Acoustic design and equipment for pupils with special hearing requirements

SECTION 6

When considering classroom acoustics, children with a permanent hearing impairment (also referred to as deaf children) have traditionally been treated as a special group, separate from the mainstream school population. This is a situation that is not supported by the surveys of the school population carried out by the British Association of Teachers of the Deaf.

6.1 Children with listening difficulties

A recent survey by the British Association of Teachers of the Deaf (BATOD)[1] showed that about 75% of deaf children were being educated within mainstream schools. With the continuing trend towards inclusive education there is no reason to suppose that this proportion should do anything but increase.

In addition to the children with permanent hearing impairments there are large numbers of children within mainstream schools who have listening difficulties placing them in need of favourable acoustic conditions. These include children:

- with speech and language difficulties
- whose first language is not English
- with visual impairments
- with fluctuating conductive deafness
- with attention deficit hyperactivity disorders (ADHD)
- with central auditory processing difficulties.

Effort given to addressing the acoustic needs of the hearing impaired population also favours other groups whose needs for good acoustic conditions are not dealt with elsewhere in this document. Put together, the number of children falling into one or more of these categories could conceivably be a significant proportion within every mainstream classroom.

6.2 Children with hearing impairments and the acoustic environment

The majority of children with hearing impairments use speech and hearing as their main form of communication. The BATOD survey[1] indicated that 67% of children with hearing impairments were using an auditory-oral approach and a further 26% used an approach which combined sign with auditory-oral components. For these groups a poor acoustic environment can be a significant barrier to inclusion.

A hearing loss is typically described with reference to the audiogram. This is a graphical representation of an individual's threshold of hearing for a number of pure tones (typically measured at 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz and 8 kHz) and presented to each ear using headphones. At face value, it suggests that the hearing impairment can be considered as a simple auditory filter and as such should predict a child's understanding of speech using traditional acoustic models. Although reliable, it says little about an individual's hearing for speech or the key skill of listening to speech with background noise. The audiogram is not a good predictor of educational outcome[2] and only a poor predictor of maximum speech recognition score[3]. Consequently, great care should be taken when considering the audiogram of a child as a predictor of the difficulties the child might have in a school environment.

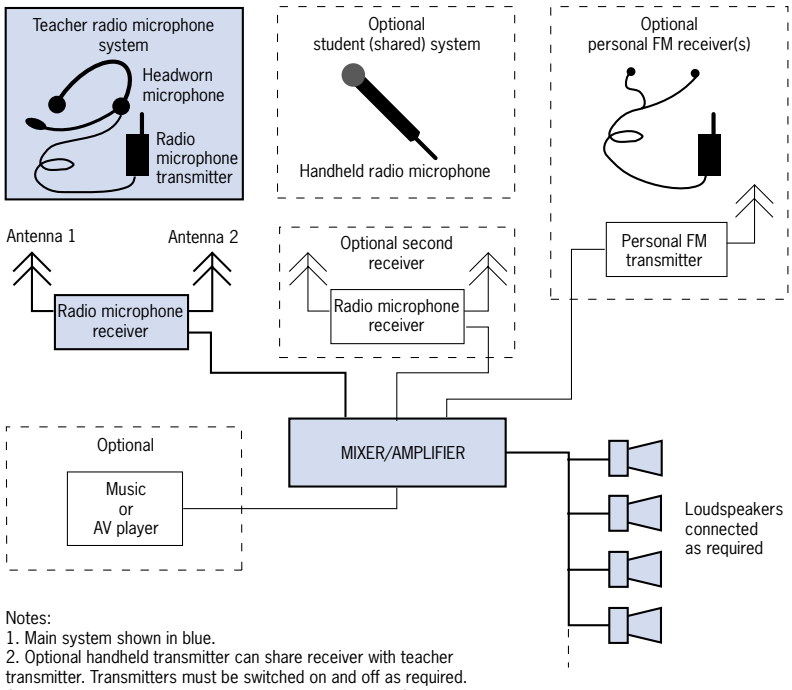
At present there is little empirical data that specifically addresses the acoustic criteria required for the hearing impaired school population (see for example the review of the literature by Picard and Bradley[4]). What is currently available, however, suggests that the individual hearing needs of the hearing impaired child are likely to be more demanding than those of children with normal hearing. It would be helpful for the professional specifying classroom acoustics for a particular child to have available measures of the child's aided hearing and consequent acoustic requirements in terms of, for example, acceptable levels of

large, stand-alone piece of equipment, an auditory trainer can be designed without the restrictions of size that exist with typical behind-the-ear hearing aids, and a good quality high level sound output with extended low and high frequency range can be achieved.

Within the mainstream educational environment, auditory trainers are most likely to be used for short periods of individual work and speech therapy sessions. However, it is also possible to link several auditory trainers together for group work. In some schools for deaf children this equipment is permanently installed within a classroom. The teacher's voice is picked up by a microphone and the output is available at every desk. Each child wears headphones that are configured to meet their individual amplification requirements. The children may also wear microphones to enable everyone in the class to participate in discussions.

6.8 Whole class technology

The use of a personal system is sometimes essential for a hearing aid user to be able to succeed in a particular environment.



Notes:
1. Main system shown in blue.
2. Optional handheld transmitter can share receiver with teacher transmitter. Transmitters must be switched on and off as required.
3. Alternative second receiver allows simultaneous use of teacher and student transmitters.
4. Personal FM transmitter(s) for use by pupils with serious hearing impairment can be connected to output of system.
5. CD, cassette and/or video player can optionally play through the system.

Fig 6.1 A simple schematic drawing of a soundfield system in a typical classroom

There is, however, a trend to use the inclusive technology termed 'sound field amplification' to ensure that the signal level of the speech is delivered to all parts of the classroom at an appropriate level above the background noise. This technology is of benefit for all with listening difficulties in the classroom, not just the hearing aid user, and has particular benefits for classroom management and the voice of the class teacher.

It is important to note that whole class technology is not a substitute for remedying poor classroom acoustics. However, it can be particularly valuable in maintaining good signal to noise levels and improving classroom management. Soundfield amplification systems are also used in conjunction with personal radio aids. In situations where a deaf child is part of a mainstream class, advice should be sought from members of a relevant professional group (educational audiologist, clinical audiologist or teacher of the deaf) as to the most appropriate technology.

6.8.1 Whole classroom soundfield systems

Soundfield systems provide distributed sound throughout a classroom. They use a wireless link between the microphone and amplifier which will operate on VHF, UHF radio or infra red frequencies. Soundfield systems have been shown to be beneficial for hearing children and children with a mild or temporary hearing loss. They will not by themselves usually provide sufficient improvement in signal-to-noise ratio for a child with a significant hearing loss, when a personal radio aid is also usually necessary.

A soundfield system is perhaps more widely known as a sound reinforcement system; the term 'soundfield' system originated from the field of Audiology and continues to be associated with classroom sound reinforcement systems. The technology has matured since it was first introduced into classrooms in the late 1970s in the USA, and has evolved to take into account new technologies and teaching management styles. Its benefits have been variously described as:

6 Acoustic design and equipment for pupils with special hearing requirements

Table 6.1 Recommendations of BATOD and ASHA for the acoustics of classrooms

Acoustic Parameter	British Association of Teachers of the Deaf[5]	American Speech Language Hearing Association[6]
Unoccupied noise level	35 dBA	30 – 35 dBA
Reverberation time (unoccupied)	0.4 s across frequency range 125 Hz to 4000 Hz	0.4 s
Signal to noise level	+20 dB across frequency range 125 Hz to 750 Hz +15 dB across frequency range 750 Hz to 4000 Hz	≥ +15 dB

noise, desirable reverberation times and required signal to noise levels. However, such hearing measures are not routinely obtained.

Because it is not possible at present to provide definitive acoustic requirements for hearing impaired individuals, it is appropriate for acousticians and architects to be aware of the requirements published by specialist professional organisations. These include the British Association of Teachers of the Deaf[5] and the American Speech Language Hearing Association[6] (see Table 6.1). Account has been taken of these recommendations in the setting of performance criteria in Section 1.

6.3 Hearing impairment and hearing aids

Modern hearing aids are designed to make speech audible to the listener without being uncomfortably loud[7]. They deal largely with the issue of audibility and are less able to address the issues of distortion that typically accompany a sensorineural hearing impairment.

One of the major challenges in the design of hearing aids is dealing with noise. Recent developments include the use of algorithms that attempt to enhance speech whilst reducing background noise, and better implementation of directional microphones. However, noise will continue to remain a significant obstacle to effective listening. Noise not only masks the amplified speech signal but also leaves a child tired from the effort required to listen. It is therefore essential that attention be given to creating a quiet classroom.

Sound insulation must be of a high standard, with the lowest background noise levels possible to ensure that a good signal to noise level is achieved. Typically a signal to noise level of +20 dB is considered desirable[5]. Short reverberation times are also critical in ensuring that sound does not build up when the class are working in groups. Care must also be taken to ensure that the level of low frequency noise is kept to a minimum. For many people with impaired hearing, low frequency noise can have a devastating impact on speech recognition, masking many important speech sounds in a manner that cannot be appreciated by those with normal hearing.

6.4 The speech signal and hearing aids

Speech, as a signal, is a critical factor in classroom listening and an important speech source is the teacher. Evidence has shown that teachers' voices are not always sufficiently powerful to deliver the necessary levels of speech required to ensure the best listening opportunities[8]. A growing body of evidence suggests that teachers are at above average risk from voice damage[9]. Few teachers have voice training and the vocal demands of teaching are probably underestimated.

Hearing aids are usually set up to amplify a 'typical' speech signal based on various measures of the long-term average speech spectrum recorded either at the ear of the speaker or at a distance of 1 m directly in front of the average speaker, as if in conversation. If the actual speech signal is weaker than average, perhaps

because of distance, or is masked by babble or steady state background noise such as that from a classroom computer fan, then the hearing impaired listener will have increased difficulty. Listening to speech will become particularly effortful and challenging[10].

Children are not only required to listen to the teacher but also to other children. Children typically have less powerful speaking voices[8] and listening to their peers is frequently identified by children with hearing impairments as being difficult. One study suggests that 38% of a child's time in the classroom might be spent working in groups and 31% of the remaining time spent in mat work[11], both situations where listening to other children is important. There are no wholly satisfactory solutions to this. Technology and careful class management have a role to play but considerable attention needs to be paid to establishing low reverberation times and maintaining low ambient noise levels in order to reduce the auditory difficulties.

To minimise the challenges to hearing, use is often made of small acoustically treated rooms attached to mainstream classrooms in the primary school. These rooms are typically large enough for a group of 4 – 8 children to work in. To allow supervision by the class teacher they will have a large window to allow a clear view into the classroom. The room will need to have a sufficient degree of sound insulation from the classroom to allow the children to talk to each other without being disturbed or disturbing the rest of the class. The favourable acoustic conditions and short distances between children and teacher, if present, ensure that communication is as easy as possible.

6.5 Listening demands within the classroom

Much of educational activity within classrooms revolves around speech. Some experts claim that 80% of all classroom activities require listening and speaking. It is important that within any room the acoustic characteristics allow for effective spoken language communication. The UK version of the Listening Inventories for Education[12] identifies the following listening demands within the classroom:

- listening to the teacher when s/he is facing away from the listener
- listening when the class is engaged in activities
- listening to the teacher while s/he is moving around the classroom
- listening when other children are answering questions
- listening when other adults are talking within the same room
- listening to peers when working in groups
- listening in situations with competing background noise from multimedia equipment.

A teacher should manage teaching in such a way as to ameliorate the challenges faced by a student with hearing difficulties. However, the better the acoustic conditions, the less challenging will be the situations described above.

6.6 Strategies developed to assist children with hearing and listening difficulties

Effective classroom management by the teacher is critical in ensuring that the children can have access to all that is spoken and there are many guidelines available for teachers (see for example publications by the Royal National Institute for the Deaf[13], the National Deaf Children's Society[14] and DfES[15]). Classroom management alone, however, cannot ensure that speech communication is sufficiently audible and intelligible if the classroom acoustics are not adequate, or if a child has a hearing or listening difficulty.

In order to ensure that children are able to hear the teacher and, to a lesser extent, their peers, a number of technological solutions have been developed, see Table 6.2. These solutions that work in tandem with the child's own hearing aids (if used) can be classified as either individual technology or whole class technology. In both these cases it is important to understand the underlying principles when specifying classroom acoustics.

Technology	Advantages	Disadvantages
Personal radio aids	Reduce the effect of the distance between speaker and listener Portable and convenient Particularly useful in situations where there is a poor signal to noise ratio at the position of the listener	Do not address the needs of group work directly Can require a high level of sophistication to gain maximum benefit Benefits can be lost if the child's personal hearing aid microphones are used in noisy environments
Classroom soundfield systems	Reduce the effect of the distance between the speaker and listener Inclusive technology Benefit to the teacher and the class Can ensure good signal to noise levels are maintained throughout the classroom	Do not address the needs of group work directly Poor classroom acoustics (eg high reverberation times or poor sound separation between neighbouring teaching areas) can limit the benefit of this technology
Personal soundfield amplification	Portable Addresses the issue of speaker to listener distance Can ensure favourable signal to noise levels for a particular listener or small group of listeners	Can be cumbersome to transport and manage Does not address the needs of group work directly
Auditory trainers and hard-wired systems	Provide excellent signal to noise levels Provide a high level of sound insulation Can be arranged to allow group work	Users are restricted in movement when using the device Can be heavy and uncomfortable to use Not an inclusive technology
Induction loop systems	Discreet and cheap Most hearing aids have a telecoil facility	Unpredictable acoustic response for the hearing aid user Spill over of signal into other rooms Do not deal with the needs of group work Susceptible to electromagnetic interference User normally isolated from environmental sounds

Table 6.2: Advantages and disadvantages of different technologies for aiding hearing and listening in the classroom

6.7 Individual technology

There are two main types of aid that can be used to assist children's hearing on an individual basis: radio aids that can be coupled to a child's hearing aids, and auditory trainers that are used with headphones.

6.7.1 Radio Aids

Radio aids (also known as radio hearing aids or personal FM systems) are widely used by children with hearing impairments in schools. They help overcome causes of difficulty in a classroom situation by:

- providing a good signal to noise level
- reducing the impact of unhelpful reverberation
- effectively maintaining a constant distance between the speaker and the listener.

All radio aids have two main components: a transmitter and a receiver. The person who is speaking (usually the teacher) wears the transmitter. A microphone picks up their voice. Typically the microphone is omnidirectional and is attached to the lapel of the speaker, however there are head worn microphones available that help ensure a consistent transmitted signal to the child.

The sounds are transmitted by an FM radio signal to the receiver, which is worn by the child. The receiver converts the signal to a sound that the child can hear.

Radio aids are usually used in conjunction with the child's hearing aids. Most children use 'direct input' (also known as 'direct connection' or 'audio input') to the hearing aids using a lead. Direct input is a facility available on many behind-the-ear (post-aural) hearing aids and a smaller number of in-the-ear hearing aids.

Alternatively, the child can use an inductive neck loop - a small wire loop that can be worn over or under clothes. The loop is connected to a radio aid receiver usually worn around the waist or attached to a belt.

Direct input is generally recommended as preferable to the use of a neck loop for children in school. This is because the level of sound that a child hears using a neck loop can be variable and there is a risk of electromagnetic interference from nearby electrical equipment.

Radio aids are also beneficial for children who have cochlear implants. The radio aid receiver is connected to the child's implant processor using a dedicated lead.

Traditionally, radio aid receivers have been worn in a chest harness or on a belt. Recent developments include miniature radio aid receivers that connect directly to a hearing aid and are worn entirely behind-the-ear. Behind-the-ear hearing aids that include built-in radio aid receivers are also being manufactured.

Most radio aids can be set up so that the child will not only hear the voice of the speaker using the transmitter, but also environmental sounds such as their own voice and the voices of other children near to them. Radio aids can do this in a number of different ways and it is often necessary to strike a balance between allowing the child to hear the voices he or she needs to listen to and the impact of hearing unwanted background noise.

For the best listening condition the hearing aid user will normally be required to mute his or her microphone on the hearing aid and listen exclusively to the transmitted voice of the speaker. This is good for formal teaching situations but requires considerable skill on the part of the teacher to include the hearing impaired child in classroom discussion. This solution is less helpful for children engaged in group activity, where the child will need to work with a small group of peers.

Most radio aids are able to operate on a range of carrier frequencies. For example, each school class might have its own frequency so that there is no interference with a neighbouring class. In the UK, radio aid channels lie in the range 173.350 MHz to 177.150 MHz. Those channels in the range 173.350 MHz to 173.640 MHz are dedicated exclusively to use by radio aids. A licence is required to use radio aids operating on frequencies between 175.100 MHz and 177.150 MHz.

The sounds heard by a child using a radio aid will depend on the quality and correct use of their own hearing aids. The level of amplification is determined by the settings of the hearing aids, not the radio aid. Accepted procedures exist for setting up a radio aid to work with hearing aids (a process sometimes known as 'balancing').

A general principle is that if a child uses a hearing aid, then s/he is also likely to find a radio aid helpful in many classroom situations.

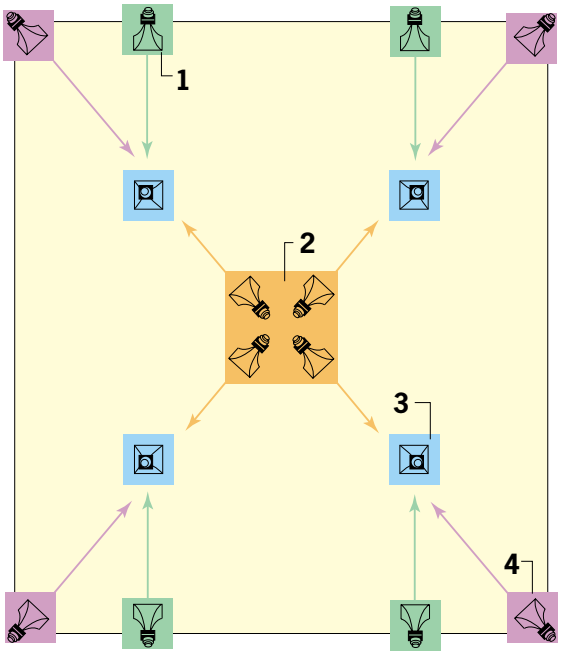
Radio aids have often been seen as the solution to poor acoustics in the classroom. However, it must be noted that they only partially solve the problem; the solution must lie in addressing the issue from three directions:

- the class teacher and classroom management style
- technology that assists listening
- careful attention to classroom acoustics.

Current information about radio aids is available from a number of sources including the National Deaf Children's Society (NDCS)[16].

6.7.2 Auditory trainers and hard-wired systems

An auditory trainer is a powerful amplifier used with high-quality headphones. As a



1 Speakers mounted one quarter of wall length from corners, mounted flush with wall, at 2 m height, directed to point on floor at angle of about 60°.
2 Speakers mounted at centre of room, 600 mm apart in square orientation, directed to the room corners.
3 Speakers mounted flush with ceiling, facing directly at floor, in centres of 4 quadrants of the ceiling.
4 Speakers mounted in room corners, directed to centre of room.

The four speaker layouts were investigated using a computer model to predict the interference effects due to phase changes of the speaker outputs.

Layout 1 causes some peaks in the room, but is likely to work reasonably well.

Layout 2 produces large interference effects and is therefore not recommended.

Layout 3 produces the most even coverage at all frequencies and the least loudspeaker interaction. It is therefore recommended for all rooms where a suspended ceiling exists. Loudspeakers should be selected to provide a wide and even coverage that is constant with frequency.

Layout 4 provides relatively even coverage of the room with interference effects which, although complex, appear relatively benign. Location of loudspeakers in room corners tends to produce a rise in the bass response of systems which will usually require equalisation using system controls to produce optimum speech clarity and naturalness.

Layouts 1 and 4 using wall mounted loudspeakers are recommended where ceiling mounted units are not practical. For layout 1 speakers should be mounted at least 1 m from the side wall. Location of wall mounted speakers at least 2 m above the floor, and at least 600 mm below the ceiling is recommended. Brackets should keep the loudspeakers very close to the wall to minimise self-interference effects.

Fig 6.2 A plan of a classroom showing four alternative speaker layouts. *The speakers are drawn horn-shaped to show the directionality of the speaker output, in fact many modern speakers are flat*

- academic improvements for all class members
- more on task behaviour
- greater attentiveness
- improved understanding of instructions
- less repetition required from the teacher
- improved measures of speech recognition
- reduced voice strain and vocal fatigue for the teacher.

6.8.2 System overview

Figure 6.1 shows a simplified block diagram of a typical soundfield system. Each element shown can be a separate unit, or some of these can be combined into an integrated unit. The current trend is for manufacturers to create more integrated products, designed especially for classroom soundfield use. Typical arrangements of loudspeakers are shown in Figure 6.2.

Table 6.3 describes the various components of a soundfield system. A possible detailed specification is included in Appendix 9.

Where a soundfield system has not been designed specifically for the classroom it should be used for a trial period before being selected from the range available. The manufacturers and resellers should all provide installation information including commissioning of installations, operating instructions and ongoing support. Large rooms or rooms that are unusually shaped will usually need specialist advice. Teachers must receive adequate training in using the systems.

6.8.3 Personal soundfield systems

A child who cannot physically wear a conventional hearing aid, who has a unilateral hearing loss, or has Central Auditory Processing Disorder or

Component	Requirements	Comments
Loudspeaker Wall mounted, ceiling mounted and flat panel speakers are used in schools.	The purpose should be to provide high quality distributed sound reinforcement throughout the whole classroom and over the whole speech frequency range. Selection of appropriate speakers should therefore address this requirement.	Often the location of loudspeakers is determined by the necessity to fit in with the current use of the classroom, when not installed as part of the original building work.
Microphone and transmitter Using Infra red, UHF or VHF carrier frequencies and high quality headworn or lapel microphones. Radio system information is available at www.radio.gov.uk	This should be a high quality system which retains both the frequency and dynamic properties of speech. It is important that teaching styles can be accommodated so a choice of microphones should be available. It is important that the transmitter can operate without interference from other systems or from public services.	In order to retain good dynamic range a compander system is typically required (see Figure 6.3). A head worn microphone can improve the consistency of the transmitted signal and help to prevent feedback that is present in systems that do not have feedback control technology. However teachers often like a choice of microphone and will use headworn, lapel or wrap around microphones depending on activity and personal preference. Battery life of at least one school day is essential for a transmitter if it is to be acceptable for school use.
Receiver Matched to the Transmitter	Will provide a complementary system to the transmitter, avoiding interference or frequency dropout.	A compander technology and diversity system is particularly suitable for classroom use, ensuring good dynamic range and avoiding frequency dropout respectively. Some teaching situations require twin channel inputs, so that a pass around radio microphone can be used. Where infra red systems are being used separate additional receivers might be necessary to avoid 'blind spots'.
Amplifier	The amplifier should be correctly matched to the loudspeaker system. It should offer a wide flat frequency response which can be adjusted if necessary. It should allow for additional inputs from multimedia within the classroom, such as the TV, computer and radio and outputs to radio systems.	Some schools might require an additional output facility for use by deaf children with personal FM systems. The amplifier is usually combined with the receiver unit.

Table 6.3 Components of a soundfield system

Attention Deficit Disorder, might use a portable soundfield system. Personal soundfield systems comprise a radio transmitter and microphone worn by the teacher and a small, portable unit for the child. The portable unit includes an FM receiver, amplifier and loudspeaker and is designed to be carried around school by the child and placed on the desk next to them. The sound of the teacher's voice is amplified and played through the loudspeaker.

6.8.4 Infra red technology

Infra red technology has been available for many years with little market presence. However, this technology has recently undergone considerable development and

Technology	Advantages	Disadvantages
Infra red Frequency range 2.3–2.5 MHz	Physically limited to enclosed room Allows equipment to be shared between rooms Wideband transmission Can be used with personal hearing aids using a neck loop (an induction loop worn round the neck)	Occasionally needs extra IR receivers in a room
Radio VHF narrowband 173.35–177.15 MHz	Reserved frequency bands for use in schools Many frequency bands available Equipment compatible across manufacturers	Poor signal quality when compared to wideband
Radio UHF wideband 790–865 MHz	Can allow a higher quality signal than narrow band equipment Many frequency bands available, although a site licence might be required	Not available for personal FM equipment

Table 6.4 Advantages and disadvantages of infra red and radio technologies

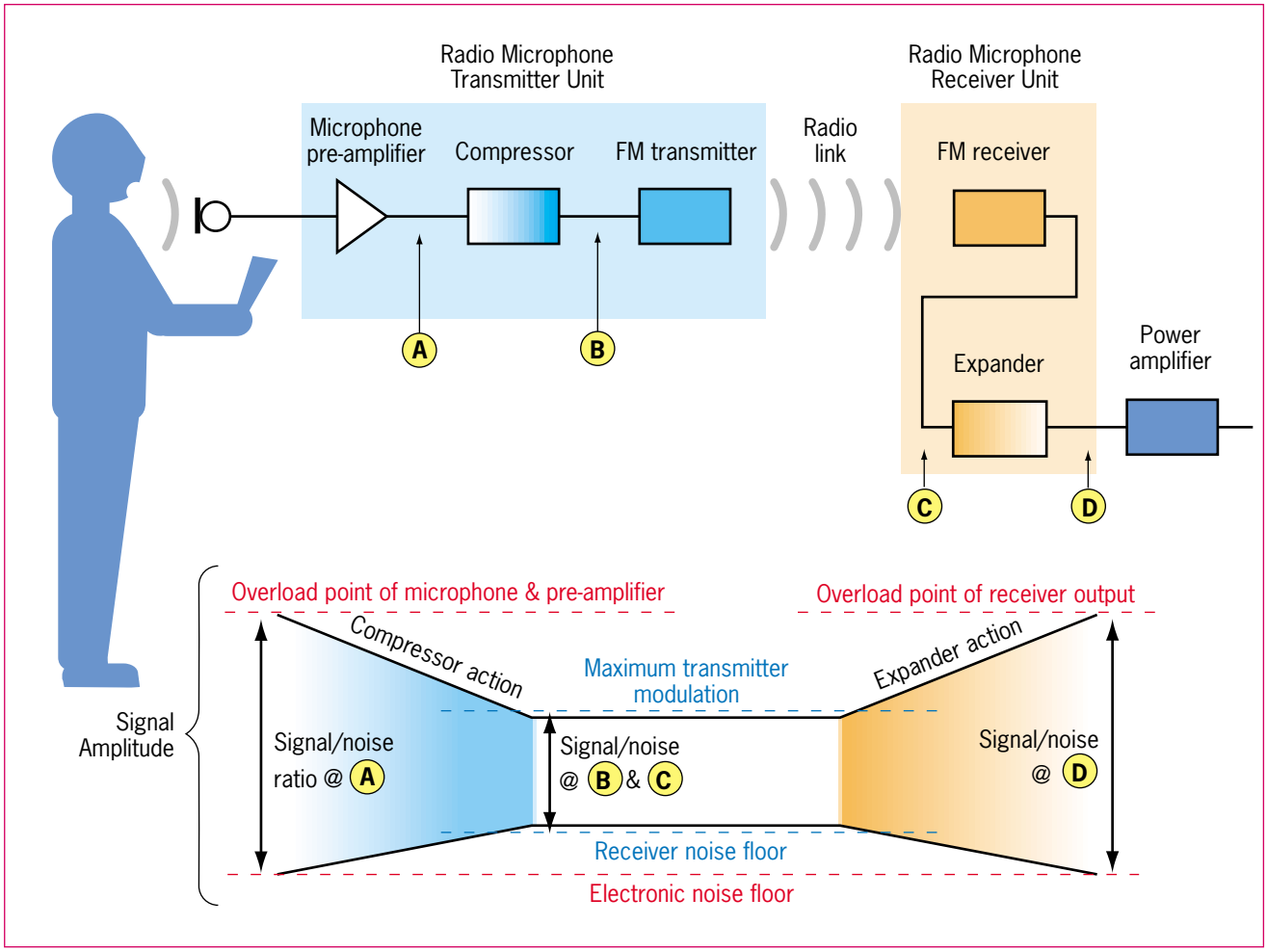


Fig 6.3 FM Radio Microphone System

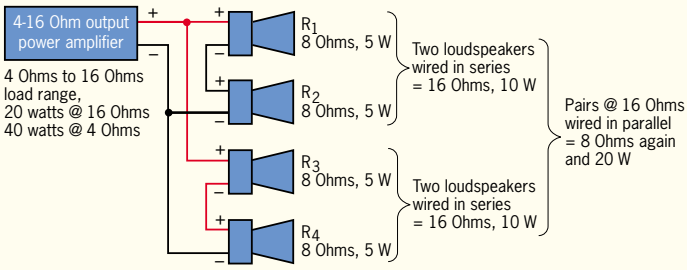
EXPLANATION OF TECHNICAL TERMS

Matching Loudspeakers and Amplifier

Audio power amplifiers for sound reinforcement are made with two main types of outputs described as "low impedance" and "100 V" or "high impedance". Similarly loudspeakers come in 4 or 8 ohms (low impedance) or 70 V or 100 V (high impedance).

Low impedance amplifiers and loudspeakers

If an amplifier is rated for 2, 4, 8 or 16 ohms, then it is a low impedance type. Care must be taken to ensure that the loudspeakers add up to a total load that is both within the amplifier's power rating (W or watts), and between its maximum and minimum load impedance range. Low impedance speakers, usually rated at 8 ohms for smaller types, have to be connected in a way that creates a total load within the range the amplifier is designed for. High impedance, 100 V or 70 V loudspeakers cannot be used satisfactorily. The advantage of low impedance systems is optimum audio performance, especially at low frequencies. Hi-fi loudspeakers are usually low impedance.



Calculating the load impedance

For loudspeakers wired in series – add up the individual impedances $R_{total} = R_1 + R_2 + ... + R_N$

– add up the individual power $P_{total} = P_1 + P_2 + ... + P_N$

For loudspeakers wired in parallel – add up reciprocals of the individual impedance

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + ... + \frac{1}{R_N}$$

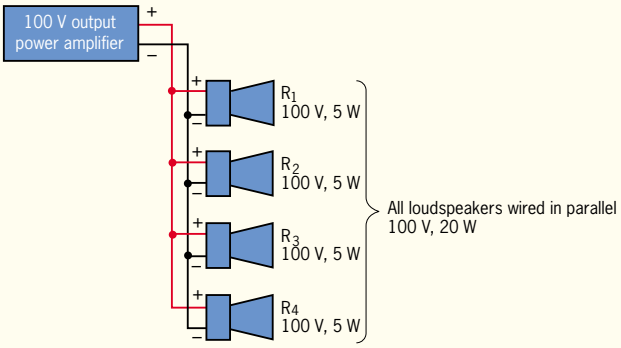
– add up the individual power $P_{total} = P_1 + P_2 + ... + P_N$

In above example $R_1 + R_2 = 8 + 8 = 16$ for each series pair = R_{1+2}, R_{3+4}

Wiring the pairs in parallel gives $\frac{1}{R_1+R_2} + \frac{1}{R_3+R_4} = \frac{1}{16} + \frac{1}{16} = \frac{2}{16} = \frac{1}{8} = \frac{1}{R_{total}}$

Therefore $R_{total} = 8$

High impedance, 70 V or 100 V amplifiers and loudspeakers



Calculating the load impedance

Impedance is taken care of automatically by the 100 V transformer in the system.

Total power is the sum of all devices connected.

is available to be used with many of the technologies identified within this section.

One of the major developments is the use of the 2.3 MHz and 2.5 MHz frequencies, allowing greater resistance to interference from fluorescent lighting and sunlight.

Table 6.4 compares the advantages and disadvantages of infra red and radio technologies.

6.8.5 Induction loop systems

Induction loop systems take advantage of the telecoil facility available with most hearing aids and cochlear implants. A telecoil is a small receiver capable of picking up audio frequency, electromagnetic signals. It is usually activated by setting a switch on the hearing aid to the "T" position. An induction loop system comprises a sound input (usually a microphone), an amplifier and a loop of cable which is run around the area in which the system is to be used. The loop generates an electromagnetic field which is picked up by the telecoil in the hearing aid. The hearing aid user will hear the sound while they are within the looped area.

Induction loop systems have many applications, from large-scale installations in theatres and cinemas to small, domestic products used to listen to the television. In the UK they are now rarely used in a classroom setting. Alternatives such as radio aids offer improved and more consistent sound quality and are less susceptible to interference. Induction loop systems can also be difficult to use in multiple applications, as the signal from one area can overspill into another.

In schools, induction loop or infra red hearing aid systems should be considered in large assembly rooms or halls. This is primarily for visitors to the school rather than for deaf pupils themselves, who would normally have their own assistive listening equipment. They should also be considered in performance spaces, meeting rooms and at reception area desks. In such situations the output from an existing PA system is often connected directly to the loop amplifier.

Pay phones in schools should have

inductive couplers (a form of induction loop).

Induction loop systems should be installed in accordance with British Standard BS7594. Their advantages and disadvantages are listed in Table 6.2.

6.8.6 Audio-visual equipment

Wherever possible, classroom equipment should be integrated with the assistive listening devices used by deaf children. For example, the audio output from audio visual equipment, televisions and cassette recorders, can be connected to radio aid or soundfield transmitters. 'Direct input' leads are available to enable the audio output of computers or language laboratory equipment to be connected directly to a child's hearing aid.

6.8.7 Other assistive devices

There is a wide range of other devices that can be used by deaf children in school, besides those that primarily assist listening. These include subtitled and signed video, speech recognition software and text telecommunication devices, eg telephones.

For further details of these devices contact the professional or voluntary organisations listed at the end of this section. Furthermore, it is recommended to seek advice to ensure that all public spaces meet the needs of deaf and hard of hearing people.

6.9 Special teaching accommodation

It is not the intention within this document to address the needs of special schools for deaf children. Specialist advice should always be sought from an educational audiologist or acoustician when designing or modifying accommodation for this particular purpose.

Many hearing impaired children attend mainstream schools with resource facilities, sometimes called 'units'. These contain specialised rooms that exceed the acoustic specifications for regular classrooms. Within these rooms, children are able to learn the language skills that might not be possible in a busy mainstream classroom. They are also

EXPLANATION OF TECHNICAL TERMS CONTINUED

High impedance, 70 V or 100 V amplifiers and loudspeakers

If an amplifier is rated for 70 V or 100 V, then it is a high impedance amplifier. It will also have a power rating. High impedance loudspeakers, rated at 70 V or 100 V must be used. All loudspeakers should be either 70 V or 100 V. In this case the loudspeakers are simply wired in parallel and their individual power requirements are added up. Thus four 100 V loudspeakers rated at 5 W would be wired in parallel and will provide a 20 W load to the amplifier. External transformers can be added to low impedance loudspeakers to convert them for high impedance use. The advantage of this method is simple wiring. PA, paging and SFS loudspeakers are usually 100 V types in the UK.

Radio Microphone System

Compander system (See Figure 6.3)

FM (frequency modulated) radio links provide a signal to noise ratio that is determined by the modulation bandwidth of the transmitter. Wider bandwidths allow fewer channels in a band of available frequencies, so regulations limit the bandwidth to two system types described as wideband FM and narrowband FM. Even wideband provides a limited signal to noise ratio of about 65 dB from real products. This is adequate if everything is perfectly adjusted so that a user's voice hits just below the maximum permitted signal level. However real users vary their voices, different users share systems AND they are often not correctly adjusted anyway. A compander system combines a compressor on the transmitter of the system, and an expander on the receiver. The two are matched in their action so that the result on the receiver output is very close to the original input signal. What happens is that a larger signal range of say 90 dB is compressed by 50% to fit into 45 dB. This allows for an improved safety margin in the transmitter so that it does not overload, and allows a wide working range that will tolerate user variations. At the receiver the 45 dB range is expanded back to 90 dB. This pushes the system noise down and the signal up. The result is a signal free from distortion due to overload and with a much reduced background noise when a soft talker is turned up at the receiver.

Diversity receiver

A FM radio microphone system emits a signal that has a fairly long wavelength. The waves can reflect from room surfaces and arrive at the receiver antenna in a way that causes the waves to cancel. The result is a "dropout" which will be heard as a disappearance of the audio from the system. If the dropout is maintained, for example if the user is standing still in a location that produces a cancellation, the receiver can even hunt and locate an alternative signal to lock onto - though this is uncommon. A diversity receiver provides two independent radio and audio paths, including two spaced antennae. The spacing minimises the risk that both antennae will receive a cancelled signal simultaneously. The unit will automatically and instantaneously select the stronger of the two signals to the audio output. While audio dropouts may be only slightly disturbing to a person with normal hearing, the hearing impaired child, especially one reliant upon a personal FM receiver, will get nothing and could therefore frequently lose the whole meaning or context of a piece of verbal information. Therefore, where possible, diversity receivers should be used.

places where children can interact within a favourable acoustic environment.

It is not uncommon for these rooms to be used for 'reverse integration', where a small group of children from the mainstream work with the hearing impaired children. Occasionally this provision may be directly attached to a mainstream class in the form of a 'quiet room' leading from the classroom. In other situations the accommodation might be a separate room or even building. Teachers and support professionals might also use the areas for a range of activities involved in the audiological management of the hearing impaired child. Case Study 7.6 describes a junior school with a hearing impaired unit, now renamed as the RPD (Resource Provision for the Deaf). The characteristics of rooms in an RPD are:

- excellent sound insulation
- very short reverberation times
- very low ambient noise levels
- flexible space for individual and small group work
- good lighting
- storage facilities for audiological equipment.

Organisations

British Association of Audiological Scientists	http://www.baas.org.uk/
British Association of Educational Audiologists	http://www.edaud.org.uk
British Association of Teachers of the Deaf	http://www.batod.org.uk
British Society of Audiology	http://www.b-s-a.demon.co.uk
National Deaf Children's Society	http://www.ndcs.org.uk
Royal National Institute of the Deaf	http://www.rnid.org.uk/

Glossary

Term	Explanation
Natural-oral approach	An approach to the education of children with hearing impairments that seeks to promote the acquisition of spoken language using residual hearing
Residual hearing	A term used to describe the hearing abilities that remain in the case of a hearing impairment
Hearing aid	A battery powered device worn by an individual, either behind the ear or in the ear. A hearing aid will be selected and programmed to provide the maximum audibility of the speech signal consistent with an individual's residual hearing.
Cochlear implant	A special kind of hearing aid where the inner ear is directly stimulated electrically via an implanted electrode.
Central Auditory Processing Difficulty	A broad term used to describe listening difficulties, which are not due to the outer, middle or inner ear.
Radio aid	An assistive listening device, designed to provide an FM radio link between a transmitter (usually on the speaker) and the listener (coupled directly to the hearing aids).

6.10 Beyond the classroom

As far as possible children with hearing impairments should be included in all school activities. Improving listening conditions through better acoustics is a very important part of this, but not the only relevant factor. There are many others such as teaching style and context, staff training, deaf awareness issues, and a whole school approach to special educational needs.

Classrooms are not the only places where hearing impaired children interact. It is often overlooked in school design, but critical learning and interaction takes place outside the classroom, and if hearing impaired children are to be fully included, attention should be given to all areas of the school where the children might be expected to interact with others. These areas include rooms where aspects of the curriculum are delivered: libraries, assembly areas, sports halls, music rooms, ICT suites and gymnasia. In these areas the need for good speech communication is essential although constrained by the activities taking place.

Inclusion in most music activities requires good acoustic conditions, good planning and structuring of lessons, and the appropriate use of assistive listening devices.

Perhaps the most difficult areas for inclusion are large spaces such as assembly halls and sports halls. These areas require careful design and forethought.

In other areas, not used for delivering the curriculum, children still need to be able to interact verbally. These include the corridors, cloakrooms, medical rooms, school office, dining room, play areas and toilets. In these communal places important social interaction often takes place and if inclusion is to be effective, these areas need to be designed with the acoustic needs of the hearing impaired child and the child with listening difficulties in mind.

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