In some cases the distortion characteristics must be considered in choosing the throat size. The pressure-volume characteristic can be considered linear only for small pressure changes. Large pressure changes result in the production of second-harmonic distortion. In a horn this distortion increases as the observed frequency is increased above cutoff. To maintain the throat distortion under 1% at any frequency requires that

$$\frac{P_a}{A_t}\left(\frac{f}{f_0}\right)^2 \leqq 450$$

where P_a is the acoustical power output in watts, A_t is the throat area in square inches, and f is the frequency at which the measurement is made. Generally this condition can be readily satisfied for tweeter or woofer horn units.

HIGH-FREQUENCY PERFORMANCE

The mass of the moving system, sound chamber, and voice coil inductance form a low-pass filter. If the sound chamber were absent, the equivalent circuit would consist of the blocked speaker impedance in series with the combination of motional capacity in parallel with the load resistance. This would form a half-filter section, the cutoff being given by

$$f_1 = \frac{(Bl) \times 10^{-9}}{2\pi\,(M_d L_c)^{1/2}}$$

Above cutoff the motional resistance becomes small and the efficiency is given by the relationship

$$\eta_a = \frac{4R_g R_h\,(Bl)^2 \times 10^{-9}}{\omega^2 M_d^2\,(R_g + R_c)^2 + [\omega^2 M_d L_c - (Bl)^2]^2 \times 10^{-9}}$$

At frequencies where the term $\omega^4 M_d^2 L_c^2$ predominates, the slope of the efficiency characteristic becomes asymptotic to 12 db per octave.

Most horn units have a sound chamber associated with

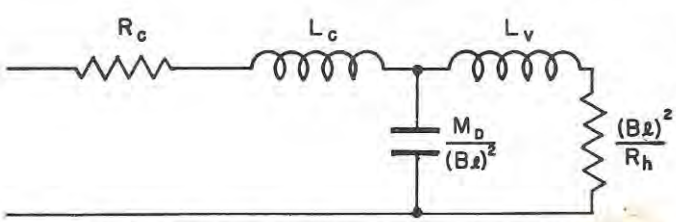

FIG. 7. Equivalent circuit of horn-type speaker at high frequencies.

them. The chamber volume combined with the moving system mass and voice coil inductance form a low-pass T section on the electrical side, as shown in Fig. 7.

The effect of adding a sound chamber of the proper size is to multiply the theoretical cutoff by a factor of the square root of 2 for a given moving system mass, or, conversely, the moving system mass may be doubled for the same cutoff frequency. The mass of the moving system appears as a shunt capacity having a value

$$C_m = \frac{M_d}{(Bl)^2 \times 10^{-9}}$$

The air chamber appears as an inductive reactance on the electrical side and is given by

$$L_v = \frac{(Bl)^2}{S_v} = \frac{4.42 \times 10^{-16}\,V\,(Bl)^2}{D_d^4}$$

If the chamber possesses circular symmetry, the value of the inductance is

$$L_v = \frac{3.47 \times 10^{-16}\,h\,(Bl)^2}{D_d^2}$$

If the horn unit is designed on a filter basis, the value of the chamber clearance is adjusted so that the preceding expression equals the voice coil inductance. This choice of h may not always be feasible, since this clearance in tweeters may depend on the maximum excursion that is to be handled at low frequencies. Also, at high frequencies the voice coil inductance is not constant because of core losses. This effectively places a shunt resistance across the voice coil which tends to reduce the inductance. Whereas the chamber extends the cutoff by 1.4 times the value in the absence of the chamber, the slope of the efficiency characteristic is 18 db per octave instead of 12 db above cutoff.

From the foregoing it can be realized that it is difficult to achieve a wide pass band in a single horn unit. The diaphragm excursion varies inversely with frequency so that relatively large chamber clearances are required combined with rugged moving systems to reproduce the lower frequencies, whereas light moving systems and small clearances are required to obtain good efficiency at high frequencies. Thus the requirements of lf power handling capacity are incompatible with the hf requirements. This is one of the factors which has led to the use of multiple horns, each covering a part of the spectrum, when performance to the limits of audibility is required.