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Effect of bending portions of the air column on the acoustical properties of a wind instrument

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The need to keep long wind musical instruments compact imposes the bending of portions of the air column. Although manufacturers and players mention its effects as being significant, the curvature is generally not included in physical models and only a few studies, in only simplified cases, attempted to evaluate its influence. The aim of our study is to quantify the influence of the curvature by modelling the wave propagation in an air column with a multimodal formalism. In a duct with a circular cross-section and a finite curvature, two infinite sets of coupled first-order differential equations are constructed for the components of the pressure and axial velocity, projected on the local transverse modes. From these an impedance matrix is defined, which can be easily calculated, particularly when considering a duct with a piecewise constant curvature. Influence of the curvature on the input impedance, effective length, or playing frequencies is then quantified, displaying notably a dependence to frequency such that, compared to an equivalent straight tube, the shift in resonance frequencies in a tube with bent sections is not always positive, as generally stated. Results are independently corroborated by numerical - finite differences - computations.