Prediction Of Nonlinear Harmonics In A Balanced Armature Micro-speaker Output

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Abstract

Balanced armature (BA) micro-speakers, or receivers, are miniaturized loudspeakers used in hearing aid instruments, earphones, and hearables. A typical design of a BA receiver includes an armature (metal beam) with a coil wound around it. The armature tip is positioned exactly in the center between the two magnets and the magnetic fields in the gaps between the armature and the magnets are equal. The current representing the audio signal runs through the coil, injecting a magnetic flux into the armature and causing the difference in magnetic field in the two gaps between the armature and magnets. This breaks the magnetic balance and creates magnetic force acting on the armature and sets it in motion. A drive pin connected to the armature on one end drives the membrane that produces sound. Typically, the sound distortion can occur when the input signal exceeds the maximum level that a device can handle, causing peaks and dips of the waveform to be clipped off. In BA receivers, the limiting effect that leads to clipping is magnetic saturation of the armature, hence the armature cannot conduct the required amount of magnetic flux anymore.

For optimal design purposes it is important to predict and quantify the sound distortion, depending on the required sound pressure level (SPL). The developers aim at calculating the maximum SPL level that can be reached without exceeding the specified required total harmonic distortion (THD) percentage, ranging from 5% to 10%.

In this investigation a time-domain FEA simulation of a fully coupled BA receiver model in COMSOL has been developed, including Magnetic Fields interface to model the electrical input and magnetic fluxes in the system, the Solid Mechanics interface to model mechanical forces created by the magnetic system, and the Thermoviscous Acoustics, Transient interface to model the acoustic part of the system, including the ear canal simulator.

The simulation results of a receiver response to an ideal sine 200 Hz waveform as electrical input in a 711 ear canal simulator are shown in Figure 1. At nominal drive level (215 mVrms) the sound pressure produced by the receiver follows the sine waveform. At high drive level (550 mVrms) the signal distortion is detected, in the form of a clipping, that causes the peaks and dips of the waveform to be symmetrically clipped off. The origin of such a distortion is linked to the limit of magnetic flux that the receiver armature can carry.

The time traces of Figure 1 can be used to derive nonlinear harmonics present in the receiver sound output to characterize the distortion in detail, for instance by identifying odd and even harmonics, their significance with respect to required THD percentage level and the corresponding SPL.

Figures used in the abstract

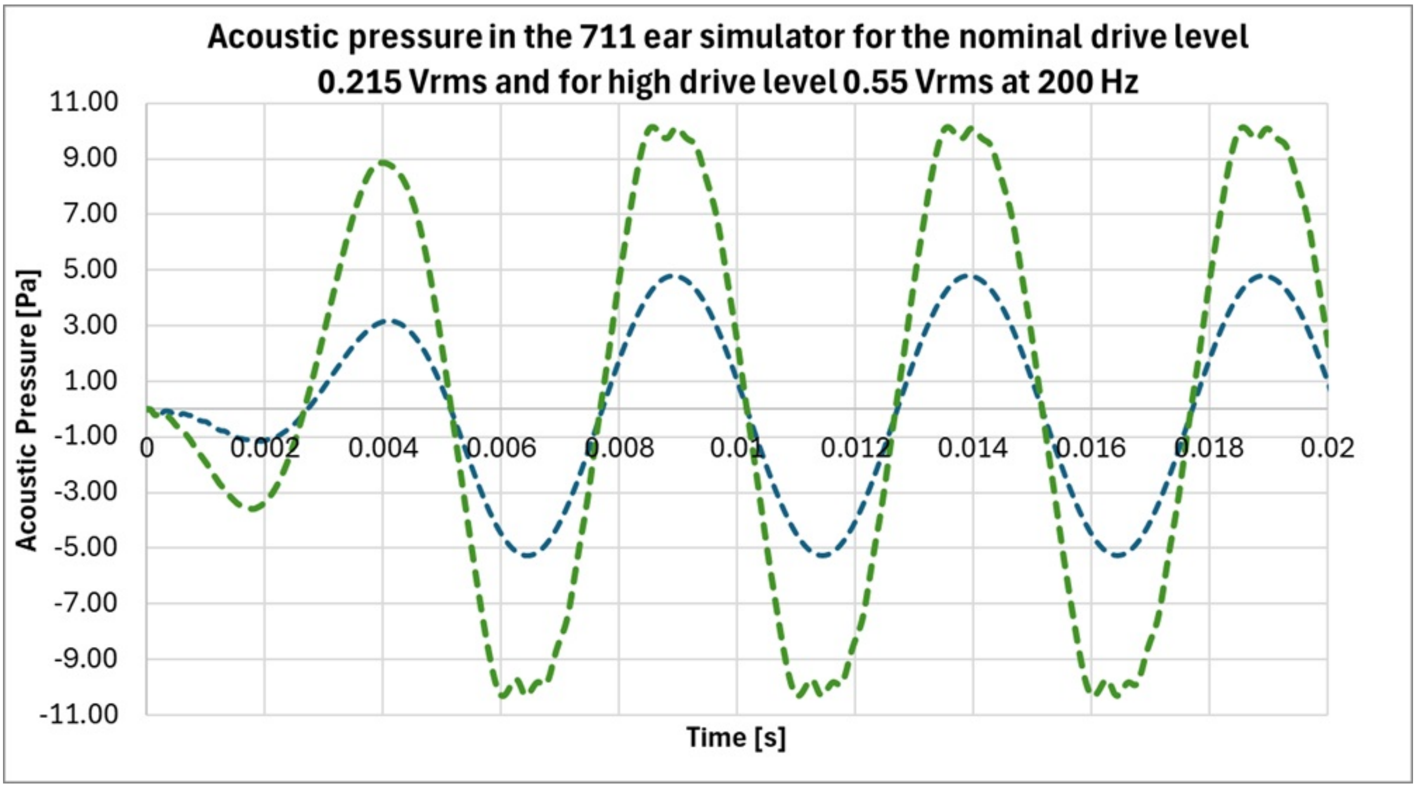

Figure 1 : Figure 1. Sound pressure for nominal and high drive levels of a BA receiver. Clipping distortion is present in the time trace for high drive level.

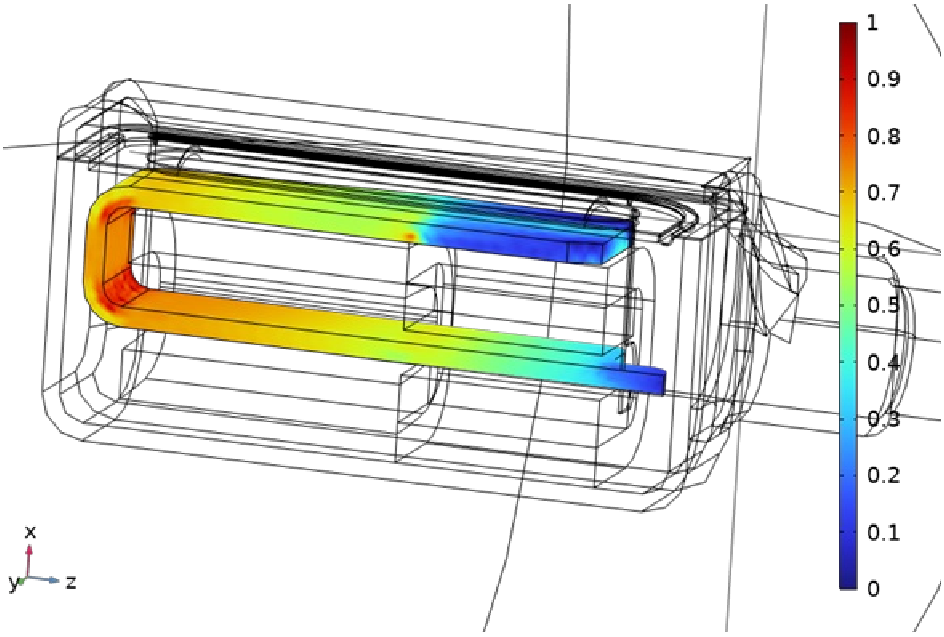

Figure 2 : Thumbnail image. Magnetic flux density in the armature of a BA receiver.