Nonlinear electroacoustic resonator at low excitation amplitudes: grazing incidence analysis.

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Abstract. The electroacoustic resonator is an efficient electro-active device for noise attenuation in enclosed cavities or acoustic waveguides. It is made of a loudspeaker (the actuator) and one or more collocated microphones (the sensors). By driving the electrical current in the speaker coil it is possible to target a desired acoustic impedance on the speaker diaphragm. A novel technique has been recently implemented which allows to target nonlinear operators at low excitation levels. In this contribution, we first expose the concept of such nonlinear control along with its numerical and experimental validation. Then, in the perspective of wave propagation control in an acoustic waveguide, such nonlinear resonator has been analysed in the grazing incidence problem, typical of acoustic liners.

Introduction

In acoustics, the potentialities of nonlinear sound absorption has been explored for designing Helmholtz resonators in the nonlinear regime, or in [2], where Targeted-Energy-Transfer (TET) was achieved from a linear acoustic cavity to a *weakly-coupled* thin visco-elastic membrane which behaves as a Duffing resonator. As the linear ones, passive nonlinear absorbers are not easily tunable for targeting different bandwidths. Moreover, they usually need high-energy threshold in order to trigger the nonlinear behaviour. An electro-active nonlinear absorber might overcome these limitations, by *transforming* the mechano-acoustical dynamics of the loudspeaker from linear to nonlinear, while keeping the same external excitation levels. Here, we expose the model-inversion control problem to transform the acoustical response of the electroacoustic resonator (ER) from LTI to potentially any causal locally-reacting response (nonlinear and/or time-variant). In this contribution, the control algorithm is implemented to achieve a Duffing target acoustical dynamics, with tunable parameters. Then, the nonlinear ER is studied in a grazing-incidence configuration, in order to exploit its potentialities for special scattering phenomena (including solitons) in acoustic waveguides.

Results and discussion

In Figure 1, the *nonlinearly controlled* ER is tested against an external sound source emitting a pure sine at 700 Hz, in a quasi-open field environment. The external sound source is activated after $t = 3$ seconds to assess the control performance also in the transient regime. The time-history of the measured velocity $\dot{u}(t)$ (solid blue) is compared with the target velocity $\dot{u}_d(t)$ in dashed red. Observe that the actual velocity follows the target one with slight difference due to model uncertainties and time delay in the digital control algorithm. Once the nonlinar control is validated in open-field, it can be analysed for modal attenuation in acoustic cavities or in terms of its scattering performances in acoustic waveguides. The latter is the application studied in this contribution, opening the doors toward the design of tunable nonlinear liners at classical excitation levels.

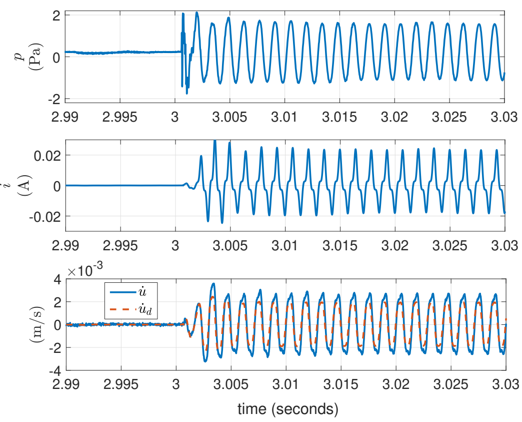

Figure 1: Time histories of pressure $p(t)$, electrical current $i(t)$, target and measured velocities ($\dot{u}_d$ and $\dot{u}(t)$ respectively) on the speaker diaphragm. An external sound source emitting a pure sine at 700 Hz, is activated after $t = 3$ seconds.

References

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