Questo è cosa pensa Colloms a proposito di trombe

da High Perfprmance Loudspeakers (4^ edizione) -1991
di Martin Colloms

Nota: lo stesso capitolo è presente nella 6^ edizione del 2005

4.7 HORN LOADING

The specialised subject of horns can only be briefly covered in this book, and interested readers are again referred to the bibliography for more detailed information[21]. While the author is aware of the danger of generalisation on this subject, in his view, horn loaded enclosures are not capable of top class subjective quality and most designs are inferior to typical direct radiator systems. The main reason for adopting horn loading, traditionally employed in public address situations, is to attain a high efficiency coupled with an improved control of directivity, vital considerations when large audiences are to be covered.

Improved acoustic matching

The intrinsic low efficiency of direct radiator diaphragms is due to their poor matching to the acoustic impedance of the air load. Almost any value of acoustic impedance may be produced at a horn throat by suitable geometrical design, and thus the match to the driver diaphragm may be optimised. Two benefits result: first, the efficiency is greatly increased and second, resistive termination presented to the diaphragm may greatly reduce the amplitude of any intrinsic response irregularities.

Efficiency

While optimum magnet design together with horn matching can result in efficiencies of nearly 50% in narrow band designs, if the frequency range is increased, great difficulty is experienced in maintaining both a smooth response and a high efficiency. A full multiway horn system capable of 40 Hz to 20 kHz over a useful 60° forward polar response, potentially may have an efficiency in the 10–20% range, but in practice this is often much less.

Bandwidth

The greatest problem is physical size. For a simple horn the lower cutoff frequency* is proportional to the effective diameter of the mouth when radiating into free space (i.e. 4π steradians). The mouth area $= \lambda_c^2/4\pi$ where λ_c is the cutoff wavelength. For example, for an f_c

* The frequency at which the acoustic impedance becomes reactive rather than resistive, i.e. the resistive component has fallen by 6 dB.

at 40 Hz, the mouth area should be 5.9 m^2. Such a design would need to be custom built into a location as part of a fixed structure, and is clearly impractical for most domestic situations. Figure 4.35 shows the influence of horn proportion and size.

The response may be extended in two ways. A small closed box may be added which loads the rear face of the diaphragm and provides an inductive impedance component. This may be adjusted to offset the increasingly capacitative throat impedance below cutoff. Additionally, if the radiation space is reduced, e.g. by mounting the system in a wall (2π) or between a wall and floor (π) or in a corner ($\pi/2$), the impedance match improves proportionately. Effectively, the flare of the horn is extended by the adjacent wall surface thereby reducing the cutoff frequency. With corner mounting a bass horn may have a basic mouth area 1/8 that of the free space mounted version, since the effective radiation space is reduced from 4π to $\pi/2$.

Position

Certain problems will arise if a horn is mounted in a corner. Maximum excitation of the room LF modes is inevitable, these producing irregularities in the radiation impedance and consequently in the sound pressure. In addition there will be mid-band colouration as the reproducing assemblies cannot always be flush fitted to the adjacent walls; this being virtually impossible with three way horns.

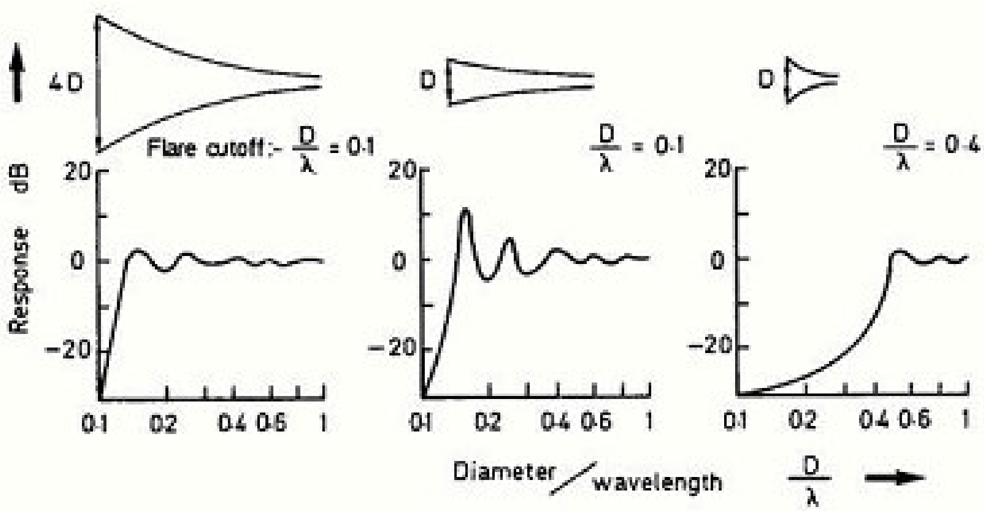

Figure 4.35 Typical response frequency characteristics of horn loudspeaker for different mouth openings and different flare cutoffs as function of the ratio of the mouth diameter to the wavelength (after Olsen)[22]

Propagation delay

Propagation delay in a horn produces large phase displacement which complicates the crossover points in a multi-way system. In theory the mouths should be aligned such that the propagation time to the listener from all energising diaphragms is the same, but the necessary physical displacement of the assemblies is impractical. However, the recent development of electronic delay lines of satisfactory quality means that the mouths of multi-way horns may now be conventionally aligned to the designer's convenience, and the differential delay and resulting phase discrepancy may be electronically compensated. The resulting system must of course be powered by separate amplifiers with active filter crossovers.

Folded horns

Theoretically a horn structure should be linear, and the smaller mid and treble types do adopt this format. However, large bass horns (15 m or more for a free field model) require some folding technique, unless the horn can be concealed; for example, built into the sub-floor structure. If the folds are too severe, reflections will occur, resulting in irregularities in the throat impedance and hence the frequency response.

Horn shape

Basic horn flares include the exponential, hyperbolic and tractrix forms (Fig. 4.36). The relationship between the cross-sectional area of an exponential horn and the axial distance x from the diaphragm is given by

$$S = S_0 e^{mx}$$

and the cutoff frequency by

$$f_c = \frac{mc}{4}$$

where S = cross-section; S_0 = throat cross-section = distance from throat; m = flare constant and c = velocity of sound.

The hyperbolic horn offers a short flare for a given cutoff combined with good driver termination, although the throat distortion is fairly high for a given output level. Horns with combinations of exponential, conical and hyperbolic profiles have also been used, the results largely depending on the empirical skill of the designer and the method of construction.

Directivity

The variable geometry of horn shapes has been taken even further by

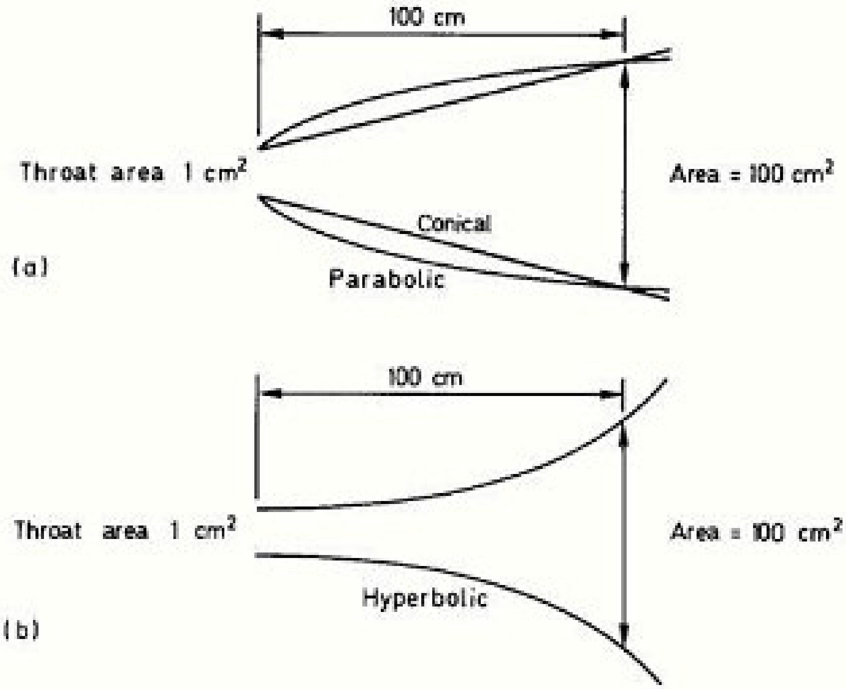

Figure 4.36 (a) Longitudinal sections of conical and parabolic horns. (b) Longitudinal sections of a hyperbolic horn (from Acoustics *by L. Beranek, copyright 1954. Used with permission of McGraw-Hill Book Co.)*

recent commercial designs where in an effort to maintain a constant horizontal directivity over a wide frequency range, the horn may be 'flattened'. The resulting mouth resembles a radial flared slot. Alternatively the horn may be 'thinned' in the vertical plane to strengthen the diffraction radiation effect to give good dispersion in the lateral plane.

In addition to the well known multi-cell methods, acoustic lenses and diffraction plate structures are also commonly employed to disperse the energy.

Upper range problems

The lower range cutoff has been discussed but a high range cutoff will also be present due to a combination of several factors. The driver diameter is of significance, as in a simple horn, where the throat is directly coupled, an upper frequency cutoff exists where the dimensions of the throat cavity are comparable with a sound wavelength. One solution involves reducing the throat cross-section considerably and, in addition, fitting a multi-channel coupling block in the remaining acoustic space. This places the throat-cavity resonance at a higher frequency, but eventually breakup will limit the maximum working frequency of a given diaphragm.

Figure 4.37 illustrates various throat structures which smooth and extend the response. An unfortunate by-product of reducing the throat section is a rise in the throat pressure change at lower frequencies, thus increasing the distortion. In part, this explains why it is impossible to design a single, wide range horn capable of high quality performance.

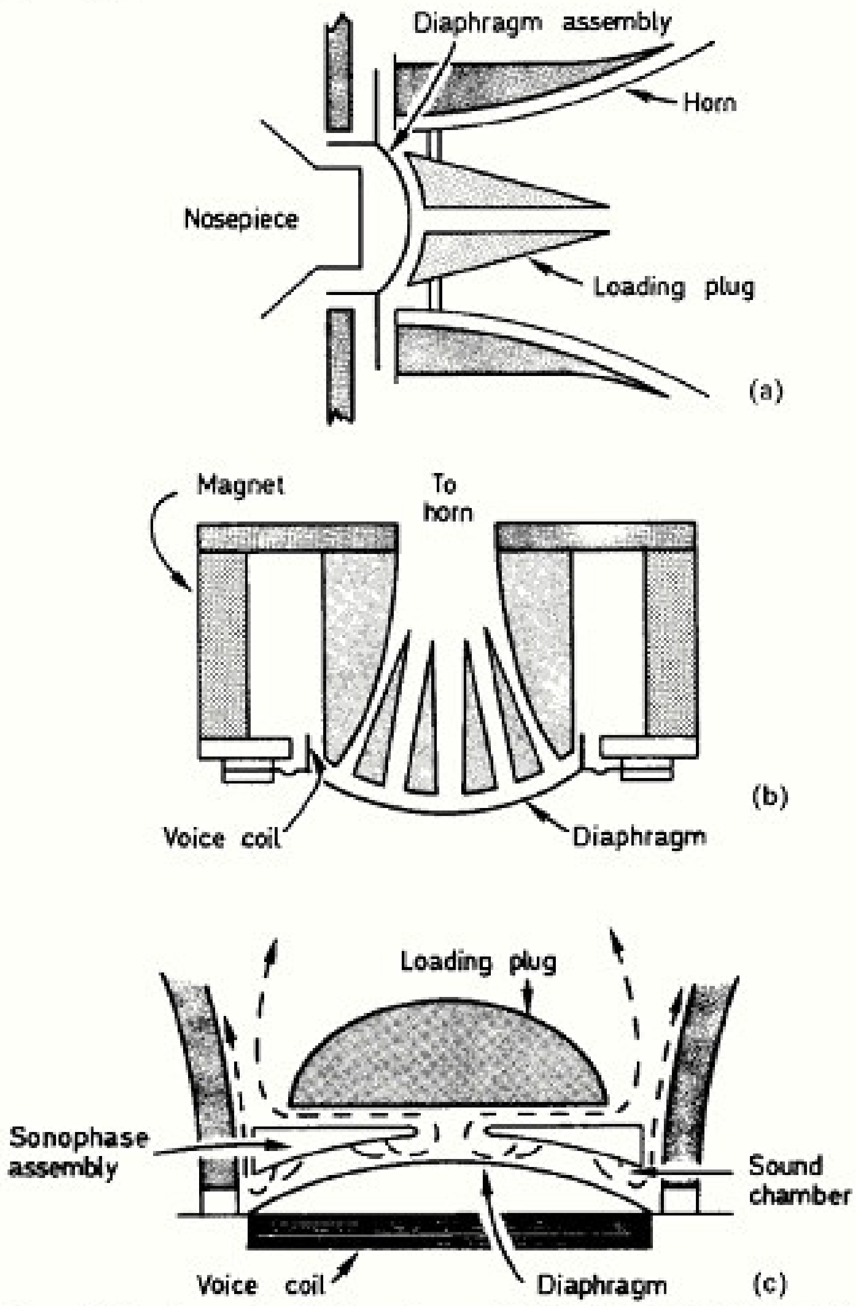

Figure 4.37 Examples of phase plugs used in the throat of HF horns (diagram (c) after Electrovoice)

Commercial horn systems

Many high output commercial systems employ horn loaded mid and treble transducers where the resulting high efficiency endows the design with a considerable power handling capacity. The LF range is usually a compromise, and generally employs a parallel combination of two or three 300 mm–350 mm high power, coned bass drivers in an optimum reflex enclosure. The latter will utilise a high efficiency response alignment which incorporates bass lift equalisation in the accompanying power amplifier.

Efficiencies of the order of 5% are possible using this technique and acoustic outputs of the order of 125 dB at 1 m are obtained with the energy maintained over a 60° forward arc up to at least 15 kHz.

The subjective performance is not on a par with direct radiator monitoring systems, but these horn designs are very satisfactory for their prime application, namely large audience sound coverage.