# Audiological Bulletin no. 32

## Estimating real-ear acoustics

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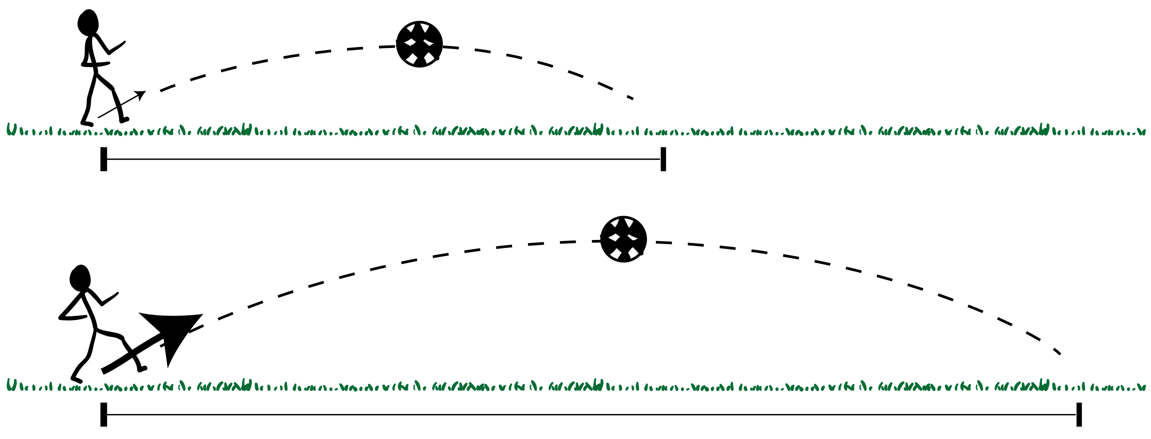
## Introduction

When developing and testing hearing aids, the hearing professional needs a possibility to measure their output and function when used by a hearing aid user. But as it is not always practical or possible to make tests and measurements on the actual user, the professional needs a substitute that can make the hearing aid react as if it was in real use.

One common substitute is an acoustic coupler, normally a 711-coupler or a 2cc-coupler. If the head shadow effect is needed, one can use the Kemar mannequin for example. These are all mechanical ways to simulate the acoustics of a real ear, but as ears are different, one such substitute cannot simulate all ears. Therefore the target for these devices is to get as close to an average hearing aid user as possible within the design limitations of each device.

Another way to test and measure the function of a hearing aid in real life is by simulating the hearing aid design on a computer. Simulating real life physical phenomena by computer is common today. Every time meteorologists forecast the weather, they simulate how weather conditions are most likely to change in the days ahead. In computer games you can fly a plane, drive a car, play tennis, golf, football or otherwise do things that resemble real life, but where your experience is based on computer simulations.

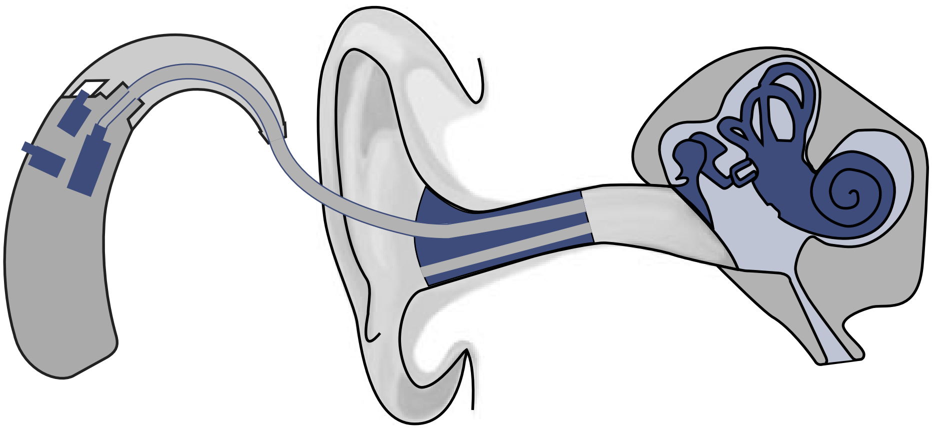
Just as it is possible to calculate how a ball reacts to being hit and how it flies through the air, it is possible to calculate how sound will propagate through a hearing aid and into the ear canal. And in the same way as a computer simulated player can hit a ball hard or soft and thereby change the way the ball flies, the simulated ear canal acoustics can be changed to study the effect of factors such as the vent diameter or the size and shape of the ear canal.



There is an important difference between physical substitutes such as acoustic couplers and computer simulation. In couplers, it is very difficult to change the parameters involved, whereas in computer simulation it is possible to exchange all the parameters (e.g. vent diameter, length, ear size, compliance) one by one and examine the effect on the sound pressure. Furthermore, as the entire setup is implemented as calculations in a computer, it is not only possible to check the sound pressure at the eardrum, but also to look at the sound pressure at other places; for example, to estimate how much sound will return to the hearing aid microphone from the ear canal, or to estimate how much sound will propagate directly into the ear canal through vents and leakages.

## What does ear acoustics involve?

What then is involved in a model of ear acoustics?

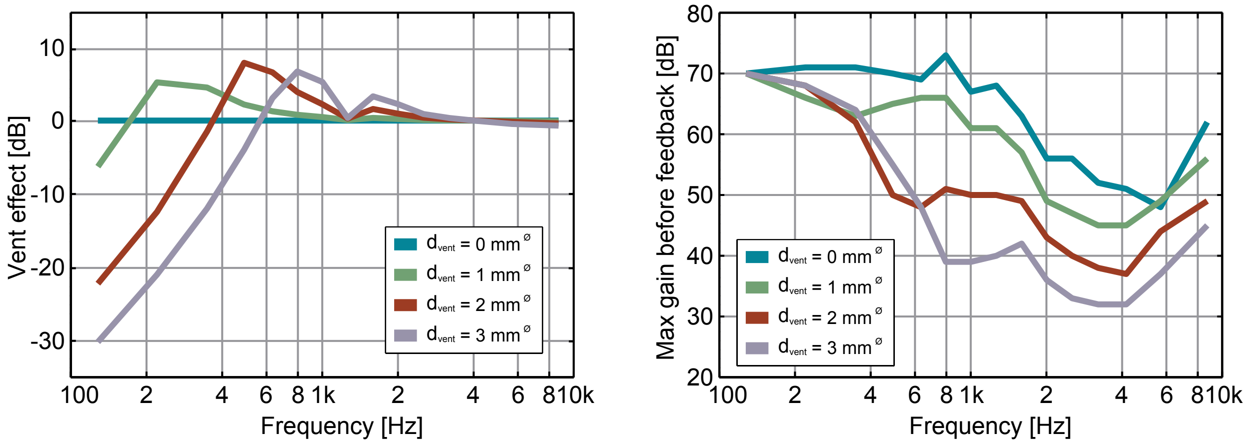


The sound has to come from somewhere. It is recorded at the hearing aid microphone, sent through the hearing aid, and played back at the receiver, which is connected to the ear canal through various tubes of different dimensions and shapes. In the ear canal, the size and shape of the ear canal itself have to be defined. The eardrum reacts to sound and the way it reacts also has an influence on the sound pressure in the ear canal. Therefore the eardrum and the reaction of the middle ear cavity also play a role. As the sound in the ear canal can be altered due to vents or leakages, these must also be put into the simulation. Besides being played back by the hearing aid, sound can also enter the ear canal directly through the vent, eardrum and leakages, and will be mixed with the sound from the hearing aid in the ear canal.

As these different elements have been described in literature on acoustics, the researcher can enter them as elements in the computer simulation. The default dimensions will, of course, be the average of a high amount of data measured on hearing aid users for the calculations to fit as many people as possible. As more individual data becomes available, individual dimensions can be exchanged to get a more precise simulation of the individual ear acoustics.

By changing the dimensions in the simulation, one can examine what happens in the real world in an easy way.

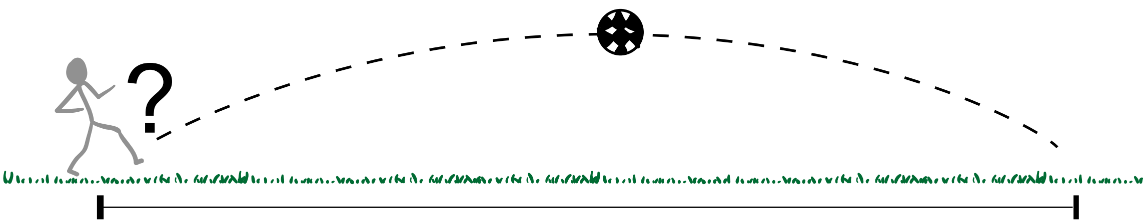
An example of this is shown in the figure below. On the left, the difference in sound pressure at the eardrum between a closed earmould and earmoulds with different sized vents is simulated for an average person. On the right, the same situation is shown but this time the attenuation between the receiver output and the microphone input is calculated, that is, the amount of gain the hearing aid can provide before producing audible feedback.




Therefore it is possible to create a substitute for a real hearing aid and a real ear in a computer program to simulate sound in real life. Using this kind of simulation, it is also possible to simulate a change in some dimensions (for example the vent diameter) and study what happens to the sound pressure at various places in the hearing aid and ear when doing so.

## Further use of simulation

Going back to the comparison with the simulated ball player in a computer game, where the player can kick a ball hard or soft and thereby affect the way the ball flies through the air, we will shortly look at another way of using computer simulations. If we look only at how far the ball flies without knowing anything about what the player has done, is it then possible to estimate how hard it was kicked?




Yes - if the ball flies a long way, we may assume that the kick was hard just as a short flight will be associated with a soft kick.

In the same way, it is possible to measure the sound pressure in the ear and, by comparing the sound pressure for different vent sizes, estimate how large a vent should be to give that sound pressure. Furthermore we can estimate the vent effect that fits best by looking at the maximum possible gain before audible feedback occurs.

## The Widex AISA concept

In the fitting of the Integrated Signal Processing (ISP) series of hearing aids from Widex, a complex simulation of real-ear acoustics ensures that the individual hearing aid user acquires the gain needed for the optimal benefit of the hearing aid.

This part of the fitting is called AISA (Assesment of In-Situ Acoustics) and it does exactly what is described above. Based on measurements of parameters during the fitting routine it estimates other parameters, for example the individual vent effect, which can be estimated by measuring the feedback gain during the feedback test.

This allows the fitting rationale to compensate for the actual, individual vent effect instead of using average data. How the AISA data is used in the compensation will be treated in the audiological bulletin "Ensuring the correct in-situ gain".

## Litterature

Further studies of modelling ear acoustics can be found in the following background material:

Brüel & Kjær, '*Ear simulator – type 4157*, Product data sheet

DP Egolf, BT Haley, HC Howell & VD Larson, *A technique for simulating the amplifier-to-eardrum transfer function of an in situ hearing aid*, JASA 84 (1), pp. 1-10, 1988

EAG Shaw & MR Stinson, *Network concepts and energy flow in the human middle ear*, JASA, Suppl 1, 69, S43, Text of invited paper @ 101th ASA meeting, 19-22 May, 1981

Kuk, F. and Nordahn, M. *Where an Accurate Fitting Begins: Assessment of In-Situ Acoustics (AISA)* (2007 Jul.) The Hearing Review, July 2006

Lybarger S.F. (1985). *Earmolds. In Handbook of Clinical Audiology.* Third edition, J. Katz (ed), Baltimore: Williams and Wilkins

MR Stinson & BW Lawton, *Specification of the geometry of the human ear canal for the prediction of sound pressure level distribution*, JASA, 85 (6), pp. 2492-2503, 1989

Nordahn, M. and Kuk, F. *Assessment of in-situ acoustics (AISA) - Making an accurate fitting even more accurate* (2006 Apr). Hearing Review, 13 supp. (4), 12-22