Design Factors in Horn-Type Speakers

DANIEL J. PLACH

Jensen Manufacturing Company, Chicago, Illinois

Maximum efficiency in a horn unit can be achieved only if a conjugate match exists between driver and horn. This match is possible only if the unloaded resonance of the driver is greater than horn cutoff frequency. Since the throat resistance of a finite horn at cutoff is a small fraction of its asymptotic value, the point of reactance annulling is chosen at this frequency.

The use of hyperbolic-exponential horns makes possible practically any desired resistance or reactance characteristic near cutoff. The hyperbolic-exponential horn allows much more uniform transmission down nearer to cutoff than is possible with the exponential type.

THE ADVANTAGES of horns have been known since the early days of the acoustic art when the conical horn found extensive use in the radiation of sound. In 1919 Webster indicated the superiority of the exponential horn over the conical type. Subsequent investigation of generalized plane-wave infinite horn theory has led to the development of a family of hyperbolic exponential horns that have more desirable characteristics than the exponential type. This family of horns has been patented by the Jensen Manufacturing Company, and projectors using these flares are currently marketed under the trade name of Hypex.[1,2]

The general expansion of this family of horns is given by the equation

$$A_x = A_t \left(\cosh \frac{x}{x_0} + T \sinh \frac{x}{x_0} \right)^2$$

The T in this equation determines the family to which the horn belongs. If T is made equal to zero, the expansion is that of a hyperbolic cosine and has the form

$$A_x = A_t \cosh^2 \left(\frac{x}{x_0} \right)$$

For a T equal to 1, the familiar exponential horn results:

$$A_x = A_t \, e^{2x/x_0}$$

If T is set equal to infinity, the conical horn is obtained, given by the relationship

$$A_x = A_t \left(1 + \frac{x}{x_0} \right)^2$$

These horns may be classified as falling into two groups, the hyperbolic cosine or "cosh horn," where T includes values between zero and 1, and the hyperbolic sine or "sinh horns," where T includes values between 1 and infinity. The expansion of the cosh horn can be put in the form

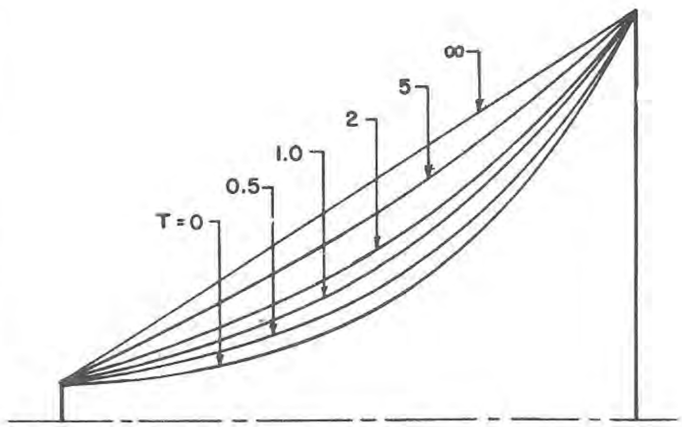

FIG. 1. Flare comparison of hyperbolic-exponential horns.

$$A_x = \frac{A_t \cosh^2 \left(\frac{x}{x_0} + a \right)}{\cosh^2 a}$$

$$T = \tanh a$$

$$\cosh a = (1 - T^2)^{-1/2}$$

For the sinh horn, the following relationships apply:

$$A_x = \frac{A_t \sinh^2 \left(\frac{x}{x_0} + a \right)}{\sinh^2 a}$$

$$T = \coth a$$

$$\sinh a = (T^2 - 1)^{-1/2}$$

Figure 1 is a comparison of horns of various T values having the same terminal dimensions. It will be noted that horns with smaller T values are characterized by smaller slopes near the throat, the T equal zero horn having zero slope at the throat. For a given cutoff frequency and throat size the horns with smaller T values expand more slowly and therefore require a somewhat greater length to achieve a given mouth size.

The throat impedance of an infinite horn may be repre-

[1] V. Salmon, U.S. Pat. 2,338,262.

[2] V. Salmon, Hypex Horns, *Electronics,* 14, 39 (July, 1941).