THE PROBLEMS ASSOCIATED WITH LOW FREQUENCIES IN HEARING AID AMPLIFICATION

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Speech consists of frequencies ranging from about 100 Hz to 10 KHz. The range important for good understanding of speech extends from about 400 to 3000 Hz. (Silverman *et al.*, 1960). In whispering, low frequencies are absent since the vibration of vocal cords does not occur. The absence of low frequencies makes the speech less audible. But in normal conversation vocal cords vibrate and consequently speech is carried to a greater distance. Further, experiments have shown that if high frequency components are suppressed, speech remains highly audible and ceases to be easily intelligible. From these findings it is evident that the low frequency components (mainly vowels) give power or energy to speech but intellgibility is provided by high frequency components (consonants). This differential functioning of high and low frequencies in the production and perception of speech has been a source of technical problem in the production and use of hearing aids.

In this paper the problems associated with low frequencies in hearing aid amplification are briefly reviewed; a modified earmould, suggested by Harrison (1969) as a possible solution to these problems, is examined; and two probable explanations as to how this acoustic modification might help are suggested.

To begin with, the problems posed by the low frequencies. In the first place if all the frequencies are uniformly amplified, low frequency components exceed the tolerance level before the components of high frequency become audible. This is because low frequencies are higher in intensity. This is shown more specifically, in Table 1, taking 145 dB speech level after amplification as an example.

TABLE 1

Speech level after amplification exceeds the tolerance limit for low frequencies

(dB SPL)

	Low Frequency	High Frequency
Normal conversation	65 dB	30 dB
Threshold		80 dB
Gain required		80 dB
Speech level after amplification	145"dB	110 dB

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If we reduce the gain by, say, 30 dB so that the low frequencies will be below the Tolerance Level, the high frequency components do not reach the threshold of audibility. It stands to reason that here the threshold for low frequency is immaterial.

Secondly, even if the low frequency amplified output does not reach the level of tolerance, the intelligibility of speech is suffered. The reason is that the low frequencies effectively mask the high frequencies at high intensity levels. For instance, a tone of 400 Hz of 100 dB SPL shifts the thresholds for all the higher frequencies from 400 to 4000 Hz by 70 to 80 dB SPL due to masking (Fletcher 1953). Here, despite the output level being less than the Tolerance Level, intelligibility of speech is affected because of high intensity level of low frequency components which are responsible for masking the higher frequencies.

TABLE 2

Speech level after amplification falls below the Tolerance Level

(dB SPL)

	Low Frequency	High Frequency
Normal conversation	65 dB	30 dB
Threshold		60 dB
Gain required		60 dB
Speech level after amplification	125 dB	90 dB

As shown in Table 2, the SPL after amplification is only 125 dB which is below Tolerance Level. However, the low frequencies of this level can easily shift the thresholds of higher frequencies by 90 to 100 dB.

Finally, environmental noise is rich in low frequencies and hence their amplification causes distraction in the subjects who use the hearing aid. This also leads to masking of speech.

In order to overcome these problems, low frequency amplification should be reduced or minimised as far as possible. To achieve this, various sophisticated devices have been introduced in hearing aids—Automatic Volume Control (A.V.C.), compression circuits and high pass filtering or low frequency suppression. However, owing to technological limitations, these problems can neither be eliminated completely nor can they be counteracted effectively.

In this context, various modifications in the making of ear moulds have been attempted and an acoustic modification that follows seems to offer a possible solution. In Chattanooga Hamilton Speech and Hearing Centre, it was observed by Harrison (1969) that modifications in the conventional ear mould can appropriately improve the performance and acceptability of hearing aid amplification. This improvement was observed with cases having Sensory Neural loss of hearing above 500 Hz. The modifications introduced in the conventional ear mould are (1) a greatly shortened canal (2) markedly enlarged bore and (3) the addition of one or more vents filled with lamb's wool (Fig. 1).

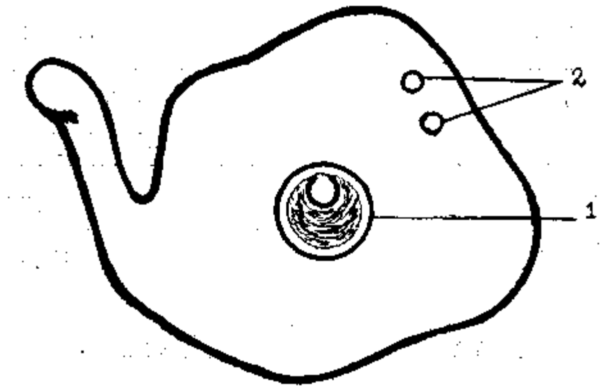

Fig.l

Modified ear rnould ihowing (1) large bore and (2) two vents filled with lamb's wool (Front view)

This type of modified ear mould was used on 83 individuals for whom hearing aids were recommended and the following conclusion was arrived at:

'The modifications adequately dissipate un-needed amplification of the low frequency components of speech or the unwanted masking caused by amplification of environmental sounds' (Harrison 1969). It goes without saying that the modified ear mould has nothing to do with amplification, but it only dissipates the output of the hearing aid.

Although the modified ear mould is found to be effective, it is not very clear as to how it works. Following is an attempt which aims at two possible explanations.

The output of the hearing aid is delivered to the ear canal and in case a spontaneous increase in pressure takes place, the vents that are provided in the mould, release the pressure. Also, the shortened canal, markedly enlarged bore and the vents filled with lamb's wool increase the volume between the receiver and the tympanic membrane contributing, consequently, to the reduction of sound pressure. Hence the subjects who may reject the aid because of uncomfortable amplification may accept it.

Another possible explanation is that the altered mould acts as a high pass acoustic filter as shown in the schematic representation below (Fig. 2).

The filter action can be clearly understood with the help of electrical anology. Capacitances (condensers) and inductances (chokes) help in filter action. In a High Pass Electrical Filter, the condensers are in series and inductances are in parallel with the output as given below (Fig. 3).

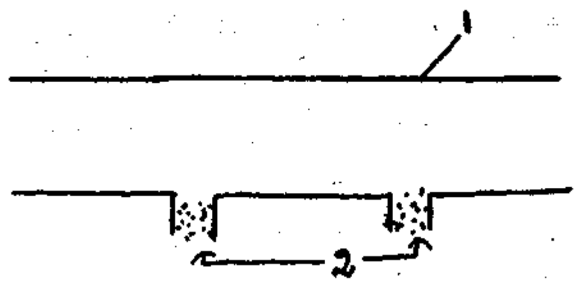

Fig. 2. Schematic representation of the modified ear mould.

1. Enlarged bore and the ear canal
2. Vents filled with lamb's wool

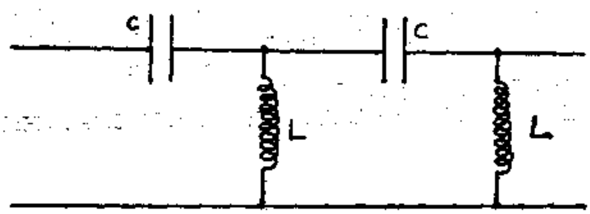

Fig. 3. High Pass Electrical Filter

C=Capacitance
L= Inductance

When frequency increases, reactance of the capacitor decreases and that of the inductance increases. Therefore low frequencies are bypassed through inductances while high frequencies are transmitted. Reactance of the capacitor is equal to $1/2\pi Fc$ and that of the inductance is $2\Pi FL$ where F is the frequency of A.C. and C and L stand for capacitance and inductance respectively. In an acoustic filter of High pass type the sound waves enter a pipe having short side tubes open to the surrounding air and attached at regular intervals along the pipe. The acoustic elements which are anologous to the inductances are the masses of volumes of air free to move back and forth in the side tubes. Between the side tubes are the sections of air whose elastic properties furnish a compliance analogous to the capacitance of an electrical filter. The acoustical behaviour of this type of structure indicates that the sound frequencies *above certain value* will be transmitted along the main tube with very little attenuation. From the schematic representation, it is obvious that the vents filled with lamb s wool act as inductances while the markedly large bore with the earcanal serves the purpose of the capacitance. The lamb's wool absorbs the low frequency components that pass through the vents and help in reducing acoustic feedback. However, the filter action cannot be accelerated by increasing the number of vents since a corresponding increase in acoustic feedback is likely to happen.

Summary

In hearing aid amplification we are confronted with difficulties in the dissipation of the low frequencies. Meanwhile, it is gratifying to note that the modified ear mould described by Harrison (1969) can help to solve the problem to a considerable extent. Two possible explanations as to how these modifications might actually work have been suggested.

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