Passive simulation of electrodynamic loudspeakers for guitar amplifiers: a port- Hamiltonian approach

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Because of technological constraints, transducers are usually not ideal. In musical and audio applications, this is the case of electrodynamic loudspeakers used eg. in guitar amplifiers. Thus, to build realistic numerical simulations of such systems, it is important to pay close attention to their nonideality. These systems include several nonlinearities, mainly due to mechanical suspensions, magnetic properties and temperature variations. Another difficulty, reported in the literature, is concerned with the non standard behaviour of the coil, that can be represented by a fractional order system. At the same time, it is not so straightforward to model such refinements while preserving basic physical properties such as causality, stability, passivity. In this paper, we introduce a new modeling of loudspeaker which accounts for both the fractional order dynamics and some relevant nonlinear effects, such that the power balance is guaranteed. We focus on the electromagnetic and mechanic modelings of the tranducer, while we apply a standard passive acoustic load on the diaphragm and neglect thermic phenomena. The approach is based on the formalism of the ”port-Hamiltonian Systems” in the continuous-time domain, which naturally preserves the energetic behavior of elementary components as well as the power exchanges including for the nonlinear cases. By transcribing this property in the digital domain, we guarantee the stability of the simulations. Several real-time audio examples will be presented to illustrate the combined or separated effetcs of the proposed refinements(magnetic and mechanic nonlinearities, fractional order derivative).