This invention relates to electrodynamic speakers for sound reproduction, and more particularly to speakers of the class referred to as "tweeters" intended primarily to reproduce the higher frequencies of the audible range.

The flatness or uniformity of the response of a speaker over the range of frequencies for which it is designed, in the direction of its axis of radiation, is frequently used as a measure of performance. The on-axis frequency response curve, however, is not a complete measure of the realism of the reproduced sound. One of the well known deficiencies of present speakers, especially those intended for the treble range, is progressive "beaming" at higher frequencies; that is, the volume of sound transmitted to positions away from the axis of the speaker, falls off appreciably as the frequency increases. Therefore, the total energy radiated is attenuated as the frequency increases. Since a normally reverberant room tends to integrate on-axis and off-axis sound, the net effect is an attenuated treble response.

Flat on-axis response combined with good dispersion, that is, uniform response over a reasonably large solid angle, apparently produces the most realistic direct to reflected sound in the room to create a maximum effect of realism. Good horizontal and vertical dispersion not only permits the speaker to be listened to at off-axis positions, but also strongly influences the quality of reproduction at positions on-axis with the speaker. Without such dispersion much of the effect of the acoustics of the hall in which the recording was made is lost, and the listener's awareness of the speaker as an artificial sound source, of dimensions much smaller than an orchestra or choral group, is sharpened.

The principal object of this invention is to produce a loudspeaker which has a substantially flat on-axis frequency response in the high frequency range, combined with a reasonably flat total power response and reasonably uniform dispersion both vertically and horizontally.

The speaker here disclosed consists, in general, of a relatively small direct-radiating diaphragm, preferably dome-shaped, having a preferably cylindrical voice coil mounted directly on its rim, a magnet assembly having an air gap in which the voice coil is disposed, and a compliant suspension composed of elastic material. The dome-shaped diaphragm 16 has a voice coil 17 attached to its rear rim 16a, and disposed in the gap defined by rim 12a. The voice coil and rim 12a define between them an air gap 18. The ends of the coil are carried out to form leads 19. The diaphragm is made of a light, rigid material, such as phenolic impregnated cloth. For example, the diaphragm may be made of two layers of cloth bonded together with their weaves at 45° to one another. The voice coil is cylindrical and of the self-supporting type, and is cemented to the diaphragm.

In the form shown in FIG. 1, plate 12 has several spaced notches 21 in rim 12a. Four notches are here shown, but three, or more than four, may be used. These notches are filled with pieces of elastic foam material 22 (one of which is shown removed in FIG. 2), which extend into the air gap 18 and are adhesively secured to the top plate 12 and to the voice coil 17, forming the suspension for the diaphragm. A pad 23 of sound absorbent material, such as glass wool, is placed between the end of pole piece 14 and the diaphragm, and a packing 24 of similar material fills the space inside the magnet, up to a screen 28 of non-magnetic mesh material which is placed around the upper part of the pole piece to keep the packing material out of the air gap.

Examples of a suitable material for the suspension pieces 22 are polyurethane foam and foamed latex. This material is put in a semi-solid or liquid uncured state, and then cured. Such a material is sufficiently adhesive in itself to adhere to the voice coil and the core is sufficiently compliant so that the resonant frequency of the diaphragm and voice coil assembly is near the lower end of the operating range for which the speaker is intended.

In the form of speaker shown in FIG. 3, the magnet assembly, diaphragm 16, and voice coil construction are essentially the same as in the form previously described, except that plate 12 is replaced by a top plate 25 with a continuous inner rim 25a. The entire air gap around the voice coil is filled with a ring 26 of elastic material which forms the suspension for the voice coil and diaphragm.

The speaker shown in FIG. 4 has the same magnet structure as that shown in FIG. 1, and the diaphragm and voice coil are the same as in the forms previously described. The suspension consists of pieces 22 of elastic foam material, as in FIG. 1, but the intervening spaces are filled with a highly compliant elastic material 27 such as butyl rubber which may be applied in liquid form. The speaker may be mounted in a baffle in any standard manner.

Some of the dimensions of the parts are shown somewhat exaggerated in the drawings for clarity. For example, the diaphragm is very thin and the voice coil is made of fine wire. The air gap 18 is in the order of .040 inch wide for a two inch diaphragm, and the notches are proportionately small.

To assemble the diaphragm in the speaker, the diaphragm is held in an appropriate fixture to center the voice coil in the gap. Pieces of the suspension forming material in uncured form are placed in the gap and cured under heat, for example at about 300° F. The material, in curing, foams and adheres to the coil and top plate. An alternative method of forming the suspension is to form the speaker in a suitable fixture, and then to pour pieces of suspension forming material into the gap. After the pieces have been cured, the butyl rubber has a negligible effect on the compliance and serves mainly to seal the speaker against dust.
The diaphragm is of light weight and is made in relatively small sizes, as the speaker is intended for the high frequency range. Preferably, the diaphragm is formed in the shape of a dome or approximately a section of a sphere for maximum rigidity. Essentially the diaphragm operates as a direct-radiating rigid piston.

A diaphragm of two inch diameter is especially suitable for a range of frequencies of 1000 to 7500 cycles per second. The diaphragm and voice coil have a mass of approximately one gram and the compliance is such as to produce a resonant frequency in the neighborhood of 1000 c.p.s. The measured on-axis response of one model of a two inch diaphragm speaker in this range was flat within plus or minus 2 decibels, and only slight attenuation in off-axis response with increase in frequency occurred. Up to 5000 cycles per second the off-axis response remained within 2 decibels of the on-axis response up to an angle of 45° in any direction from the axis. At 7500 cycles per second the off-axis attenuation at 30° was still less than 3 decibels, and at 45° within 6 or 7 decibels. Above 7500 c.p.s. the off-axis attenuation increased somewhat, but was considerably less than that exhibited by high frequency speakers of conventional types.

For a higher frequency range a smaller diaphragm, for example a 1½ inch diameter diaphragm, may be used. One model of a speaker of this size exhibited negligible off-axis attenuation through an angle of 45° over the 7500 to 10,000 c.p.s. range, and the on-axis response was flat within plus or minus 1.5 decibels up to 20,000 c.p.s. At 15,000 c.p.s. the off-axis attenuation at 45° was within 6 decibels.

It is understood that the shape of the diaphragm, coil, and magnet may be varied, for example the edge of the diaphragm, the coil, and gap may be polygonal. The construction of the magnet assembly may also be varied. For example, the pole piece structure may include a permanent magnet.

What is claimed is:

1. A loudspeaker comprising a magnet structure having a rim defining a generally circular air gap, said rim having circumferentially spaced notches, a generally circular diaphragm, a generally cylindrical voice coil attached to said diaphragm and disposed in said gap in spaced relationship to said rim, and pieces of elastic material disposed in said notches and extending to said coil, said pieces being adhesively secured to said rim and said coil and constituting suspension means for said diaphragm.

2. A loudspeaker comprising a magnet structure having a rim defining a generally circular air gap, said rim having circumferentially spaced notches, a generally circular diaphragm, a generally cylindrical voice coil attached to said diaphragm and disposed in said gap in spaced relationship to said rim, and an elastic suspension means disposed in said gap and adhesively secured to said rim and said voice coil, said suspension means comprising pieces of foam rubber-like material disposed in said notches and extending to said coil, and highly compliant rubber-like material bridging said gap between said pieces.

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