Control of an acoustic mode by a digitally created Nonlinear Electroacoustic Absorbeur at low excitation levels: Analytical and Experimental results

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Abstract. In this study, an acoustic mode of a tube is controlled by a digitally created Nonlinear Electroacoustic Absorber (NEA) at low excitation levels, where the nonlinear threshold is usually not reached in the field of acoustics with passive nonlinear energy sink. A comparison is carried out between a linear Electroacoustic Absorber, similar to a Tuned Mass Damper (TMD) in mechanics, and a digital NEA. The innovative method for creating a NEA lies on Real Time Integration of the dynamics of the device. It allows to choose any behavior of the system by digitally programming the corresponding targeted dynamics. Here, a loudpspeaker Impedance Control law with a cubic stiffness is considered, as this system is well known in mechanics and provides nonlinear phenomena that are highlighted at low and moderate excitation levels in our study.

Introduction

In the field of acoustics, one can observe nonlinear phenomena when the amplitudes of motion and pressure reached a certain threshold. Nonlinear passives absorbers are usually activated at high amplitudes. Bellet et al. [1] have implemented a visco-elastic membrane behaving as a pure cubic stiffness oscillator above 143 dB Sound Pressure Level (SPL), to control an acoustic mode. Gourdon et al. [4] have implemented a Helmholtz resonator, similar to a TMD in mechanics, in its nonlinear regime and therefore have succeeded to create a nonlinear oscillator above 138 dB SPL. More recently, Guo et al. [3] placed a microphone in the back cavity of a loudspeaker, allowing to add a nonlinear current proportional to the cubic law of the displacement of the membrane to the linear current, modifying the classic Impedance Control around 100 dB. The aim of our study is to create a NEA composed of microphones collocated to a loudspeaker, and monitored by a processor. This processor calculates the current to inject into the loudspeaker coil based on the sensed pressure at each time step to implement any previously digitally defined nonlinear behavior. The first simulations have been realized by De Bono [2]. This innovative method to implement a NEA lies on the evaluation of a target dynamic of the loudspeaker to achieve a desired behavior. The process is based on measured pressure at each time step. Impedance Control is electro-active, but acoustically passive, unlike Active Noise Control, and therefore has to be distinguished. As a result, Impedance Control leads to a low energy consumption, as the electrical current needed is low. In the study, an acoustic mode created with a reduced section of a tube is weakly coupled to the NEA using a coupling box.

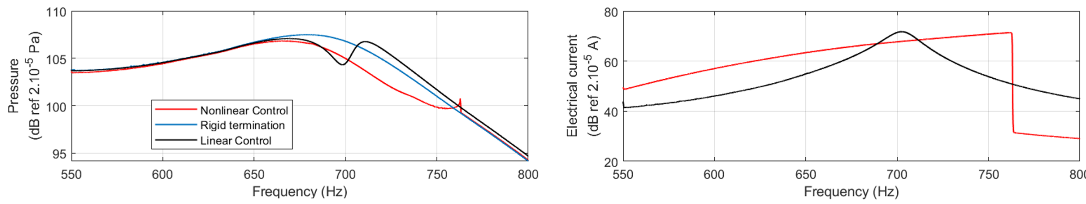

Figure 1: Obtained experimental results in the form of pressure and current for sweeping frequency excitation

Results and discussion

This study highlights the creation of a NEA at low excitation amplitudes. As a result the two peaks usually obtained with a TMD vanish with the NEA. A jump phenomenon in the pressure inside the tube can be seen as the electrical current of the NEA jumps, exposing an unstable zone that can be easily predicted by both analytical and experimental results in the case of a Two Degree Of Freedom system containing a duffing oscillator. A nonlinear behavior of the oscillator is shown.

References

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