SOUND WAVES IN PARABOLIC ROOMS

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ABSTRACT

The first quantitative attempts at the analysis of acoustical properties of rooms were made by Wallace Sabine in 1896 by using what might be termed "geometrical acoustics" in analogy with geometrical optics. The "goodness" of a room was shown to be related to the nature of the transient response of that room, assumed to be the same for all frequencies of sound. More precise measurements have since shown, however, that this response for a given room varies with the frequency of the sound source, and, moreover, even with the location of the source within the room. With Knudsen's discovery (1) that reverberent sound has the characteristic frequency of the nomral modes of vibration of the room, which may or may not correspond to the frequency of the sound source, a new method of analysis was initiated.

Wave acoustics, as contrasted to geometrical acoustics, treats a room as an assemblage of characteristic standing waves, or normal modes of vibration. When a source is turned on in the room, the initial pulse excites transient free vibrations, having the frequencies of the normal modes, which damp out, leaving a steady state vibration of the same freuency as the source. This steady state vibration is considered to be made up of a large number of the characteristic standing waves whose amplitudes are dependent upon the frequency of the source, the "acoustic impedance" for the particular standing wave, and the position of the source. The picture is thus one of the characteristic standing waves being "driven" by the source. When the source is turned off the standing waves remain but take on their natural frequencies, damping out exponentially according to their free vibration properties.

Wave acoustics therefore deals with three aspects of sound waves in rooms: (1) the steady state response; (2) the transient response; (3) the interaction of the sound waves with the bounding surfaces.

Acoustic impedance, which has been found a more useful quantity in such analysis than the absorption coefficient, is defined as the complex ratio of the sound pressure at the surface of a bounding material to the air velocity normal to the surface just outside the surface. It is a function of frequency and direction of propagation of the wave.

The general procedure in applying wave acoustics to a room is first to solve the wave equation for the normal modes of vibration with the appropriate boundary conditions, given by the values of the acoustic impedance of the walls. It is then possible to obtain a transient solution from the steady state

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solution by the methods of operational calculus. Such theoretical studies have been carried out for rectangular rooms, cylindrical rooms, triangular rooms and spherical rooms. Morse and Bolt (2) present a review of such methods and applications.

The present report concerns parabolic rooms—that is rooms whose walls are confocal parabolic cylinders, with flat floor and ceiling. No simple method of obtaining normal modes of vibration for asymmetric parabolic cylinders could be found. Zero order modes of symmetric parabolic cylinders were found exactly, being quarter order Bessel functions, and an approximate formula for their frequencies was derived, making possible construction of an approximate frequency space.

Comparing results with those for rooms previously studied led to the following conclusions: (1) a symmetric parabolic cylinder behaves acoustically almost like a circular cylinder, both having (a) the same form of equation for the number of frequencies less than a given frequency, (b) doubly degenerate curved wall axial modes, and (c) similar effects on the performance of absorbing materials; (2) loss of radial symmetry in passing from a circular to a symmetric parabolic cylinder results in doubling the number of allowed "radial" frequencies in a given range, parabolic radial frequencies being equidistantly spaced above and below corresponding circular cylinder radial frequencies; (3) frequency distribution in an asymmetric parabolic cylinder is fairly uniform, double degeneracies of the symmetric case disappearing with destruction of reflection symmetry of the two curved walls; (4) an exact or usable approximate solution for the asymmetric parabolic cylinder would be useful in indicating whether or not variation of response with position could be eliminated sufficiently without destroying desirable features of this shape.

LITERATURE CITED

1. Knudsen, V. O. 1932. Resonance in Small Rooms. J. Acoust. Soc. Am. *4*: 20.

2. Morse, P. H. and R. H. Bolt. 1944. Sound Waves in Rooms. Revs. Modern Phys. *16*: 69.