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Modeling of "anomalous" velocity dispersion in trabecular bone: effect of multiple scattering and of viscous absorption

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Speed of sound is now widely used in the clinic to assess bone strength and susceptibility to fracture. Therefore, much effort has been spent on the understanding of ultrasonic wave propagation in trabecular bone, which is an attenuating composite material in which negative values of velocity dispersion have been measured, but remain poorly explained physically. In this work, the physical determinants of velocity dispersion are described with a 2D homogenization model of the wave propagation in trabecular bone. The medium is assumed to be constituted of infinite viscoelastic cylinders (trabeculae) immersed in a saturating viscoelastic matrix (marrow). The coupling between multiple scattering and absorption phenomena allows the computation of phase velocity and of dispersion as a function of bone properties. Negative values of velocity dispersion are predicted, in good agreement with experimental results obtained in phantoms mimicking trabecular bone. In trabecular bone, mostly negative but also positive values of velocity dispersion are predicted, which spans within the range of values measured experimentally. Scattering effects are responsible for the negative values of dispersion whereas the frequency dependence of the attenuation coefficient in bone marrow and/or in the trabeculae is shown to induce an increase of dispersion.