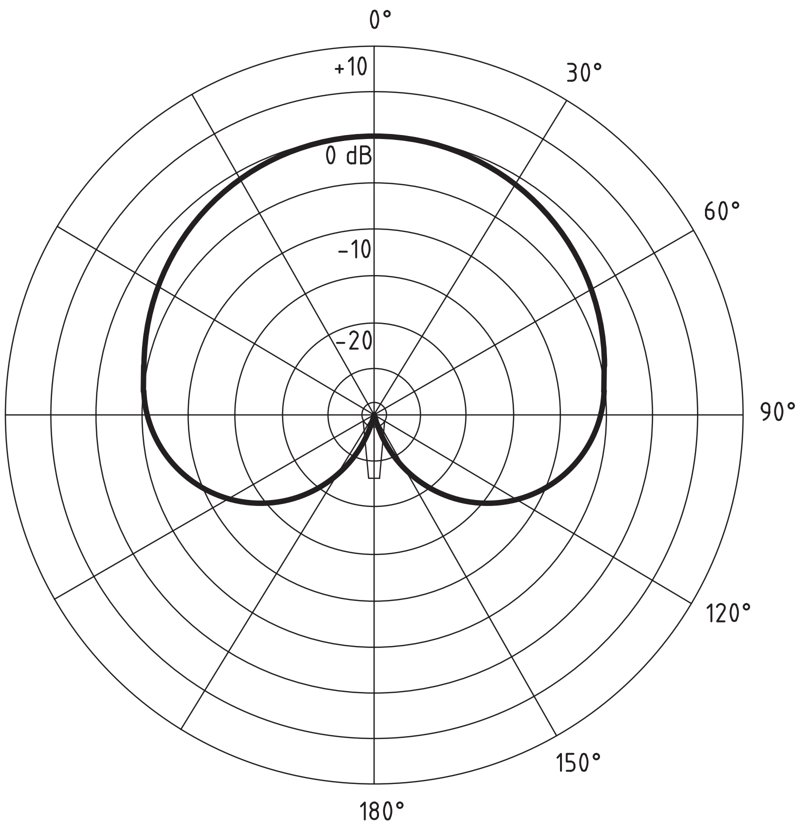


Figure 7 **Directional response of a supercardioid microphone: decibel scale**

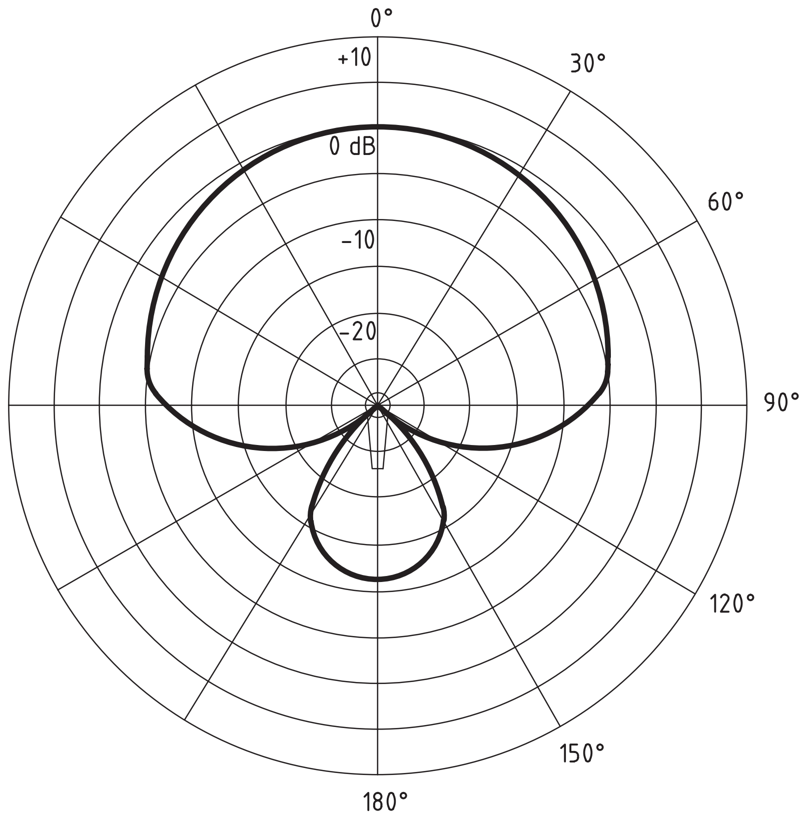
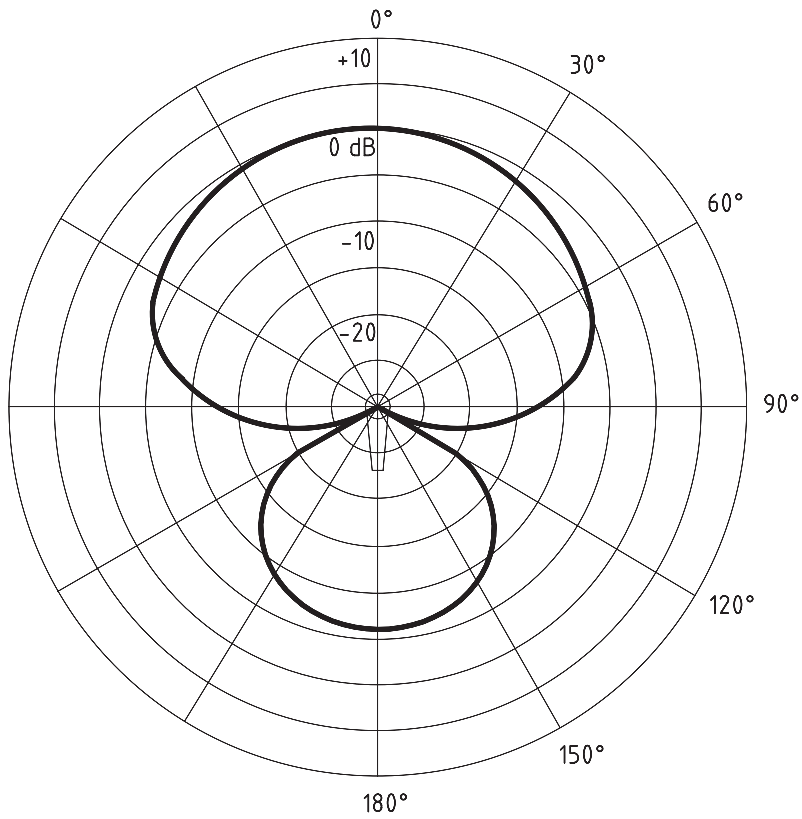


Figure 8 **Directional response of a hypercardioid microphone: decibel scale**



NOTE Some microphones of this type have an approximately cardioid response (see Figure 6) at low frequencies.

Figure 9 **Directional response of a highly directional shotgun (rifle) microphone where f = 250 Hz and barrel length is 275 mm**

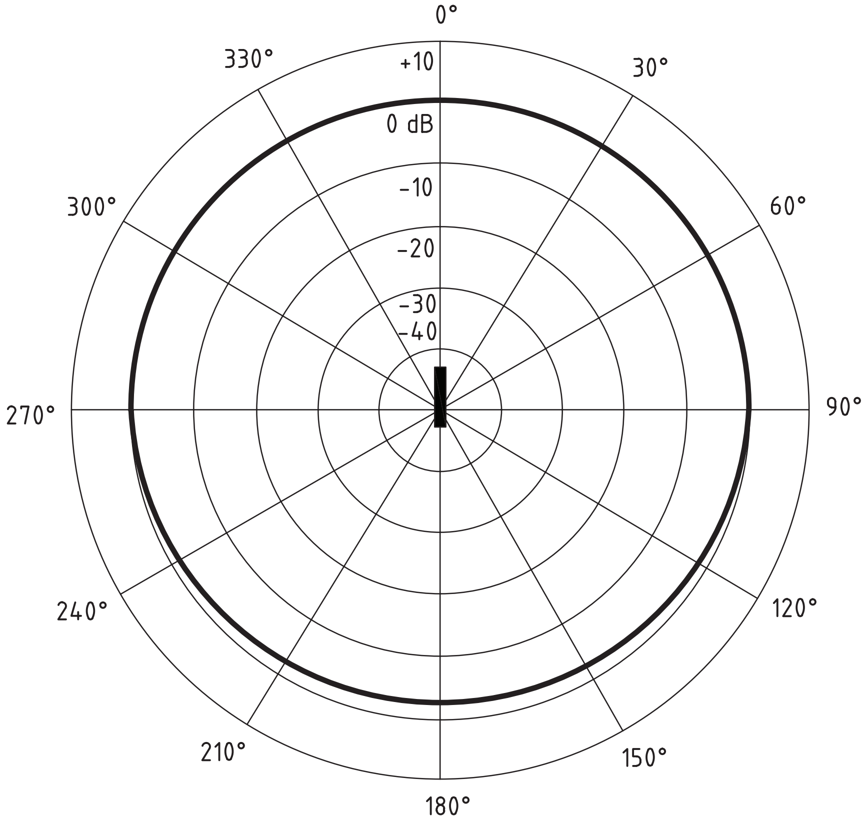


Figure 10 **Directional response of a highly directional shotgun (rifle) microphone where f = 2.5 kHz and barrel length is 275 mm**

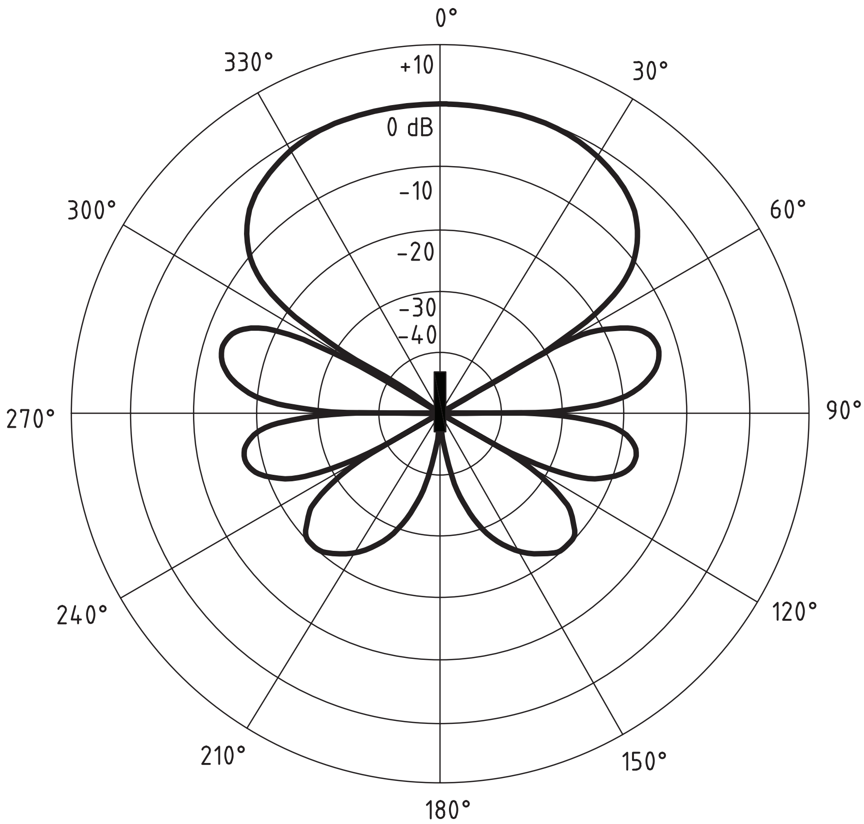


Figure 11 **Directional response of a highly directional shotgun (rifle) microphone where f = 10 kHz and barrel length is 275 mm**

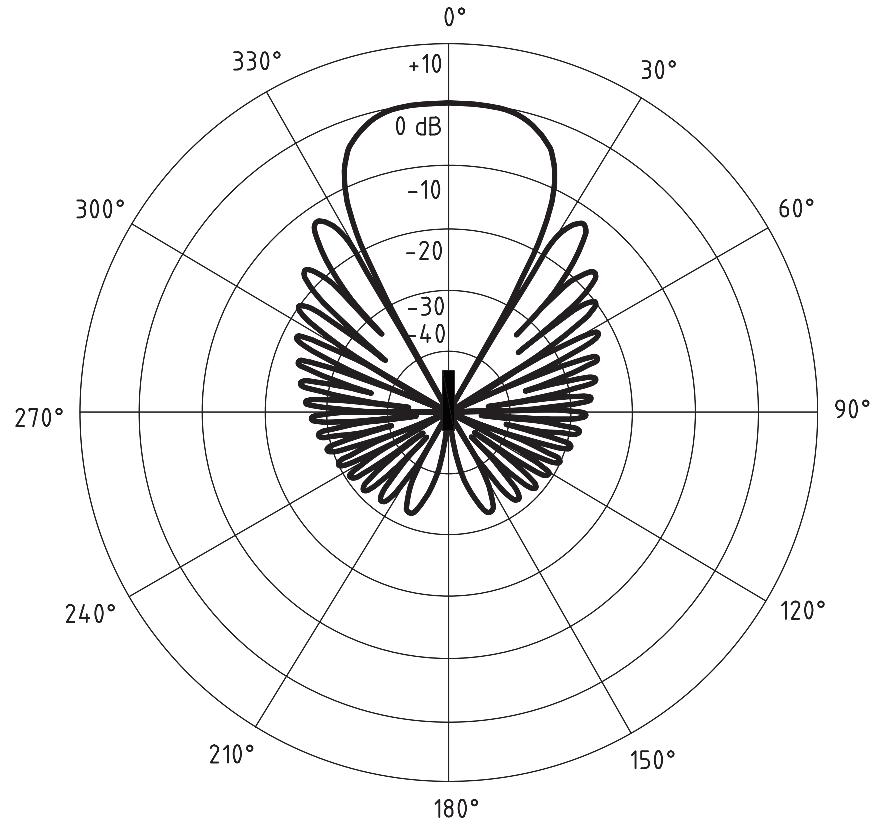
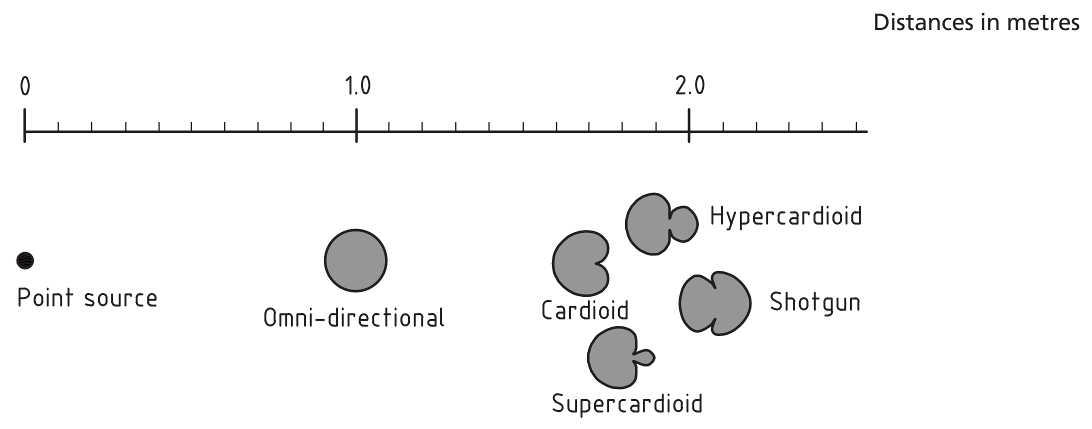
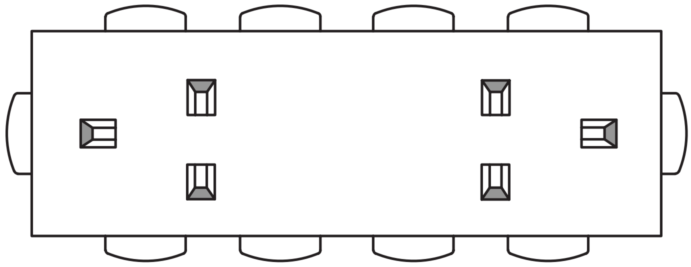


Figure 12 **Relative operating distances of directional microphones for equal direct-to-reverberant signal ratios**

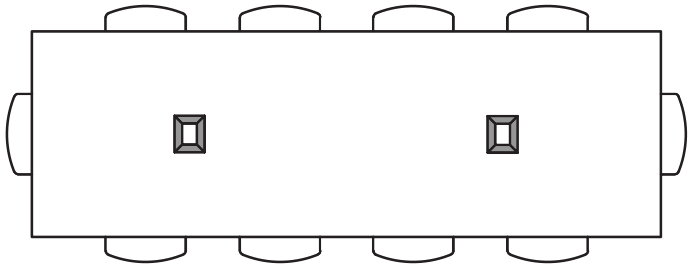


Type of microphone	Distance relative to that of an omni-directional microphone	Approximate angle between the directions at which the response is −3 dB relative to the axial response
Omni-directional	1.0 ×	360°
Cardioid	1.7 ×	130°
Supercardioid	1.9 ×	115°
Hypercardioid	2.0 ×	105°
Shotgun	Depends on the frequency and design of the microphone	Depends on the frequency and design of the microphone

Figure 13 **Two methods of positioning microphones on a conference table**



a) Microphones positioned in accordance with the 3-to-1 rule, using cardioid microphones



b) Alternate placement using two cardioid microphones

Figure 14 **The 3 to 1 ratio for microphone positioning (normal)**

Dimensions are in millimetres

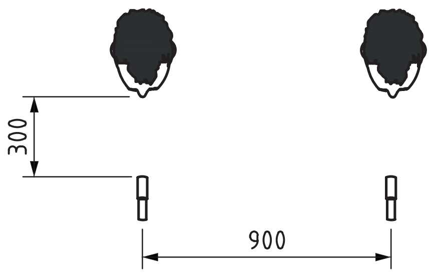


Figure 15 **A reduced 3 to 1 ratio using angled microphones**

Dimensions are in millimetres

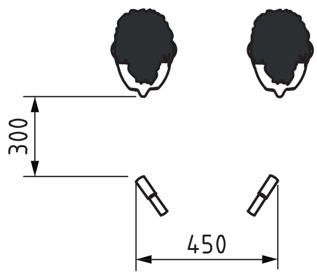


Figure 16 **Illustrations of good and bad microphone placements**

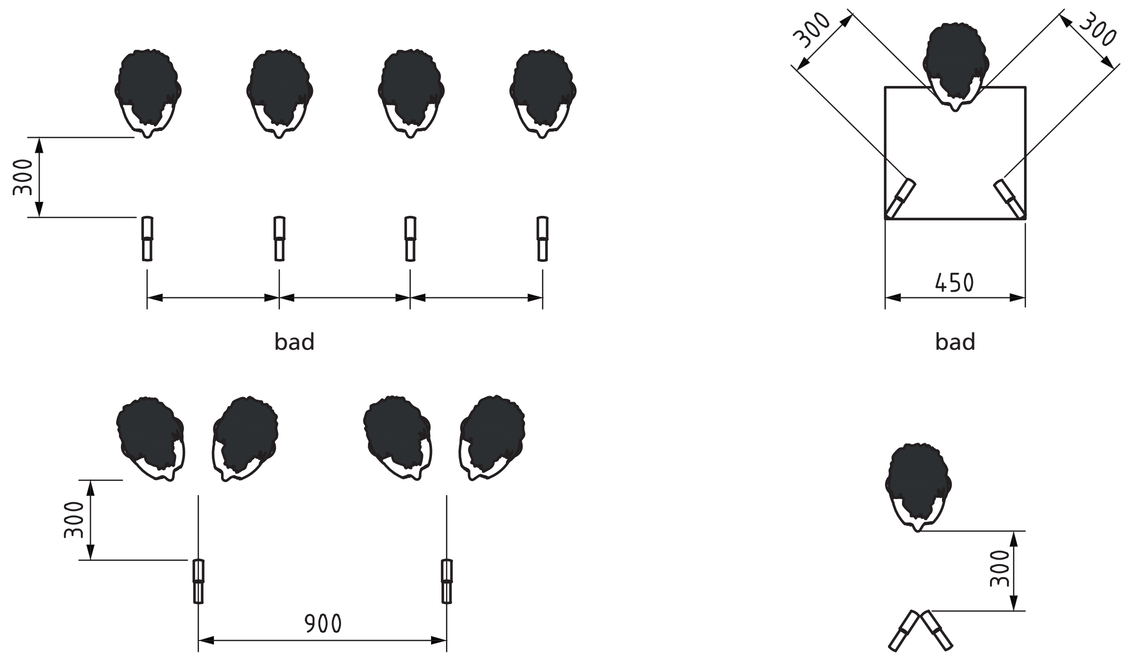
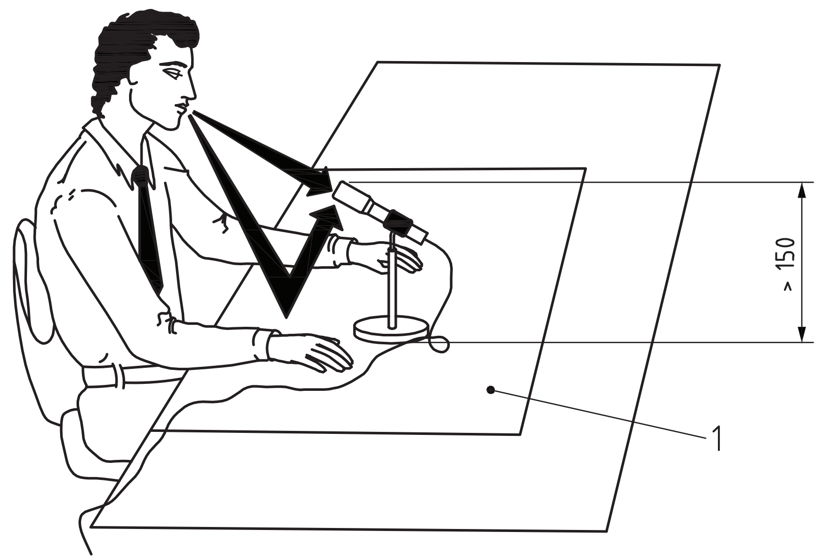


Figure 17 **Optimization of the height of the microphone above the table**



Key

1 Layer of soft material

12 Objective measurement of intelligibility

NOTE 1 Several methods currently exist of objectively measuring speech intelligibility, one of which is the speech transmission index (STI) (see BS EN 60268-16).

The STI method may be used to measure the potential intelligibility of an AFILS, by using a calibrated telecoil receiver instead of a measuring microphone. For hard-of-hearing users, an STI value of at least 0.65 is normally the minimum acceptable level.

NOTE 2 The STI technique is particularly useful as it takes into account both reverberation and noise. The technique presupposes that the AFILS meets the frequency response criterion of a maximum variation of ±3 dB over the range 100 Hz to 5 kHz

13 Safety and reliability considerations

13.1 Electronic equipment

Electronic equipment used in AFILS should conform to BS EN 60065.

Supplies of user-replaceable spare parts should be readily available and easily accessible.

13.2 Wiring

The installation of mains wiring and protective devices used in AFILS should conform to BS 7671.

The loop conductor(s), microphone and other signal cables should be regarded as Category 2 circuits as defined in BS 7671 and should be segregated from mains and other cables in Category 1 circuits.

The loop conductor(s) should have adequate cross-sectional area to carry the maximum continuous r.m.s. loop current that the amplifier can deliver for more than 10 s.

NOTE Current ratings of cables can be found in the following:

a) Table C.2;

b) BS 6004, BS EN 60228:2005, BS 6500, DEF STAN 61-12-6, and other relevant British Standards;

c) the manufacturer's data.

In the absence of information, tests to determine the current rating should be carried out.

A transportable AFILS, which might have to be handled frequently, may use a cable which is particularly flexible and resistant to conductor damage due to bending.

13.3 Connection to television receivers

Many television receivers have the circuits in electrical contact with the mains supply; unless the receiver has external connections for loudspeakers, headphones or line-level audio output (such as on a SCART connector; see BS EN 50049-1), it is essential that no attempt is made to connect an AFILS to it electrically without first consulting the manufacturer, as the safety of the receiver might be compromised and a fatal accident could result. AFILS kits which use a microphone, or other non-contact means of obtaining the audio signal may be used, in accordance with the manufacturer's instructions, without safety hazard.

Section 4: Installing an AFILS

14 Responsibility of the installer

*COMMENTARY ON CLAUSE **14***
This section provides recommendations for the work associated with installation of the AFILS equipment in a building. This work might be undertaken by the same organization that designed the system or by a different organization. For example, the designer and installer might be a single, specialist AFILS contractor. Alternatively, the purchaser might be responsible for the design of the AFILS (which might be undertaken by consultants acting on behalf of the purchaser), and the design might then be communicated, by means of a specification and/or drawings, to a specialist AFILS contractor or to an electrical installation contractor, which would, in either case, then be responsible for installation.

*Various contractual arrangements are possible but it is important that one organization is responsible for compliance with this section of the standard and that this responsibility is agreed prior to the start of the installation contract (see Clause **8**).*

It is not, in general, the responsibility of the installer to check or verify whether the design of the system complies in full with the recommendations of this standard, unless the installer is also the designer. The responsibility of the installer is to install the system in accordance with the requirements of the design specification and to follow good practice in the installation work. However, in practice, compliance with a number of recommendations of Section 3 impacts on both design and installation, and may, therefore, be delegated by the designer to the installer, provided the responsibility for compliance is clear in any specification or contract, that the installer is competent to address the issues and that the responsibility is accepted by the installer. For example, the designer may delegate decisions regarding cable routes to the installer, by simple reference in the design to comply with this clause.

*At the design stage, the designer might have inadequate information to enable compliance with all recommendations of Section **3**. For example, drawings on which the design is based might not show sufficient information about structural features or final fittings of the building to enable the design to conform to BS EN 60118-4:2006 in respect of field strength and bandwidth. Accordingly, it is often necessary for compliance with certain clauses of Section **3**, or verification of compliance, to rest with an installer.*

Even though identification of design shortcomings is not generally the responsibility of an installer, good practice dictates that, if the installer is aware of such shortcomings, particularly those arising from features of the building that might not have been known to the designer, they ought to be drawn to the attention of the designer, user or purchaser.

AFILS may be used for multipurpose venues and controls may be provided for reassigning or reconfiguring the equipment. Care is needed to ensure that access to these controls does not unnecessarily include access to critical controls such as loop drive.

The responsibilities associated with the installation of the system should be clearly defined, agreed and documented prior to the commencement of work.

The installer should comply with the recommendations of Clause **15**.

The installer should ensure that:

a) adequate space is provided around the equipment for access;

b) the structure can accept the weight of the equipment;

c) adequate cooling/ventilation is provided to keep the equipment within its rated temperature range.

All cables should be clearly identified, at least at each end and at all the joints *en route*. The locations of cables and joints should be accurately recorded for future reference.

The installation of microphones should be in accordance with the recommendations of Clause **11**.

To facilitate safe maintenance work, the installer should ensure that all AFILS equipment that is likely to need routine attention is sited in accessible locations.

All metallic parts of the installation including conduit, trunking, ducting, cabling and enclosures, should be separated from any metalwork forming part of a lightning protection system.

NOTE 1 Further guidance is given in BS 6651:1999, in particular in Clause ***19*** *and* ***A.2*** *of that standard.*

The installer should provide as-fitted drawings which include, at least:

1) the positions of all AFILS equipment;

2) the positions of all loop cables including the type, sizes and actual routes of cables;

3) the position(s) of microphone(s);

4) the positions of all equipment that might require routine attention or adjustment.

NOTE 2 The cable routes shown need to comprise a reasonable representation of the route followed to enable a competent person to locate the cable in the event of a fault or need for modification or extension of the system; a simple schematic showing the sequence in which devices are wired is unlikely to satisfy this recommendation, other than in small, simple systems.

In the case of extensions or alterations, existing as-fitted drawings should be updated.

On completion of the installation work, the installer should issue a certificate in accordance with the model given in Annex D, signed by a competent person.

NOTE 3 Under BS 7671, the installer of the mains supply is required to issue an electrical installation certificate in accordance with the requirements of that standard.

A designer may accept responsibility for variations from any of the above recommendations and communicate this in the form of specific written requirements (e.g. within a specification). In this case, the installer should record the relevant variations within the installation certificate issued by the installer.

15 Installation practices and workmanship

*COMMENTARY ON CLAUSE **15***
The nature and quality of the installation work needs to be such as to maintain the integrity of the AFILS and minimize the duration and extent of disablement of the system during maintenance or modifications.
Penetration of construction (e.g. for the passage of cables, conduit, trunking or tray) has to be made good to prevent the free passage of fire or smoke, regardless of whether the construction has a recognized degree of fire resistance.

Installation practices and workmanship should, where applicable, conform to the requirements of BS 7671.

Cables that are directly fixed to surfaces should be neatly run and securely fixed at suitable intervals, in accordance with the recommendations of the cable manufacturer. Cables should not rely solely on suspended ceilings for their support.

The installer should ensure that all wiring and cable types conform to the design documentation.

Cables should be installed without external joints wherever practicable. All terminations and other connectors should be such as to minimize the probability of early failure. Other than in the case of joints at or within system components such as amplifiers and microphones, terminals and connectors used to joint cables should be constructed of materials that will withstand a similar environment and be of similar durability to that of the cable. All joints, other than those within system components, should be enclosed within junction boxes, labelled with the word "AFILS" to avoid confusion with other services.

Copper foil tape is often used under carpets and vinyl flooring; this may be identified using printed tape identifying it as an AFILS loop cable.

Arrangements for earthing should be in accordance with the recommendations of the manufacturer.

NOTE The loop cable should NOT be earthed unless the amplifier manufacturer explicitly states that is should, or can, be earthed. Otherwise, serious damage to the amplifier is very likely to result.

Care should be taken to ensure the electrical continuity of electromagnetic screens, including metallic sheaths of microphone cables.

Where new conduit, trunking or tray is installed, its capacity should be in accordance with the recommendations given in BS 7671.

Where a cable passes through an external wall, it should be contained in a smooth-bore sleeve of metal or other non-hygroscopic material sealed into the wall. This sleeve should slope downwards towards the outside and should be plugged with a suitable non-hardening waterproof compound to prevent the entry of rain, dust and vermin.

Where a cable passes through an internal wall, a small clearance hole should be provided. If additional mechanical protection is necessary, a smooth-bore sleeve should be sealed into the wall.

Care should be taken to ensure that the ends of any sleeves are free from sharp edges which might damage cables during installation.

When a cable, other than a floor-level loop cable, passes through a floor, the recommendations above should be applied. The sleeve should extend as far above floor level as is required to provide adequate protection of the cable, but never less than 300 mm.

Where cables, conduits, trunking or trays pass through floors, walls, partitions or ceilings, the surrounding hole should be as small as reasonably practicable and made good with fire stopping materials that ensure that the fire resistance of the construction is not materially reduced. Spaces through which fire or smoke could spread should not be left around the cable, conduit, trunking or tray.

If cables or conduits are installed in channels, ducts, trunking or shafts that pass through floors, walls, partitions or ceilings, barriers with the appropriate level of fire resistance should be provided within the channels, etc., to prevent the spread of fire unless, in the case of ducts and shafts, the construction of the duct or shaft affords equivalent fire resistance to the structure penetrated; in the latter case fire stopping need only be provided where cables pass into, or out of, the duct or shaft.

16 Inspection and testing of wiring

*COMMENTARY ON CLAUSE **16***
On completion of wiring, or sections of wiring, the installer needs to carry out tests to ensure the integrity of cable insulation and adequacy of earthing. Usually, the tests on cables are carried out with equipment disconnected and prior to completion of the entire system. Further tests need, therefore, to be carried out on completion of the system and these tests form part of the commissioning process.

All installed cables with a manufacturer’s voltage rating suitable for mains use should be subject to insulation testing at 500 V d.c. Prior to this test, cables should be disconnected from all equipment that could be damaged by the test.

Insulation resistance, measured in the above test, between conductors, between each conductor and earth, and between each conductor and any screen, should be, at least 2 MΩ.

Continuity of all circuits should be tested.

Earth continuity and, for mains supply circuits, earth fault loop impedance, should be tested to ensure compliance with BS 7671.

The following should be tested on completion of the installation work, after connection of all loops, unless there is specific agreement that they will form part of the commissioning process:

a) if possible, the 1 kHz impedance of each loop circuit in type A3, and type A4 systems; if not possible, the DC resistance of each loop circuit should be measured and recorded;

b) correct polarity of circuits where this is required in type A4 systems;

c) any other tests specified by the manufacturer of the system.

The results of all tests should be recorded and made available to the organization responsible for commissioning the system.

17 Commissioning

*COMMENTARY ON CLAUSE **17***
*The process of commissioning involves thorough testing of the installed AFILS to ensure that it operates correctly in accordance with the recommendations of this standard and with the specification. At completion of commissioning, it also needs to be confirmed that all relevant documentation has been handed over to the user (see Clause **18**). The organization responsible for commissioning the system might, or might not, be the same organization that designed and/or installed the system, but the responsibility for commissioning needs to be clearly defined prior to the start of the installation work.*

*It is not, in general, the responsibility of the commissioning engineer to verify compliance of the design, or of the installation work, with Section **3** and Section **4** of this standard.The responsibility of the commissioning engineer is to verify that the system operates correctly in the manner designed and that the installation workmanship is generally of an adequate standard. However, in practice, it might be difficult to ensure that the system complies in full with all recommendations of Section **3** until the time of commissioning. For example, commissioning might represent the first (and only) opportunity to ensure that structural features of the building, of which the designer might have been unaware, do not compromise the effectiveness of the system as it was originally designed.*

The system (if not of type A1) should be commissioned by a competent person, who has access to the requirements of the designer (i.e. the system specification) and any other relevant documentation or drawings.

NOTE 1 The performance of systems of type A1 is fixed by design and commissioning is not appropriate.

Any person responsible for commissioning an AFILS in accordance with the recommendations of this standard should possess a thorough knowledge and understanding of Section **3**, Section **4** and Section **5** of this standard.

At commissioning, the entire system should be inspected and tested to ensure that it operates satisfactorily and that, in particular:

a) magnetic field strengths and signal-to-noise ratios conform to the requirements of BS EN 60118-4:2006. Testing of type A2 systems should be performed at the points specified in Figure 18, at heights above the floor of 1.2 m and 1.7 m. In accordance with BS EN 60118-4:2006, Annex A, the measured field strength levels should be within ±4.5 dB when 400 mA/m is achieved at one point at least. At a height of 1.45 m, the field strength level may be greater than +4.5 dB L but should not exceed +8 dB L, as this may overload some hearing aids;

b) an acceptable level of intelligibility is achieved throughout the useful magnetic field volume;

c) no changes to the building since the time of the agreed design have compromised the conformity of the system to this standard (e.g. by erection of new partitioning or metal structures that affect the effectiveness of the AFILS);

d) mains power supplies are inspected as far as reasonably practicable to ensure compliance with the recommendations of Clause **15**;

e) all relevant documentation (see Clause **18**) has been provided to the user or purchaser.

On completion of commissioning, a certificate signed by a competent person in accordance with the model given in Annex D has been issued.

All results obtained during the commissioning process should be clearly recorded.

The reference point or line, and the centre line, establish the geometry of field strength drawings. Because of the diversity of mounting arrangements for the source of magnetic field and the range of physical dimensions, it is not possible to relate the measuring points to its position. The area where people are expected to stand should be determined first and the position of the reference point or line determined from it.

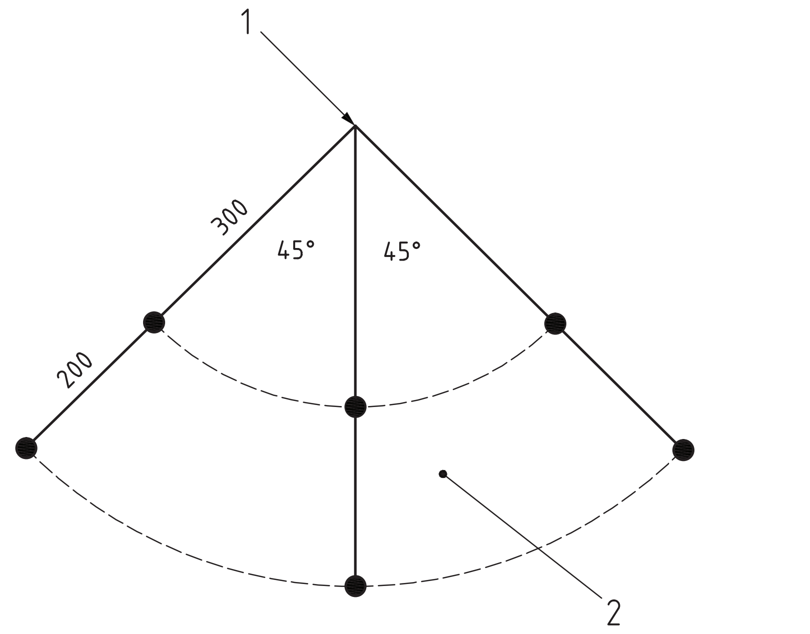
Figure 18a) is should be used for magnetic field sources of small dimensions; Figure 18b) is more suitable where a larger vertical loop is used.

It is recommended to indicate on the floor the area where people are expected to stand.

NOTE 2 The source of the magnetic field is not is necessarily positioned where the "reference point" or "reference line" is defined: these are just used as references to determine where the user is likely to be positioned, and hence where the field strength needs to be controlled. The source itself is typically further away from the user than the reference point or line is, in order to achieve an acceptably low gradient of field strength levels, but the actual distance is likely to be limited by the physical characteristics of the installation.

Figure 18 **Measuring field strength of type 2 AFILS – Plan views**

Distances in millimetres

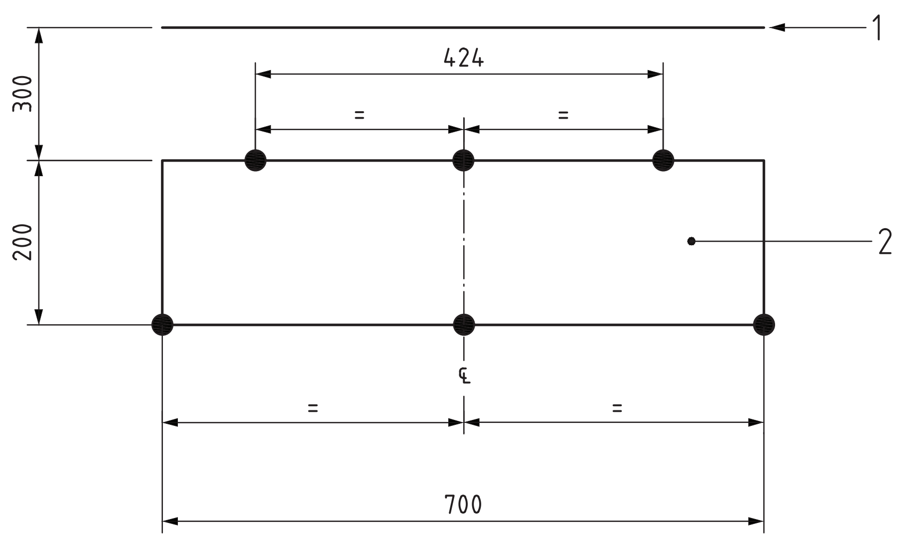


a) Magnetic field sources of small dimensions

Key

1 Reference point

2 Area where people are expected to stand



b) Larger vertical magnetic field sources

Key

1 Reference line

2 Area where people are expected to stand

18 Documentation

*COMMENTARY ON CLAUSE **18***
On completion of the system, adequate records and other documentation have to be provided to the user or purchaser. (The user and purchaser might, or might not, be the same organization.) The responsibility for provision of the documentation may rest with more than one organization and needs to be defined before an order for the system is placed. On completion of commissioning, it needs to be ensured that, either the documentation has been provided to the relevant parties, or that any absent documentation is identified for appropriate action (see commissioning above).

Particular importance needs to be attached to the preparation and accuracy of "as fitted" drawings and operation and maintenance manuals. The manuals need to be adequately specific to the system. Without these drawings and manuals, maintenance or future modification of the system might be difficult.

The following documentation should be provided to the purchaser or user of the system:

NOTE 1 The contract for design, supply, installation and commissioning of the system needs to define the type of documentation which is to be provided by each organization involved.

a) certificates for design, installation and commissioning of the system (Clause **20**);

b) an adequate operation and maintenance manual for the system; this should provide information, specific to the system in question, regarding the following:

   1) a list of equipment provided and its configuration (e.g. schematic diagram)

   2) use and operation of the system;

   3) service and maintenance of the system in accordance with Section **7**;

   4) the importance of ensuring that changes to the building, such as relocation of partitions, and new metal structures do not affect the standard of coverage in the space;

c) "as fitted" drawings indicating at least the following:

   1) the positions of all AFILS equipment;

   2) the positions of all microphones;

   3) the type, sizes and actual routes of cables;

   NOTE 2 The cable routes shown need to comprise a reasonable representation of the route followed, such as to enable a competent person to locate the cable in the event of a fault or need for modification or extension of the system; a simple schematic showing the sequence in which loops are wired is unlikely to satisfy this recommendation, other than in small, simple systems.

   NOTE 3 In some complex buildings a cabling schedule cross-referencing the drawings may be necessary in order to help explain the cable routes.

   NOTE 4 In the case of extensions or alterations, existing "as fitted" drawings have to be updated.

d) a log book for recording the information as recommended herein;

e) a record of any agreed variations from the original design specification;

f) records as are required by Clause **20** and Clause **22**.

19 Certification

*COMMENTARY ON CLAUSE **19***

On completion of design, installation and commissioning, a separate certificate needs to be issued for each of these three processes, confirming compliance with the recommendations of this standard for the stage in question (i.e. design, installation or commissioning) or identifying variations. These three processes might be undertaken by one organization, or might be carried out by independent organizations, whichever arrangement applies, three separate certificates ultimately need to be issued. It needs to be possible for an organization to issue a certificate for the process for which they are responsible, regardless of whether a certificate has been issued for either of the other processes.

It is essential that the person(s) who sign(s) these certificates is competent to verify whether the recommendations of this standard in respect of the process to which the certificate refers have, or have not, been satisfied. The purchaser or user might, subsequently, rely on the certificate as, for example, evidence of compliance with legislation. Liability could arise on the part of any organization that issues a certificate without due care in ensuring its validity.

The purchaser ought to be asked to complete an acceptance certificate provided by the organization bearing contractual responsibility for the system upon completion. The purpose of this certificate is to provide a record that the purchaser is satisfied that the requirements of the specification have been met. The certificate also needs to confirm that adequate documentation has been handed over to the user, that the user has been instructed in the use of the system and understands their obligations in respect of the maintenance of the system. The purchaser might wish to carry out an independent inspection of the system, or to witness certain tests (which may include any or all commissioning tests) as a pre-requisite for completion of the acceptance certificate).

For certain (usually large and/or complex systems), the purchaser or user might wish to arrange for independent verification of compliance with the recommendations of this standard. If so, a verification certificate needs to be issued by the verifier.

On, or as soon as practicable after, completion of each of the following processes, a certificate should be issued by the organization responsible for the process, certifying compliance with BS EN 60118-4:2006 and the recommendations of this standard in respect of the process or, if variations exist, clearly identifying these variations:

a) design;

b) installation;

c) commissioning;

d) acceptance.

If a purchaser or user commissions an independent audit of the system to verify, as far as practicable, that the recommendations of this standard have been met (see Clause **22**), the purchaser should request that the organization responsible for the audit issues a verification certificate.

Where modifications are carried out to a system, the purchaser should require that the organization responsible for the work issues a new commissioning certificate.

NOTE 1 If a system is modified or a new system is installed, it might also be necessary to check for overspill effects to and from any other AFILS in proximity.

NOTE 2 Model certificates of design, installation, commissioning, acceptance and verification are contained in Annex D.

The certificate issued for any of these processes may vary in format from that shown in Annex D but, as a minimum, the information and statements of conformity within the model certificates should be provided.

20 Acceptance

*COMMENTARY ON CLAUSE **20***
On completion of the system, arrangements need to be made for formal handover of the system to the purchaser or user, and formal acceptance of the system by the purchaser (or representative of the purchaser).

Before accepting the handover of the system, the purchaser or a representative needs to ensure that they are satisfied with the installed system, and that the user has an adequate understanding of the operation of the system. In the case of small, simple systems, or systems installed in the premises of small organizations with little relevant in-house expertise, acceptance might involve little more than a brief inspection of the system by the user, demonstration of its operation by the commissioning engineer, and handover of the relevant documents to the user. In large, complex systems, it is likely that the purchaser would wish to witness relevant tests, as part of a formal and structured acceptance procedure.

*As evidence of acceptance, an acceptance certificate needs to be signed by the purchaser (see Clause **20**).*

Acceptance procedures should be carried out in accordance with the agreed purchase specification (see Section **2**), including any tests that are to be witnessed and details of the witnessing procedure.

Before accepting a system, the purchaser (or appropriate representative of the purchaser) should ensure, at least, that:

a) all installation work appears to be satisfactory;

b) the system is capable of meeting the field strength, frequency response and signal-to-noise ratio requirements of BS EN 60118-4:2006;

c) the system is capable of giving intelligible broadcasts;

d) the following documents have been provided to the purchaser or user:

    1) "as fitted" drawings;

    2) operating and maintenance instructions;

    3) certificates of design, installation and commissioning;

    4) a log book to record the periodic testing of the system (see Clause **28**);

e) sufficient representatives of the user have been adequately trained in the operation of the system, including, at least, all means of broadcasting emergency signals and the correct use of emergency microphones (if installed);

f) the nominated responsible person (as defined in the Equality Act [3])has been advised of their responsibilities and how these might be discharged;

g) all relevant tests, defined in the purchase specification, have been witnessed;

h) as evidence of acceptance, the purchaser (or appropriate representative of the purchaser) should sign an acceptance certificate (see Clause **19**).

21 Verification

*COMMENTARY ON CLAUSE **21***
The purchaser or user might decide that there is a need for verification of compliance of the installed system with this standard as a result of one or more of the following:

a) the division of work elements between different organizations;

b) the evolution of the building design during construction;

c) the lack of detailed information at the time of design.

The verifying organization might be one of those involved in the design, supply, installation or commissioning processes (e.g. the system supplier or the designer) or an independent third party.

In the event that the verification process identifies areas of non-compliance, the purchaser or user might require a further verification of the affected areas after correction.

Where a purchaser or user considers that it would be beneficial, for example if there is significant potential for the installed system to deviate from the recommendations of this standard, verification of compliance with this standard should be arranged.

Any person responsible for verification should be competent in the design of AFILS in accordance with this standard and familiar with the relevant installation practices.

The scope and extent of the verification process should be agreed between the purchaser or user and the organization responsible for verification.

On completion, a verification certificate should be issued (a model certificate is given in Annex D). The verification certificate should also contain information on the scope and extent of the verification carried out or identify where this information is available.

Section 5: Operation and maintenance

22 General

The continued advertising of an AFILS which is inoperative might constitute misrepresentation, so any failure which cannot be rectified promptly should be notified to the management without delay and to potential users by a notice adjacent to the AFILS sign(s) (see Figure 3).

NOTE Notification that an AFILS is in operation may be given by an illuminated AFILS sign.

23 Routine testing

*COMMENTARY ON CLAUSE **23***
Experience normally shows that the electronic equipment is significantly more reliable than the system mechanical components, for example loop wires, microphones, connectors, connecting leads and switches and, although some modern AFILS incorporate a high degree of automatic operation, it is still necessary for the responsible person to ensure that the system operates correctly and any faults are acted upon.

It is therefore important that regular tests are carried out to ensure that there has not been any major failure of the AFILS.

In large or complex systems, it may be impractical to carry out all the required tests on one occasion and it may be necessary for tests to be carried out to a defined programme over a fixed period.

On a weekly basis, the responsible person should ensure the satisfactory operation of the AFILS by use of a test signal and either a fixed loop monitor receiver (see Annex A) or a portable field strength meter. It is essential to supplement this with a listening test using real speech into the microphone(s) to ensure that the microphone(s) are working correctly and amplifier control settings have not been inappropriately changed.

These routine tests and any user complaints should be recorded in the system log book.

24 Inspection and servicing

*COMMENTARY ON CLAUSE **24***
It is essential that the system is subject to periodic inspection and servicing so that faults are identified, preventive measures can be taken to ensure the continued reliability of the system, and that the user is made aware of any changes to the building that affect the performance afforded by the system.

Periodic inspection and servicing needs to be carried out by a competent person with specialist knowledge of AFILS, adequate access to spares and sufficient information regarding the system. The procedure below applies to fixed systems but should be applied as far as possible to portable and mobile systems; inspection and test of these may need to be more frequent if much remedial action is required after a year.

During periodic visits, at intervals not exceeding 12 months, the following inspection and test of the system should be carried out:

a) the system log book should be examined. It should be ensured that any faults recorded have received appropriate attention;

b) a visual inspection should be made to check whether structural or occupancy changes have affected the compliance of the system with the recommendations of this standard for field coverage and overspill. Particular care should be taken to verify whether:
   1) any new or relocated partitions have been erected affecting the volume to be covered;
   2) any changes to the use or occupancy of an area makes the existing AFILS design unsuitable, for example increase in magnetic or acoustic ambient noise;
   3) any building alterations or extensions require the installation of additional AFILS equipment;
c) any structural or occupancy changes that have been found as a result of the inspection carried out in Clause **16** should be reported to the responsible person so that appropriate design and implementation of corrective works can be commissioned;
d) all controls and visual indicators at control and indicating equipment should be checked for correct operation;
e) all further checks and tests recommended by the manufacturer of the AFILS equipment and other components of the system should be carried out;
f) the following physical checks should be made:
   1) ensure that the amplifier ventilation holes are clear and no unauthorized articles are stacked on it;
   2) check mains leads, microphone leads and loop wiring (where accessible) for fraying, damage, or incorrect location which could affect safety;
   3) for temporary or modified systems, clean any connectors that appear to be tarnished, before they are inserted;
   4) clean dust and grime from the system equipment;
   5) check and remake as necessary all leads that are heavily used (or abused) to improve reliability; it should be noted that leads with moulded plugs can fail with little or no warning, as their internal condition cannot be accurately assessed;
g) the field strength should be checked to see that it meets the design minimum within the working area;
h) the frequency response of the AFILS should be checked to see that it meets the minimum design requirement;
i) the signal-to-noise ratio when all the electrical equipment normally used in the environment should be checked to ensure that it is functioning;
j) the organization commissioned for the corrective works should be competent in AFILS design as recommended in Section **2**; following modification, the system should be re-commissioned to the extent needed, all documentation should be brought up to date to reflect the new status and a modification certificate should be issued.

Following the work carried out above, any outstanding defects should be reported to the responsible person and the system log book should be completed.

On successful completion of any remedial works, an inspection and servicing certificate should be issued (see Annex D).

25 Non-routine attention

COMMENTARY ON CLAUSE ***25***
The arrangements in Clause ***25*** *are intended to maintain the system in operation under normal circumstances. However, from time to time, the AFILS is likely to require non-routine attention, including special maintenance. Non-routine maintenance includes:*

- *a special inspection of an existing AFILS when a new organization takes over maintenance of the system;*
- *repair of faults or damage;*
- *modification to take account of extensions, alterations or changes in occupancy;*
- *inspection and test of the system following a user complaint.*

25.1 Special inspection on appointment of a new maintenance organization

The following should be undertaken on appointment of a new maintenance organization.

a) For an existing system, a special inspection should be carried out and records should be studied in order to produce a plan for effective maintenance of the system.

b) Areas of non-compliance with this standard should be documented and identified to the responsible person and, although the degree of a non-compliance is subjective, the following non-compliances should be regarded as requiring resolution:

  1) areas of non coverage;

  2) areas of unacceptable field strength;

  3) areas where overspill is an issue for security or intelligibility;

  4) where inappropriate solutions are used, e.g. a portable unit permanently placed on a counter, when a counter loop should be installed;

  5) standards of electrical safety such that the recommendations of Section **4** are not satisfied.

c) If no log book suitable for enabling compliance with the recommendations exists, a suitable log book should be provided by the maintenance organization.

25.2 Arrangements for repair of faults or damage

The following should be undertaken if a fault or damage to the system is detected.

a) Where maintenance is carried out by a third party, there should be an agreement for call out to deal with any fault or damage that occurs to the system, and this agreement should be such that a technician of the maintenance organization can normally attend the premises in an acceptable period after a call from the user.

b) The name and telephone number of any third party responsible for maintenance of the system should be prominently displayed, and the records and documentation as identified in Clause **18** should be kept updated;

c) The user should record all faults or damage in the system log book, and should arrange for repair to be carried out as soon as possible.

25.3 Modifications to the system

*COMMENTARY ON **25.3***
Modifications to the system can arise for a number of reasons. Examples include extension of the system to cover areas of the building previously uncovered or newly constructed.

Since modification of a system effectively involves an element of re-design, responsibility for modification of a system needs to rest with a person who has relevant design competence.

The following recommendations are applicable to all modification work.

a) Responsibility for modification of an AFILS should rest, ultimately, with a person who is competent in the principles of AFILS design, is conversant with this standard and conversant with the installed system, including access to the "as fitted" drawings;

   NOTE This person may, for example, be the original designer, or may be a competent representative of the user or maintenance organization.

b) On completion of the modifications, all "as fitted" drawings and other relevant system records should be updated as appropriate;

c) On commissioning of the work and completion of the tests, a modification certificate should be issued, confirming that the work has been carried out in accordance with the recommendations of this standard, or identifying any variations (see Annex D for a model modification certificate).

d) Where responsibility for the compliance, or otherwise, of the modified system with the recommendations of Section **2** of this standard rests with any person other than the organization carrying out the modification, that person should sign the appropriate section of the modification certificate and ensure it is made available with the system documentation (see Clause **18**).

Section 6: User responsibilities

26 Responsible person

A single, named responsible person should be appointed to supervise all matters pertaining to the AFILS. The responsible person should be given sufficient authority to carry out the duties described in this section and should normally be the keeper of the documentation as described in Clause **18**.

The responsible person should ensure that the AFILS is checked at least once a week, or before each use if the AFILS is used less frequently than once a week, to confirm that there are no faults on the system.

The responsible person should ensure that arrangements are in place for testing and maintenance of the system in accordance with the recommendations of Section **5** of this standard.

The responsible person should ensure that the system logbook (see Clause **27**) is kept up to date and is available for inspection by any authorized person.

The responsible person should ensure that authorized operators of the AFILS are instructed in the proper use of the system. Particular care should be taken to ensure that operators are able to interpret fault indications and that they are adequately familiar with the appropriate controls and the circumstances in which they should, and should not, be used.

The responsible person should ensure that the persons responsible for routine testing are trained in the use of the portable field strength meter or fixed loop monitor, whichever is applicable.

The responsible person should establish a liaison between those responsible for changes in, or maintenance of, the building fabric (including redecoration) to ensure that the work does not unnecessarily compromise the performance of the system or create system faults. If structural or occupancy changes occur or are planned, the responsible person should ensure that any necessary changes to the AFILS are considered at an early stage.

When changes are made to the system, the responsible person should ensure that operating instructions and "as fitted" drawings, supplied in accordance with the recommendations of Clause **19** respectively, are updated.

The responsible person should ensure that the spare parts agreed between the user and the organization responsible for the maintenance of the system are held within the premises.

27 Logbook

The following information should be recorded in the logbook:

a) the name of the responsible person;

b) details of the maintenance organization;

c) brief details of maintenance arrangements;

d) dates, times and types of all tests;

e) dates, times and types of all faults and defects; and

f) dates and types of all maintenance (e.g. maintenance visit or non-routine attention).

It is important to ensure that the log book is updated to reflect any changes of responsible person, maintenance organization, or maintenance arrangements.

Section 7: System components

28 AFILS amplifiers

*COMMENTARY ON CLAUSE **28***
AFILS amplifiers normally have several special features that are not generally provided on amplifiers intended for driving loudspeakers:

- *input signal detection and indication;*
- *associated gain control ("input level");*
- *output current detection and indication;*
- *associated gain control ("drive");*
- *limited bandwidth, 100 Hz to 5 kHz;*
- *automatic gain control (AGC).*

The two gain controls have different functions; the input level control sets the signal level at the input of the AGC stage in the amplifier, while the drive control sets the output current that is produced when the input signal is large enough to bring the AGC fully into effect. Normally, these controls are set at the commissioning stage and are not accessible to ordinary users of the system.

Most hearing aids have no useful response below 100 Hz and above 5 kHz, and AFILS signals outside this frequency range may result in unwanted effects.

The limitation to 5 kHz is largely because hearing-aid users with sensorineural loss also have no useful response above 5 kHz.

28.1 Features

AFILS amplifiers should be provided with:

- input signal detection and indication;
- output current detection and indication;
- automatic gain control (AGC);
- gain controls acting before and after the AGC stage.

The gain controls should normally be set at the commissioning stage and should be accessible only to technical persons.

28.2 Frequency response

*COMMENTARY ON **28.2***
The loop has both inductance and resistance and there are two different techniques for supplying the loop current. If the impedance is predominantly resistive even at 5 kHz, the required system frequency response can be achieved with an amplifier having the very low output source impedance normally associated with amplifiers for driving loudspeakers. This technique is called "voltage drive". If the loop impedance is predominantly inductive at 5 kHz, a voltage-drive amplifier does not give an adequate frequency response unless a high-frequency response boost is applied. This, however, demands an increased output voltage capability and can lead to a requirement for a large heat sink, because the power dissipation in the output devices with an inductive load is much higher than with a resistive load.

These disadvantages can be overcome by designing the amplifier to have a higher, controlled output source impedance (usually achieved by a mixture of current and voltage negative feedback). There are two variants of this technique, known as "current drive": there may or may not be a bandwidth control low-pass filter in the low-level stages of the amplifier. The combination of output source impedance and loop impedance also provides a low-pass filter action, which may or may not have an effect within the operating pass-band of 100 Hz to 5 kHz.

The required output source impedance of a current-drive amplifier is related to the largest loop inductance that it is intended to drive. If there is no bandwidth limitation within the amplifier, the optimum source resistance is equal to the inductive reactance of the loop at 5 kHz (since the resistive component of the loop impedance is normally negligible in comparison with the inductive reactance at 5 kHz). Amplifiers intended to drive arrays, which generally have a higher inductance than a single-turn loop of the same overall area, need a correspondingly higher output source impedance.

28.2.1 General

The choice of techniques for a given application should be guided by the information in Table 1 and Table 2.

Table 2 **Application of loop-drive techniques to systems with loops of different dimensions**

Type of system	Current drive	Voltage drive
Neck loop	Single-turn loop, with an operating current in the region of 0.5 A (corresponding to a magnetic field strength of 400 mA/m at the hearing aid)	Multi-turn loop with series resistor (4 Ω to 32 Ω), suitable for operation from the headphone output of many audio products
Portable self-contained system	Multi-turn loop with an operating current of several amps.	Not practicable
Counter ("ticket-office") system	Multi-turn loop with an operating current of several amps.	Not practicable
Home area-coverage system (such as 3 m × 5 m)	Single-turn loop	Single-turn loop of thin wire, giving 2 Ω to 4 Ω resistance
Larger area-coverage system	Single-turn loop	Practicable only as a custom design using a Poperwell equalizer (see Annex C)
Array system (for counteracting metal loss and/or overspill)	Multiple loops	Not practicable

28.2.2 High-frequency response

Whichever technique is used, the output current frequency response target, without any compensation for metal loss should be –3 dB at 5 kHz referred to the current at 1 kHz, in accordance with BS EN 60118-4:2006, and the attenuation slope should be asymptotic to at least 6 dB/octave and preferably more.

The method of measurement is given in BS EN 62489-1.

28.2.3 Low-frequency response

The output current frequency response target should be −3 dB at 100 Hz referred to the current at 1 kHz, in accordance with BS EN 60118-4:2006, and the attenuation slope should be asymptotic to at least 6 dB/octave and preferably more.

The method of measurement is given in BS EN 62489-1.

28.2.4 Overall frequency response

The overall frequency response of the amplifier alone is subordinate to the requirement for the frequency response of the magnetic field strength specified in BS EN 60118-4:2006. See also BS EN 62489-1.

29 Loops

29.1 Small loops

Small loops may have one turn or several. They may range in size from a neck loop, which may, when arranged as a circle on a flat surface, have a diameter of about 150 mm, up to a counter loop which may be nearly 1 m^2.

29.2 Large loops

Loops having dimensions between about 1 m and 2 m should not normally be used, except in counter systems, because unless the listener is quite close to the loop, a large current is required in a single turn in order to obtain sufficient magnetic field strength, but the inductance of even a two-turn loop is higher than desirable from amplifier design considerations. The smallest practical "area-coverage" loop that should be used is approximately 3 m × 2 m.

29.3 Loop resistance

This obviously depends on the thickness of the conductor; it may be calculated from first principles:

$$R = \frac{\rho l}{a}$$

where

R is resistance;

ρ is the resistivity of conductor material (normally copper);

a is the area of cross-section of the conductor;

or determined from tables, but the values in tables are often "worst-case" values, taking production tolerances into account, and might relate to a temperature well above normal ambient temperature.

29.4 Loop inductance

A simple expression that may be used for the inductance L (in μH) of a single-turn large rectangular loop, using a wire conductor is:

$$L = 2l$$

where

the multiplier can range from 1.6 to 2.0;

l is the perimeter (in m).

A flat tape conductor may be assumed to give a somewhat lower inductance L:

$$L = 1.3l$$

where

the multiplier varies somewhat with the conductor and loop dimensions;

l is the perimeter (in m).

For a small rectangular loop, sides A and B, formed of wire with diameter d, a more complex formula should be used (see [1]):

$$L = \frac{\mu}{\pi}\left\{B\ln\left(\frac{2A}{d}\right) + A\ln\left(\frac{2B}{d}\right)\right\}$$

NOTE There are still more complex formulae in the literature, and the formulae for circular loops and other configurations are much more complex (see [1], [2]).

Annex A (normative) Induction-loop monitor receivers

A.1 General

A fixed monitor receiver should be sited so that non-technical staff and members of the public can easily verify whether the AFILS is working. In auditoriums, care should be taken that the audible and/or visible output is not distracting and the monitor output may also be relayed to the sound system control point. Portable monitor receivers should be used for checking the performance of the system in all parts of the coverage area, on a routine basis and after any changes have been made to the system or the building, or potential sources of interference have been introduced.

A.2 Recommendations for fixed receivers

Fixed receivers should conform to the following recommendations.

a) The receiver should provide an audio output to a loudspeaker. A lockable preset gain control, which cannot reduce the audio output to zero, should be provided. A "press-to-listen" switch may be provided, which should be labelled as such. An alternative output may be provided for headphones, at which the open-circuit output voltage should not exceed 5 V under any circumstances, and the output source impedance should be 120 Ω ±10%. If a headphone output is fitted, suitable headphones, of a type that attenuates external noise, should be supplied with the receiver. The loudspeaker should give an output sound pressure level (SPL) exceeding 80 dB at 300 mm with the gain control at maximum and a field strength at 1 kHz of –12 dB L. The loudspeaker amplifier should not overload under these conditions.

b) The receiver should provide an illuminated signal that it is in operation and another to show that it is receiving an adequate magnetic field strength.

c) If a signal output is provided for remote monitoring, the output should be balanced and should have a rated voltage of 0.775 V, corresponding to –8 dB L (i.e. 0.16 $A \cdot m^{-1}$) on the meter, and a source impedance of approximately 75 Ω.

d) An alarm output, if required, to indicate failure of reception, should be in the form of an isolated, normally closed, relay contact rated at 24 V d.c., 1 A. The threshold of detection for the alarm circuit should be chosen so that it reliably detects a real fault in spite of any magnetic interference that may be present, without false triggering, due, for example, to pauses in the original signal.

e) The direction of maximum response of the magnetic pick-up device should be marked on the equipment enclosure.

A.3 Recommendations for portable receivers

Portable receivers should conform to the following recommendations.

a) The recommendations of **A.2** for fixed receivers should be followed, except that there is no need for a provision for a loudspeaker, and an output for headphones is essential. If the open-circuit output voltage is limited to less than 5 V (for example if a 4.5 V battery is used), the output source resistance may be reduced in proportion from 120 Ω.

b) A battery condition check or "battery low" indication should be provided.

Annex B (informative) What is an audio-frequency induction-loop system (AFILS) and how does it work?

B.1 General

An AFILS is a method of improving communication with hearing-aid users using magnetic fields.

A basic AFILS comprises a cable in the form of a loop, often laid around the perimeter of the room, hall, church, theatre, etc. in which the AFILS facility is to be provided. Other types of AFILS include portable systems and systems for counters and help points. The loop cable is connected via an amplifier to one or more microphones or other source(s) of sound signals, such as a radio receiver or CD player. The amplifier produces an audio-frequency electric current in the loop cable, causing a magnetic field to be produced in the vicinity of the loop. This magnetic field is a reproduction of the signal feeding the amplifier, and can be picked up by suitable hearing aids and receivers.

This standard is principally concerned with AFILS for hearing enhancement, for which receivers are normally hearing aids equipped with a telecoil (the use of which is conventionally designated as "set to T"). The majority of hearing aids in use in the United Kingdom incorporate this feature. Hearing aids set to T pick up the magnetic field and produce sound in the ear of the wearer. For hearing aids without this feature, a special loop listener is required.

NOTE 1 In newer hearing aids, the T input may be assigned to a user-selectable program that can be selected by (typically) operating a small push-button on the hearing aid. It is important to note that it may be difficult to determine externally if such a hearing aid is fitted with a coil, and if it has been assigned to a program.

The expression MT is conventionally used to indicate a situation in which both magnetic and acoustic signals are being picked up simultaneously by the hearing aid or receiver. This combined setting may be preferred by the user in certain situations – for instance, in order to be able to hear alerting or emergency sounds or alarms.

The standard also discusses other situations where an AFILS may be used, such as information systems for museum tours.

NOTE 2 Sound consists of vibrations, usually in air. The number of vibrations per second is related to the pitch (high or low) of the sound, and is called the "frequency", which is measured in hertz (Hz). 1 Hz is equal to one vibration per second. Frequencies within the range from 20 Hz to 20 000 Hz (20 kHz) conventionally cover the range of human hearing. For the purposes of this standard, the extremes of this range are of lesser importance, and attention is concentrated on a restricted range, from 100 Hz (a little more than one octave below middle C) to 5 kHz (approximately four octaves above middle C).

B.2 Benefits of AFILS (for hearing enhancement)

Whilst hearing aid(s) worn by a person with impaired hearing can provide a useful improvement to the effectiveness of hearing local conversations, they are not so effective when listening to speech or music at a distance. This is because the microphone of the hearing aid picks up the wanted speech or music together with the general noise and reverberation of the room and the unwanted speech of other conversations.

General noise and unwanted conversations present less of a problem for people with normal hearing, as they are better able to focus on to the wanted sound. If a suitable microphone is placed near the source of wanted sound, and coupled by some means to a hearing aid or other suitable listening device, the problems of reverberation and unwanted noise are, to a large extent, overcome, and the listener hears the sound more clearly.

While the coupling between remote microphones and hearing aids (or other listening devices) may be achieved by means of wires, infra-red radiation or radio transmission, magnetic induction provides a simple means by which users of hearing aids with a T (telecoil) function can receive the transmissions without the need for additional equipment. The wearer can be located anywhere covered by the induction loop and can move around, stand up, or sit down as necessary. There is no inconvenience of a trailing wire and use can be made of the user's own hearing aid which is correctly matched to the hearing deficiency. An AFILS does not require special receivers to be issued to and collected from the users. This saves equipment and the associated administrative costs.

AFILS are appropriate for installation where information needs to be imparted, for example in theatres, conference rooms, cinemas, places of worship, meeting halls, shopping areas, and education establishments, and also for passenger handling buildings associated with rail, sea and air transport. Smaller scale installations in household premises and residential homes can increase enjoyment of radio, television programmes and personal computers. AFILS can also prove to be valuable for interview areas, ticket booths and service counters (ticket office systems). All of these facilities can enable people with impaired hearing to participate more fully in the relevant proceedings.

The majority of AFILS can be successfully designed and installed at reasonable cost. Advice on likely costs can be obtained from caring organizations or from appropriate trade associations. As a general rule, small systems in simple buildings can give good results with a simple approach to design and maintenance. Large installations and those in complicated buildings do, however, require considerable care and may prove to be relatively more costly.

B.3 Limitations of AFILS

When using a hearing aid set to T, and there can be long periods without any signal being sent to the system, hearing aid users might think that the system is not working. In these instances it may be desirable to give reassurance that the system is in operation by the use of a confidence signal.

The benefits given by AFILS are lost if the system is not properly managed and maintained to ensure that it is available when required and adjusted to suit the circumstances.

Failure of an AFILS may not be evident to the owners or managers of the installation unless monitoring is provided (see Annex A).

The operation of an AFILS can be affected by:

a) the effect of metal in the building structure and within the coverage area;

b) magnetic field overspill from adjacent AFILS;

c) magnetic noise interference.

The overall effects of these factors should be identified during the site assessment (see Clause **9**).

Annex C (informative) Explanations of the basis of the design equations given in Section 3

C.1 Magnetic field strength

C.1.1 Magnetic field strength produced by an element of conductor

By Ampère's rule (also attributed to Laplace, and to Biot and Savart), the magnetizing force δH at a point P, distance d from a conductor element δx in conductor XL carrying a current I is given by the following equation:

$$\delta H = I\left(\delta x\right)\cos\left(\frac{\varphi}{4\pi d^2}\right)$$

where

φ is the angle between the line joining the point to the element and the perpendicular from the point to the line containing the element [see Figure C.1a)].

If a is the length of the perpendicular PX, then:

$$\cos\varphi = \frac{a}{d}$$

and:

$$\delta\varphi = \left(\delta x\right)\cos\left(\frac{\varphi}{d}\right)$$

so that:

$$\left(\delta x\right)\cos\left(\frac{\varphi}{d^2}\right) = \frac{\delta\varphi}{d} = \frac{\left(\delta\varphi\right)\cos\varphi}{a}$$

and:

$$\delta H = \frac{I\left(\delta\varphi\right)\cos\varphi}{4\pi a}$$

C.1.2 Field strength produced by a circular loop at a point on its axis

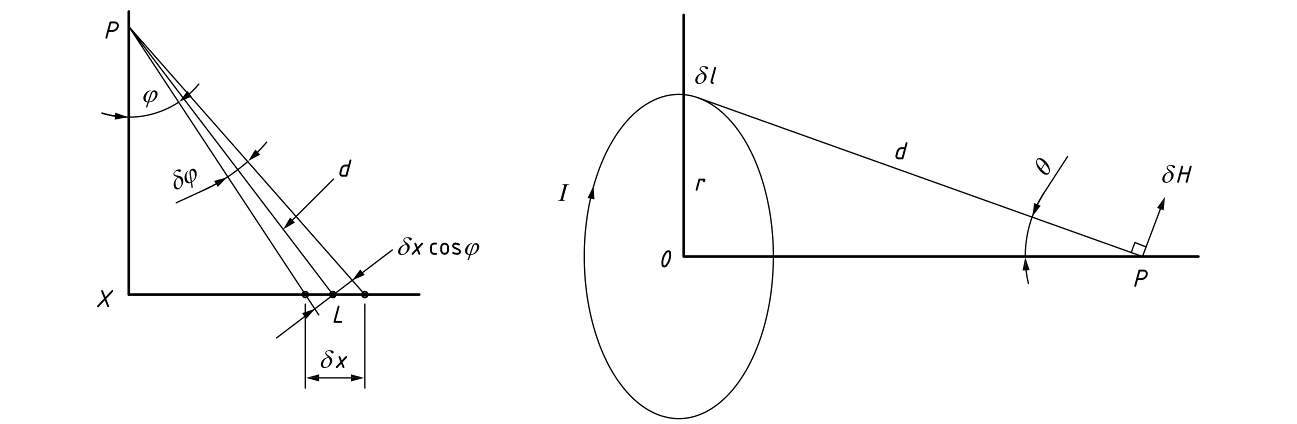
Consider a conductor in the form of a circular loop of radius *r* and centre *C*, carrying a current *I* [see Figure C.1b)]. The field strength *H* at the point *P* on the axis of the loop is given by the following equation:

$$H = \sum(\delta H)\sin\theta$$

along the axis, and, by symmetry, the components perpendicular to the axis sum to zero. Thus:

$$H = \sum \frac{I(\delta l)\sin\theta}{4\pi d^2}$$

Figure C.1 **Diagram for calculating magnetic field strength**



a) Produced by an element of conductor XL b) Produced by a circular loop

Now, $\sin\theta = r / d$, so that:

$$H = \frac{Ir^2}{2d^3} = \frac{Ir^2}{2(r^2 + h^2)^{3/2}}$$

If $h = 0$, $r = d$, so that the field strength H_0 at the centre of a circular loop is given by:

$$H_0 = \frac{I}{2r}$$

The ratio of the field strength at the centre to that at any point on the axis is given by:

$$\frac{H_0}{H} = \frac{\left(r^2 + h^2\right)^{3/2}}{r^3}$$

Expressed in terms of the height ratio h_n, which for a circular loop is equal to h/r, this becomes:

$$\frac{H_0}{H} = \left(1 + h_n^2\right)^{3/2}$$

Values of this function for values of h_n from 0 to 12 are given in Table C.1, for comparison with the corresponding values for square and rectangular loops.

C.1.3 Magnetic field strength at the centre of a rectangular loop

Consider a conductor, in the form of a rectangular loop WXYZ, sides *A* and *B*, with centre O, carrying a current (see Figure C.2).

The field at O due to element δx (see **C.1.1**) is given by:

$$\delta H = I \cos\psi \left(\frac{\delta\psi}{2\pi B}\right)$$

since OE = *B*/2. Therefore, the field at O due to conductor WX is given by:

$$H_{\mathrm{wx}} = \frac{I}{2\pi B}\int_{-\Phi}^{\Phi} \cos\psi \, \mathrm{d}\psi$$

where

$$\Phi = \arctan\left(\frac{\mathrm{WE}}{\mathrm{OE}}\right) = \arctan\left(\frac{A}{B}\right)$$

Thus:

$$H_{\mathrm{WX}} = \left(\frac{I}{\pi B}\right)\left(\frac{A}{\sqrt{\left(A^2 + B^2\right)}}\right)$$

Similarly, the field at O due to CD is given by the same equation, and that due to BC or DA is given by:

$$H_{\mathrm{XY}} = H_{\mathrm{ZW}} = \left(\frac{I}{\pi B}\right)\left[\frac{B}{\sqrt{\left(A^2 + B^2\right)}}\right]$$

and all these fields are in the same direction, so the total field strength at O is given by:

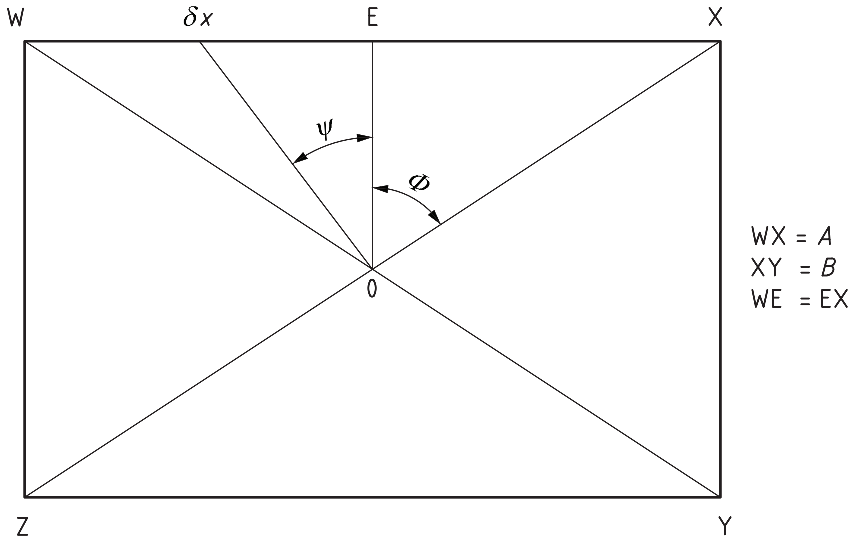
$$H_0 = \left(\frac{2I}{\pi}\right)\left[\frac{A}{B\sqrt{\left(A^2 + B^2\right)}} + \frac{B}{A\sqrt{\left(A^2 + B^2\right)}}\right]$$

$$= \frac{2I\sqrt{\left(A^2 + B^2\right)}}{\pi AB}$$

Table C.1 **Factor by which the loop current has to be increased, compared with that required for a given magnetic field strength at the centre of a square loop, to obtain the same field strength for a rectangular loop at a point at height ratio of h_n above or below the centre of the loop**

Height ratio, h_n	Rectangular loop												Circular loop
	Values of aspect ratio γ												
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	
0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.100	1.013	1.015	1.019	1.024	1.029	1.034	1.039	1.044	1.049	1.054	1.059	1.064	1.015
0.200	1.050	1.059	1.076	1.095	1.115	1.135	1.155	1.176	1.196	1.216	1.236	1.256	1.061
0.300	1.114	1.134	1.171	1.213	1.258	1.303	1.348	1.394	1.439	1.484	1.530	1.575	1.138
0.400	1.206	1.239	1.304	1.378	1.456	1.536	1.616	1.696	1.777	1.857	1.938	2.018	1.249
0.500	1.326	1.377	1.475	1.589	1.709	1.832	1.956	2.081	2.206	2.332	2.457	2.583	1.398
0.600	1.477	1.548	1.685	1.846	2.017	2.191	2.369	2.547	2.726	2.906	3.086	3.266	1.586
0.700	1.663	1.755	1.937	2.150	2.378	2.613	2.851	3.092	3.334	3.577	3.821	4.065	1.819
0.800	1.884	2.001	2.231	2.503	2.795	3.097	3.404	3.715	4.029	4.344	4.660	4.977	2.100
0.900	2.145	2.288	2.570	2.906	3.268	3.644	4.028	4.417	4.810	5.205	5.603	6.001	2.435
1.000	2.449	2.619	2.958	3.363	3.801	4.256	4.724	5.198	5.678	6.162	6.648	7.136	2.828
1.100	2.800	2.999	3.398	3.876	4.395	4.937	5.494	6.060	6.634	7.213	7.796	8.383	3.285
1.200	3.200	3.431	3.893	4.450	5.055	5.688	6.341	7.006	7.681	8.362	9.050	9.741	3.811
1.300	3.654	3.918	4.448	5.088	5.784	6.515	7.269	8.039	8.821	9.612	10.410	11.214	4.412
1.400	4.165	4.465	5.067	5.794	6.587	7.421	8.282	9.163	10.058	10.965	11.881	12.804	5.093
1.500	4.738	5.075	5.754	6.574	7.469	8.412	9.386	10.383	11.398	12.426	13.466	14.515	5.859
1.600	5.375	5.753	6.513	7.431	8.435	9.491	10.584	11.703	12.844	14.000	15.170	16.351	6.717
1.700	6.083	6.504	7.349	8.371	9.488	10.665	11.882	13.130	14.402	15.692	16.999	18.318	7.672
1.800	6.863	7.330	8.267	9.399	10.636	11.938	13.286	14.668	16.077	17.508	18.957	20.421	8.731
1.900	7.721	8.237	9.271	10.519	11.882	13.317	14.802	16.325	17.877	19.454	21.051	22.666	9.898
2.000	8.660	9.228	10.366	11.737	13.233	14.806	16.435	18.104	19.807	21.536	23.288	25.060	11.180

Figure C.2 **Diagram for calculating magnetic field strength at the centre of a rectangular loop**



C.1.4 Magnetic field strength at an arbitrary point

To calculate the magnetic field strength at an arbitrary point due to a current in a rectangular loop, leading to the current required for a given field strength at the centre of the loop and the variation of field strength with distance from the plane of the loop, consider Figure C.3 in which XQY is a conductor having a right-angle bend at Q.

By Ampère's rule, the magnetic field vector perpendicular to plane PXQ, due to current I in an element of conductor δy is given by:

$$\delta H_{\mathrm{XQ}} = \frac{I \delta y \cos\varphi}{4\pi s^2}$$

where

$$\cos\varphi = \frac{\mathrm{PX}}{\mathrm{PL}} = \frac{m}{s}; \text{ and}$$

$$\delta y = \frac{s\delta\varphi}{\cos\varphi}$$

Thus:

$$\delta H_{\mathrm{XQ}} = \frac{I\delta\varphi}{4\pi s} = \frac{I\delta\varphi\cos\varphi}{4\pi m}$$

so that the field due to all the conductor parallel to the y-axis, i.e. XQ (see Figure C.3), is given by:

$$H_{\mathrm{XQ}} = \frac{I}{4\pi m}\int_0^{\Phi} \cos\varphi \, \mathrm{d}\varphi$$

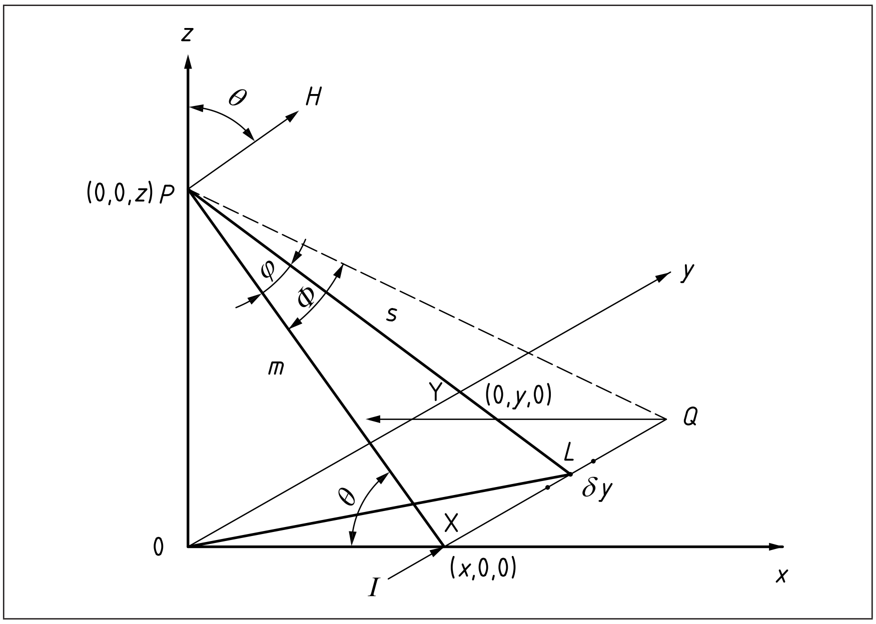
where

$$\cos\Phi = \left(\frac{x^2 + z^2}{x^2 + y^2 + z^2}\right)^{1/2}$$

Hence:

$$H_{XQ} = \frac{I}{4\pi m}\left(\sin\Phi - \sin 0\right) = \frac{I}{4\pi m}\sin\Phi$$

Figure C.3 **Diagram for calculating magnetic field strength at an arbitrary point**



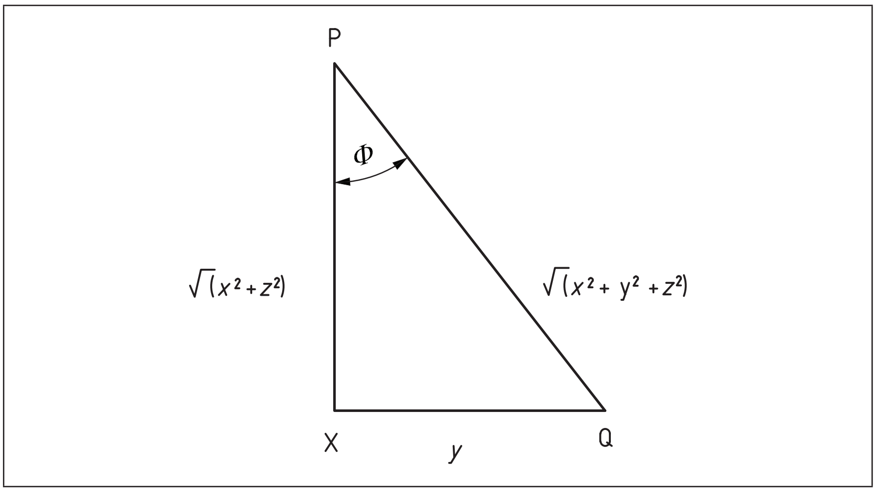
From Figure C.4:

$$\sin\Phi = \frac{y}{\sqrt{\left(x^2 + y^2 + z^2\right)}}$$

so that:

$$H_{XQ} = \frac{I}{4\pi m}\left[\frac{y}{\sqrt{\left(x^2 + y^2 + z^2\right)}}\right] = \frac{Iy}{4\pi\sqrt{\left(x^2 + z^2\right)}\sqrt{\left(x^2 + y^2 + z^2\right)}}$$

Figure C.4 **Diagram for calculating cosΦ and sinΦ**



The component in the *z*-direction, H_{XQz}, due to the conductor parallel to the *y*-axis (see Figure C.3) is given by:

$$H_{XQz} = H_{XQ}\cos\theta = \frac{Ixy}{4\pi\left(x^2+z^2\right)\sqrt{\left(x^2+y^2+z^2\right)}}$$

A similar expression gives the component due to the conductor parallel to the *x*-axis, so that the total field strength in the *z*-direction H_{XQYz} is given by:

$$H_{XQYz} = \frac{Ixy}{4\pi\sqrt{\left((x^2+y^2+z^2\right)}}\left(\frac{1}{x^2+y^2}+\frac{1}{y^2+z^2}\right)$$

which agrees with equation (1) given in [2].

Similarly, the horizontal component in the *x*-direction, which is due to the conductor parallel to the *y*-axis, is given by:

$$H_{QYx} = H_{QY}\cos\theta = \frac{Iyz}{4\pi\left(x^2+z^2\right)\sqrt{\left(x^2+y^2+z^2\right)}}$$

which agrees with equation (2) given in [2], and there is an analogous expression for the horizontal component in the *y*-direction.

These expressions become indeterminate at the interesting point (0, 0, 0), so, using the method given in [2] but using the notation given in this standard, a rectangular loop is built up with sides $A = 2p$, $B = 2q$, as shown in Figure C.5, and the new variables $x_1 = (p - x)$, $x_2 = (p + x)$, $y_1 = (q - y)$ and $y_2 = (q + y)$ are defined. The field strength in the *z*-direction at a point (*x*, *y*, *z*) for a current *I* in the loop is then given by the equation:

$$H_z(x,y,z) = \frac{I}{4\pi}\sum_{i=1}^{2}\sum_{j=1}^{2}\frac{x_i y_j}{\sqrt{\left(x_i^2+y_j^2+z^2\right)}}\left(\frac{1}{x_i^2+z^2}+\frac{1}{y_j^2+z^2}\right)$$

At the point (0, 0, 0), the centre of the loop, this becomes:

$$H_0 = \frac{I}{\pi}\left[\frac{\sqrt{\left(p^2+q^2\right)}}{pq}\right]$$

as derived directly in **C.1.3**, so that:

$$H_0 = \frac{2ID}{\pi AB}$$

Hence,

$$I = \frac{\pi A B H_0}{2D}$$

Also, the field strength at a point (0, 0, z), which represents a point vertically above or below the centre of a horizontal loop, is given by:

$$H_{0z} = \frac{I}{\pi}\left[\frac{pq}{\sqrt{\left(p^2+q^2+z^2\right)}}\right]\left(\frac{1}{p^2+z^2}+\frac{1}{q^2+z^2}\right)$$

For a square loop, $p = q = r$. Put $z = h$. Then:

$$H_{0z} = \frac{I}{\pi}\left[\frac{r^2}{\sqrt{\left(2r^2+h^2\right)}}\right]\left(\frac{2}{r^2+h^2}\right)$$

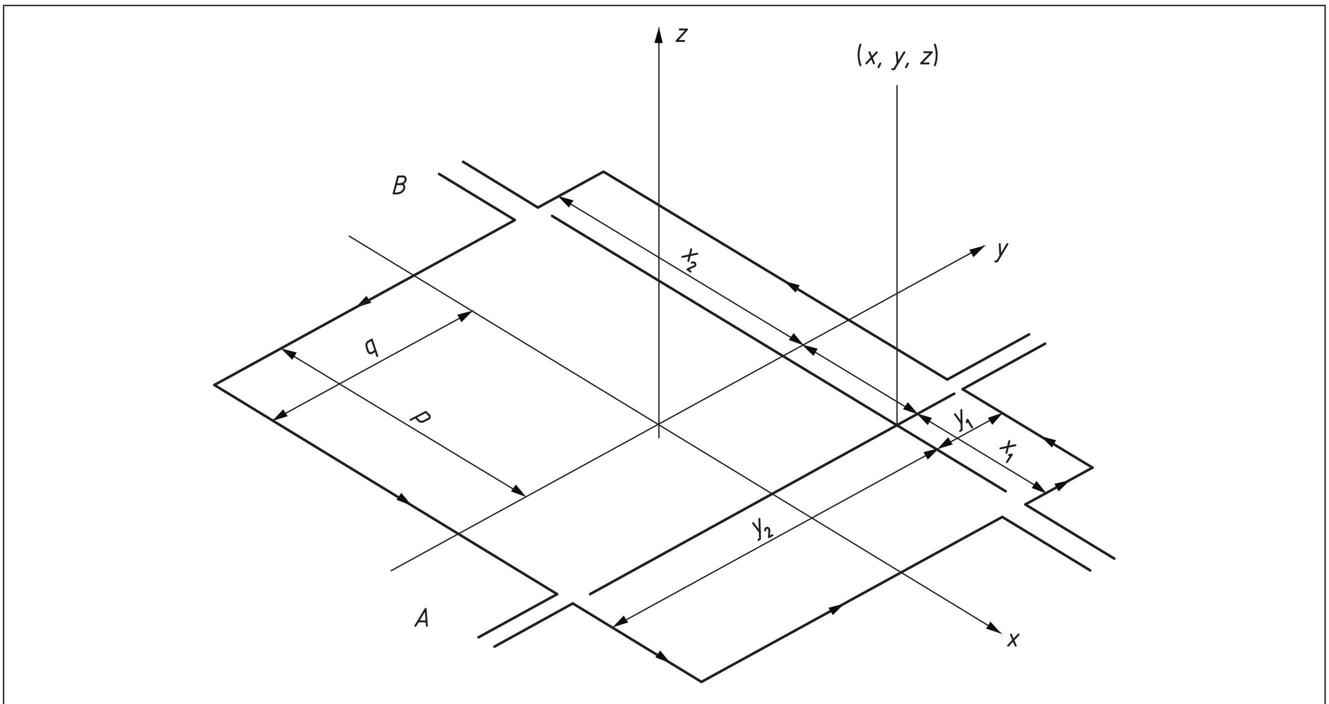
Hence,

$$\frac{H_0}{H_{0z}} = \frac{\left(1+h^2\right)\sqrt{\left(2r^2+h^2\right)}}{\sqrt{2}(r^3)}$$

and, if $h_n = h/r$, the height ratio:

$$\frac{H_0}{H_{0z}} = \frac{\left(1+h_n^2\right)\sqrt{\left(2+h_n^2\right)}}{\sqrt{2}}$$

Figure C.5 **Diagram for calculating magnetic field strength at point (*x*, *y*, *z*)**



In the general case of a rectangular loop, aspect ratio $\gamma = q/p$, substituting γ and $h_n = h/\sqrt{(pq)}$ in the equation for H_{0z} above gives:

$$\frac{H_0}{H_{0z}} = \frac{\sqrt{\left[\left(1+\gamma^2\right)\left(\gamma^2+\gamma h_n^2+1\right)\right]}\left(\gamma+h_n^2\right)\left(1+\gamma h_n^2\right)}{\left(\gamma^2+2\gamma h_n^2+1\right)}$$

This equation connects the field strength at height ratio h_n with the field strength at the centre of a rectangular loop of aspect ratio γ. The field strength decreases more slowly with perpendicular distance from the plane of a square loop than from that of a loop of any other aspect ratio.

C.2 Loop conductor sizes and resistances

C.2.1 General

In order to develop the equations given in Clause **29**, it is necessary to derive the resistance of the loop conductor in terms of its material (assumed to be copper), its area of cross section and its length, from first principles. This derivation is given in **C.2.2** and the same method can also be used to determine the resistance of a loop using a type of conductor for which there is no British Standard, such as a ribbon cable for use under carpeting.

Where the loop conductor conforms to BS EN 60228:2005, Class 1 or Class 5 then Table C.2 and Table C.3 of this standard can be used for quick reference.

C.2.2 Resistance of the loop conductor and relation between conductor size and cut-off frequency for a voltage-driven loop

The average resistivity of copper, as used in wire, at 0 °C is ρ_0 = 16.5 nΩ·m, and the temperature coefficient of resistance is $a = 3.93 \times 10^{-3}\ \mathrm{K}^{-1}$ at room temperature. The loop conductor is heated by the current flowing through it, so it is above room temperature. External sources of heat such as central heating pipes can also raise the temperature of the conductor to a greater extent than the heating due to the current. The temperature rise of a copper conductor is slightly larger than proportional to the square of the current, because the temperature coefficient of resistance is positive. The operating temperature for a PVC-insulated conductor in a cable conforming to BS 6004, at its rated current, is 70 °C. For a conductor whose rated current is sufficient to produce a magnetic field strength of 0.56 $\mathrm{A{\cdot}m^{-1}}$, the long-term average current (producing a field strength of 0.1 $\mathrm{A{\cdot}m^{-1}}$) is therefore sufficient to produce a temperature rise of about 2 K above an assumed 20 °C ambient temperature, which is negligible in this case. The resistivity at θ = 20 °C is given by:

$$\rho_{20} = \rho_0\left(1 + a\theta\right) = 17.8\ \mathrm{n\Omega \cdot m}$$

Both the resistivity and the temperature coefficient of resistance of manufactured conductors may differ slightly from these values (see Table C.2 and Table C.3). The resistance in ohms of a rectangular loop, sides A and B, of copper wire with diameter d is given by:

$$R = \frac{8\rho_{20}\left(A+B\right)}{\pi d^2} = \frac{1.42\times10^{-7}\left(A+B\right)}{\pi d^2}$$

For a voltage-driven loop at the cut-off frequency f_c (at which the current falls by 3 dB referred to its low-frequency value), the loop resistance and inductive reactance are equal. That is:

$$2\pi f_c \times 4\times10^{-6}\left(A+B\right)=\frac{1.42\times10^{-7}\left(A+B\right)}{\pi d^2}$$

Table C.2 **Class 5 flexible annealed copper conductors for standard single-core and multi-core cables**

Nominal cross section	**Number/diameter of conductors**	**Effective diameter**	**Maximum resistance at 20 °C**	**Current rating**
mm^2	mm^{-1}	mm	$m\Omega\cdot m^{-1}$	A
0.22	7/0.2	0.53	92.0	1.4
0.40	13/0.2	0.71	48.0	1.8
0.50	16/0.2	0.80	39.0	3
0.75	24/0.2	0.98	26.0	6
1.00	32/0.2	1.10	19.5	10
1.25	40/0.2	1.26	15.6	13

NOTE 1 Effective diameter values are calculated.

NOTE 2 The current ratings are taken from BS 7671:2008+A1, Table 4F3A (except for cross-sections from 0.22 mm^2 to 0.75 mm^2).

Hence, the cross-sectional area (in m^2) is given by:

$$\frac{\pi d^2}{4}=\frac{1.42\times10^{-7}}{32\pi f_c\times10^{-6}}=\frac{1.42\times10^{-3}}{f_c}$$

It should be noted that the terms (A + B) cancel, so that the result does not depend on the loop dimensions.

C.2.3 Quick reference tables (derived from BS EN 60228:2005)

The values of resistance given in Table C.2 and Table C.3 are the maximum values permitted (or extrapolated from those) in BS EN 60228:2005. Values calculated by the method given in **C.2.1**, and actual measured values, are usually lower.

Table C.3 **Class 1 solid annealed copper conductors for single-core and multi-core cables**

Nominal cross section	**Effective diameter**	**Maximum resistance at 20 °C**	**Current rating**
mm^2	mm	$m\Omega\cdot m^{-1}$	A
0.50	0.80	36.0	—
0.75	0.98	24.5	—
1.00	1.10	18.1	11.0
1.50	1.38	12.1	14.5
2.50	1.80	7.41	19.5
4.00	2.26	4.61	26.0

NOTE 1 Effective diameter values are calculated.

NOTE 2 The current ratings are taken from BS 7671:2008+A1, Table 4D1A and Table 4D2A (except for cross-sections from 0.5 mm^2 to 0.75 mm^2).

C.3 Inductance of two parallel wires, leading to the inductance of a rectangular loop

This analysis uses the method given in [4]. Consider two parallel wires, P and Q, radius *a* and separation *D*, with $D \gg a$, carrying a current *I* in opposite directions. For the wire P, the magnetic field strength at radius *r*, H_r is given by:

$$H_r = \frac{I}{2\pi r}$$

and the flux density at radius *r*, B_r is given by:

$$B_r = \frac{\mu I}{2\pi r}$$

Consider a cylindrical shell, radius *r* and thickness δr. The total flux in 1 m length of shell, φ is given by:

$$\varphi = B_r \delta r = \frac{\mu I}{2\pi r}\left(\frac{\delta r}{r}\right)$$

This flux links with wire P alone.

Linkage with conductor P due to flux in an element, Φ_{Pe} is given by:

$$\Phi_{\mathrm{Pe}} = \frac{\mu I}{2\pi}\left(\frac{\delta r}{r}\right)$$

Thus, total linkages with P due to current in P, Φ_{PP} is given by:

$$\Phi_{\mathrm{PP}} = \frac{\mu I}{2\pi}\int_a^R \frac{\mathrm{d}r}{r} = \frac{\mu I}{2\pi}\ln\left(\frac{R}{a}\right)$$

where *R* is a very large radius.

Similarly, total linkages with Q due to current in P, Φ_{QP} is given by:

$$\Phi_{\mathrm{QP}} = \frac{\mu I}{2\pi}\int_D^R \frac{\mathrm{d}r}{r} = \frac{\mu I}{2\pi}\ln\left(\frac{R}{D}\right)$$

total linkages with Q due to current in Q, Φ_{QQ} is given by:

$$\Phi_{\mathrm{QQ}} = \frac{\mu I}{2\pi}\ln\left(\frac{R}{a}\right)$$

total linkages with P due to current in Q, Φ_{PQ} is given by:

$$\Phi_{\mathrm{PQ}} = \frac{\mu I}{2\pi}\ln\left(\frac{R}{D}\right)$$

Thus, total linkages with P, Φ_{P} is given by:

$$\Phi_{\mathrm{P}} = \frac{\mu I}{2\pi}\left[\ln\left(\frac{R}{a}\right) - \ln\left(\frac{R}{D}\right)\right] = \frac{\mu I}{2\pi}\ln\left(\frac{D}{a}\right)$$

and the total linkages with Q are also equal to this. Therefore, the total inductance of the two wires (i.e. the linkages for unit current), per metre of length, L is given by:

$$L = \frac{\mu}{\pi}\ln\left(\frac{D}{a}\right) = \frac{\mu}{\pi}\ln\left(\frac{2D}{d}\right)$$

where the wire diameter $d = 2a$. At low frequencies, there is flux inside the conductor which produces an additional inductance of $\mu/4\pi$ in henrys per metre, but in most of the cases considered here, this is negligible. It would not be negligible if ferromagnetic wire were used.

For two pairs of wires, forming a rectangular loop of sides A and B, the inductance L_e is therefore, by superposition:

$$L_e = \frac{\mu}{\pi}\left[B\ln\left(\frac{2A}{d}\right) + A\ln\left(\frac{2B}{d}\right)\right]$$

This equation is difficult to handle. The side of a square loop of equal perimeter to the rectangular loop would be $(A + B)/2$, and the inductance L_a of this would be:

$$L_a = \frac{\mu}{\pi}(A+B)\ln\left(\frac{A+B}{d}\right)$$

It is found by calculation that, for aspect ratios (B/A) between 1 and 12 (and therefore between 0.083 and 12, since A and B can be interchanged), the ratio of L_a/L_e does not exceed 1.2 for values of A/d from 2 000 to 128 000, which more than covers the likely practical range. Table C.4 gives values for this ratio.

The practical range of A/d may be considered to extend from the case of a loop of smaller side 3 m (used in a household system, for instance) to a loop of the maximum practicable size of about 40 m side. If the conductor diameters were (in conflict with the design methods presented here) 1.4 mm and 0.6 mm respectively, then A/d varies from 2 143 to 66 666.7, and for square loops of these dimensions:

$$8.0 \le \ln\left(\frac{2A}{d}\right) \le 12.0$$

Setting $\ln\left(\frac{A+B}{d}\right) = 10$:

$$L = \frac{10\mu}{\pi}(A+B)$$

Normally, $\mu = \mu_0 = 4\pi \times 10^{-7}$ H·m^{-1}, so that:

$$L = 4 \times 10^{-6}(A+B)$$

where L is measured in henrys; or

$$L = 4(A+B)$$

where L is measured in microhenrys.

NOTE A more extensive treatment of the calculation of inductance may be found in [2].

Table C.4 **Ratio or approximate to exact inductance**

A/*d*	L_a/L_e											
	Values of γ											
	1	2	3	4	5	6	7	8	9	10	11	12
2 000 000	1.000	1.020	1.049	1.075	1.097	1.117	1.134	1.149	1.163	1.176	1.187	1.198
4 000 000	1.000	1.019	1.045	1.069	1.090	1.108	1.124	1.138	1.151	1.163	1.173	1.183
8 000 000	1.000	1.018	1.042	1.064	1.083	1.100	1.115	1.128	1.140	1.151	1.161	1.170
16 000 000	1.000	1.016	1.039	1.060	1.078	1.094	1.108	1.120	1.131	1.141	1.151	1.159
32 000 000	1.000	1.015	1.037	1.056	1.073	1.088	1.101	1.113	1.123	1.133	1.141	1.149
64 000 000	1.000	1.015	1.035	1.053	1.069	1.083	1.095	1.106	1.116	1.125	1.133	1.141
128 000 000	1.000	1.014	1.033	1.050	1.065	1.078	1.090	1.100	1.110	1.118	1.126	1.133

C.4 Variation of the impedance of a loop of fixed dimensions with conductor resistance

Values of $L_{|z|}$ are given in Table C.5.

Table C.5 **Values of $L_{|z|}$**

ωL	$L_{\|z\|}$											
	Values of r_n											
	0.100	0.158	0.251	0.398	0.631	1.000	1.585	2.512	3.981	6.310	10.000	15.849
0.100	– 16.990	– 14.545	– 11.361	– 7.734	– 3.982	0.043	4.017	8.007	12.003	16.001	20.000	24.000
0.158	– 14.545	– 12.990	– 10.545	– 7.361	– 3.734	0.108	4.043	8.017	12.007	16.003	20.001	24.000
0.251	– 11.361	– 10.545	– 8.990	– 6.545	– 3.361	0.266	4.108	8.043	12.017	16.007	20.003	24.001
0.398	– 7.734	– 7.361	– 6.545	– 4.990	– 2.545	0.639	4.266	8.108	12.043	16.017	20.007	24.003
0.631	– 3.892	– 3.734	– 3.361	– 2.545	– 0.990	1.455	4.639	8.266	12.108	16.043	20.017	24.007
1.000	0.043	0.108	0.266	0.639	1.455	3.010	5.455	8.639	12.266	16.108	20.043	24.017
1.585	4.017	4.043	4.108	4.266	4.639	5.455	7.010	9.455	12.639	16.266	20.108	24.043
2.512	8.007	8.017	8.043	8.108	8.266	8.639	9.455	11.010	13.455	16.639	20.266	24.108
3.981	12.003	12.007	12.017	12.043	12.108	12.266	12.639	13.455	15.010	17.455	20.639	24.266
6.310	16.001	16.003	16.007	16.017	16.043	16.108	16.266	16.639	17.455	19.010	21.455	24.639
10.000	20.000	20.001	20.003	20.007	20.017	20.043	20.108	20.266	20.639	21.455	23.010	25.455

C.5 High-level equalizer

Referring to Figure C.6:

$$\frac{I}{V} = \left[\left(R_2 + sL \right) + \frac{R_1}{sC\left(R_1 + 1/sC \right)} \right]^{-1}$$

Let $CR_1 = \tau_1$ and $L/R_2 = \tau_2$, then:

$$\frac{I}{V} = \frac{\left(1 + s\tau_1\right)}{R_2\left(1 + s\tau_1\right)\left(1 + s\tau_2\right) + R_1}$$

Let $R_1 = aR_2$ and $\tau_2 = \beta\tau_1$, then:

$$\frac{IR_2}{V} = \frac{\left(1 + s\tau_1\right)}{\left(1 + a\right) + s\left(1 + \beta\right)\tau_1 + s^2\beta\tau_1^2}$$

Let $\gamma = 1/(1 + a)$ and $\tau = \sqrt{(\beta\gamma)}\tau_1$, then:

$$\frac{IR_2}{V} = \frac{\gamma\left(1 + s\tau/\sqrt{\beta\gamma}\right)}{1 + s\tau\gamma\left(1 + \beta\right)/\sqrt{\beta\gamma} + s^2\tau^2}$$

It is possible to obtain a maximally flat response using this network, but it is not possible to find usable analytical expressions for the circuit values in terms of the upper –3 dB frequency ω_c, and it is important to be able to do this in practice. A practicable solution, giving a small peak in the response at approximately $0.4\omega_c$ (not exceeding 0.82 dB), is to force the squares of the moduli of numerator and denominator, after substituting $s = j\omega$, into the forms $1 + \tau^2$ and $1 + \tau^4$ respectively. Hence $\sqrt{(\beta\gamma)} = 1$ and $\gamma(1 + \beta)/\sqrt{(\beta\gamma)} = \sqrt{2}$, i.e. $\beta = 1 + \sqrt{2}$, $\gamma = \sqrt{2} - 1$ and $a = \sqrt{2}$. Also $\tau_1 = \tau/\sqrt{(\beta\gamma)} = \tau$.

At the upper –3 dB band-limit frequency ω_c:

$$\frac{\left(1 + \omega_c^2\tau^2\right)}{\left(1 + \omega_c^4\tau^4\right)} = \frac{1}{\sqrt{2}}$$

Therefore:

$$\omega_c^2\tau^2 = 1 + \sqrt{2\sqrt{2} - 1}$$

so that:

$$\tau = \tau_1 = \frac{\sqrt{1 + \sqrt{2\sqrt{2} - 1}}}{\omega_c} = \frac{1.534}{\omega_c}$$

and:

$$\tau_2 = (1 + \sqrt{2})\tau_1 = \frac{3.703}{\omega_c}$$

Thus:

$$R_2 = \frac{\omega_c L}{3.703}$$

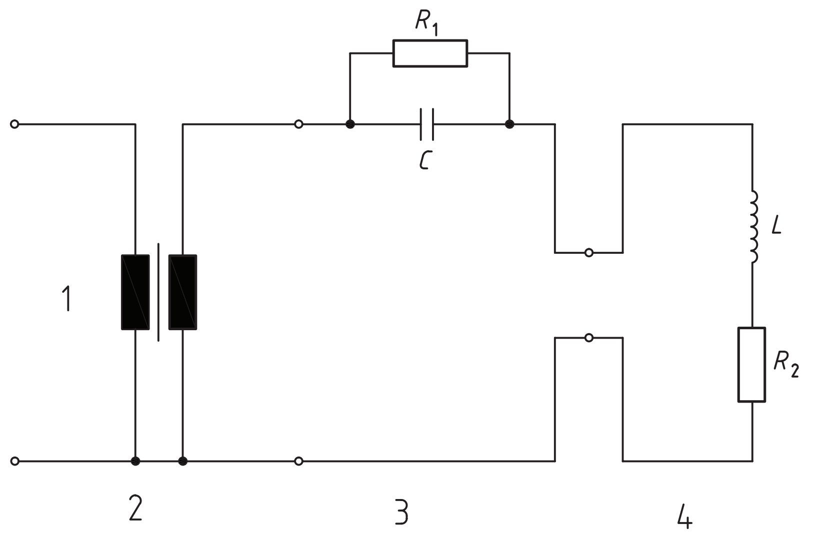
$$R_1 = aR_2 = \sqrt{2}R_2$$

and

$$C = \frac{\tau_1}{R_1} = \frac{4.015}{\omega_c^2 L}$$

An example of the frequency response achieved with a loop inductance of 100 µH is shown in Figure C.7.

Figure C.6 **Circuit diagram of a "high-level" or Poperwell equalizer (for insertion between the amplifier and the loop)**



Key

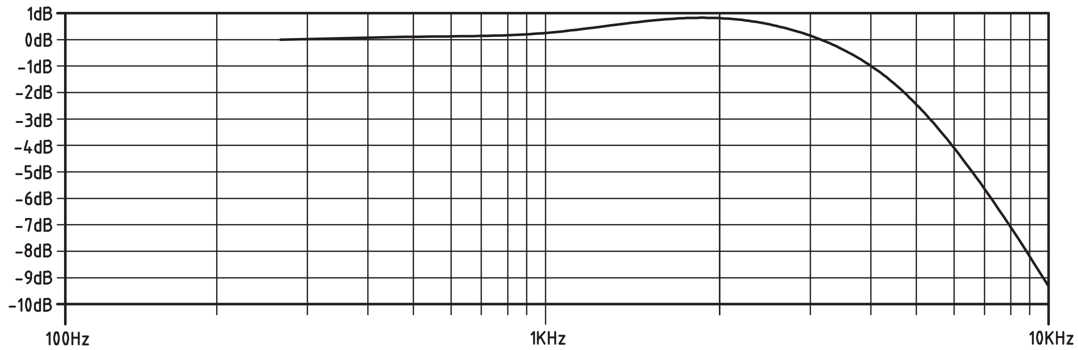
1 From amplifier

2 Optional transformer

3 Equalizer

4 Loop

Figure C.7 **Frequency response obtained with a high-level equalizer**



Annex D (informative) Model certificates

D.1 Design certificate

Certificate of design of the AFILS at:

Address: ....

....

.... Postcode: ....

I/we being the competent person(s) responsible (as indicated by my/our signatures below) for the design of the AFILS, particulars of which are set below, CERTIFY that the said design for which I/we have been responsible complies to the best of my/our knowledge and belief with the recommendations of BS 7594:2011, Section **3** except for the variations, if any, stated in this certificate.

Name (in block letters): .... Position: ....

Signature: .... Date: ....

For and on behalf of: ....

Address: ....

....

.... Postcode: ....

Variations from the recommendations of BS 7594:2011, Section **3**:

....

....

....

Extent of system covered by the certificate:

....

....

....

Installation and commissioning

It is strongly recommended that installation and commissioning be undertaken in accordance with the recommendations of BS 7594:2011, Section **4** respectively.

Verification

Verification that the system complies with BS 7594:2011 should be carried out, on completion, in accordance with BS 7594:2011, Clause **21**.

Yes ☐ No ☐ To be decided by the purchaser ☐

Maintenance

It is strongly recommended that, after completion, the system is maintained in accordance with BS 7594:2011, Section **5**.

User responsibilities

The user should appoint a responsible person to supervise all matters pertaining to the AFILS in accordance with the recommendations of BS 7594:2011, Section **6**.

D.2 Installation certificate

Certificate of installation of the AFILS at:

Address: ....

....

.... Postcode: ....

I/we being the competent person(s) responsible (as indicated by my/our signatures below) for the installation of the AFILS, particulars of which are set below, CERTIFY that the said installation for which I/we have been responsible complies to the best of my/our knowledge and belief with the recommendations of BS 7594:2011, Section **4** except for the variations, if any, stated in this certificate.

Name (in block letters): .... Position: ....

Signature: .... Date: ....

For and on behalf of: ....

Address: ....

....

.... Postcode: ....

The extent of liability of the signatory is limited to the system described below.

Extent of system covered by the certificate:

....

....

....

....

Specification against which the system was installed:

....

....

....

....

Variations from the specification an/or BS 7594:2011, Section **4**:

....

....

....

....

Wiring has been tested in accordance with the recommendations of BS 7594:2011, Clause **16**. Test results have been recorded and provided to:

....

Unless supplied by others, the "as fitted" drawings have been supplied to the person responsible for commissioning the system [see BS 7594:2011, Clause **18**]

D.3 Commissioning certificate

Certificate of commissioning for the AFILS at:

Address: ....

....

.... Postcode: ....

I/we being the competent person(s) responsible (as indicated by my/our signatures below) for the commissioning of the AFILS, particulars of which are set below, CERTIFY that the said installation for which I/we have been responsible complies to the best of my/our knowledge and belief with the recommendations BS 7594:2011, Section **4** except for the variations, if any, stated in this certificate.

Name (in block letters): .... Position: ....

Signature: .... Date: ....

For and on behalf of: ....

Address: ....

....

.... Postcode: ....

The extent of liability of the signatory is limited to the system described below.

Extent of system covered by the certificate:

....

....

....

....

Variations from the recommendations of BS 7594:2011, Section **4**.

....

....

....

....

☐ All equipment operates correctly.

☐ Installation work is, as far as can be reasonably ascertained, of an acceptable standard.

☐ The entire system has been inspected and tested in accordance with the recommendations of BS 7594:2011, Clause **16**.

☐ The system performs as required by the specification prepared by:

....

a copy of which I/we have given.

☐ The documentation described in BS 7594:2011, Clause **18** has been provided to the user.

The following work should be completed before/after (delete as applicable) the system becomes operational:

....

D.4 Acceptance certificate

Certificate of acceptance for the AFILS at:

Address: ....

....

.... Postcode:...

I/we being the competent person(s) responsible (as indicated by my/our signatures below) for the acceptance of the AFILS, particulars of which are set below, ACCEPT the system on behalf of:

....

....

....

Name (in block letters):..Position:...

Signature: .... Date:...

For and on behalf of: ....

Address: ....

....

.... Postcode:...

The extent of liability of the signatory is limited to the system described below.

Extent of system covered by the certificate:

....

....

....

....

☐ All installation work appears to be satisfactory.

☐ The system is capable of giving an audible and intelligible signal.

The following documents have been provided to the purchaser or user:

☐ "As fitted" drawings.

☐ Operating and maintenance instructions.

☐ Certificate of design, installation and commissioning.

☐ A log book.

☐ Sufficient representatives of the user have been properly instructed in the use of the system

☐ All relevant tests, defined in the purchasing specification, have been witnessed. (Delete if not applicable.)

The following work is required before the system can be accepted:

....

....

....

D.5 Verification certificate (optional)

Certificate of verification for the AFILS at:

Address: ....

....

....

.... Postcode:..

I/we being the competent person(s) responsible (as indicated by my/our signatures below) for the verification of the AFILS, particulars of which are set below, CERTIFY that the verification work for which I/we have been responsible complies to the best of my/our knowledge and belief with the recommendations BS 7594:2011, Clause **21**.

Name (in block letters):..Position:..

Signature: .... Date:..

For and on behalf of: ....

Address: ....

....

....

.... Postcode:..

The extent of liability of the signatory is limited to the system described below.

Extent of system covered by the certificate:

....

....

....

Scope and extent of the verification work:

....

....

....

....

....

☐ In my/our opinion, that as far as can reasonably be ascertained from the scope of work described above, the system complies with, and has been commissioned in accordance with, the recommendations of BS 7594:2011, other than in respect of variations already identified in the certificates of design, installation or commissioning.

The following non-compliances with the recommendations of BS 7594:2011 have been identified (other than those recorded as variations in the certificates of design, installation or commissioning):

....

....

....

....

....

D.6 Inspection and servicing certificate

Certificate of servicing for the AFILS at:

Address: ....

....

....

.... Postcode: ....

I/we being the competent person(s) responsible (as indicated by my/our signatures below) for the servicing of the AFILS, particulars of which are set below, CERTIFY that the said installation for which I/we have been responsible complies to the best of my/our knowledge and belief with the recommendations BS 7594:2011, Section **4** except for the variations, if any, stated in this certificate.

Name (in block letters): .... Position: ....

Signature: .... Date: ....

For and on behalf of: ....

Address: ....

....

....

.... Postcode: ....

The extent of liability of the signatory is limited to the system described below.

Extent of system covered by the certificate:

....

....

....

....

Variations from the recommendations of BS 7594:2011, Section **4**.

....

....

....

....

☐ Relevant details of the work carried out and faults identified have been entered in the system log book.

....

....

....

....

....

D.7 Modification certificate

Certificate of modification for the AFILS at:

Address: ....

....

....

.... Postcode: ....

I/we being the competent person(s) responsible (as indicated by my/our signatures below) for the modification of the AFILS, particulars of which are set below, CERTIFY that the said installation for which I/we have been responsible complies to the best of my/our knowledge and belief with the recommendations BS 7594:2011, Section **4** except for the variations, if any, stated in this certificate.

Name (in block letters): .... Position: ....

Signature: .... Date: ....

For and on behalf of: ....

Address: ....

....

....

.... Postcode: ....

The extent of liability of the signatory is limited to the system described below.

Extent of system covered by the certificate:

....

....

....

....

Variations from the recommendations of BS 7594:2011, Section **4**.

....

....

....

....

☐ Following the modifications, the system has been tested in accordance with the recommendations of BS 7594:2011, Clause **16**.

☐ Following the modifications, "as fitted" drawings and other system records have been updated as appropriate.

I/we the undersigned confirm that the modifications have introduced no additional variations from the recommendations of BS 7594:2011 other than those recorded above:

Signed: ....

Capacity: ....

(e.g. maintenance organization, system designer, consultant or user representative)

Annex E (informative) Explanation of the specification and measurement of magnetic field strength of induction-loop systems

The first edition of BS EN 60118-4/IEC 60118-4 (BS 6083-4, now withdrawn) specified a "long-term" average field strength of 0.1 A·m^{-1} r.m.s., without defining "long term". This figure represented an arbitrary but convenient value based on data relating to sensitivities of typical hearing aids and of commonly encountered background magnetic noise levels. Measurements of field strength at 1 kHz can be performed with a sinusoidal signal and an ordinary audio-frequency voltmeter. However, such a measurement does not verify that the required field strength is produced by the speech signals, because the microphone gain control setting(s) may be too low or too high. It is essential to measure the field strength produced by actual speech signals.

It is not possible to ensure a long term average of 0.1 A·m^{-1}, unless the amplification system possesses sufficient headroom to accommodate short term bursts of louder speech. The standard indicated in a Note that 12 dB headroom is sufficient for this purpose, i.e. a short-term maximum field strength of 0.4 A·m^{-1} r.m.s. is needed.

It was recognized that a definitive headroom requirement could not be stated simply. In particular, it would not be possible to specify exactly both long-term and short-term values, without an exact definition of the signal being handled. Such a definition would, however, be in conflict with the generality required in a standard intended for work with a wide range of speech (and music) signals. As a result, reference to the issue of headroom was restricted to a note in the standard. However, this is inconsistent with the need to ensure that the amplifier is not driven into non-linearity during short periods of louder speech. It also led to the misunderstanding that a field strength of 0.1 A·m^{-1} was adequate, when measured with the specified meter.

The current edition of the standard (i.e. BS EN 60118-4:2006/ IEC 60118-4:2006) is therefore based on a reference value of field strength of 400 mA·m^{-1}, corresponding to the loudest speech signals.

The original standard assumed that the short-term magnetic field strength would be measured by means of a sound level meter whose microphone had been replaced by a magnetic pick-up coil. (For measurements at a fixed frequency it is not necessary to compensate for the rising frequency response of such an arrangement.) This meter has an r.m.s. detector and an integration time of 125 ms.

Because of the practical need to check for undistorted output on the more extreme bursts of speech, it is considered by some equipment manufacturers and system designers that a peak programme meter (PPM, see BS EN 60268-10) is more suited to the task of measuring the magnetic field strength (or loop current) of AFILS when delivering real programme material. Such an instrument is also simpler than one incorporating an r.m.s. detector. The current edition of the standard therefore allows the use of either the r.m.s./125 ms meter or the PPM.

Because the integration time of a PPM is very short (i.e. it is a peak programme meter), it may, with some speech signals, register higher levels on short bursts of speech than an r.m.s. meter having an integration time of 125 ms, even though both meters read the same on a sinusoidal signal.

Almost all AFILS amplifiers incorporate automatic gain control (AGC), to maintain loop current levels despite fluctuations in the sound level presented to the microphone(s). However, different techniques are in use, and these differences can affect the closeness of the relationship between the readings of the r.m.s./125 ms meter and the PPM. These differences rarely exceed 3 dB, which is normally just perceptible as a change in "loudness". Nevertheless, 3 dB would be important if BS EN 60118-4:2006/IEC 60118-4:2006 did not include a provision to adjust the magnetic field strength as a result of the opinions of the users of the system on whether the reproduction is of an appropriate loudness.

NOTE Bear in mind that the AFILS system designer and operator have no control over the settings of the volume controls of the hearing-aids, which, in some cases, might not be under the control of anyone except the hearing-aid dispenser.

As a result of the above considerations, it is advisable to follow the instructions of the manufacturer of the amplifier as to the type of field strength meter to be used and the field strength to be obtained. The final goal, however, is to satisfy the users of the system, not to achieve any particular numerical results. But this cannot be taken as a licence to ignore the measured results entirely.

Annex F (normative) Specification of the PPM-based field strength meter

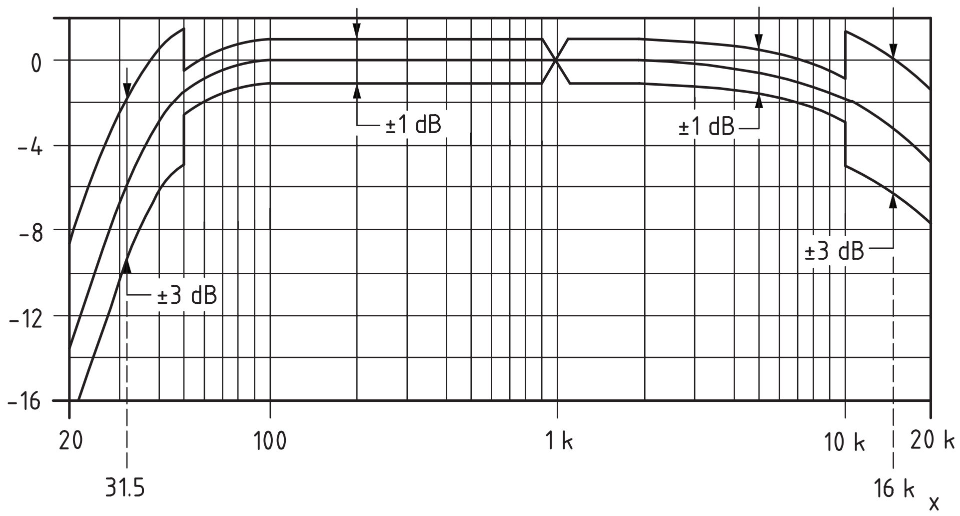
F.1 General

F.1.1 The meter should provide a measurement of magnetic field strength, accurate within 1 dB at 1 kHz, using an electronic display having PPM characteristics, i.e. an attack time-constant of 6.33 ms if the electronic display has negligible latency and a return time of 2.3 s for 20 dB fall (corresponding to a discharge time-constant of 1 s). The display should be scaled in decibels, with +6 dB as the highest scale value, and should have a range of at least 56 dB. 0 dB should correspond to an r.m.s. magnetic field strength of 0.4 A/m, measured with a continuous sinusoidal signal.

F.1.2 A switch should be provided to select two frequency response characteristics. The switch positions should be labelled "A-weighted" and "EQ" (equalized). In the "A-weighted" position, the frequency response measured at each electrical output for a constant magnetic field strength should conform to the requirements for A-weighting for Class II sound level meters specified in BS EN 61672-1. In the "EQ" position, the response should fall within the mask shown in Figure F.2.

NOTE It is necessary to provide both an "A-weighted" frequency response, approximating to that of the human ear to low-level sounds, as well as an "EQ" response for frequency response measurements and other technical tests on the system. The latter response gives meaningless results in the presence of high but tolerable levels of mains-related magnetic interference.

Figure F.1 **"EQ" or "wideband" frequency response: target curve and tolerances on response**



Key

x Response, dB y Frequency, Hz

NOTE 1 The performance is normally checked at the frequencies where the tolerance are shown.

NOTE 2 The reference 0 dB is the actual response at 1 kHz irrespective of where this falls within the 1 dB tolerance given in a).

F.2 Checking of magnetic field strength meters

In common with all measuring instruments, a field strength meter used in checking or commissioning an AFILS should be tested (calibrated) at intervals, to ensure that it is indicating correctly and that any errors do not exceed the permitted values.

The meter can be tested by subjecting the probe to a known value of magnetic field strength at the relevant frequencies.

A convenient method of producing a determinate value of magnetic field strength is a short circular coil. The magnetic field strength (in $A \cdot m^{-1}$) at the centre of a short circular coil is given by:

$$H = \frac{nI}{d}$$

where

- n is the number of turns of wire of the coil;
- I is the current in the coil (in A);
- d is the diameter of the coil (in m)

The values of n, I and d can have any convenient values, but d should not be so small that minor deviations of the position of the probe from the centre of the coil will have a significant effect. A deviation of one-twentieth of a diameter (50 mm for a 1 m diameter coil) produces an increase in magnetic field strength of about 3.5%. To avoid problems with inaccurate centring of the probe, a coil diameter of 560 mm is convenient (see BS EN 60118-1). The 0.4 $A \cdot m^{-1}$ r.m.s. reference strength therefore requires 0.224 ampere-turns.

NOTE A more complex but smaller apparatus, which can also produce a uniform magnetic field within a volume suitable for the present purpose is described in BS 6840-1:1987.

A coil comprising a single turn carrying 224 mA is suitable. This current can conveniently be provided by an audio-frequency oscillator feeding an audio amplifier. The current can be measured using the "a.c. current" range of an analogue or digital multimeter. This instrument should have been calibrated recently to assure its accuracy at the relevant frequencies.

The coil should be wound on a suitably sized former, for example a 560 mm diameter disc of plywood having a shallow groove around its edge to locate the wire and a central hole (say 100 mm diameter) to accept the probe. Four radial lines on the surface of the disc will assist in correct location of the probe.

Ferromagnetic and conductive parts should be avoided, though a "chocolate-block" terminal block to terminate the winding is acceptable.

The wires from the amplifier to the coil should be a twisted pair.

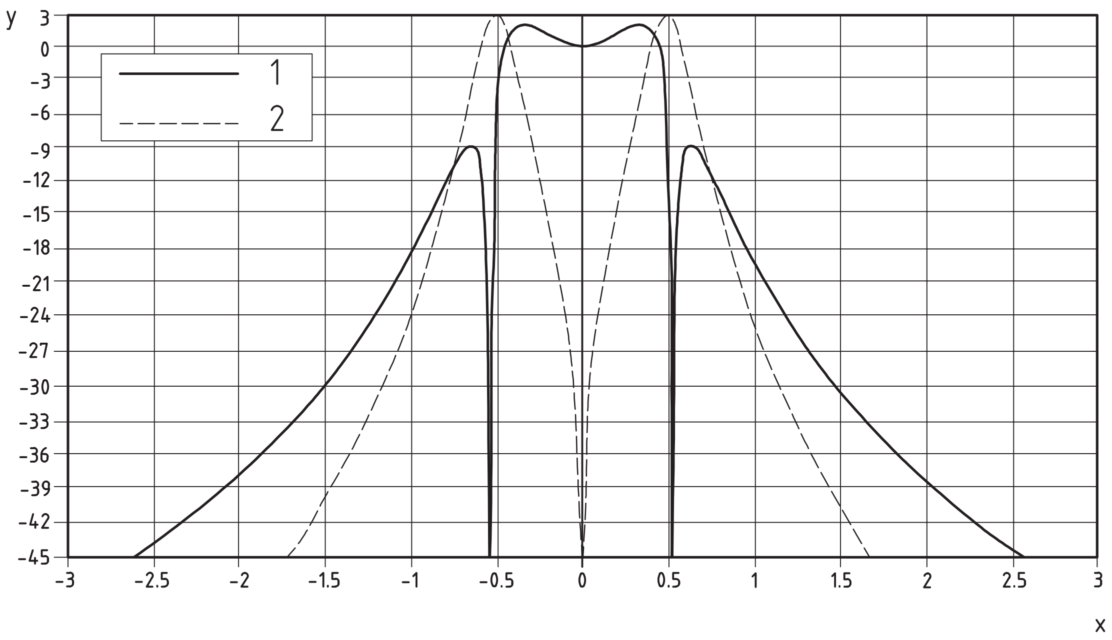
The oscillator, amplifier and current meter should be at least 2 m away from the coil, so as not to affect the magnetic field produced. Similarly, the space around the coil should be free from ferromagnetic and conductive material.

The probe should be placed at the centre of the coil, using the radial lines as a guide. The probe should be orthogonal to the plane of the coil and in its plane.

Annex G (informative) Magnetic field direction near the loop conductor

Figure G.1 shows the patterns of the vertical and horizontal components of the magnetic field of a horizontal loop, and *vice versa* for a vertical loop (such as used in a small loop system). The loop is square and the distance of the listening point from the loop plane is 0.14 times the loop width.

Figure G.1 **Magnetic field patterns**



Key

x Distance from centre/loop width

y Relative axial field strength level, dB

1 Component normal to the loop plane

2 Component parallel to the loop plane

For a horizontal loop, it can be seen that over most of the area of the loop, the vertical component is much stronger than the horizontal. The angle of the magnetic field direction to the vertical is given by:

$$\theta = \arctan(10^{L/20})$$

where L is the level difference between the horizontal and vertical components. For example, if L is –9 dB, θ = 19.5° and the level difference L' in decibels between the vertical component and the resultant vector is:

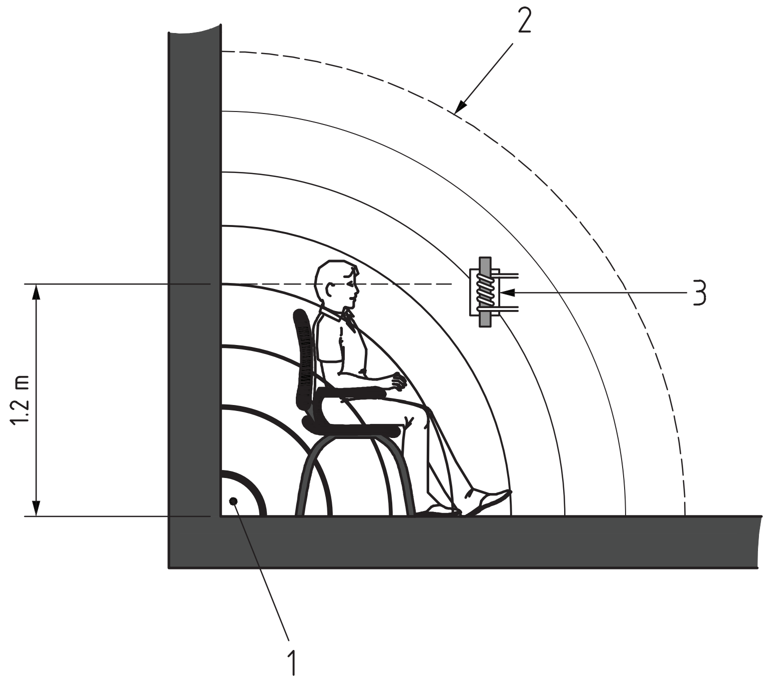
$$L' = 20\lg(\cos\theta)$$

which, in the present case, is –0.5 dB.

However, at distances from the centre of the loop of approximately 0.4 to 0.6 times the loop width the horizontal component of the magnetic field is comparable with, or much stronger than, the vertical component. In this region, the attitude of the hearing-aid user's head may cause the field direction to be perpendicular to the axis of the telecoil, or nearly so, resulting in a significant loss of signal strength.

This effect is illustrated in Figure G.2 and Figure G.3.

Figure G.2 **Magnetic field directions for a floor-level loop**



Key

1 Loop conductor

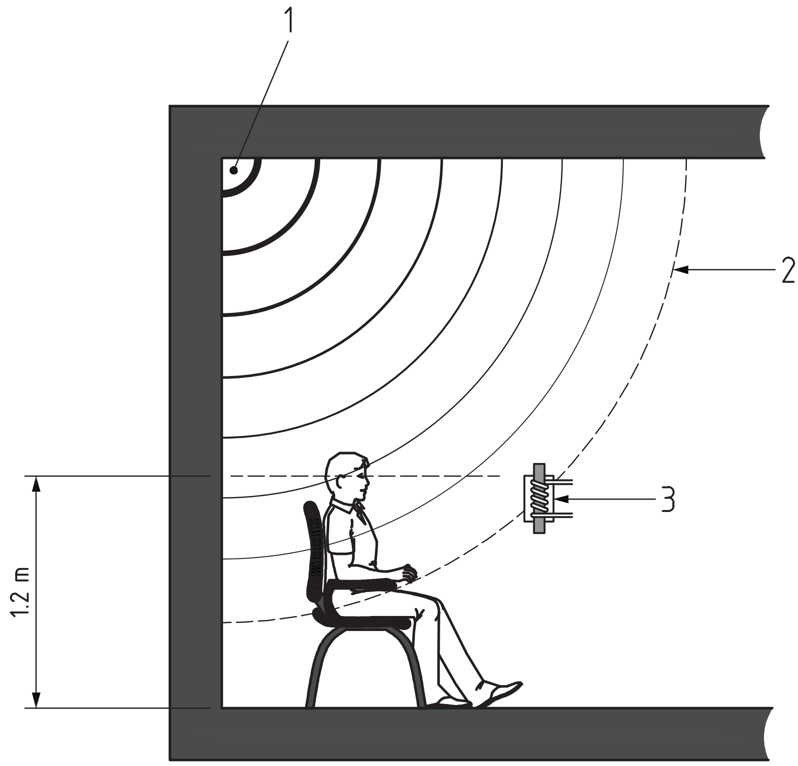
2 Magnetic field direction lines

3 Telecoil orientation

This effect can be eliminated by using a two-loop array with two amplifiers and a wide-band quadrature circuit. Further information on this subject may be included in a future amendment to this standard.

For a vertical loop, as used in some small loop systems, the above considerations are reversed. Because the listener is normally much further away from the loop in proportion to its dimensions than is the case for a large loop, the shape of the field patterns is somewhat different and there are two regions, centred approximately on the top and bottom loop conductors, where the field vector is substantially vertical. Clearly, a large region, centred on the centre of the loop, is outside the useful magnetic field volume.

Figure G.3 **Magnetic field directions for a ceiling-level loop**



Key

1 Loop conductor

2 Magnetic field direction lines

3 Telecoil orientation

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