LOUDSPEAKER ENCLOSURE DESIGN

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I.—Alternative Methods: Their Advantages and Disadvantages

IN the first part of this article the theory underlying the principal types of loudspeaker enclosure is reviewed, and formulæ associated with the major design factors are given.

This will be followed later by a discussion of some recent developments in which an improved low-frequency performance has been achieved in cabinets of relatively small volume.

THE loudspeaker enclosure has the task of doing something (useful or otherwise) with the low-frequency radiation from the rear of the loudspeaker cone, which would otherwise cancel the radiation from the front of the cone.

Before examining various methods of overcoming this, let us establish the principles on which our future arguments will be based.

We shall regard the moving parts of a loudspeaker as a mechanical system which at low frequencies is analogous to an electrical circuit, as shown in its simplest form in Fig. 1.

The complete analogy is revealed by an examination of the electrical and mechanical equations viz.

$$\text{Force} = M\frac{d^2S}{dt^2} + R\frac{dS}{dt} + SK$$

$$\text{E.m.f.} = L\frac{d^2Q}{dt^2} + R\frac{dQ}{dt} + \frac{Q}{C}$$

where M = mass, L = inductance, S = displacement, Q = charge, C = capacitance, K = stiffness and R = resistance.

There are, of course, other analogies, but the above lends itself more readily to discussions of the proposed nature.

Assume for a moment that the loudspeaker is mounted on an infinite baffle. It will be seen, that the power developed in R_a (Fig. 1) is a function of the current through it. Comparing the above equations it will be seen that $i\left(=\frac{dQ}{dt}\right)$ is analogous to the cone velocity $v\left(=\frac{dS}{dt}\right)$. Hence it is the cone velocity, and not the displacement, that is responsible directly for the radiated output power, v^2R_a.

From this it would seem that, if the radiated power is to be independent of frequency, the resistive components of the circuit should be high relative to the reactive components. This is not so in practice, since at frequencies where the wavelength is longer than twice the cone diameter the value of R_a falls as the frequency is lowered. The reactance of M_c also falls, however, and the increasing velocity resulting from this may largely compensate for the fall in R_a to the extent that the radiation remains substantially constant, down to a frequency where $\omega M_c - \frac{1}{\omega C_c} \to 0$. Here the velocity of the cone rises sharply, and is limited only by R_d, R_c and R_a. This produces an increase in the radiated power and is the resonant frequency of the loudspeaker.

Below this frequency, the impedance of the circuit rises as the frequency falls, due to the reactance of C_c, consequently the radiation falls very sharply. The resonant frequency may thus set the limit to the low-frequency response of the loudspeaker.

The above may be shown by considering the expression for the radiated power at the frequencies being discussed:

$$P = v^2 R_a = \frac{\text{Force}^2}{Z^2_M} \cdot \frac{2\pi\rho f^2}{c} \cdot (\pi r^2)^2,$$ where r is the radius of the cone.

Above resonance if $R_M << X_M$ (mass)

$$P \propto \frac{\text{Force}^2}{X^2_M} \cdot f^2$$

This is the condition of mass control, and since $X_M{}^2 \propto f^2$, P is independent of f.

Above, at, or below resonance, if $R_M >> X_M$

$$P \propto \frac{\text{Force}^2}{R_M{}^2} \cdot f^2 \propto f^2$$

This is the condition of constant velocity, and P falls with f at the rate of 6dB/octave.

Below resonance if $R_M << X_M$ (stiffness),

$$P \propto \frac{\text{Force}^2}{X_M{}^2} \cdot f^2 \propto f^4$$

This is the condition of constant amplitude and P falls with f at the rate of 12dB/octave.

Above resonance if R_M is comparable to X_M

$$P \propto \frac{\text{Force}^2}{Z_M{}^2} \cdot f^2$$

and P falls with frequency at a rate determined by the ratio $\frac{f^2}{R_M{}^2 + X_M{}^2}$.

In all cases the radiation resistance is small

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