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MUSIC FOR DEAF AND PARTIALLY HEARING PEOPLE

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INTRODUCTION

It is often said that blindness cuts one off from things but deafness cuts one off from people. Deafness is a disability comparable to blindness in severity yet it gets little sympathy: on the contrary deaf people are often the subject of humour.

The importance of music really needs no justification to this audience, but it might be as well to point out the large part music plays in the lives of people who would not consider themselves music lovers. True, the latter might notice how much they were involved with music only if it were absent (eg in cinema and TV) but it would be sorely missed. Music has a calming and time passing effect quite apart from it being enjoyable and sometimes uplifting.

Deaf people are already cut off from much ordinary communication and contact. The impetus for this work came from the desire to reduce this isolation in the field of music and, through enhanced perception, to allow music to be enjoyed to the greatest degree possible.

There is no doubt that musicality is a function of the mind and not of the ears: the ears are simply the channel [1], [2].

About 1 child in a thousand is born deaf. To this figure can be added those who go deaf in early years through a range of childhood ailments. However the proportion for partially hearing people is much higher. People who become deaf after childhood through illness or accident are usually known as *deafened* and among those are found nearly all of the very very small number of people with no hearing at all. Older people who are more often than not hearing impaired to some degree, and where the hearing loss is pronounced they are known as *hard of hearing*.

Totalling all forms of hearing impairment gives an estimate of about 1 person in 7 with a significant hearing loss.

TYPES OF DEAFNESS AND THE SCOPE FOR ENHANCING THE PERCEPTION OF MUSIC

Contrary to popular impression, people who are deaf are able to hear to some useful extent, in all but a very small proportion of cases. This applies even to the profoundly deaf. Technology can be harnessed to use this residual hearing to best advantage. The author describes the process as "tailoring the sound" to suit the individual's hearing. Naturally, the task is much easier for the hard of hearing and for those young subjects with partial hearing, and the challenge here is to find effective and inexpensive solutions. For those with less hearing this "tailoring" is supplemented by a visual display and/or by devices to give a vibro-tactile impression of the music.

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In the case of those deafened people who have no useful hearing at all both the visual display and the most sophisticated version of the vibro-tactile equipment are believed to be essential. In addition, it appears on limited evidence, that the subject needs to have built up a substantial "model" of music before becoming deafened, which is as one might intuitively expect.

The visual display and the vibro-tactile system are beyond the scope of this paper but the display will be demonstrated at the conference and the vibro-tactile system briefly described.

There are two main categories of deafness: conductive and sensory-neural. An example of the former would be a perforated ear drum. Conductive deafness is nowadays less of a problem than it was with advances in pre and post natal care and in medical and surgical treatment. Further, a conductive hearing loss does not exceed 60 to 65 dB. Even where both the ear drum and ossicle chain are completely absent the loss would not exceed this figure. A loss of about 40 dB is more typically found. Hence with suitable amplification and equalisation, it is possible to arrange a hearing situation which is adequate, or even very satisfactory, for music. Conductive hearing loss will therefore be discussed no further in this paper.

In contrast, sensory-neural hearing loss is not just a matter of a given attenuation of sound at each frequency in the hearing range but in addition gives rise to a loss of clarity due to loss of temporal and frequency resolution. Excessive amplification giving too high an input volume exacerbates this loss of clarity (hence the advice not to shout at deaf people).

In addition, for people with moderate to severe sensory-neural loss, there is nearly always another problem: that of reduced dynamic range. To discuss this we need to introduce the concept of the *loudness discomfort level* (LDL), and to relate this to *threshold of hearing*, and the *threshold of pain*. The meaning of these terms is self explanatory.

A person with good hearing has a threshold of hearing in the range - 10 dB to + 10 dB hearing level, the figure generally decreasing with age, so that +20 dB might be typical of middle aged people. The LDL will be in the region of 105 to 115 dB with the threshold of pain in perhaps the region 120 to 130 dB.

By contrast the threshold for a person with moderate to severe sensory-neural deafness might be 50 - 75 dB hearing level and the LDL would very probably be similar or somewhat lower than for a person with good hearing (not higher as one might reasonably expect). A typical value for the LDL would be 90-100 dB hearing level. This means that the dynamic range is restricted to 15-50 dB and in extreme cases can be as low as 5 dB.

When a small increase in input volume gives a disproportionate increase in perceived volume the person is said to suffer from *recruitment of volume* - often a most debilitating condition. Unfortunately this term seems to be ill defined and is sometimes applied to any case where the gap between threshold and LDL is less than some arbitrary figure.

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When deafness becomes more profound, eg a hearing loss of 100 to 120 dB, then recruitment is not often a problem.

Two further charateristics of sensory neural deafness are impaired pitch perception and impaired temporal resolution.

THE USE OF DYNAMIC RANGE COMPRESSION

Since music varies in volume over a range of about 35 to 110 dBA the need for volume compression is obvious: without it a deaf person will suffer discomfort or even pain and will react by turning the volume down (or if using a hearing aid by turning it down or off). In consequence the quiet passages cannot then be heard and a deaf person will often ask "has the music stopped now?

A hearing curve for such a case is shown in fig 1 and the use of a dynamic range compressor to alleviate the situation is shown in fig 2. A suggested procedure for making the adjustments will be found in [3].

Unfortunately the gap between the threshold and the LDL varies considerably with frequency. This means that different degrees of dynamic range would appear to be required at different frequencies. Attempts have been made in the speech field to divide the frequency range into as many as 16 bands with individual compression for each [4]. However, the information of the spectral shape of the sound is then lost and results for improvements in speech comprehension have generally been disappointing. Equal or better results for speech seem to have been obtained using only two bands [5]. The same may not of course apply to music since the spectral shape may be less important.

Compression has a deleterious effect on music in that practical compressors can neither look ahead nor react instantaneously. The author has been attempting to minimise these effects for music by finding suitable settings for compression in two stages, the first being slow acting compression, almost like an AGC system (where the benefits for speech intelligibility are quite well established) [6], with the second fast acting.

Another approach which can be used as well as or instead of the above is as follows. It seemed obvious that account should be taken of the fact that in practice, many deaf people are adversely affected only by loud bass notes or loud treble notes. Hence an approach is to split the overall sound into two widely overlapping bands, "bass" and "treble". This can conveniently be achieved using a pair of graphic equalisers. Compression can then be applied to the two bands individually. If such two band compression proves adequate it will keep down the costs.

For some individuals it has been found necessary to compress just the bass or just the treble. This reduces the cost of the system required as well as the deleterious effects of compression, simply by minimising the use of compression to where it is actually required for the individual.

EQUALISATION

Equalisation is the second part of the "tailoring process". While equalisation is most useful it is quite wrong to imagine that one can merely take the audiogram curve and invert it to provide an effectively flat response. Firstly

the ordinary audiogram shows the threshold of detection of sound at each frequency: it does not show whether musical sound can be interpreted at a given level. Secondly sound at some frequencies may be perceived as distorted or perhaps accompanied by an unacceptable level of perceived noise, so the far from boosting certain frequencies they should be cut for the best subjective result.

From a moderate amount of practical testing the author has concluded that one might almost ignore the audiogram and set up the equalisation by guiding the user through a procedure he carries out himself.

Graphic equalisers with seven or more bands for each stereo channel are commercially available at moderate cost. However the range is usually restricted to + & - 12 dB which is quite inadequate in many cases. A parameterically controlled amplifier is then useful in carrying out the "course" equalisation, leaving the fine adjustment to the graphic equaliser. Alternatively, for people for whom stereo is not useful, an inexpensive solution can be to use both halves of an equaliser, intended for stereo, in sequence. A simple resistive divider between the two halves may be necessary to prevent excessive signal levels causing distortion.

However one needs to take care before discarding stereo sound. Some profoundly deaf people have astonished the author by their abilities in distinguishing stereo from mono recordings.

A considerable number of profoundly deaf people have reasonably good hearing in the extreme bass range. Attenuation rather than amplification may be required at these frequencies. This is mentioned mainly to draw attention to the very extreme equalisation which may be required. An additional reason for taking great care with equalisation in such cases is to avoid masking of the higher frequencies.

WHY NOT SIMPLY RELY ON THE HEARING AID?

Since the purpose of a hearing aid is indeed to "tailor" the sound to suit the individual, why not make use of it instead of using external audio equipment and loudspeakers or headphones? The question is a reasonable one particularly as the more modern and sophisticated aids include equalisation and compression.

Firstly the aids are optimised for speech, not music. Secondly, many aids employ peak clipping to limit the volume. For speech intelligibility, clipping is often preferred to compression, but its effect on music is of course disastrous. Thirdly, compromises have to be made in view of the desired physical size, weight and battery life. Moreover, the operating voltage is very low which places restrictions on the circuit design. An >PA additional reason is that unfortunately deaf people are not always using the most appropriate hearing aid for their hearing loss.

For listening to recorded music none of these compromises need be made.

However in some cases of profound deafness the author has found that better results have been obtained with the hearing aid than listening through headphones. Why should this be? Reasons advanced are:

1. The headphones may not be loud enough. (Is it possible to obtain headphones giving good quality sound which are also capable of high sound output levels?)

2. The person may have become used to sound distorted in a certain way and prefer this to some sound which is "purer" to good ears.

3. Dynamic range compression, across the range of frequencies, may have been carried out less well than by the hearing aid.

FURTHER ENHANCING THE PERCEPTION OF MUSIC

So far the methods can be applied to any source of recorded sound. We can go further if we use sound generated by electronic means. The sound of conventional acoustic musical instruments often contains a good deal of noise. If this noise is not included in synthesised sounds produced by say an electronic organ or harpsichord, then people will complain that it sounds wrong - they will probably say that it sounds "electronic". However for deaf people different criteria apply and the author has had good results with sound synthesised without added noise compared to acoustic instruments of generally similar timbre.

With freedom to choose envelope shapes which give clear perception, good results have been obtained with sound envelopes which give a rapid attack, a fairly rapid initial decay and which then remain at a constant sustain level. (No real instrument sound has a similar envelope.) Alternatively, similar results can be obtained by doubling an electronic harpsichord with an electronic organ, both sounds being chosen on the basis of "purity" and without added noise. It is believed that the initial rapid attack and fairly rapid decay help to clearly define a new note and the sustained part helps in the perception of pitch.

A pitch shift into the best hearing range can be made and this is especially easy to accomplish if a MIDI system is in use. The MIDI system is also particularly convenient for the arranging of doubling of instruments, either in unison or at octaves.

A step further can be taken with computer generated music, whether the sound is generated internally or via MIDI external devices. To discuss this we introduce the terms *release time*, *release rate* and *detachment gap*. When a a keyboard instrument is being played, the release time is the moment a key formerly held down is released. The release rate is the rate at which the sound dies away. If a note is released before the next note is played the note will sound detached (giving a staccato effect) whereas legato notes are produced by not releasing a key until the next note in that voice is sounded. The time between the release and the start of the next note in the same voice (part) is the detachment gap.

Useful results have been obtained by making the detachment gap significantly longer than would be desired by people with good hearing. If one had ones own private orchestra one could ask them to play in a more detached way! with the computer system one merely selects a detachment gap!

Note that for detachment to be effective the release time has to be short otherwise the first note will not have died away sufficiently before the next note starts.

With sound generated in this way, there is no need for a dynamic range compressor: the volume profile can readily be adjusted by the computer system, giving more precise control with no degradation of quality.

In order to utilise the visual display system adopted and/or the vibro-tactile system, the music must in any case be computer generated. A complete package has been produced to which the name *VISTAMUSIC* has been given, standing for VISual and TActile MUSIC.

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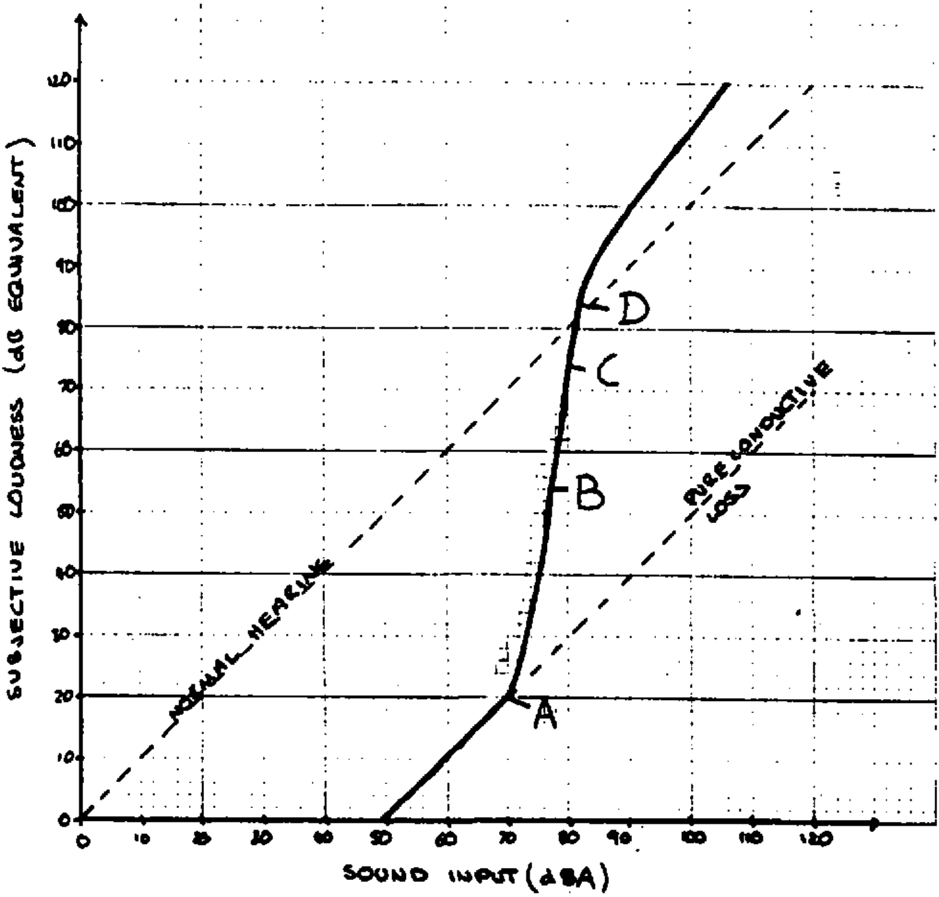
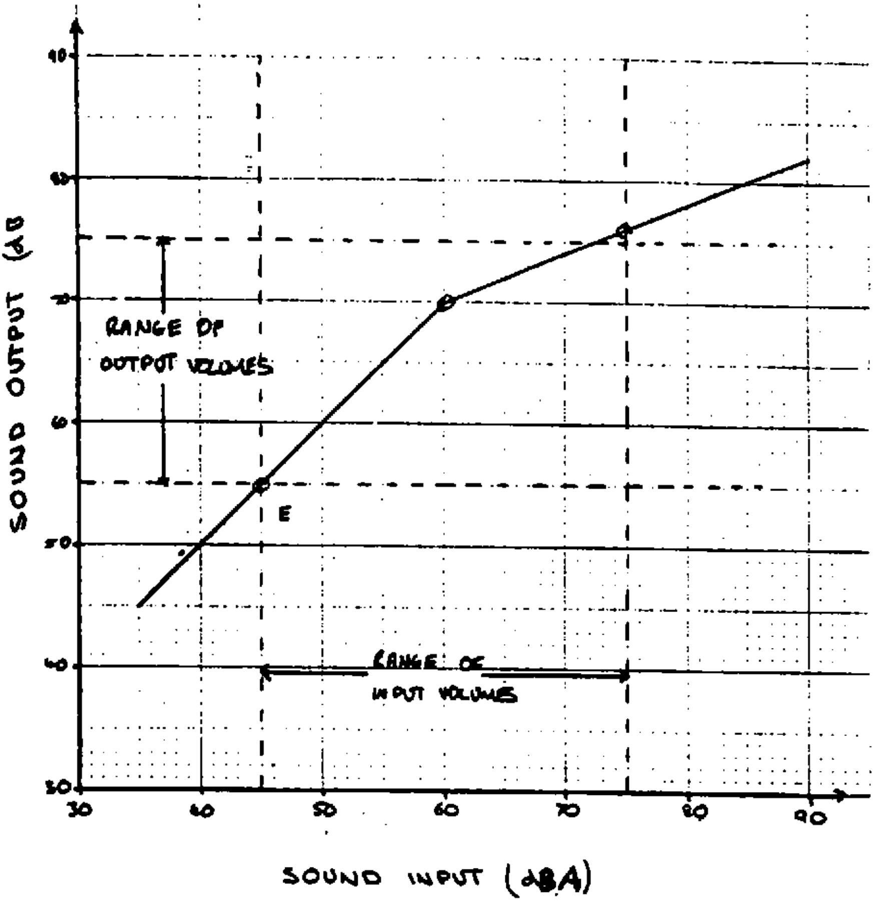
FIG 1



A – Point of change of slope
B – Onset of distortion
C – Loudness discomfort level
D – Onset of extreme discomfort or pain

FIG 2


SOUND OUTPUT (dB
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RANGE OF
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30
40
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SOUND INPUT (dBA)