Nonlinear Distortion Mechanisms and Efficiency of Balanced-Armature Loudspeakers

Nonlinear distortion added by the loudspeaker (often referred to as a receiver) in a hearing aid reduces the signal-to-noise ratio in the acoustic output and may degrade the user's ability to understand speech. The balanced-armature-type loudspeakers predominantly used in hearing aids are inherently nonlinear devices, since any displacement of the loudspeaker diaphragm inevitably changes the magnetic and electrical characteristics of the loudspeaker. Additionally, for the balanced-armature loudspeaker the signal has to be transmitted through the magnetic domain (as a magnetic B-field) and the linearity of the magnetic material is therefore of great importance. This thesis describes the inherent nonlinear parameters of the balanced-armature loudspeaker and demonstrates how the nonlinearity of these parameters may be reduced by design. A simple technique for incorporating magnetic leakage effects is introduced and it is shown how the leakage affects the linearity of the loudspeaker. Magnetic hysteresis, saturation and eddy current losses and how these effects might affect the performance of the loudspeaker are also discussed. FEM simulation software is used to investigate magnetic effects and to validate simpler equivalent circuit models. A large scale model of a balanced-armature loudspeaker has been developed and its inherent nonlinear parameters have been measured and compared to the theoretically predicted values. A measurement setup for determining the magnetic properties of soft magnetic materials has also been developed, since it is of great importance to understand what kind of linear and nonlinear transformations the magnetic materials impose on the signal. In hearing aid applications the power efficiency of the loudspeaker is important because every reduction in power consumption will help prolong battery life and thereby reduce the frequency of necessary service checks. A great deal of the power consumed in a hearing aid goes into the amplifier that drives the loudspeaker. If the efficiency of the balanced-armature loudspeaker can be improved, the operation time of the hearing aid may be extended or the size of the hearing aid could be reduced using a smaller battery, or new features and more advanced algorithms could be embedded without compromising the operation time of the hearing aid. A new loudspeaker efficiency performance metric is proposed and it is shown how the balanced-armature loudspeaker may be optimized in terms of this. The maximum level of the acoustic output of a balanced-armature loudspeaker is an important performance parameter since these miniature loudspeakers sometimes need to be capable of compensating for substantial hearing losses. It is demonstrated that magnetic saturation of the loudspeaker armature is likely to be the most significant cause of compression in the balanced-armature loudspeaker. It is furthermore shown which conditions should be fulfilled in order to reduce the risk of armature saturation and thereby increase the maximum output and reduce distortion.

General information
Publication status: Published
Organisations: Department of Electrical Engineering, Acoustic Technology
Contributors: Jensen, J.
Number of pages: 212
Publication date: 2014

Publication information
Publisher: Technical University of Denmark, Department of Electrical Engineering
ISBN (Print): 978-87-92465-48-1
Original language: English
Source: PublicationPreSubmission
Source-ID: 104277940