Deriving fractional acoustic wave equations from mechanical and thermal constitutive equations

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It is argued that fractional acoustic wave equations come in two kinds. The first kind is constructed ad hoc to have loss operators that fit power law measurements. The second kind is more fundamental as they in addition are based on underlying physical equations. Here that means constitutive equations. These equations are the fractional Kelvin-Voigt and the more general fractional Zener stress-strain relationships as well as a fractional version of the Fourier heat law. The propertes of the wave equations are given in terms of attenuation, and phase/group velocities for low-, intermediate- and high-frequency regions. In the most general case, the attenuation exhibits power law behavior in all frequency ranges while the phase and group velocities increase sharply in the intermediate frequency range and converge to a constant, finite value for high frequencies. It is also shown that the fractional Zener wave equation is equivalent to the multiple relaxation model for attenuation.