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Basic types of discontinuity in circular acoustic waveguide.

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Abstract

It is considered the interaction of acoustic waves with two basic discontinuities – “diameter step” and “rigid diaphragm with coaxial opening” – in cylindrical acoustic waveguide with a rigid wall. The problem is considered and solved in accurate formulation for the case of axial symmetry and below the first radial resonance (f_{r1}) in the waveguide. Obtained data demonstrate that well-known one-dimensional (1-D) model provides good results for the diameter step if the frequency does not exceed 18 – 50 % of the f_{r1}. New calculated data for the diameter step demonstrate that this discontinuity follows to the reciprocity principle (below f_{r1}) – the parameter of non-reciprocity does not exceed calculation errors. Data for the diaphragm demonstrate good agreement with the Lamb formula for a rigid screen with parallel slots: 2-D problem in the Cartesian coordinates. Calculation errors for the both discontinuities were checked with the energy conservation law. The difference between sum of power fluxes in reflected and transmitted waves and power flux in the incident wave does not exceed 1%.

NOTES to this article.

Geometry of noted basic discontinuities is shown on Fig. 1 (from this article).

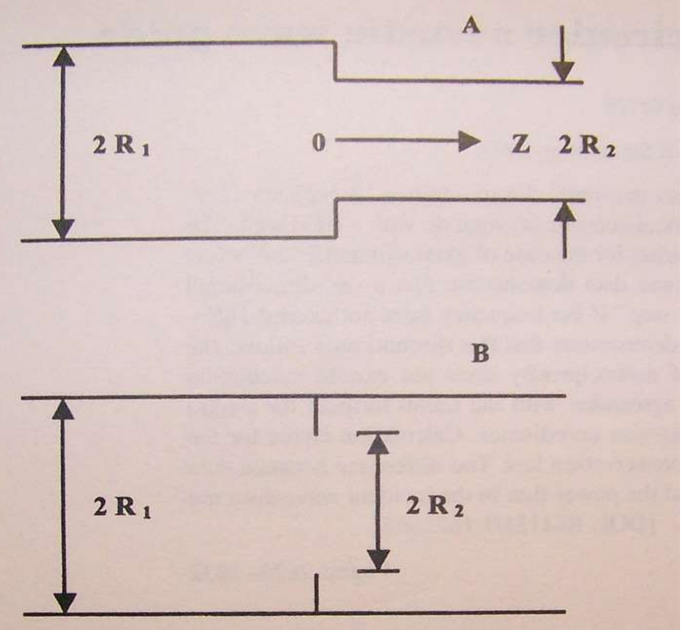

FIG. 1. Two basic types of discontinuity in an acoustic waveguide with a rigid wall: diameter step (a) and rigid diaphragm with a coaxial opening (b).

Each book about acoustics contains well-known approximate expressions for reflection (R_0) and transmission (T_0) coefficients for the discontinuity "diameter step".

$$R_0 = \frac{S_1 - S_2}{S_1 + S_2} \qquad T_0 = \frac{2S_1}{S_1 + S_2}$$

where: S_1 and S_2 are areas of cross section for the waveguides with radii R_1 and R_2 . There is no any expression for the reflection/transmission coefficients of discontinuity "rigid diaphragm with coaxial opening" in existing books about acoustics.

Next important detail is a frequency of the first radial resonance f_{r1} in the cylindrical waveguide with radius R_1.

$$f_{r1} = \frac{3.832c}{2\pi R_1}$$

All calculations in this article were done for frequency range $0 < f < f_{r1}$. It means: the calculations were done for the first traveling mode in the waveguide. This mode can be called: zero mode of the waveguide. Phase velocity c of this mode equals to wave velocity of plane waves in unbounded acoustic medium.
It was shown that expressions (1) may be considered as ~ accurate expressions if considering frequency does not exceed 18% - 50% of the f_{r1} (minimal f_{r1}).

There were used following boundary conditions at the planes of both considered discontinuities:
- continuity of the pressure and velocity of the acoustic medium in the pass
- zero normal velocity at the rigid wall.

The discontinuity "diameter step" was considered in two forms: transmission into smaller tube and transmission into larger tube. Existence of noted two forms follows from above noted boundary conditions. Tables of calculated data are presented for

$$R_2/R_1 = 0.5 \text{ and } 2.0$$

All calculated data were checked by 2 independent methods:
- power flux in the incident wave should be equal to the sum of power fluxes in the transmitted and reflected waves
- the reciprocity principle in acoustics should be correct

All calculated data demonstrated: calculation errors did not exceed 1 %.

It was used new model of small flat source of velocity. This model of the source was introduced earlier (in 1993) in publication [2] from the list of references to this article. Actually, it is slightly modified (flat) version of point-type source of velocity, placed at the axis of symmetry in cylindrical waveguide (case of axial symmetry).