Fractional Derivative Loudspeaker Models for Nonlinear Suspensions and Voice Coils

Moving-coil loudspeakers exhibit a number of linear effects, such as viscoelastic suspension creep and lossy inductance of the voice coil, which complicate their frequency response. Nonlinear models of the loudspeaker must include these effects in order to make accurate predictions for nonlinear compensation algorithms. While viscoelasticity and lossy inductance have been modeled using a variety of methods in the frequency domain, the discrete time-domain description using fractional order derivatives is both accurate and easily incorporated into existing nonlinear models. The influence of the fractional order derivative is demonstrated using a fractional order oscillator, resulting in a response that closely resembles viscoelastic suspension creep in a loudspeaker or an increase in displacement toward low frequencies. A full bandwidth loudspeaker model with a fractional order viscoelastic suspension and a fractional order lossy voice coil was used to fit measurement data from two loudspeakers. Further simulations with a nonlinear position-dependent suspension and a nonlinear position-dependent inductance were conducted, and this revealed unexpected frequency components due to the infinite memory of fractional derivatives.

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