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Frequency response of bubble pulsations in tubes with arbitrary wall impedance

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A model is presented for the linear pulsation of a small bubble in a tube with locally reactive walls but with otherwise arbitrary wall impedance. The model is based on the normal mode expansion of the Green's function presented by Morse and Ingard [*Theoretical Acoustics* (McGraw-Hill, 1968), Eq. (9.2.10)]. The specific case of a cylindrical tube is considered. For a bubble that is located in the center of the tube and that is small compared with both tube diameter and wavelength, the radiation impedance on the bubble is given by a summation of the normal modes evaluated in the center of the tube. From the radiation impedance, the frequency response of the bubble to an applied sound field is obtained. For tube walls that are either rigid of pressure release, the solution agrees with the frequency response calculated using the method of images for a square tube having the same cross-sectional area. In tubes with hard walls the resonance frequency decreases as tube radius decreases because of radiation damping. In tubes with very soft walls the radiation damping is negligible below the cutoff frequency of the lowest mode, and the resonance frequency increases slightly as tube radius is decreased.