Audiological Bulletin no. 30

Mixing sound sources in the ear canal

News from Audiological Research and Communication

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9 502 1042 001 / 05-07

Introduction

When sound enters the ear canal through a hearing aid, it is mixed with sound entering the ear directly through a vent or leakages around the earmould, as well as any bone-conducted sound, resulting in the final sound pressure level presented to the hearing aid user. If one sound is much louder than the others, determining the result is easy: the much louder sound predominates over the softer sounds. But what happens if two sounds are of just about the same loudness?

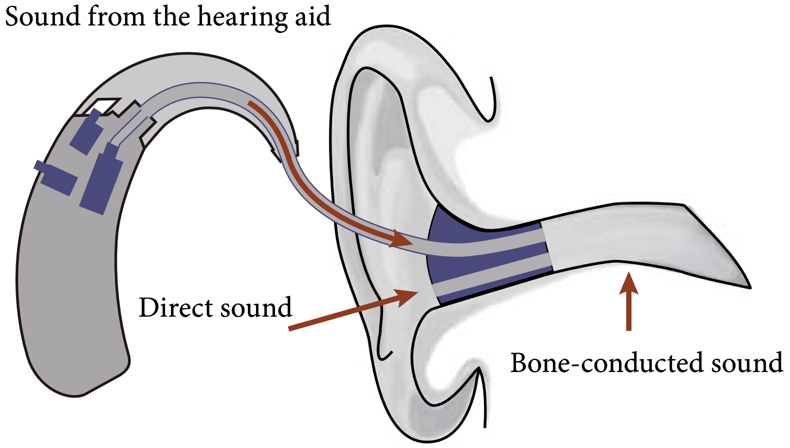

Figure 1: Three potential sound sources present in the ear canal.

Mixing sound sources

One might think that mixing two sounds always results in an even louder sound. But this is not the case. When carried through the air, sound can be described as sound waves that result from small changes in the static air pressure. Our eardrum is built to react to these changes and thereby enable us to hear sound.

As a simple example, we can take a pure tone signal and look at the pressure change over a short period of time. This might look like the figure below:

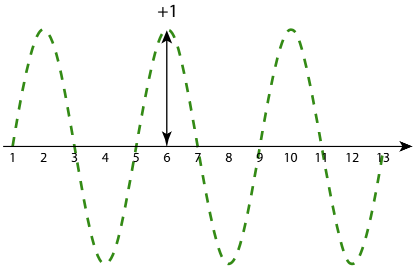

Figure 2 One sound wave: Sound pressure / Amplitude of a signal over time.

In this example, the pressure changes periodically around the black axis as illustrated. This periodically changing pressure will sound like a pure tone. The amplitude of the sound is the magnitude of displacement from the black arrow (the static air pressure). The distance in time between the peaks in the curve defines the frequency of the sound. The magnitude of displacement around the static air pressure is also called the “sound pressure”.

What happens if we now present two different sound pressure levels that change at the same speed and are identical in amplitude, but where the peak of the first sound fits the negative peak of the second sound?

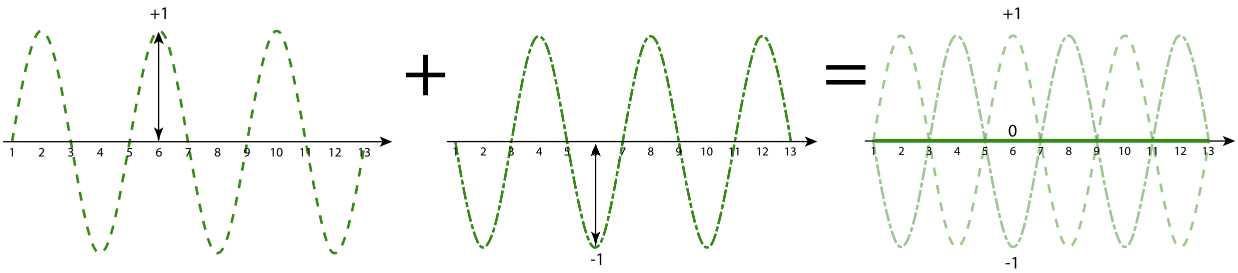

Figure 3: Two sound waves of the same frequency, but with different starting points.

As one of the sound waves tries to increase the sound pressure, the other one will decrease it by the same amount. The result is that one wave cancels the other and the pressure does not change at all. Thus the two sounds have cancelled each other out.

The two sound waves in the example above are identical, with the exception of an offset of one half peak-to-peak distance from each other. The same example with no offset (or an offset of a full peak-to-peak distance) is shown below:

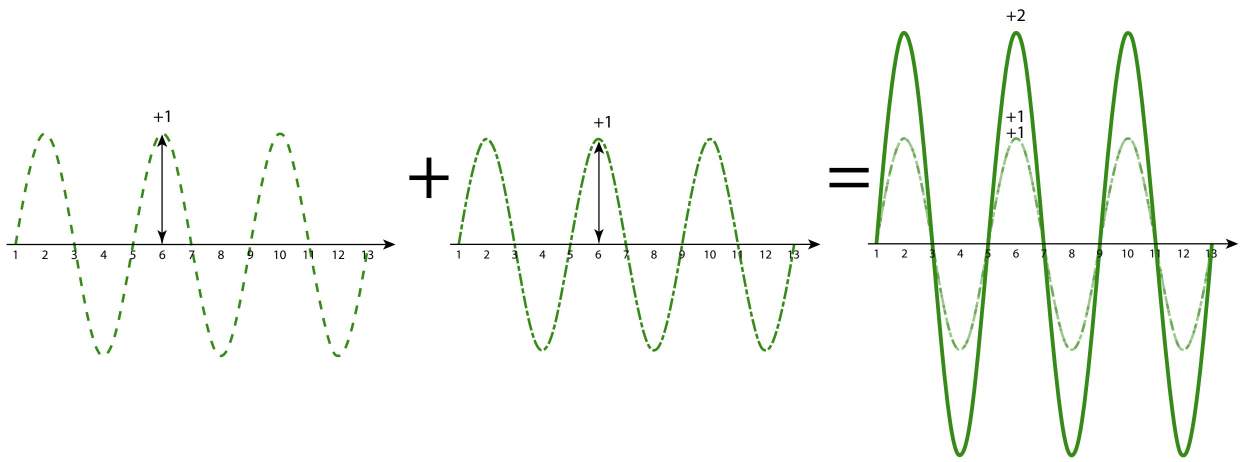

Figure 4: Two sound waves of the same frequency and same starting points.

When this is the case, the two sounds complement each other. The amplitudes are added and the result is a doubling of the sound pressure.

Conclusion: When two sounds of the same kind are offset from one another, the resulting sound can be anywhere between total cancellation (no sound) or a doubling of the sound pressure.

The offset of the two sounds is generally called the “phase difference” and is measured in degrees, where 0 degrees is no offset (sound waves are in phase), 180 degrees is a half peak-to-peak distance (sound waves are in opposite phase) and 360 degrees is a full peak-to-peak distance (sound waves are in phase again).

Mixing sounds in practice – level and phase

When listening to music, two sounds will enter the ear canal and reach the eardrum of a hearing aid user. One is the amplified sound from the hearing aid, the other is the sound transmitted directly to the ear canal through leakages around the earmould and the vent in the earmould. We also call this sound "direct sound".

In figure 5, the frequency responses of these two sounds are shown together with the response of the mixed sound. The graph shows that the direct sound dominates at the low frequencies, where the vent dampens the hearing aid sound. The hearing aid sound is much louder at the high frequencies, where the vent dampens the direct sound.

Between the high and the low frequencies is an area where the two sounds are at approximately the same level. You could say that they "compete". In this area, the resulting sound experienced by the hearing aid user depends on the phase difference between the two sounds at each frequency. At some frequencies the two sounds will be in phase, leading to an increase of the combined sound level; at other freqencies they will be out of phase, leading to full or partial cancellation of the sound.

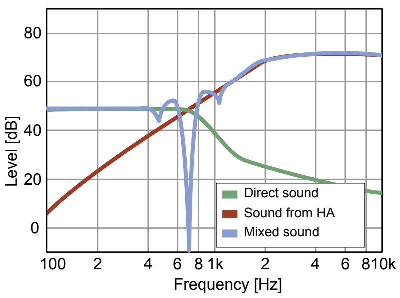

Figure 5: Sound pressure level as a function of frequency for hearing aid sound, direct sound and mixed sound. The signal in this example could be music or speech mixed with environmental noise.

Summary

The result of mixing two sound signals is not always a louder sound. If one of the signals is much louder than the other, the soft sound will not have any influence at all. As a rule of thumb, this is the case when the difference in sound pressure level is 10dB or more.

If, on the other hand, the two signals are equal in loudness (amplitude), the resulting sound may vary between a situation where the two sounds cancel each other and one where they complement each other and double the sound pressure.

Both situations are normally seen in hearing aid fittings where the gain is low and an opening in the earmould lets sound pass directly into the ear canal, where it then competes with the sound from the hearing aid. This is the case for open fittings and large vents. To ensure good sound quality for the hearing aid user and to eliminate these effects of competing sounds, the fitting software must take the acoustic configuration of the ear-set into account.