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(54) **Horn loaded type loudspeaker**

Hornlautsprecher

Haut-parleur à pavillon

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Description

Introduction

[0001] The present invention relates to loudspeakers, in particular of the so-called "horn loaded" type.

Background

[0002] The transduction of electrical power into acoustic power is normally achieved using an axisymmetric conical or domed diaphragm composed of some stiff material, typically aluminium, attached to a concentric motor system composed of a cylindrical coil of high conductivity wire immersed in a radial magnetic field. Passing an alternating current through the coil produces a corresponding force and resultant motion of the diaphragm.

[0003] The cyclic motion of the diaphragm creates a varying pressure in the air adjacent to it which propagates outwards as a longitudinal wave. Containing the output from one side in an enclosure eliminates cancellation between the opposing pressure phase that exists on both sides of the diaphragm.

[0004] As with every energy conversion process, the overall efficiency is determined by the impedances of the source and the load. In the case of the loudspeaker described above, the acoustic impedance presented to the diaphragm by the free air is a very poor match to the high mass diaphragm. This can be considerably improved by feeding the air from the front of the diaphragm into a duct of smaller cross-sectional area. The change in impedance effected by such a change is in the ratio of the diaphragm area divided by the duct area which appropriate choice can yield an optimum load and hence maximum efficiency.

[0005] In order to conduct the acoustic power from this small area duct a tapered waveguide, commonly known as a horn, is usually employed. Provided that the rate at which the area increases as a function of distance is sufficiently gentle then all the power will propagate along the horn. Usually an exponential relation between area and distance is employed. The narrow and wide parts of the horn are referred to as the throat and mouth respectively. A frequently used guideline for the dimension of the mouth is that it should be equal in perimeter to the longest wavelength of interest.

[0006] Figures 1 to 4 of the accompanying drawings show various forms of prior horn-loaded loudspeakers, each comprising a compression driver unit 1 and horn element 2.

[0007] Using a simple throat as shown in Figure 1 suffers from certain limitations. When the wavelength is equal to the diaphragm diameter a cancellation occurs between sound emanating from the edge of the diaphragm and that immediately adjacent to the central throat which results in a null in the output. This is repeated at further, higher, frequencies where the diaphragm diameter is equal to integer multiples of the wavelength.

[0008] At the mouth it is found that at high frequencies the output begins to beam which is to say that it is concentrated in an ever-decreasing cone angle. As a result a listener positioned away from the central axis will suffer a loss of high frequencies.

[0009] A common requirement is to mount a number of horns in a circular arc in order to cover a wide listening area. This can only be achieved without interference if the wavefronts from each horn have a centre of curvature coincident with that of the array. With the simple horn this is not possible since the centre is, at best, located at the throat, and is in fact usually well forward of the throat. Furthermore in order to form a continuous wavefront the horn mouths must have common straight edges and while employing a rectangular horn is possible, the diminution of the high frequencies off-axis is still more problematic in the corners.

[0010] Various solutions have been proposed to both of these limitations independently. To avoid the cancellation at the diaphragm, the throat may be sub-divided into a plurality of smaller apertures, which take their input from a corresponding fraction of the diaphragm area. These may take the form of a number of concentric rings (Figure 3), radial slots or an evenly disposed array of round holes (Figure 2). Extending from each of the apertures is a tapered duct which forms the beginning of the horn. These are generally arranged to meet at a point equidistant from the throat. From this point onward a single flared waveguide carries the summed signal toward the mouth.

[0011] Each of these solutions have particular benefits in terms of manufacture but all result in raising the frequency at which the first cancellation occurs to a point where the separation of the small throats is equal to the wavelength.

[0012] A method adopted for achieving a more even wavefront at the horn mouth involved subdividing the horn into 'cells' (Figure 4). Each horn is assumed to be fed with an equal signal and hence the intensity across the array of mouths was more uniform at high frequencies than with a single horn.

[0013] Performance was often limited in by practical shortcomings in the implementation. The inner edge of the partitions was seldom very sharp and caused reflection back toward the diaphragm as well as unequal signal distribution to each cell. Additionally the straight axis of each cell still imposes a wavefront centre positioned at the meeting point of those axes which is then inevitably immediately ahead of the driver output precluding the formation of a single homogenous wavefront when several units are used in a circular array. Finally these "multicell" horns tended to employ a small number of divisions, typically two by four or occasionally three by five, which necessitated the use of individual cells with mouth dimensions in excess of several wavelengths. As a result the individual cells still suffered from beaming and mutual interference well within the audible range of frequencies.

[0014] US 2,127,110 discloses a loudspeaker unit in-

cluding a horn, divided into a plurality of sections.

Summary of the Invention

[0015] Broadly, the present invention provides a loudspeaker unit comprising a diaphragm and motor system and plurality of small flared waveguides of such length and arranged in such a way as to create a wavefront of a predetermined form.

[0016] According to the present invention there is provided a horn-loaded compression driver loudspeaker unit comprising: a motor and diaphragm system for transducing electrical energy to acoustic energy; an external face from which the acoustic energy is radiated to the exterior of the unit; and characterised by a horn element to which the diaphragm and motor system are attached; an end face of the horn element and the diaphragm defining, adjacent the diaphragm, an air chamber in which, in use, pressure waves are produced by the driven motion of the diaphragm, the air chamber being closed to the exterior of the loudspeaker except via a plurality of flared, acoustic-energy waveguides leading from the chamber to discrete sub-divisions of said external face to create a wavefront of a predetermined shape, the cross-sectional area of each waveguide increasing monotonically along the length thereof in the direction from the diaphragm to the face, the waveguides being formed by respective passages leading through the horn element, each passage having at one end a first opening, adjacent the diaphragm, into the chamber, and at the other end a second opening in the respective sub-division of the external face.

[0017] The invention also provides a method of manufacturing a loudspeaker unit according to the invention which comprises the step of forming the horn element by casting liquid resin around an array of flexible patterns following the same area law as the waveguides.

[0018] In the illustrated embodiment of the invention described below with reference 20 to the accompanying drawings, two solutions to the two main problems found in horn loaded loudspeakers are brought together into a single device. The horn throat is divided into a multiplicity of small apertures arranged in an even manner across the diaphragm surface. From each aperture an individual tapered waveguide or "hornlet" extends as far as a surface with a prescribed form which forms the mouth. Each 'hornlet' is formed with identical length in order to assure uniformity of phase of the wavefront at the mouth. The form of the mouth can be chosen to suit the application- and a variety of tessellating shapes might be used depending on the final requirement for the total wavefront. The curvature of the wavefront is arbitrary and can be arranged to place the centre at a point well behind the motor system. This allows devices to be arrayed without discontinuities in the total wavefront

[0019] For example, in order to create a completely spherical wavefront an equilateral triangular mouth composed of triangular hornlets might be adopted. Twenty

such devices could then be united to form a sphere.

[0020] A frequent requirement in sound reinforcement is to have a circular array in the horizontal plane and a linear array in the vertical. Such an arrangement gives rise to a cylindrical wavefront and would most conveniently be achieved using rectangular hornlets disposed on a curved rectangular mouth plane.

[0021] The invention will be further described by way of non-limitative example with reference to the accompanying drawings in which:

Figures 1 to 4 are views showing cross-sections of certain prior horn-loaded loudspeakers;

Figure 5A is a view showing a cross-section of a loudspeaker unit according to one embodiment of the invention;

Figure 5B is an enlarged detail of Figure 5A; and Figures 6 and 7 are views of loudspeakers assembled out of loudspeaker units embodying the invention.

Figure 5B is an enlarged view of the inner part of the loudspeaker of Figure 5A. The loudspeaker has a compression driver unit 50 with a domed diaphragm 51 driven by a motor 52.

[0022] The motor 52 comprises two axially aligned annular plates 53, 54 between which are sandwiched an annular permanent magnet 55. The front plate 53 has a rearwardly directed cylindrical collar 56 integral with its radially inner edge portion. The rear end of the collar 56 has on its outer circumferential surface a chamfered ring 57 which, together with the correspondingly chamfered edge of the aligned inner periphery of the plate 54, forms a cylindrical air gap G. The plates 53 and 54 are of soft iron or other material of high magnetic permeability, so as to form a magnetic circuit in which magnetic flux produced by the magnet 55 is concentrated in the air gap G.

[0023] The domed diaphragm 51 is part of an aluminium cap 58 with a part-spherical dome 59 which is fixed in an airtight manner to the rear face of the plate 54 via an integral, ridged, suspension region 60 of the cap 58. At the junction between the region 60 and the dome 59, the cap has an integral cylindrical former 61 projecting forwardly into the air gap G and around which is wound a voice coil 62.

[0024] The other main part of the loudspeaker unit of Figure 5, apart from the compression driver unit, is the horn throat element 70. This is a body of acoustically "dead" material, which extends forwardly from the compression driver unit in a flared shape. The element 70 has the compression driver unit 50 rigidly mounted at its rear; the rear part of the element 70 comprises a generally conically shaped region 71 having a circumferential recess 72 whose periphery is complementarily shaped to the inner circumferential surface of the collar 56, so that the compression driver unit is rigidly and tightly fixed to the element 70 which thereby serves to mount the compression driver unit 50.

[0025] The region 71 of element 70 is coaxial with the compression driver unit 50 and has a part-spherical rear surface 73. The sphere to which the surface 73 conforms is the same as that of the dome 59, but offset axially a small distance. There is thus defined between the dome 59 and surface 73 an air chamber 74 which is closed to the exterior of the loudspeaker unit except via a number of passages 75, which will be described in more detail below, and which extend, from a number of apertures 76 into the chamber 74. These apertures are evenly distributed over the area of the diaphragm dome 59 and effectively "sample" the pressure field at the points where they open into the chamber 74. The passages extend forwardly of the loudspeaker unit through the material of the element 70 to sound-radiating openings or mouths 77 at the front of the loudspeaker unit.

[0026] In this illustrated embodiment, the apertures 76 are distributed evenly over the surface of the diaphragm dome because the mouths 77 are of equal area. More generally they should sample the diaphragm area in the same proportion as the areas of the mouths 77 they feed,

[0027] It can be seen from Fig. 5B that the apertures 76 are distributed across the radial extent of the end face of the horn element 70.

[0028] When an alternating electrical drive signal is applied to the voice coil 62, a mechanical force is developed which drives the voice coil former, and hence the diaphragm, back and forth, thus subjecting the air in the chamber to corresponding compression and rarefaction. The apertures 76 enable acoustic pressure waves so generated by motion of the diaphragm to propagate into and along the passages 75 and to radiate to the exterior of the loudspeaker unit via the radiating openings 77. The rear, i.e. upper, surface, in Figures 5A and B, of at least the rear of the diaphragm is located within an airtight enclosure to attenuate acoustic energy radiated from the rear of the diaphragm and prevent interference with that from the front.

[0029] Each of the passages 75 is of a monotonically increasingly cross-sectional area, so as to couple the acoustic energy transduced by the compression driver unit into the surrounding air. The increasing cross-sectional areas of the passages preferably at least approximate an exponential function to optimise the coupling efficiency. It is desirable to avoid step changes in the areas of the passages 75, as these would constitute discontinuities which could give rise to undesired acoustic effects e.g. reflection.

[0030] An important feature of the passages 75 is that they are all of substantially the same acoustic length so that the waves emitted from the openings 77 are in phase with one another. This enables the wavefront of the acoustic energy radiated from the loudspeaker unit as a whole to be shaped as desired by the designer of the unit, by suitable positioning of the openings 77. As noted above, to accommodate "slack" as it were in the lengths of certain of these passages they may be convoluted into, e.g. a helical configuration.

[0031] Each of the passages 75 functions as a miniature acoustic horn and so might be termed a "hornlet".

[0032] It will be appreciated from the above that the loudspeaker unit of Figure 5 that the design of the element 70 achieves the following:

- The openings 77 allow a surface contour, and hence radiated wavefront, of a desired shape to be built up by a multi-faceted arrangement (the facets being the individual openings 77, and the area of the material of the element 70 defining the openings 77 being negligible compared to the areas of the openings 77) which enables a wavefront of a required shape to be propagated from the front face of the unit.
- Each opening 77 is driven with acoustic energy conducted from the chamber 74 via a respective passage 75, acting as a waveguide. The fact that the passages 75 are all of the same length in this illustrated embodiment ensures that the outputs from the openings 77 are all in phase with one another. The fact that the passages 75 are individual to respective openings 77 means that the openings 77 are driven with energy from individual "point" sources 76, without interference between them.

[0033] Note that although in this embodiment the passages 75 are of equal length, this is not an essential feature of the invention; rather, the important point is that the use of this technique allows an arbitrary wavefront shape to be achieved. This applies not only to the lengths of the passages but also to their cross-sectional shapes and areas.

[0034] The mouths 77 could be of any of a variety of unequal shapes which tessellate over a surface, e.g. some could be square and ones between them octagons; they could also tessellate in a non-periodic manner (e.g. Roger Penrose's "versatiles").

[0035] Depending on the application, the loudspeaker unit may be mounted in its own acoustic enclosure or in one shared with other such units where a number of them are to be assembled together. In either case, the enclosure may also include other forms of loudspeaker unit suitable to achieve coverage of the desired audio spectrum; for example, a unit as per Figure 5 might handle the high frequency range and one or more others, e.g. conical units could handle the middle and lower frequency ranges.

[0036] A convenient way of manufacturing the throat element 70 is to cast it from a liquid resin system around an array of flexible patterns following the same area law as that required in the final hornlets. The ends destined to become the mouths are arranged about the requisite surface shape while the throat ends are guided into locating holes a plate having the same profile as the diaphragm. Suitable materials might be silicone rubber for the patterns and epoxy resin for the casting.

[0037] It may be found that the distance between the central elements of the mouth and the diaphragm is ap-

preciably shorter than those at the periphery and necessitates a certain degree of convolution of the pattern. Guiding the central patterns into a gentle helix neatly accommodates this extra length.

[0038] Fig.6 shows a part-cylindrical loudspeaker system 100 made up of a number of smaller part-cylindrical loudspeakers 101 embodying the invention. It will be appreciated that more of the units can be added to form a complete cylinder and that the length of the (part-)cylinder may be extended by stacking the units 101 end-to-end. Similarly, Fig.7 shows a spherical loudspeaker assembly 200 assembled from a number of loudspeakers 201; these units have three surfaces which abut corresponding surfaces of adjacent units and a mouth 77 whose rim conforms to the surface of the sphere.

[0039] Numerous variations are encompassed within the scope of the invention as defined in the appended claims. The invention is not restricted to using the output from the concave side of a spherical diaphragm, nor does the output have to pass through the motor. For example, the invention may be applied to a conventional cone-type loudspeaker for lower frequencies.

Claims

1. A horn-loaded compression driver loudspeaker unit comprising:

a motor (52) and diaphragm system (51) for transducing electrical energy to acoustic energy;
 an external face from which the acoustic energy is radiated to the exterior of the unit; and
characterised by a horn element (70) to which the diaphragm (51) and motor system (52) are attached;
 an end face of the horn element (70) and the diaphragm defining, adjacent the diaphragm, an air chamber (74) in which, in use, pressure waves are produced by the driven motion of the diaphragm, the air chamber being closed to the exterior of the loudspeaker except via a plurality of flared, acoustic-energy waveguides (75) leading from the chamber to discrete sub-divisions of said external face to create a wavefront of a predetermined shape, the cross-sectional area of each waveguide (75) increasing monotonically along the length thereof in the direction from the diaphragm (51) to the face, the waveguides (75) being formed by respective passages leading through the horn element (70), each passage having at one end a first opening (76), adjacent the diaphragm (51), into the chamber, and at the other end a second opening (77) in the respective sub-division of the external face.

2. A loudspeaker unit according to claim 1, wherein the

increasing cross-sectional area of each waveguide (75) substantially follows an exponential function.

3. A loudspeaker unit according to any one of the preceding claims wherein the waveguides (75) are of substantially equal length.
4. A loudspeaker unit according to any one of the preceding claims wherein the second openings (76) of the passages are of a tessellating shape.
5. A loudspeaker unit according to any one of the preceding claims, wherein the external face conforms to a part-spherical surface.
6. A loudspeaker unit according to any one of claims 1 to 4, wherein the external face conforms to a part-cylindrical surface.
7. A loudspeaker unit according to any one of the preceding claims, wherein the first openings (76) of the waveguides are distributed across the radial extent of the end face of the horn element (70).
8. A loudspeaker unit according to any one of the preceding claims, wherein the horn element (70) is cast from liquid resin.
9. A loudspeaker system comprising a plurality of loudspeakers according to any one of the preceding claims assembled together such that their faces conform to subdivisions of a surface.
10. A loudspeaker system according to claim 9, wherein the surface is at least partly spherical.
11. A loudspeaker system according to claim 9, wherein the surface is at least partly cylindrical.
12. A method of manufacture of the loudspeaker unit according to any one of claims 1 to 8, comprising the step of forming the horn element (70) by casting liquid resin around an array of flexible patterns following the same area law as the waveguides (75).

Patentansprüche

1. Horngeladene Kompressionstreiber-Lautsprecher-einheit, welche umfasst:

einen Motor (52) und ein Membransystem (51) zum Umwandeln von elektrischer Energie in akustische Energie;
 eine außenliegende Fläche, von der die akustische Energie zur Außenseite der Einheit abgestrahlt wird; und
gekennzeichnet durch ein Hornelement (70),

an dem die Membran (51) und das Motorsystem (52) angebracht sind;
wobei eine Endfläche des Hornelements (70) und die Membran angrenzend an die Membran eine Luftkammer (74) ausbilden, in der bei Verwendung durch die angetriebene Bewegung der Membran Druckwellen erzeugt werden, wobei die Luftkammer außer **durch** mehrere glockenförmige Akustikenergie-Wellenleiter (75), die von der Kammer zu separaten Unterabschnitten der Außenfläche führen, um eine Wellenfront mit festgelegter Form zu erzeugen, zur Außenseite des Lautsprechers geschlossen ist, wobei die Querschnittfläche jedes Wellenleiters (75) monoton entlang dessen Länge in Richtung von der Membran (51) zu der Vorderfläche zunimmt, wobei die Wellenleiter (75) **durch** jeweilige Durchlässe ausgebildet sind, die **durch** das Hornelement (70) führen, wobei jeder Durchlass an einem Ende eine erste Öffnung (76) angrenzend an die Membran (51) in die Kammer und an dem anderen Ende eine zweite Öffnung (77) in den jeweiligen Unterabschnitt der Außenfläche aufweist.

2. Lautsprechereinheit nach Anspruch 1, **dadurch gekennzeichnet, dass** die zunehmende Querschnittfläche jedes Wellenleiters (75) im Wesentlichen einer Exponentialfunktion folgt.
3. Lautsprechereinheit nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Wellenleiter (75) im Wesentlichen von gleicher Länge sind.
4. Lautsprechereinheit nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die zweiten Öffnungen (76) der Durchlässe von teselierender Form sind.
5. Lautsprechereinheit nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Außenfläche einer teilweise kugelförmigen Fläche entspricht.
6. Lautsprechereinheit nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet, dass** die Außenfläche einer teilweise zylindrischen Fläche entspricht.
7. Lautsprechereinheit nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die ersten Öffnungen (76) der Wellenleiter über die radiale Ausdehnung der Endfläche des Hornelements (70) verteilt sind.
8. Lautsprechereinheit nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass**

das Hornelement (70) aus flüssigem Harz gegossen ist.

9. Lautsprechersystem, das mehrere Lautsprecher nach einem der vorhergehenden Ansprüche umfasst, die so zusammengebaut sind, dass ihre Flächen Unterabschnitten einer Oberfläche entsprechen.
10. Lautsprechersystem nach Anspruch 9, **dadurch gekennzeichnet, dass** die Oberfläche mindestens teilweise kugelförmig ist.
11. Lautsprechersystem nach Anspruch 9, **dadurch gekennzeichnet, dass** die Oberfläche mindestens teilweise zylindrisch ist.
12. Verfahren zum Herstellen der Lautsprechereinheit nach einem der Ansprüche 1 bis 8, welches den Schritt des Ausbildens des Hornelements (70) durch Gießen von flüssigem Harz um eine Anordnung von beweglichen Strukturen, die dem gleichen Flächen-gesetz wie die Wellenleiter folgen, umfasst.

Revendications

1. Unité de haut-parleur à pavillon à entraînement par compression comprenant :

un système à moteur (52) et à membrane (51) pour transformer de l'énergie électrique en énergie acoustique ;

une face externe à partir de laquelle l'énergie acoustique est rayonnée à l'extérieur de l'unité ; et

caractérisée par un élément de pavillon (70) auquel le système à membrane (51) et moteur (52) est fixé ;

une face d'extrémité de l'élément de pavillon (70) et la membrane définissant, à proximité de la membrane, une chambre d'air (74) dans laquelle, en utilisation, des ondes de pression sont produites par le mouvement entraîné de la membrane, la chambre d'air étant fermée vers l'extérieur du haut-parleur, excepté via une pluralité de guides d'ondes d'énergie acoustique (75) évasés menant de la chambre à des subdivisions discrètes de ladite face externe pour créer un front d'onde d'une forme prédéterminée, la section de chaque guide d'ondes (75) augmentant de manière monotone le long de sa longueur dans la direction de la membrane (51) vers la face, les guides d'ondes (75) étant formés par des passages respectifs menant à travers l'élément de pavillon (70), chaque passage ayant à une extrémité une première ouverture (76), à proximité de la membrane (51), dans la

chambre, et à l'autre extrémité une deuxième ouverture (77) dans la subdivision respective de la face externe.

2. Unité de haut-parleur selon la revendication 1, dans laquelle la section croissante de chaque guide d'ondes (75) suit sensiblement une fonction exponentielle. 5
3. Unité de haut-parleur selon l'une quelconque des revendications précédentes, dans laquelle les guides d'ondes (75) ont sensiblement la même longueur. 10
4. Unité de haut-parleur selon l'une quelconque des revendications précédentes, dans laquelle les deuxièmes ouvertures (76) des passages ont une forme en mosaïque. 15
5. Unité de haut-parleur selon l'une quelconque des revendications précédentes, dans laquelle la face externe correspond à une surface partiellement sphérique. 20
6. Unité de haut-parleur selon l'une quelconque des revendications 1 à 4, dans laquelle la face externe correspond à une surface partiellement cylindrique. 25
7. Unité de haut-parleur selon l'une quelconque des revendications précédentes, dans laquelle les premières ouvertures (76) des guides d'ondes sont réparties sur l'étendue radiale de la face d'extrémité de l'élément de pavillon (70). 30
8. Unité de haut-parleur selon l'une quelconque des revendications précédentes, dans laquelle l'élément de pavillon (70) est coulé en une résine liquide. 35
9. Système de haut-parleurs comprenant une pluralité de haut-parleurs selon l'une quelconque des revendications précédentes assemblés les uns aux autres de sorte que leurs faces correspondent à des subdivisions d'une surface. 40
10. Système de haut-parleurs selon la revendication 9, dans lequel la surface est au moins partiellement sphérique. 45
11. Système de haut-parleurs selon la revendication 9, dans lequel la surface est au moins partiellement cylindrique. 50
12. Procédé de fabrication de l'unité de haut-parleur selon l'une quelconque des revendications 1 à 8, comprenant l'étape consistant à former l'élément de pavillon (70) en coulant une résine liquide autour d'un ensemble de structures flexibles suivant la même loi de surface que les guides d'ondes (75). 55

Fig.1.

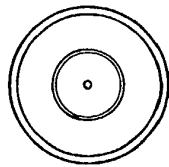


Fig.2.

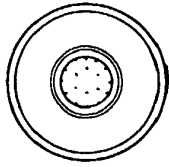


Fig.3.

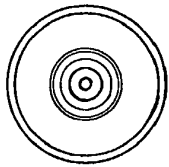


Fig.4.

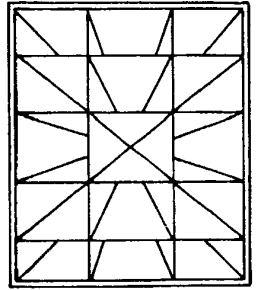
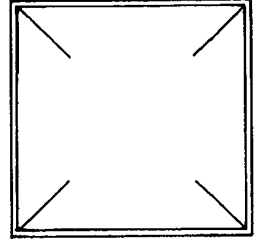
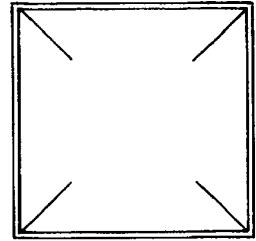
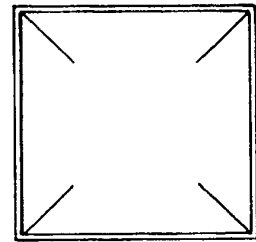
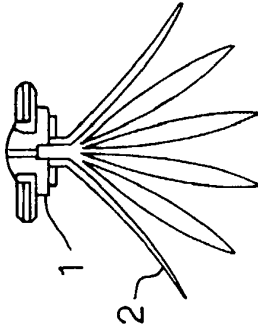
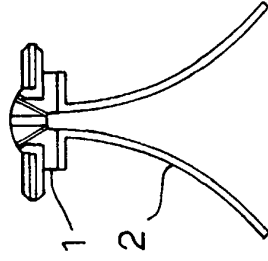
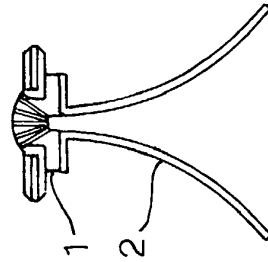
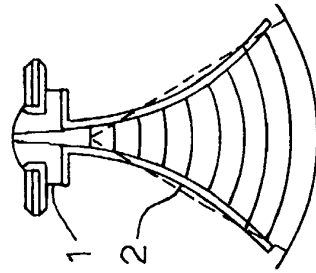


Fig.5A.

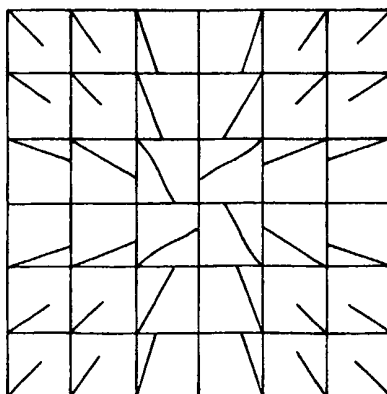
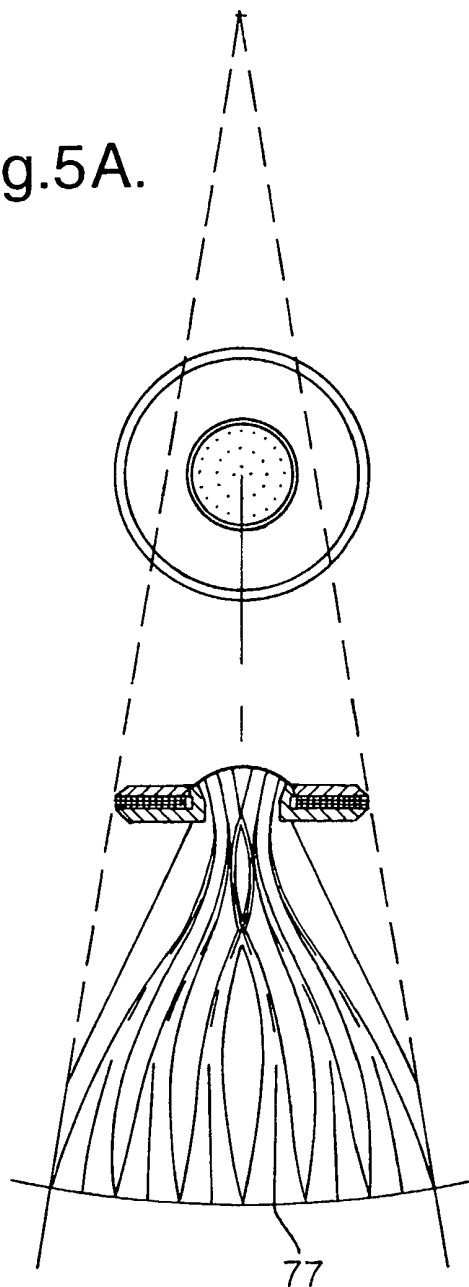


Fig.5B.

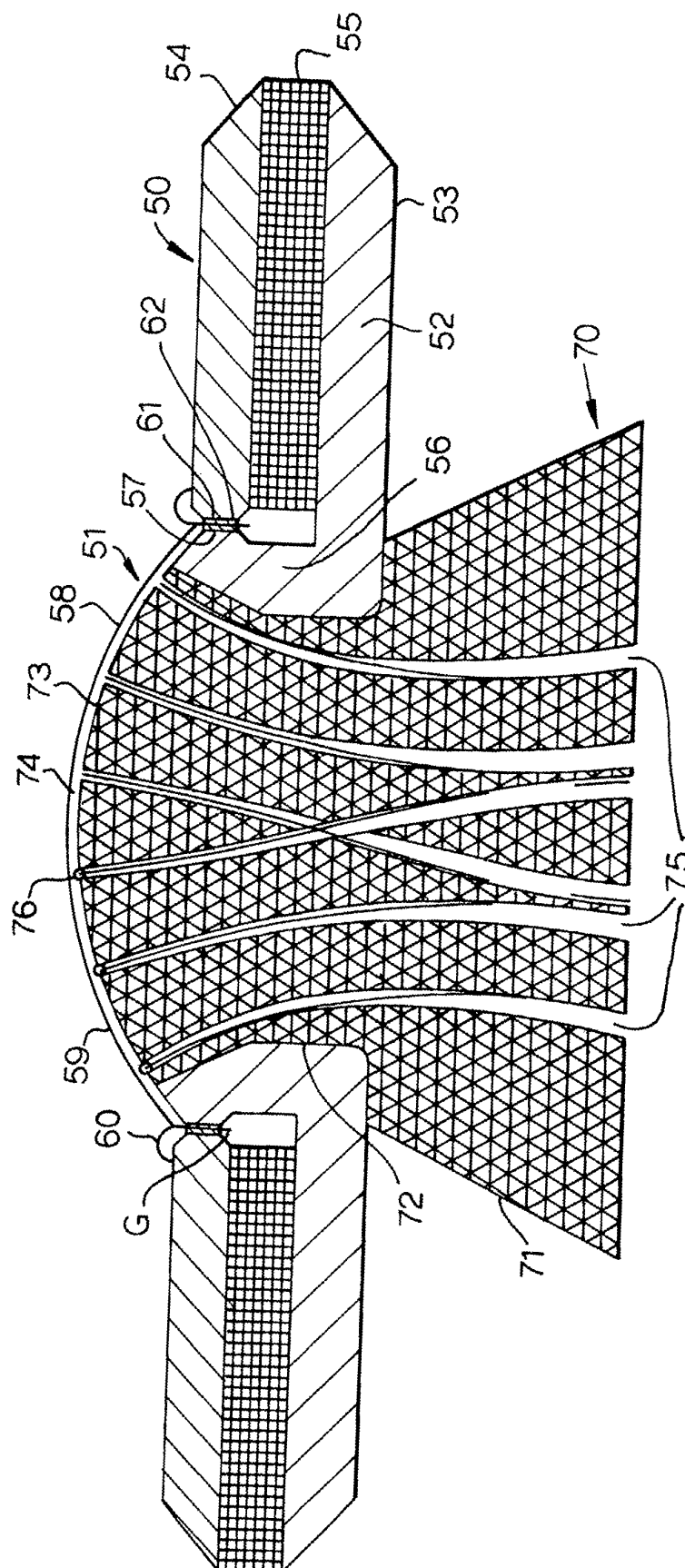
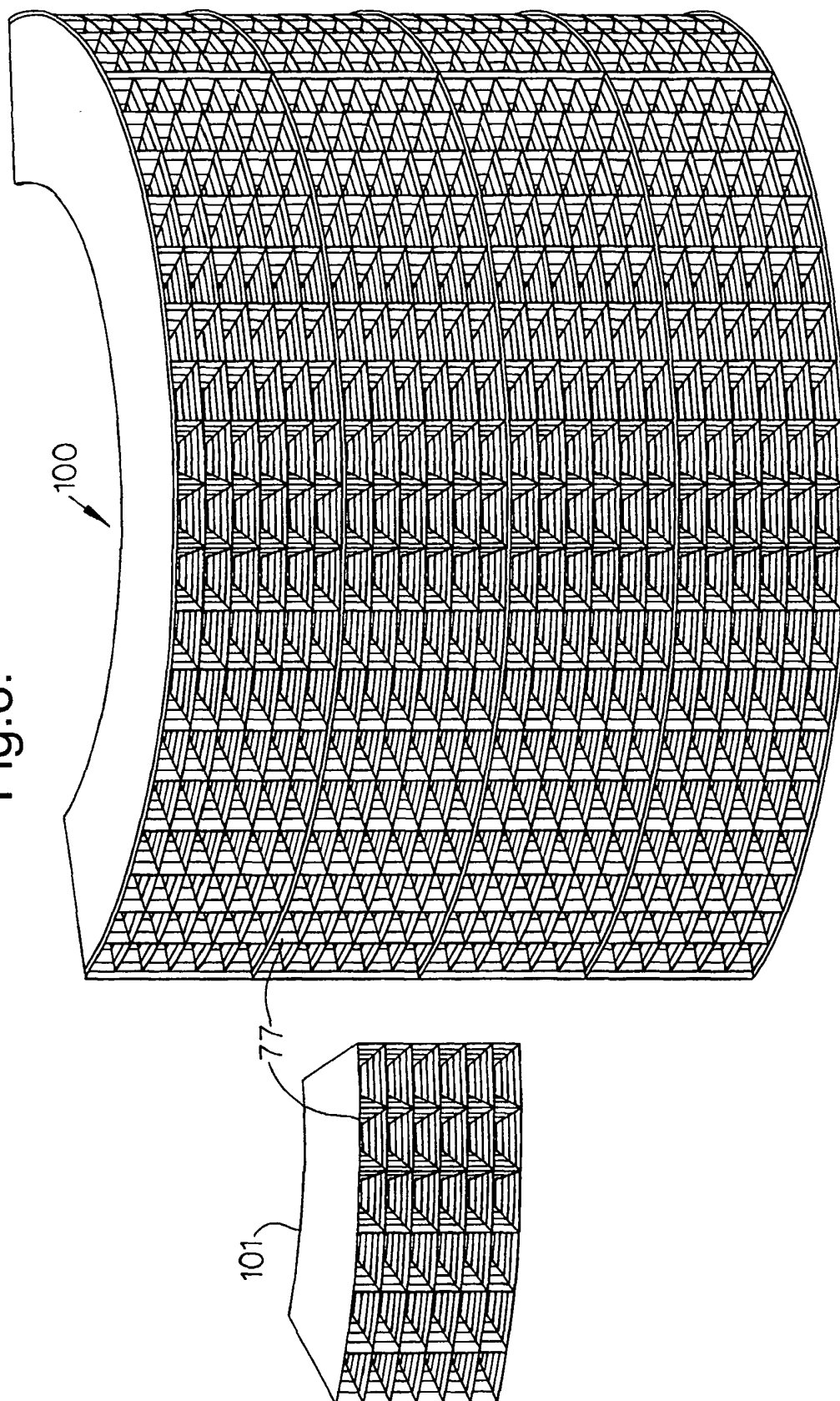


Fig.6.



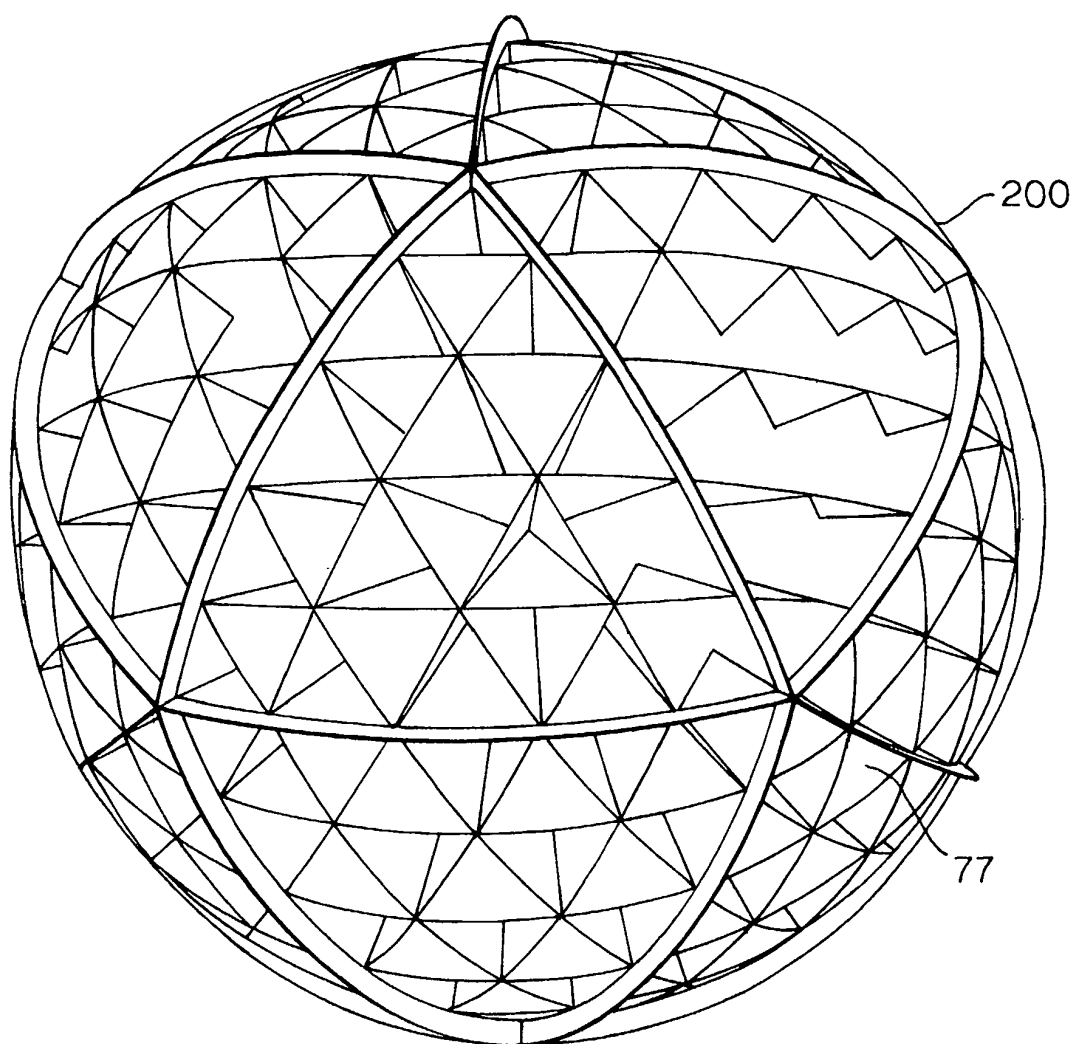
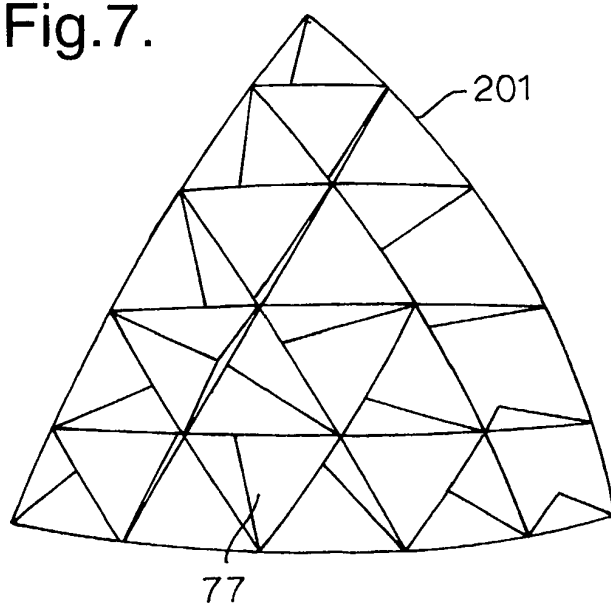


Fig.7.



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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