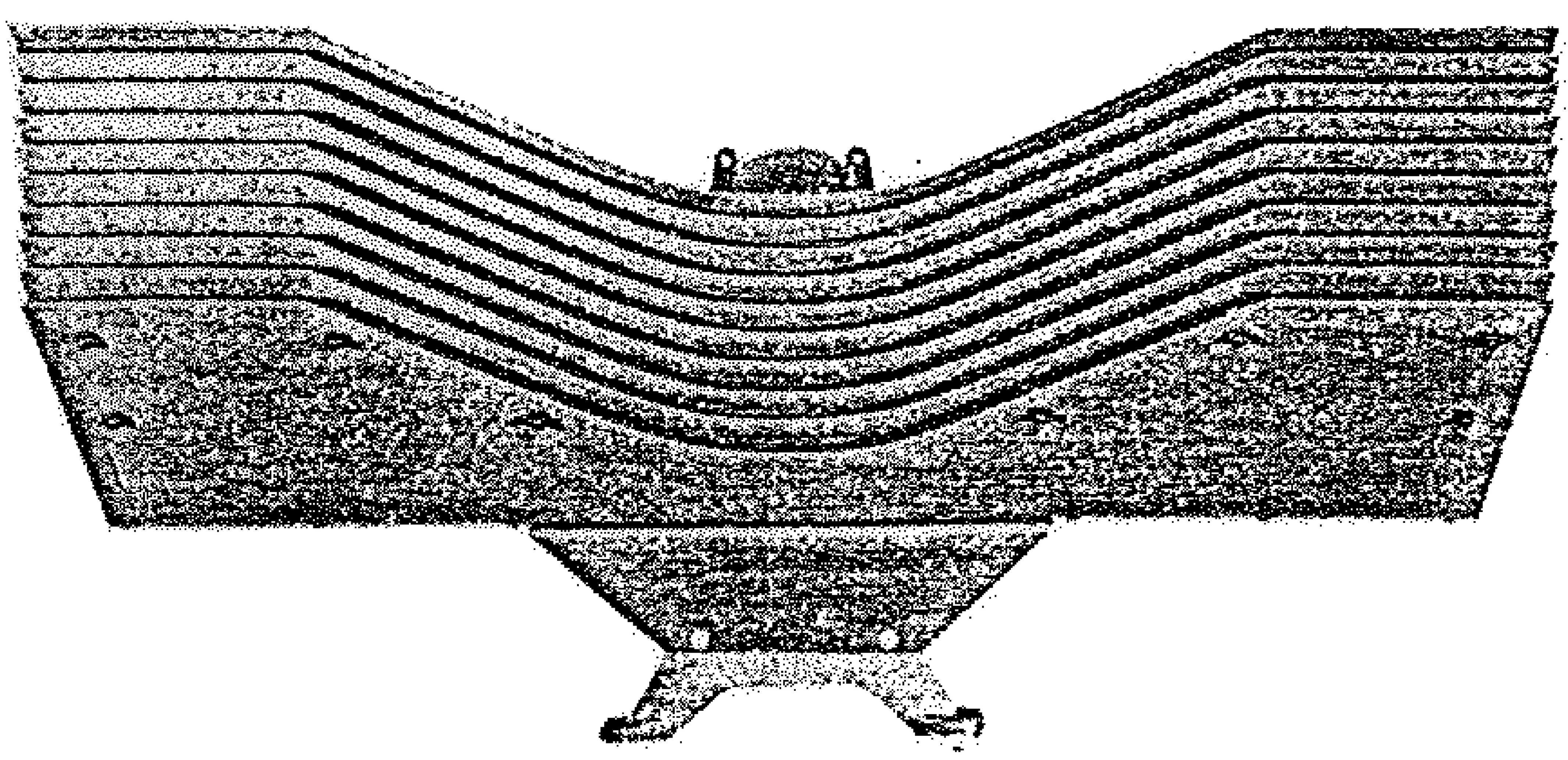

Fig. 2. Front view of T551A acoustic lens assembly.

be produced since the waves will be forced to traverse the longer inclined path. It is then a question of shaping the plates to obtain the desired type of lens action. The effective index of refraction, n, can be shown to be equal to the reciprocal of the cosine of the angle between the slanted plates and the direction of the oncoming wave. In such path-length devices, n remains constant with frequency to a point where the plate spacing approaches a half-wavelength, and an index of refraction up to 1.5 is readily achieved.

Figure 2 shows such a lens designed to give 80° of coverage horizontally and 50° of coverage in the vertical direction. To obtain this type of coverage calls for a bicylindrical lens which is obtained by shaping the individual plates in accordance with the following:

The final surfaces of the refracting lens are determined empirically; however, the first approximation involves the following calculation of an aplanatic surface which will convert a plane wave to a spherical wave:

Referring to Fig. 3, let F represent the point on the axis of the lens from which all refracted rays will appear to be radiated. The distance from the curved surface on the axis to the apparent focal point is represented by f, and t is the thickness of the lens at the narrowest point.

Since S_1 is plane and normal to the incident plane wave, the incident rays are undeflected after entering the first surface.

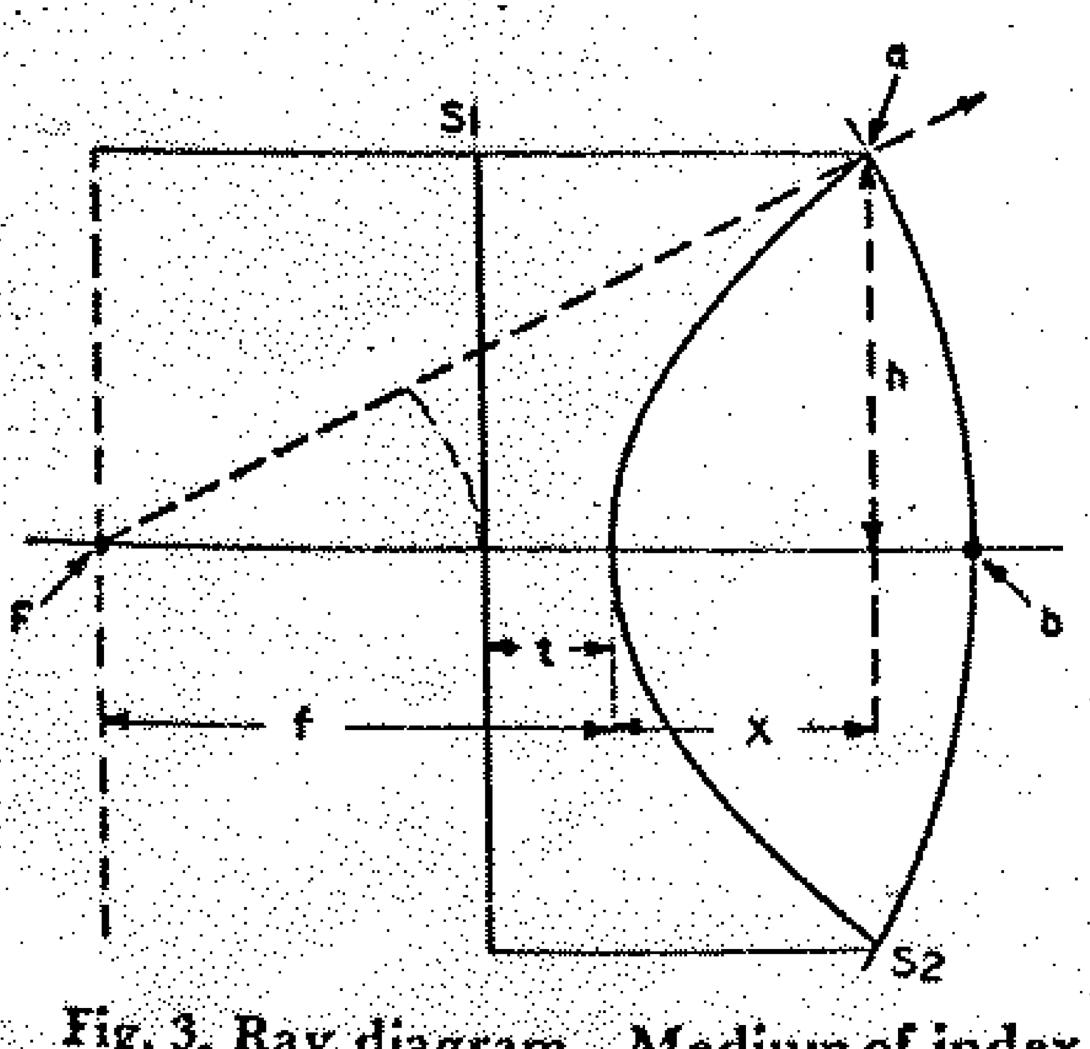

Fig. 3. Ray diagram. Medium of index n between surfaces S_1 and S_2. Index of refraction unity outside S_1 and S_2.

In order for an incident ray entering the lens at some arbitrary distance, h, from the axis of the lens to appear to have come from F after leaving surface S_2, the time required to travel from F to a should equal the time required for an axial ray to travel from F to b. That is:

$$\frac{f-t}{v_0} + \frac{nt}{v_0} + \frac{\sqrt{(f+x)^2 + h^2} - f}{v_0} = \frac{n(t+x)}{v_0} + \frac{f-t}{v_0}$$

which simplifies to

$$(n^2 - 1)x^2 + 2fx(n - 1) - h^2 = 0$$

which is a hyperbolic surface.

These calculations produce an idealized acoustic lens, the plates of which must be modified in shape empirically to produce the desired overall results. Experience has further shown that closing the sides of the plates introduces sizable irregularities in the frequency response. On the other hand, with the sides open, the plates must be extended horizontally for a minimum of some 5 or 6 in. beyond the curved edges of the plates to obtain a smooth frequency response with uniform angular distribution.

The driver unit is coupled to a short elliptical horn terminated in a bicylindrical slant-plate lens. Figure 4 shows the results of tests made under open-air conditions at 10 kc on the horizontal axis with and without a cylindrical lens. This gives a fairly good idea of the refracting power of the lens.

Figure 5 shows the horizontal distribution of an 80° horn assembly at four frequencies as measured under open-air conditions. Similar measurements of the vertical distribution are shown in Fig. 6. The horizontal distribution of the same unit as measured on a studio sound stage is shown in Fig. 7. Warble tones were used in this case and the curves shown are of the average response. The sound-stage measurements and the equivalent open-air measurements will be found to be in close agreement.

By way of comparison, Figs. 8 and 9 show the horizontal and vertical distribution of a typical 2 × 5 multicellular theater-type horn, measured under open-air conditions. The rather sizable lobes in the distribution characteristic are apparently typical of this type of loudspeaker and are particularly undesirable for stereophonic reproduction.

The 50° acoustic lens employs the principle of the obstacle array in the form of perforated plates. Since the horizontal and vertical distribution angles are the same in this case, a horn having a circular cross section is used. Figure 10 shows this type of lens. The driver unit is the same as that used with the 80° unit. The distribution curves obtained with this unit are substantially similar to those obtained with the 80° lens except for the smaller angle of horizontal coverage. Here again, as in the case of the slant-plate lens, closing the sides of the perforated plates introduces a rise at the upper end of the frequency response as well as a too rapid falling off of the angular distribution with increase of angle from the axis of the lens. These undesirable factors have been corrected by introducing rectangular openings in the side walls of the casting in which the perforated plates are mounted.

The very low frequencies of the audible spectrum contribute essentially nothing to stereophonic localization. The design problems pertaining to low-frequency horns are therefore the same as those for single-channel reproduction; namely, the design of the driver units and the coupling between these units and their horn.

For the systems under discussion, two low-frequency horn systems have been developed, one equipped with two driver units and one with four driver units. These consist essentially of short front-loaded horns having efficiencies of approximately 25%. In order to avoid high-frequency attenuation due to an air volume between the driver diaphragm and the horn throat, the ratio of the diaphragm area to the horn-throat area has been kept at 1:1. In order to minimize distortion at low frequencies, the voice coils of the drivers overhang the pole pieces by about 20%. A theoretical response curve for a four-driver, low-frequency horn assembly is shown in Fig. 11.

The dividing network which couples the low-frequency and high-frequency horn assemblies to the amplifier output has a crossover at 500 cycles with a 12-db/octave attenuation on both sides of this point. The network input and output impedances are 16 ohms. In the 50-w horn system one network serves to couple one high-frequency and two low-frequency drivers. In the 100-w horn system, two networks are employed to couple two high-frequency and four low-frequency drivers.