June 9, 1964 E. THALER 3,136,382

ACOUSTIC TRANSDUCER

Filed Feb. 14, 1962 4 Sheets-Sheet 1

FIG. 1

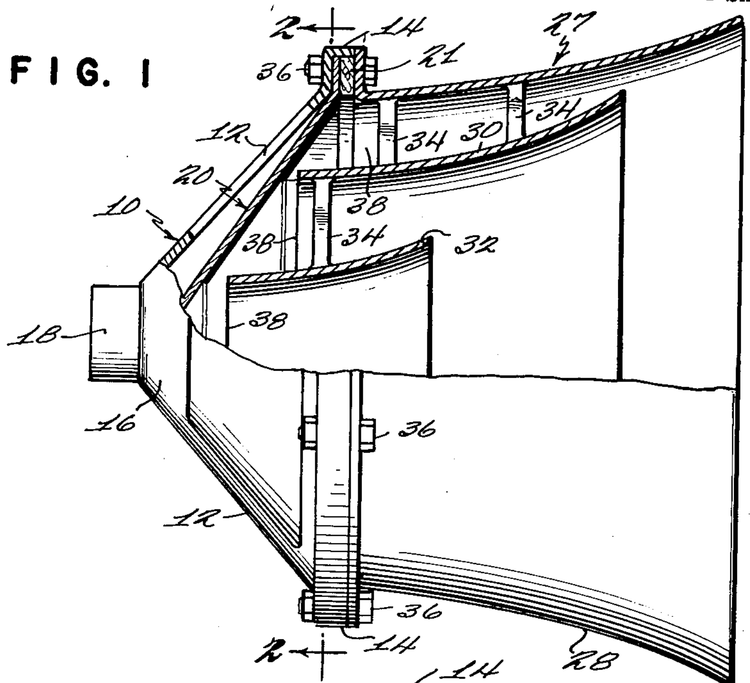
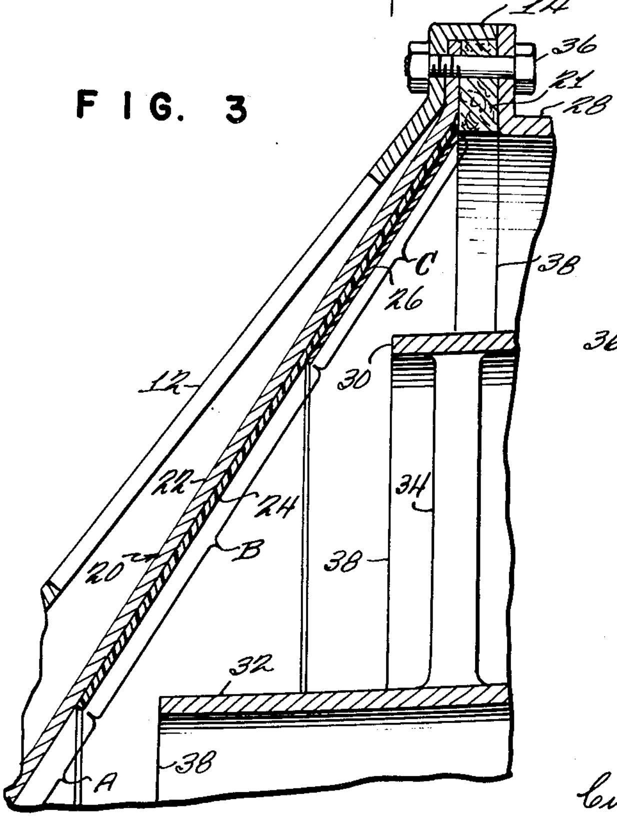


FIG. 3



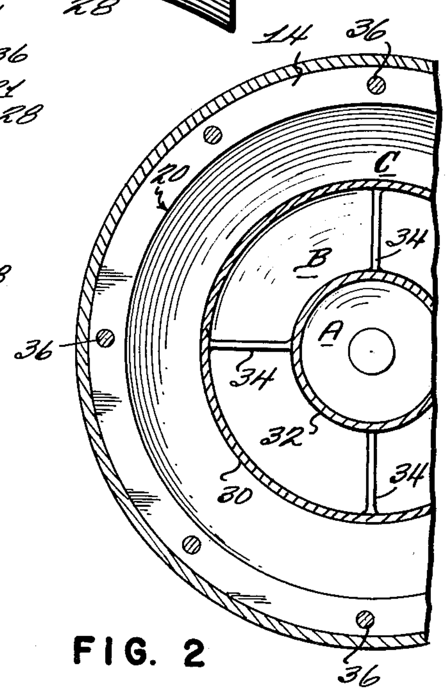


FIG. 2

INVENTOR.
EDWARD THALER
BY
Cushman, Darby & Cushman
ATTORNEYS

BEST AVAILABLE COP'

June 9, 1964 E. THALER 3,136,382

ACOUSTIC TRANSDUCER

Filed Feb. 14, 1962 4 Sheets-Sheet 2

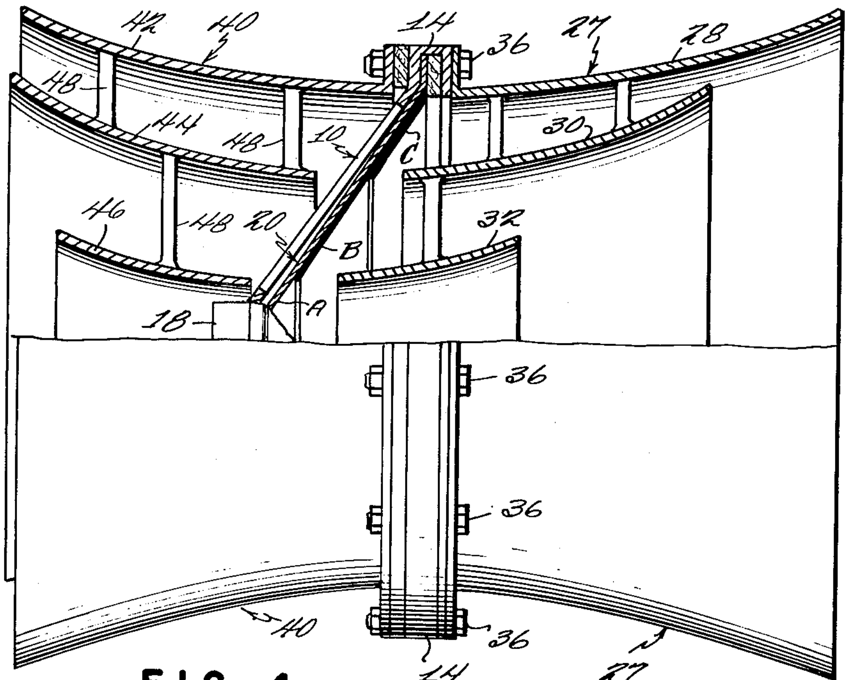


FIG. 4

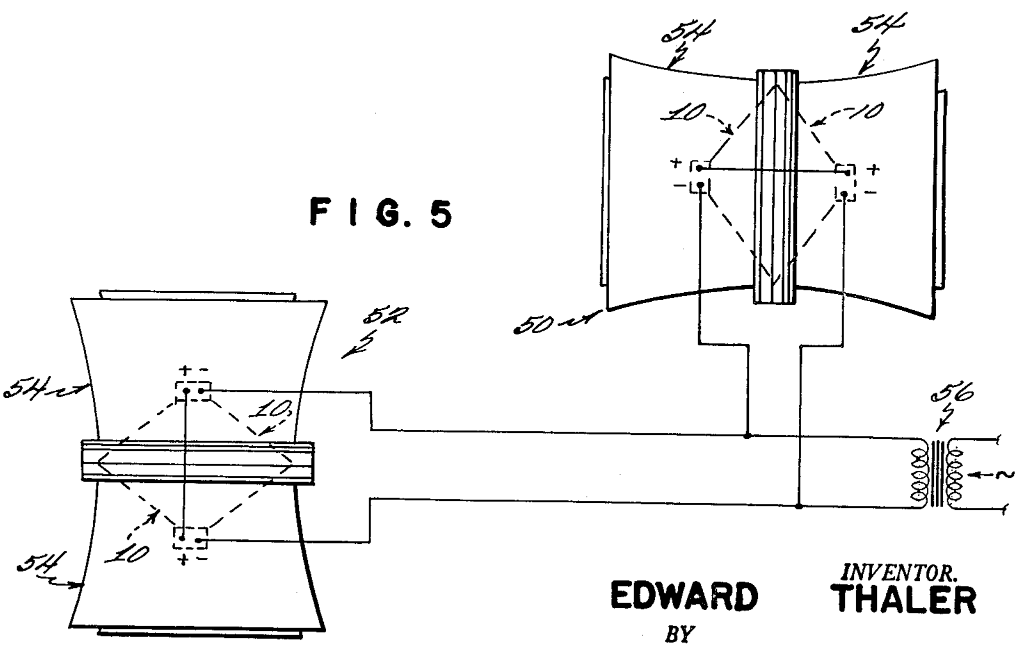


FIG. 5

INVENTOR.
EDWARD THALER
BY
Cushman, Darby & Cushman
ATTORNEYS

BEST AVAILABLE COP'

June 9, 1964 E. THALER 3,136,382

ACOUSTIC TRANSDUCER

Filed Feb. 14, 1962

4 Sheets-Sheet 3

FIG. 6

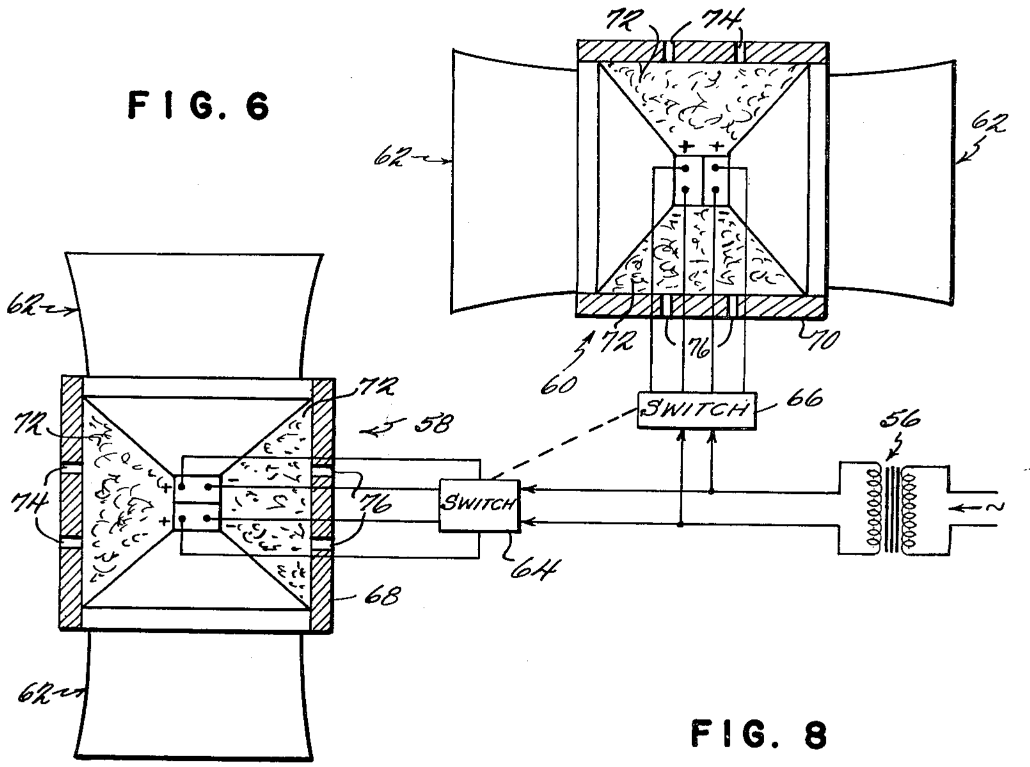
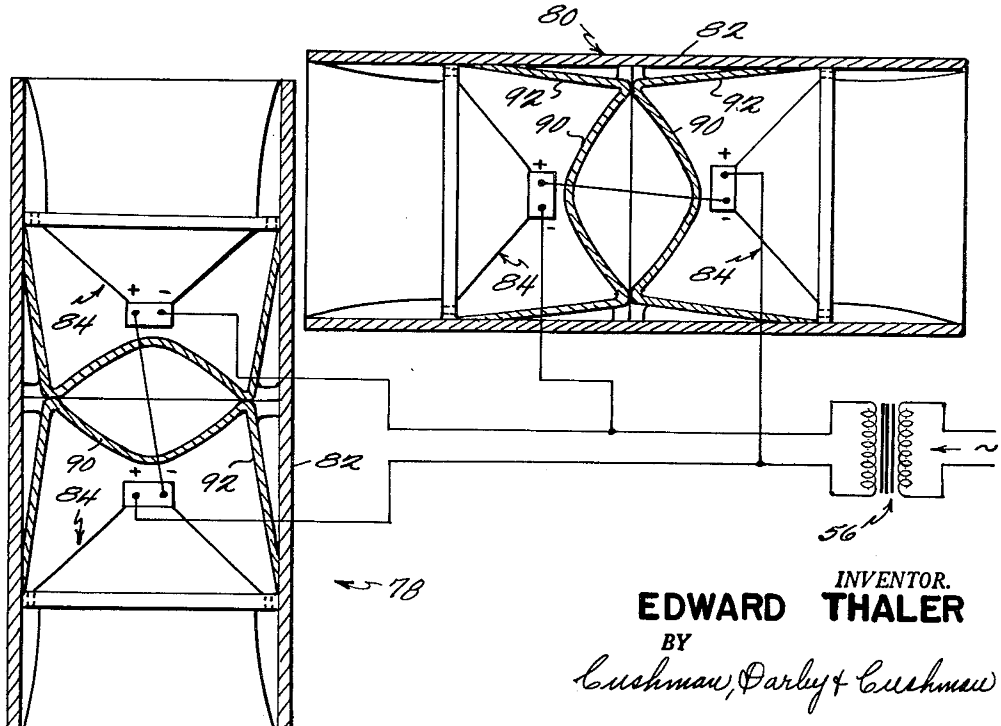


FIG. 8



INVENTOR.
EDWARD THALER
BY
Cushman, Darby & Cushman
ATTORNEYS

June 9, 1964 E. THALER 3,136,382

ACOUSTIC TRANSDUCER

Filed Feb. 14, 1962 4 Sheets-Sheet 4

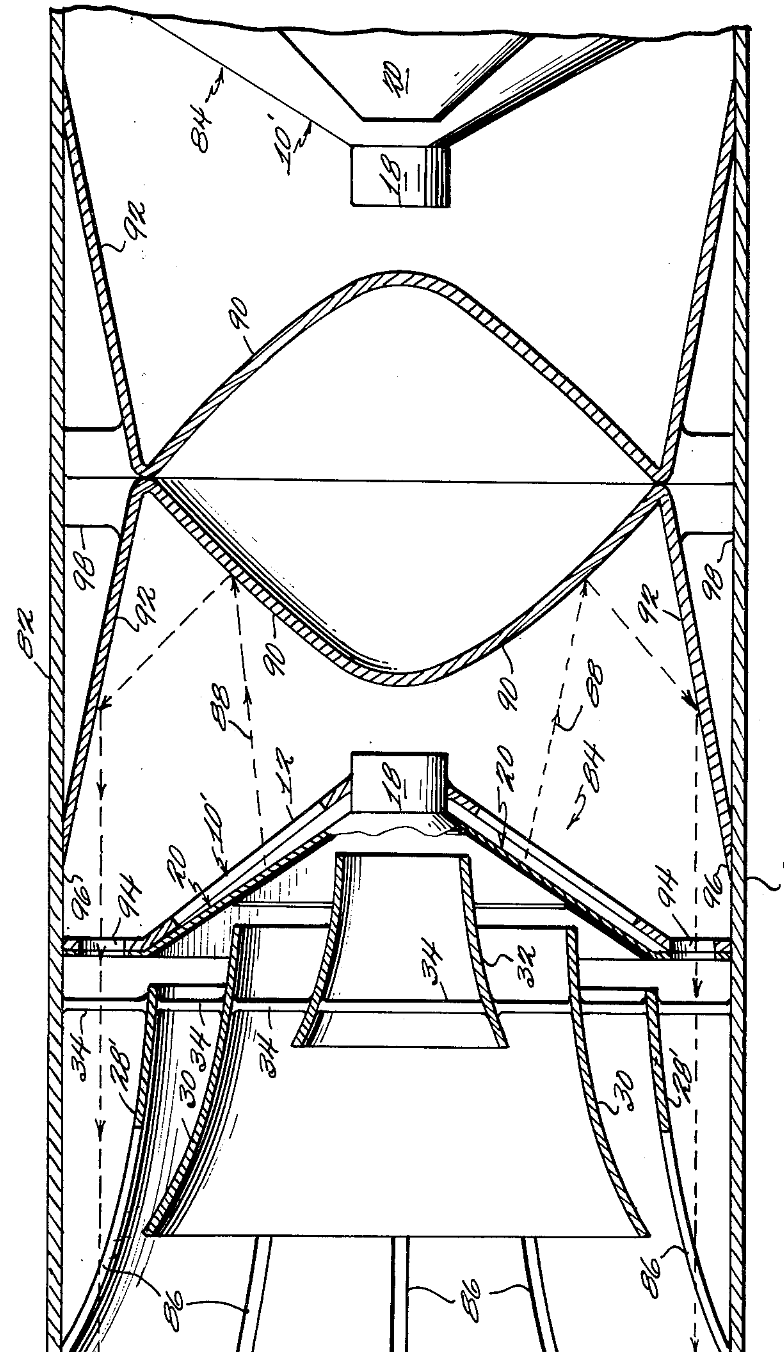


FIG. 7

INVENTOR.
EDWARD THALER
BY
Cushman, Darby & Cushman
ATTORNEYS

United States Patent Office

3,136,382

Patented June 9, 1964

3,136,382

ACOUSTIC TRANSDUCER

Edward Thaler, 19 Grove St., Middletown, N.Y.

Filed Feb. 14, 1962, Ser. No. 173,226
33 Claims. (Cl. 181—31)

This invention relates to a high fidelity acoustical energy transforming or transducing system and to component parts thereof, particularly to an improved loudspeaker diaphragm and to loudspeakers themselves as well as to loudspeaker arrangements and systems employing the aforesaid improved diaphragm.

Though this invention is applicable to microphones as well as loudspeakers the following discussion and detailed description is directed mainly to loudspeakers as exemplary of acoustic transducers.

The loudspeaker is the most important component in a hi-fi system. This device must transduce (or reproduce) the sounds created, for example, by many musical instruments—mimic them separately as well as duplicate their sounds simultaneously.

Consider, for a moment, a simple loudspeaker and each of its component parts and their functions. A loudspeaker in its simplest form converts electrical energy into mechanical or sound energy. In order to have such a device emit sound, a certain amount of electrical energy, or current, must be supplied. This current is fed into a coil of wire (voice coil) which, in turn, causes a variable magnetic field about the coil. The voice coil is situated between the fields of a permanent magnet for example, and in this field is made to move back and forth as its own magnetic field, which is the variable magnetic field, interacts with the field created by the permanent magnet. The voice coil, in turn, moves a diaphragm upon which it is mounted and it is this diaphragmatic motion which agitates the air and thus creates sound by the corresponding air vibrations.

Any vibrating mass, such as a speaker diaphragm, or cone as sometimes called, has one frequency at which it vibrates most easily. At the lower frequencies a cone acts as a piston and the entire structure moves as a single unit from apex to rim. A more rapid vibration corresponds to a higher frequency and a large mass of material cannot move as rapidly; thus these high frequencies tend to confine their vibrations to the smallest area of the cone or the apex of the cone. If it is desired to increase the bass range, the cone size is increased but then high range reproduction is sacrificed; or, to increase high range reproduction cone size is diminished only to find full bass reproduction sacrificed. Thus, it would seem that two separate speakers—one designed for high range reproduction (tweeter) and a second to respond more faithfully to low range reproduction (woofer)—would overcome this difficulty. Separate speaker response requires frequency discrimination so as to allow only the proper frequency impulses to reach the desired speaker, since for example, a low bass note should not be allowed to activate the tweeter. Thus, a frequency screening device interposed before the electrical energy activates the speakers, effects an artificial division which creates a sense of separateness and artificiality in the listener.

According to the present invention, the need for high and low range speakers and any required frequency dividing network is eliminated. This is accomplished, in accordance with one feature of the invention, by effectively dividing the loudspeaker diaphragm into a plurality of substantially concentric, contiguous, surface rings, which may have the same or different widths, and coating at least all but the inner ring to cause the thickness of each successive ring to be greater progressively from the center area of the diaphragm. The coating alters the mass which vibrates, so each different surface ring has a different frequency or range of frequencies to which it is most responsive.

Another feature of the invention resides in disposing adjacent a diaphragm of the improved type just referred to, a plurality of similar outwardly flaring concentric horns with their throats being respectively adjacent the aforesaid surface rings of the diaphragm. Preferably, each horn has an exponential flare, and the smallest one of the horns inherently has the highest resonant peak so it is eminently suitable for coupling the highest response part of the diaphragm, the inner ring area thereof, to the air. This horn, in turn, is surrounded by a second horn of lower frequency resonant response characteristics, and the second horn has its throat diameter corresponding approximately to the outer diameter of the second smallest ring of the diaphragm, so as to couple to the air the frequency to which that ring is responsive. At the periphery of the diaphragm is the largest diameter horn whose throat corresponds substantially to the diameter of the cone itself, to couple to the air the lowest possible vibrating response that the diaphragm is capable of producing.

With such a varied thickness diaphragm and associated horns, there is provided a loudspeaker which is specifically designed for the many varied response characteristics desired therefrom. The horn coupling effect creates nearly an ideal efficiency to each response to which the speaker is capable, and, in conjunction with the redispersion effect of the horns, is capable also of eliminating the noticeable single source localization which is characteristic of conventional speakers. The redispersion-coupling reverses the funnelling of microphone-conventional speaker reproduction, i.e., it effects a redispersion spread and coupling similar to the reverse of that affected by a microphone, rather than effecting the extremely limited range of dispersion accomplished by conventional speaker reproducing systems.

It is therefore an object of this invention to provide loudspeaker diaphragms of the improved type above mentioned, and to provide therewith at least one set of horns disposed relative to the different thickness rings of the diaphragm in the manner aforesaid.

Another object of this invention is the provision of two sets of such horns respectively projecting from opposite sides of an improved type diaphragm, or two horned loudspeakers with my improved type diaphragms disposed face to face, or back to back, and appropriately energized.

Another object of this invention is the provision of a louspeaker system which employs a plurality of the aforementioned sets of dual diaphragm-horn loudspeaker arrangements for either monaural stereophonic, or pseudo-stereophonic reproduction.

Other objects, features, and advantages of this invention will become apparent to those of ordinary skill in the art upon reading the appended claims and the following detailed description in conjunction with the attached drawings, in which:

FIGURE 1 is one embodiment of this invention, partially broken away and partially in cross-section, as it includes an improved diaphragm and associated set of horns,

FIGURE 2 is a partial transverse cross-sectional view taken approximately along the line 2—2 of FIGURE 1,

FIGURE 3 is a partial, enlarged, longitudinal cross-sectional view of FIGURE 1,

FIGURE 4 shows another loudspeaker embodiment of this invention, partially broken away and partially in cross-section,

FIGURE 5 is a schematic illustration showing a further embodiment of this invention,

FIGURE 6 is another schematic illustration of a still further embodiment of this invention,

FIGURE 7 is a partial longitudinal cross-sectional view of another embodiment of a dual loud-speaker arrangement in accordance with this invention, and

FIGURE 8 is a schematic indication of the manner in which two FIGURE 7 loudspeaker arrangements may be electrically connected.

The loudspeaker in FIGURE 1 may include a conventional conical shaped spider basket or frame **10** which has a plurality of struts or the like **12** diverging forwardly to an outer rim **14**, and converging rearwardly toward an apex to an inner rim **16** to which is secured the magnetic and electrical section or diaphragm driving or vibrating means **18** of the speaker. The speaker may be of the permanent magnet type, of the electromagnet type, or of any other type desired, to the movable part of which can be coupled in any conventional manner a vibratory diaphragm. Such a diaphragm is indicated by numeral **20** in FIGURE 1, and as illustrated is secured at its outer periphery to rim **14**, as by an adhesive for example. A conventional gasket **21**, of rubber, cork, or plastic for example, may be adhered over the periphery of the diaphragm in the outer rim area. Diaphragm **20**, however, differs from a conventional diaphragm in that, as more clearly shown in FIGURES 2 and 3, the conventional paper, fiber, or like type diaphragmatic cone-shaped vibratory element or basic diaphragm **22** is effectively divided into three substantially concentric, contiguous, ring areas A, B, C the outer two of which are coated so as to cause the overall resulting thickness of diaphragm **20** in the respective ring areas A, B and C to be of increasing thickness progressing outwardly from the inner ring A.

The inner ring A may also be coated, but as illustrated it need not be. In any case, any desired number N of ring areas may be effected and at least $N-1$ of those areas are coated so that all N areas have different thickness. To effect the different thicknesses for the B and C rings, a layer **24** of coating may be first applied to both the B and C rings after the A ring has been masked or otherwise prevented from receiving coating **24**. Then, the B ring is also masked and another coating layer **26** is applied to the C ring only. The coating layers **24** and **26** may be of a plastic material, such as epoxy-resin, sprayed, painted, or otherwise deposited onto the conventional cone **22**, to a thickness of, for example, 0.001 inch, in which case, of course, ring C will be 0.001 inch thicker than ring B, and ring B will be 0.001 inch thicker than ring A. The thickness of any given ring is approximately the same throughout its circumferential length and radial width, and the radial width of the rings may be the same, or different as shown in FIGURE 2, if desired. Though FIGURE 1 shows the front side or inner surface of the diaphragm coated, the rear side or outer surface may be similarly coated instead or also. Cone **22** may be straight sided as shown, or its sides may have any other conventional configuration, such as corrugated or pressed-in steps, but in any case it is of substantially uniform thickness throughout its complete area.

Heretofore, there has been proposed a one piece diaphragm which varies in radial thickness, but such a diaphragm is generally unsuitable for high fidelity reproduction because it moves as one mass in motion. On the other hand, a diaphragm constructed in accordance with this invention, so as to be a multiple-piece or layer structure by virtue of different thickness coatings on a conventional diaphragm, can effectively act as several diaphragms in motion at different rates. The coating gives structural support to the cone, acting as a "brake" preventing cone breakup. The increasing thickness of the coating along various concentric configurations of the cone enhances the ability of the diaphragm to behave differently since each ring then has its own unique resistive force. The coatings therefore permit the overall diaphragm **20** to selectively transduce at any point that wave frequency for which that particular part of the diaphragm can most desirably respond. It also acts as a brake by this selective resistance. That is, where the motion of the diaphragm is greatest, and therefore the tendency to stay in motion the greatest, as is the case at the periphery of the diaphragm, the greatest selective resistance is present since it is there that the coating is the thickest. Less carry-over from one part of the diaphragm to another is permitted by the differential thickness coating. That is, as above indicated, the total mass of diaphragm **20** can behave as separate concentrically determined masses, thereby gaining differential. This also eliminates or diminishes self-harmonic or inter-harmonic distortion. The resistive effect, by braking or dampening the responsive ring mass in motion when that motion is no longer called for by the frequency being transduced, prevents acoustic hangover. Considering these advantages separately, and especially in combination, provides for an improved diaphragm heretofore unattained in reproductive quality.

In addition to the varied thickness diaphragm **20**, a loudspeaker in accordance with this invention includes a plurality of horns, one for each different thickness of diaphragm, making a total in the illustrated exemplary horn set **27** of three horns **28**, **30**, and **32** as shown in FIGURE 1. These horns are substantially concentric, generally circular in transverse cross section, and all have a similar outward flare as illustrated. Each is preferably exponentially flared. The horns may be held in a concentric disposition in any desired manner, as by braces or struts **34**, with the outer horn **28** being secured to the speaker frame **10** in any desired manner as by bolts **36**. As will be noted, the smaller diameter opening or throat **38** of each of the horns **28**, **30** and **32** has an inner diameter substantially equal to the outer diameter of a respective one of the ring areas A, B and C. That is, the throat of horn **32** has an inner diameter corresponding to the outer diameter of diaphragm ring A, while the throats of horns **30** and **28** respectively have inner diameters corresponding to the outer diameters of rings B and C. These throats are disposed substantially concentric with their respective rings, on the face or front side thereof, and are preferably positioned as close as possible to the diaphragm **20** without possible intervention with maximum vibrations thereof. On the other hand, the horns need not be disposed that close to the diaphragm, for example the throats of horns **30** and **32** may both be in vertical alignment with the throat of horn **28** in FIGURE 1, but in such a case the coupling-to-air function of the inner horns may not be as efficient as in the embodiment illustrated.

The use of such horns is highly desirable in accordance with this invention, for they enhance the advantages above referred to relative to the improved diaphragm. To a large extent, the coupling and sound diffusing and dispersion effect of these horns depends on, and is integrally related to, each part of the diaphragm determined by the circumference of the horn throat, the circumference of the diaphragm to which it is oriented, and the wave length of reproduction corresponding to the air column of the horn to which that wavelength relates. As previously indicated, the horns are preferably exponentially flared. Such a horn has a spectrum to which it is partial. That is, its air column acts as an intermediary between the elected ring area of the diaphragm to which it is oriented, and which in turn, by its gradient thickness of coating selectively vibrates. It is this partiality to particular wave frequencies that allows an exponential horn to transmit sound to the air with nearly ideal efficiency. By utilizing exponentially flared horns, the sound is projected with parallel linearity, thereby eliminating the varying curve characteristics of sound as it is projected from a speaker from the high to the low frequency range. This parallel linearity eliminates much of the point source type of sound emanating from the conventional speakers, and also eliminates inter-modal distortions. It is therefore mainly for the purpose of linear projection, as well as selective coupling, that exponentially flared horns are preferably employed. A desirable, though secondary, effect which also results due to such horn employment, is a natural dispersion and diffusion of undistorted sound, i.e., sound without increased distortion or artificial coloration.

FIGURE 4 illustrates a further embodiment of the invention, with a second set **40** of three horns, **42, 44** and **46** similar to the aforedescribed horn set **27**. The horns in the second set are held substantially concentric as by use of struts **48**. As in the case of the horn set **27**, the larger diameter outer horn **42** of the second horn set may also be secured to the rim **14** of the speaker frame **10** by bolts **36**, but the throats of horn set **40** are disposed adjacent the outer or back side of diaphragm **20**. The diameters of these throats are similar to the diameters of the throats of horns **28, 30** and **32** respectively, so the inner diameter of each horn in set **40** is approximately equal to the outer diameter of the respective diaphragm rings A, B and C. With the loudspeaker arrangement illustrated in FIGURE 4, only a single diaphragm **20** is necessary to effect sound dispersion into generally opposite directions, it being apparent of course that the larger opening or mouths of the respective horn sets **27** and **40** open away from each other in opposite directions.

Opposite direction dispersion may also be accomplished by utilizing either of the loudspeaker arrangements **50** or **52** illustrated in FIGURE 5. In each one of these arrangements, two sets **54** of three (for example) horns, each set being similar to the horn set **40** in FIGURE 4, is disposed near the rear or outward side of a speaker frame **10** which has associated with it a diaphragm (not shown) that is exactly like diaphragm **20** in FIGURES 1–4. The speaker frames **10** and associated diaphragms in each of the arrangements **50** and **52** are disposed facing each other with the rims of the frames being in a contigous relationship for example. The two frames may be secured together in any desired manner. Electrically speaking, the two loudspeaker arrangements **50** and **52** are connected in parallel to a common energizing source **56** with the individual loudspeakers in each of the arrangements **50** and **52** being connected serially in phase opposition, i.e., with polarity reversal as indicated by the + and — signs.

The separate arrangements **50** and **52** may be disposed one over the other with the four different horn mouth sets opening in four different directions, for example arrangement **52** may be disposed perpendicular to and above (or below) arrangement **50**. Any other four different general directions of dispersion may be effected either with the arrangements **50** and **52** superposed or with them being at separated points in a room for example.

Because the two loudspeakers in either one of the arrangements **50** and **52** are connected serially in phase opposition, there is no problem involved in closing the diaphragm face of one with the diaphragm face of the other, since both diaphragms thereby move in the same spatial direction at any given instant of time of energization from source **56**.

From FIGURE 5, it will be appreciated that in accordance with this invention there is no real necessity for a set of horns being disposed on the front side of the improved diaphragm of this invention, since the FIGURE 4 arrangement will operate to provide high fidelity sound via horn set **40** even if horn set **27** is not utilized. It is therefore within the scope of this invention to provide a set of horns disposed adjacent the rear side of the improved diaphragm, as well as the embodiments shown in FIGURES 1 and 4.

It will also be appreciated that this invention contemplates use of a single loudspeaker arrangement such as arrangement **50** in FIGURE 5, to the exclusion of arrangement **52**, as well as in combination therewith. As previously indicated, units **50** and **52** may be stacked one above the other but deployed at right angles to each other. This creates an omnidirectional system suitable particularly for monaural listening. For stereo or pseudo-stereo effect, units **50** and **52** may be deployed at opposite sides of a room. In like manner, two units of the type described relative to FIGURE 4 may be similarly disposed for monaural listening or for stereo or pseudo-stereo effects.

Another embodiment of the invention is shown in FIGURE 6. In this case the two units or loudspeaker arrangements **58** and **60** are alike and each is comprised of two horned loudspeakers **62** each of which is preferably like the FIGURE 1 embodiment, with the two horned loudspeakers in each of the arrangements **58** and **60** being disposed back to back, rather than face to face as in FIGURE 5. When switches **64** and **66** are thrown so as to connect the two loudspeakers in each of the units **58** and **60** serially in phase opposition, such as in the case illustrated in FIGURE 5, then the respective baffle boxes **68** and **70** and/or the acoustic absorbing material **72** therein are unnecessary and not employed, since in this series polarity reversal situation the two improved diaphragms in the respective loudspeakers **62** of each unit **58** and **60** move in the same spatial direction at any instant of time as in the FIGURE 5 case, for example, one diaphragm in unit **58** of FIGURE 6 moves forwardly at the same time as the other diaphragm moves rearwardly, and vice versa. By virtue of the separation of the front and rear waves of any one diaphragm and the necessary travel of the sound waves through a set of horns, by the time that any front and rearwarly projected waves, which are initially of course 180° out of phase with each other, can meet in air, the directions of one or the other if not both have been sufficiently changed to prevent most, if not all, cancellation therebetween, similar to the way an inverted rear wave from a basic reflex type of enclosure gets to be in phase with its frontal waves. This is all to say, that to a large extent, the effect of the horns, which is always imposed upon the issuing sound before it is heard, prevents the interaction of waves when they are in opposite phase. In most cases this is the situation, but in certain selected cases cancellation might be a noticeable feature such as in a narrow, confined, "lively" room.

In this latter case, the complete FIGURE 6 embodiment of either or both units **58** and **60** may be employed with switches **64** and **66** thrown so as to cause the loudspeakers to be connected serially in phase, i.e., without polarity reversal between associated speakers. Under such circumstances both horned loudspeakers of unit **58** for example, will forwardly project positive waves at the same instant of time and simultaneously rearwardly project negative waves, or vice versa. Therefore, since the diaphragms are arranged in a back to back disposition, they no longer move in the same spatial direction at any given instant of time, but in opposite directions, giving rise to the problem of compression and rarefaction of air between speakers. Though the simultaneous rearwardly projected waves of each of the diaphragms of either unit **58** or **60** may both be referred to as negative (or positive) with respect to the diaphragm from which same issues, it is apparent that these two simultaneously rearwardly projected waves are of opposite polarity relative to each other in the area between the two speakers. To overcome the unwanted inter-speaker waves, the baffle boxes **68** and **70** with their acoustic material **72** are employed. It will be noted that each of these boxes includes slotted air vents **74** and **76**. The baffle boxes serve the dual purpose of (*a*) absorbing the rear waves with the acoustic material **72**, and (*b*) allowing via air vents **74** the air in the baffle box between the speakers to be compressed and rarefied without inhibitng diaphragmatic movement.

As in the case of FIGURE 5, the loudspeaker arrangements **58** and **60** of FIGURE 6 may be superposed at right angles for monaural listening, or they may be deployed at opposite sides of a room for stereo or pseudo-stereo effects. In addition, it will be appreciated from the description of FIGURE 6, that the two loudspeakers in each of the arrangements 50 and 52 in FIGURE 5 may be connected serially in phase, rather than with polarity reversal as illustrated, if a baffle box or the like is interposed between the two speaker units in a manner similar to that described relative to FIGURE 6.

Still a further embodiment of this invention is illustrated in FIGURES 7 and 8, which indicate a preferable arrangement when the two associated speakers are serially connected in phase as shown by the + and − signs in each of the units 78 and 80 in FIGURE 8. The structure of each such units may perhaps best be appreciated by reference to FIGURE 7. Inside each of the opposite ends of a tube or outer sound channeling frame 82 is disposed a respective horned loudspeaker 84 similar to the type shown in FIGURE 1, except in this instance the outer horn 28′ includes a plurality of axially extending apertures or slots 86 around its circumference. These slots are for the purpose of allowing the schematically depicted waves 88, projected from the rear of diaphragm 20 and inverted in phase due after reflection against surfaces 90 and 92, to be mixed with the waves forwardly projected by diaphragm 20. The inverted rearward waves after reflection off of surface 92 are communicated forwardly to slots 86 through respective channeling apertures 94 in the outer rim of speaker frame 10′. These apertures may be axially extended, if desired, to form tunnels between speaker frame 10′ and the beginning of the respective aperture 86 in the outer horn 28′. Of course, with the rearward wave being inverted by its reflection and distance of travel relative to the forwardly projected wave, these two waves as they join in the air are substantially in phase.

Any cross-section of the structure of the reflector forming surface 90 has in a reversedly disposed sense, substantially the same shape as the speaker diaphragm 20. This reflector may be separate from, or as illustrated integral with, the reflector which forms the reflecting surface 92, and in any case the reflecting surfaces 90 and 92 are suitably positioned within, and secured to, if desired, the outer frame 82 by any desirable means at points 96 and 98. The reflector or reflectors forming surface 90 and 92 may be made of plastic, a plastic coated board, aluminum, or any other acoustical reflecting material which has a smooth inner surface. In any case, the reflectors between the opposite end loudspeakers completely acoustically separate the rear sides of the two speakers. Therefore, and since the rearward wave of each of the opposite end diaphragms is inverted so as to be in phase with the respective forwardly projected waves, there is no need of acoustical absorption of the rearward waves, and the two loudspeakers may be serially connected in phase as indicated by the + and − signs in FIGURE 8.

Of course, the two units 78 and 80 in FIGURE 8 may be deployed in any of the manners heretofore indicated relative to FIGURES 5 and 6. Additionally, it will be appreciated from the foregoing description of the operation of the modification illustrated in FIGURES 7 and 8, that the two speakers in either or both of the units 78 or 80 may actually be reversed so as to face each other with their respective horn sets then projecting from the rear of the respective diaphragms as long as the reflectors are appropriately shaped to cause the waves from the front or inside conical side of the diaphragms to be reflected outwardly over the respective diaphragm and into substantial directional alignment and phase with the respective waves that issue from the associated set of horns.

Though circular speakers have generally been indicated in the above description of the several embodiments of this invention, it will be appreciated that oval or other configurations of speakers and diaphragms may be employed within the scope of this invention. As a representative example using a circular coned diaphragm, the following dimensions may be considered without limitation intended. For example the uncoated ring area A in FIGURES 2 and 3 may be 2 inches in outer diameter, ring area B 6 inches in outer diameter, and ring area C 8 inches in outer diameter, while the respectively associated horns 32, 30 and 28 of FIGURE 1, have similar inner diameter throat dimensions, with horn 28 having a 12 inch diameter mouth and being 7½ inches long, horn 30 having a 9 inch mouth diameter and being 6 inches long, and horn 32 having a 4 inch mouth diameter and being 4 inches long.

It may be noted that one may start with a most basic unit, for example the loudspeaker illustrated in FIGURE 1, or that shown in FIGURE 4 without the front horn set 27, and add thereto subsequently as desired. The basic unit never becomes obsolete, so the problem of converting from monaural to a stereo setup does not arise since the basic monaural unit is adaptable to be built into a stereo or pseudo-stereo embodiment.

From the foregoing it will be apparent that this invention obviates many of the problems arising with conventional loudspeakers and arrangements and systems thereof. The two most disturbing types of distortion encountered in speakers are termed "transient distortion" and "inter-modulation distortion." Transient distortion is the result of inertia, or the resistance of a cone in motion to respond to changes applied to it. For example, if note G follows note E, then E affects G as a sort of "acoustic hangover." Selective coating of the speaker cone so that the peripheral part of the speaker has the greatest mass results in a structural integrity for that specific part. The air resistance encompassed by that part of the cone having to force air through the largest horn with which it is in resonance applies "air brakes" to this mass in motion. Therefore, the change in mass, which effects a greater mass in motion and therefore a greater tendency to stay in motion, is counterbalanced by the "air brakes" effect of the interposed column of air resisting that greater mass in motion, i.e., the greater the mass in motion the greater the air column to resist this motion.

Inter-modulation distortion is the distortion produced when one tone produced together with another tone results in each tone affecting the other and causes spurious sounds of other frequencies than those intended. Internal inter-modulations of this sort are less likely to occur in a cone that is selectively coated in accordance with this invention. In my improved speaker, since each different tone emanates from a different cone source and in a sense travels along its own horn to be coupled to the air, such a tone is pure and unaffected by the other tones travelling along their own separate routes.

The conventional speaker depends upon resonating frequencies to enhance the tones emanating from the vibrations of the cone. These resonating bodies in turn, in a sense, couple the vibrations to the air. My improved speaker with the horn coupling device eliminates the need for corner placements or placements along certain walls in a particular room, or even the need of a resonating cabinet. Since it is independent of these factors it operates efficiently without regard to speaker placement. The external structure is also vibration-free since, as noted, there is no cabinet resonance or vibrating bodies employed and this makes functional utilization almost unlimited and unrestricted. Also, since cabinet resonance is not a factor, the size of this speaker horn system is a fraction of the huge, conventional type acoustic giants.

As previously indicated, when a loudspeaker is in operation, the sound waves coming from the front surface of the cone are also duplicated by the rear surface of the cone. These frontal waves and rear waves are produced simultaneously. The waves produced by the rear surface of the cone are the exact opposite of those produced by the front surface. When these two (out of phase) sets of waves meet, cancellation of the frontal waves by the rear waves occurs. Many and complicated are the prior art attempts to frustrate this cancellation. In my described system, however, the rear waves are not a hindrance, but rather enhance the acoustic delivery. I accomplish this by employing horn coupling to the front of the speaker as well as to the rear of the speaker. The creation of a long air path completely negates cancellation as a factor.

The ability of two of my speakers to move and at the same time to brake each other as previously indicated, negates acoustic hangover almost completely and fractionates inter-modulation distortion.

Thus it is apparent there has been described apparatus which fully provides for all of the objects, features, and advantages herein indicated. Further modifications of the invention will become apparent to those of ordinary skill in the art upon reading this disclosure, but it is intended that my invention be limited not by the foregoing description and drawings, but by the scope of the following claims.

What is claimed is:

1. An acoustical energy transducing diaphragm comprising a vibrating element of one material and effectively divided into at least three substantially concentric contiguous ring areas each having a respective surface width, and coating means of another material on, and increasing the thickness of, at least two of said areas, said coating means increasing the thickness of said diaphragm so that the resultant thicknesses of all said ring areas are different and successively greater progressing outwardly from the center of said diaphragm whereby said ring areas are capable of handling different frequencies.

2. A diaphragm as in claim 1 having a conical shape.

3. A diaphragm as in claim 1 wherein said coating means is disposed on the front face of said diaphragm.

4. A diaphragm as in claim 1 wherein the said resulting thickness of any one of said areas is substantially uniform throughout that area.

5. A diaphragm as in claim 1 wherein said coating means comprises respective plastic coatings.

6. An acoustical energy transducing device comprising a diaphragm having a vibrating element of uniform thickness throughout and effectively divided into N substantially concentric contiguous ring areas each having a respective surface width, coating means on, and increasing the thickness of, at least $N-1$ of said areas for causing the resultant thicknesses of all said ring areas to be different and successively greater progressing outwardly from the center of said diaphragm, and a set of N similarly outwardly flaring concentric horns having respective throats disposed respectively adjacent said rings.

7. A device as in claim 6 wherein the said diaphragm has a front side which said throats face.

8. A device as in claim 6 wherein the said diaphragm has a back side which said throats face.

9. A device as in claim 6 wherein said horns are each exponential horns.

10. A device as in claim 6 including a second set of N similarly outwardly flaring concentric horns disposed with their throats respectively adjacent said rings and having respective mouths opening in a substantially opposite direction as and away from the mouths of the first mentioned set of horns.

11. An acoustical energy transducing arrangement comprising first and second devices each as in claim 6 with the horns in each set thereof having respective mouths, said devices being disposed adjacent one another with the mouths of the respective horn sets opening away from each other in substantially opposite directions.

12. An arrangement as in claim 11 wherein said devices are electrically connected serially in phase opposition.

13. A loudspeaker system comprising first and second arrangements each as in claim 11 wherein each of the said devices is a loudspeaker the said horns of which have respective mouths, wherein the mouths of the respective loudspeaker horn sets open in four different directions, and wherein each loudspeaker has a respective driving means for vibrating its diaphragm, and further including means for electrically energizing the said two driving means of one of said arrangements in parallel with the two driving means of the other said arrangement and serially energizing the two driving means in phase opposition.

14. An arrangement as in claim 11 wherein said devices are electrically connected serially in phase.

15. An arrangement as in claim 11 wherein each of said diaphragms has front and rear sides and said first and second devices are disposed with their respective diaphragms facing each other and the said sets of horn throats are adjacent the respective rear sides of said diaphragms.

16. A loudspeaker system comprising the arrangement of claim 15 wherein each of said devices is a loudspeaker and has a respective driving means for vibrating its said diaphragm, and further including means for electrically energizing the said driving means serially in phase opposition.

17. An arrangement as in claim 11 wherein each of said diaphragms has front and back sides and said first and second devices are disposed with their respective diaphragms back to back and the said sets of horn throats are adjacent the respective front sides of said diaphragms.

18. A loudspeaker system comprising the arrangement of claim 17 wherein each of said devices is a loudspeaker and has a respective driving means for vibrating said diaphragms, and further including means for electrically energizing the said driving means of said first and second devices serially in phase opposition.

19. An arrangement as in claim 17 and further including acoustic absorbing material between the said diaphragms.

20. An arrangement as in claim 19 wherein there is space between the said back sides of said diaphragms, and further including means for enclosing the space between the back sides of said diaphragms except for vents for accommodating any compressed or rarefied air therein, said absorbing material being in the said space enclosed by the enclosing means.

21. A loudspeaker system comprising the arrangement of claim 19 wherein each of said devices is a loudspeaker and has a respective driving means for vibrating its said diaphragm, and further including means for electrically energizing the said driving means serially and in phase.

22. An arrangement as in claim 17 and further including means between the said diaphragms for reflecting the respective, rear sound waves away from each other.

23. An arrangement as in claim 22 wherein each of said devices is a loudspeaker and said reflecting means serves to reflect and phase invert any sound waves projected from the back side of either of said diaphragms so as to cause the so reflected and inverted waves to be substantially in phase with sound waves projected by the front side of the respective diaphragm.

24. An arrangement as in claim 23 and further including means, comprising apertures in the outer one of the horns in each of the said sets thereof, for channeling the said reflected and inverted waves into substantial alignment with the waves projected from the respective said front sides.

25. A loudspeaker system comprising first and second arrangements each as in claim 11 wherein each of the said devices is a loudspeaker the said horns of which have respective mouths, wherein the mouths of the respective loudspeaker horn sets open in four different directions, and wherein each loudspeaker has a respective driving means for vibrating its diaphragm, and further including means for electrically energizing the said two driving means of one of said arrangements in parallel with the two driving means of the other said arrange-

ment and serially energizing the two driving means in phase.

26. A loudspeaker comprising conical diaphragm means increasing in thickness in steps from near apex to near periphery and a plurality of horn means disposed substantially concentrically adjacent said steps.

27. A loudspeaker as in claim 26 wherein said plurality of horn means includes at least one set of a plurality of substantially concentric horns similarly flaring outwardly from respective ones of said steps with horn throats respectively corresponding in inner diameter at least approximately to the outer diameters of said steps.

28. A loudspeaker as in claim 27 wherein the horns flare outwardly from an outer surface of said conical diaphragm means.

29. A loudspeaker as in claim 27 wherein the horns flare outwardly from an inner surface of said conical diaphragm means.

30. A loudspeaker as in claim 27 wherein said diaphragm having inner front and outer back side means is a single cone-shaped diaphragm and said set of horns is disposed adjacent one of the said front and back sides of said diaphragm, and further including means disposed adjacent the other of said sides for reflecting sound waves therefrom over said diaphragm and in the general direction of sound waves projected by said one side.

31. A loudspeaker as in claim 30 wherein said horns are disposed adjacent the inner front side of said diaphragm, and includes means including said reflecting means and a plurality of apertures in the outer one of the said horns, for phase changing and channeling sound waves projected from the outer back side of said diaphragm substantially into the same phase condition and direction as those projected from the inner front side of said diaphragm.

32. A loudspeaker as in claim 27 wherein said plurality of horn means comprises two sets of a plurality of substantially concentric horns, each of the horns in each set similarly flaring outwardly from respective ones of said steps with different horn sets having mouths opening in different directions away from each other and with the horn throats of each set respectively corresponding in inner diameter at least approximately to the outer diameters of said steps.

33. A loudspeaker arrangement comprising first and second loudspeakers each as in claim 32 and disposed so that the respective horn sets have their mouths opening in four different directions, and means for driving each of said diaphragm means from a common source.

References Cited in the file of this patent

UNITED STATES PATENTS

1,872,081	Hawley	Aug. 16, 1932
1,872,583	Hawley	Aug. 16, 1932
1,939,447	Honig	Dec. 12, 1933
2,084,945	Cornwell	June 22, 1937
2,102,212	Olson	Dec. 14, 1937
2,146,975	Nagelvoort	Feb. 14, 1939
2,541,946	Stark	Feb. 13, 1951
2,768,702	Lowry	Oct. 30, 1956
2,812,825	Matthews	Nov. 12, 1957
2,819,773	Lowell	Jan. 14, 1958
2,905,259	Ashe	Sept. 22, 1959
2,969,848	Farwell	Jan. 31, 1961
3,093,207	Bozak	June 11, 1963

FOREIGN PATENTS

369,992	Great Britain	Mar. 21, 1932

OTHER REFERENCES

Publication, "Speaker Treatment for Improved Bass" by Cameron Barritt, Audio Engineering, December 1952, pages 23, 54–56.