Design for Clean Bass

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The search for better loudspeaker enclosures centers around improvement in low-frequency radiation in small spaces. The author presents a simple and effective design.

THE MODERN TREND towards extension of reproduction into the upper limits of human hearing sounds thin and shrill if a corresponding extension of the bass range is not made simultaneously. There are many methods of extending bass reproduction, but most of these have inherent disadvantages and give rise to false or synthetic bass and annoying boom.

Truest reproduction has been accomplished only by the use of large exponential horns. This is because the exponential horn acts as an impedance matching transformer enabling the loudspeaker to set in motion the large amounts of air necessary for true reproduction. The exponential horn greatly reduces the motion of the loudspeaker, thus reducing distortion and increasing the power handling ability of the speaker system.

At low frequencies a loudspeaker operates as a constant velocity transducer. That is, for constant radiated power, the velocity of the cone remains constant as the frequency is halved, but the amplitude is doubled. In the lower audio spectrum extremely large amplitudes are required to radiate even small amounts of power. These large amplitudes give rise to distortion due to the non-linear suspensions of the cone and non-linear flux densities in the air gap. A horn greatly increases the air loading on the cone and reduces the amplitude the cone must travel to radiate the same amount of power. This materially reduces distortion.

A true exponential horn is a passageway whose area doubles along discrete increments of length. Two factors govern the succes of a horn operated at low frequencies. First, the taper of the horn should be such that the propagation of low frequencies through the horn is accomplished easily. For good low-frequency reproduction, the taper should be very gradual. Second, the mouth area of the horn must be adequate if smooth response is to be realized. If the mouth area is inadequate, reflections occur at the mouth and the response tends to resemble a picket fence. The above criteria may be expressed mathematically as

$$A = A_0 \varepsilon^{xm}$$

where A = area at any point along horn axis

A_0 = area of throat of horn

x = distance along axis of horn

$m = \frac{4\pi f_c}{c}$ constant denoting taper rate of horn

f_c = cut off frequency of horn

c = velocity of sound in air

The mouth area of the horn should equal approximately the area of a circle whose diameter is $1/\pi$ times the wave length of the lowest frequency to be reproduced.

If we desire to make a true horn with an 80-cps cut-off, then the rate of taper should be such that the area doubles every 9 in., and the mouth should have an area of approximately 2110 sq. in. If we desire to operate this horn from a 12-in. driver having an effective cone area of 75 sq. in., then the horn must be nearly 4 ft. long. If a lower cut-off frequency is desired, then the taper will be slower and a larger mouth area will be required, and the length will be greatly increased. Thus it is easy to see that straight horns are impractical for home use. Many ingenious methods of folding horns have been developed, but the complexities of construction have made them relatively expensive, and the maintaining of an optimum mouth area has made these types of units too large for home use.

The Super Horn (patent pending) has been developed to overcome all these difficulties and still meet all the above requirements of a true horn. By operating a horn where three mutually perpendicular surfaces intersect such as in the corner of the room, the walls and floor (or ceiling) act as an extension of the horn mouth giving rise to images I_1, I_2, I_3, I_4, and I_5 (See *Fig.* 1). Thus, the effective mouth area equals six times the true mouth area.

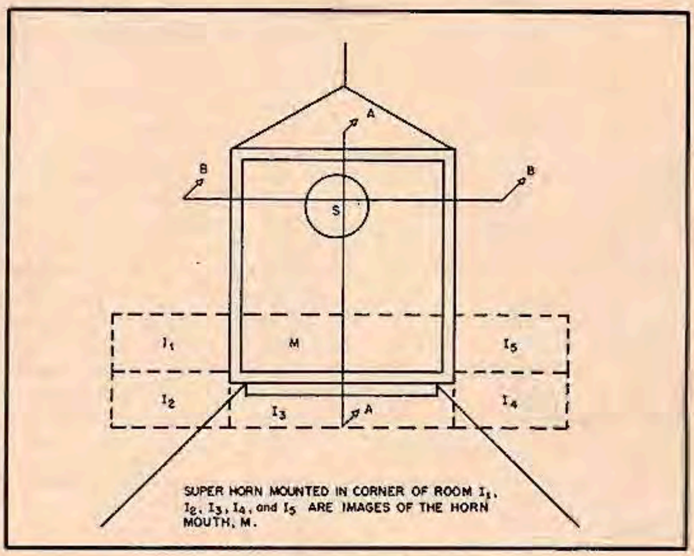

Fig. 1. Images of horn-mouth opening effectively multiply actual opening when speaker is corner-mounted.

The construction of the Super Horn is such that panels *1, 2, 4,* and *5* act as an exponential horn following a true exponential within one per cent. (See *Figs.* 2, and 3). The throat of the horn (T) is formed by the top edge of panel *2*, and panels *4* and *5*. The mouth (M) is defined by the bottom edge of panel *3*, the bottom edge of panel *1*, and edges of panels *4* and *5*. V_c acts as a coupling chamber to keep high frequencies out of the horn. X_1 and X_2 indicate the distance over which area of the horn doubles. The area at Q is double that of the throat and the area of the mouth is double that of Q. Once a flare-rate is chosen, the rest of the dimensions of the cabinet may be determined geometrically.

Two models of the Super Horn are presently available. One designed for 12-in. speakers has a taper rate to give a 78-cps cutoff and has an effective mouth area of 1728 sq. in. This satisfies very closely the above requirements of

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good horn design. The second, designed for 15-in. speakers has a taper rate to give a cutoff of 70 cps and has an effective mouth area of approximately 2500 sq. in., again satisfying the above requirements.

Figure 4 shows the impedance vs. frequency curve of a G.E. S1201D speaker mounted in an infinite baffle. The bass resonance of this combination is 54 cps. This curve and that of *Figs.*

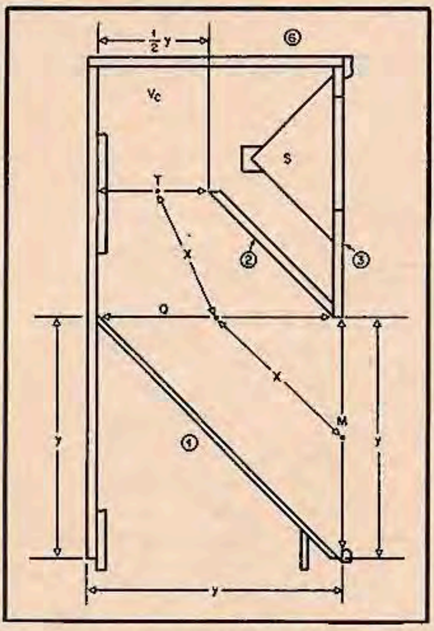

Fig. 2. Cross section of Super Horn through plane A-A of Fig. 1. Circled numbers indicate panel references in text

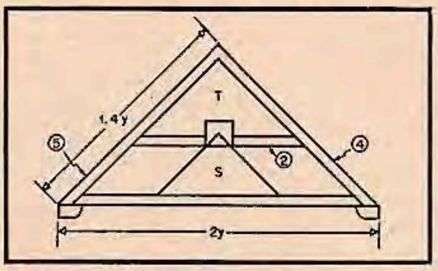

Fig. 3. Cross section of horn through plane B-B

5 and 6 were made by using the circuit shown in *Fig. 7* and adjusting the decade resistance box until the voltage drop across it equalled the voltage across the speaker, thus indicating impedance directly. *Figure* 5 shows the impedance curve of the same speaker in a well padded enclosed box of 4 cu. ft. volume Note that the resonance has been raised to 61 cps, or 20 per cent. *Figure* 6 shows the impedance curve of the same speaker in the Super Horn designed for 12-in. speakers. Note that the resonant frequency of the speaker has been reduced to 38 cps, or 27 per cent below infinite baffle mounting, or 40 per cent below that obtained in a totally enclosed box of the same approximate volume. Nearly a full octave has been added to the clean reproduction. This lowering of the resonant frequency shows that the air loading on the speaker is increased more than three times in the 40-cps region and even more at higher frequencies. Note the reduced amplitude of the resonant peak. This shows how the acoustical damping is increased.

It has been observed that radiation from the horn drops off rapidly below the cutoff frequency, but some frontal radiation from the cone of the speaker reinforces the lower frequencies and extends the reproduction. The acoustic loading is maintained down into the 40-cps region and acts as an acoustic damping on the cone, greatly improving the transient response and power handling ability of the system.

Early experimental work with this design indicated that if the best possible reproducer were to be constructed, then certain steps would have to be taken to eliminate panel vibration. The sides and front panel are made of ¾-in. plywood. The internal panels *1* and *2* are made of ⅝-in. plywood, and these panels act as additional bracing for the sides. A spline or bone is run down the back at the intersection of the sides to give additional bracing, and to act as a back leg.

The ultimate test of any reproducer is how it sounds. When using live tape as source material, a good speaker and an *Ultra Linear* amplifier, the illusion of presence with the Super Horn is amazing. Organ music moves up and down

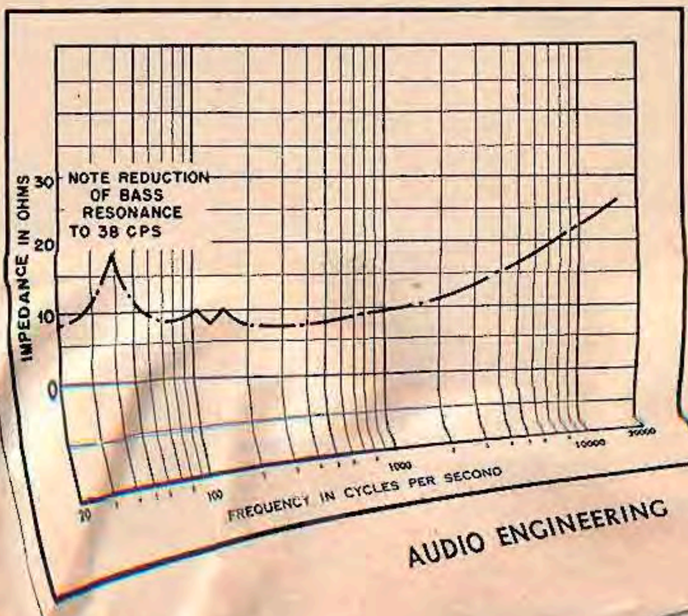

Fig. 6. Impedance curve of GE S-1201 D speaker mechanism in Super Horn.

the scale and fundamentals are clearly reproduced. Bass transients, e.g. kettle drums, have a cleanness which only an untuned and highly damped reproducer can give. Plucked strings and the tym-

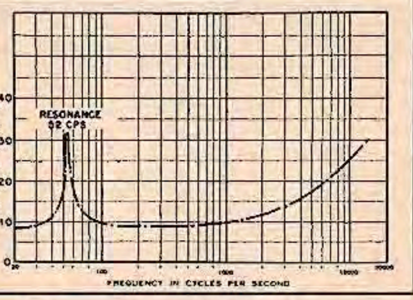

Fig. 4. Impedance curve for GE S-1201D speaker mechanism in true infinite baffle.

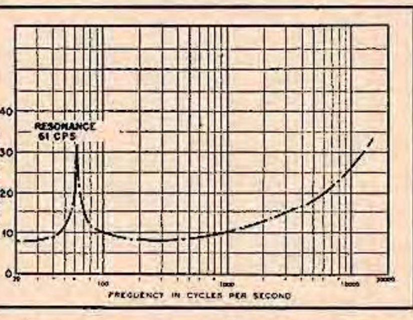

Fig. 5. Impedance curve of speaker of Fig. 4 in enclosed box.

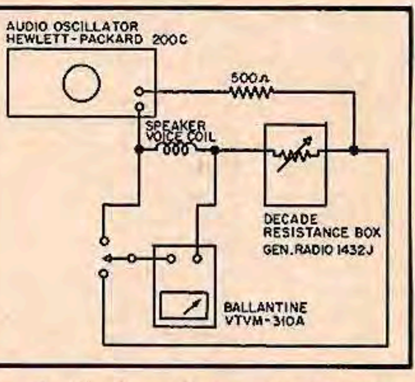

Fig. 7. Circuit used to make impedance measurements.

External appearance of the Gately Super Horn.

pani are easily separated. The smoothness of response and lack of tuning give the bass viols a rich full sound, and rid them of the Johnny-one-note sawing sound associated with some other types of enclosures. The excellent coupling between the horn and the floor gives the reproduction a presence not otherwise obtained.

Bibliography

Harry F. Olson, *Elements of Acoustical Engineering*, D. Van Nostrand Company, Inc. New York, 1940.