United States Patent

[11] 3,573,400

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[21] Appl. No. 752,560
[22] Filed Aug. 14, 1968
[45] Patented Apr. 6, 1971

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[54] **DIRECTIONAL MICROPHONE**
10 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** 179/121, 179/111
[51] **Int. Cl.** H04r 1/32
[50] **Field of Search** 179/121, 121 (DIR), 1 (DIR), 111

[56] **References Cited**

UNITED STATES PATENTS

2,787,671	4/1957	Grosskopf et al.	179/111
2,793,255	5/1957	Schlenker	179/121

FOREIGN PATENTS

1,003,835	7/1962	Great Britain	179/1
884,516	7/1953	Germany	179/111

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ABSTRACT: A directional microphone with toroidal sensitivity characteristics which can be selectively distorted is constructed with an arrangement of acoustic tubes which sample an acoustic field at a number of separated points on an inner circle and at separated points on a concentric outer circle. The acoustic signals from the inner points are summed in a first acoustic cavity and the signals from the outer points are summed in a second cavity. The first and second cavities are separated by a foil electret or other electroacoustic transducer which produces a signal proportional to the difference in sound pressure between them. Several of the acoustic tubes may be adjusted to alter the shape of the microphone's sensitivity pattern in the plane of maximum sensitivity and the entire acoustic system is selectively dimensioned to equalize the system's inherent frequency response.

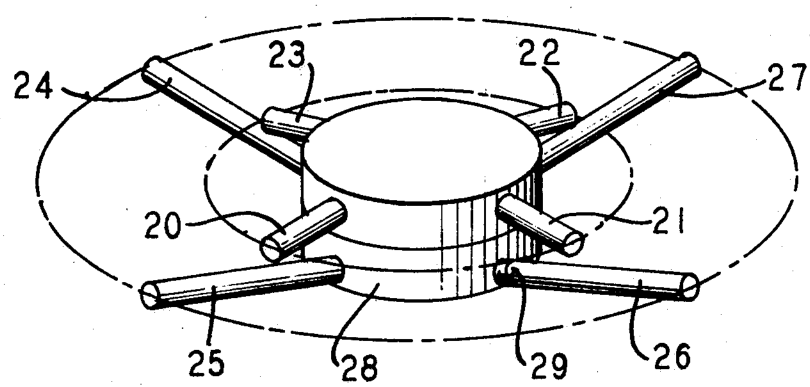

FIG. 1

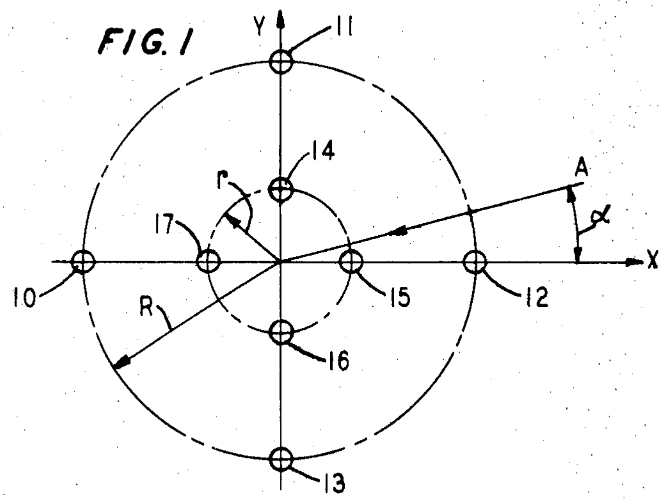

FIG. 2

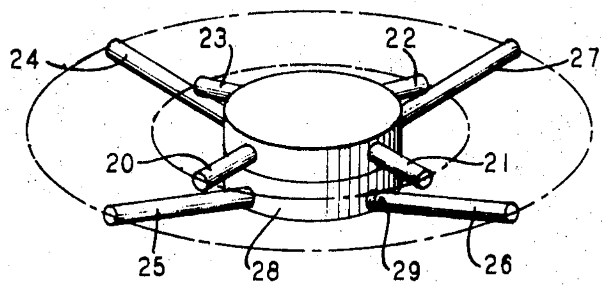

FIG. 3

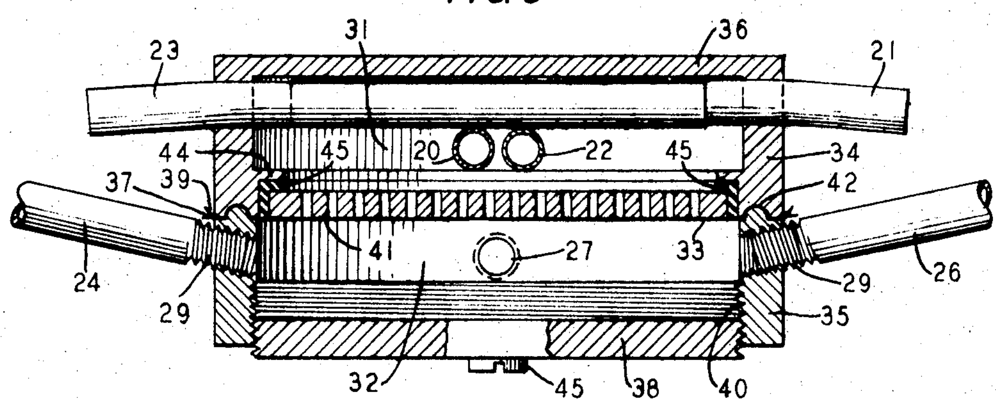

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FIG. 4

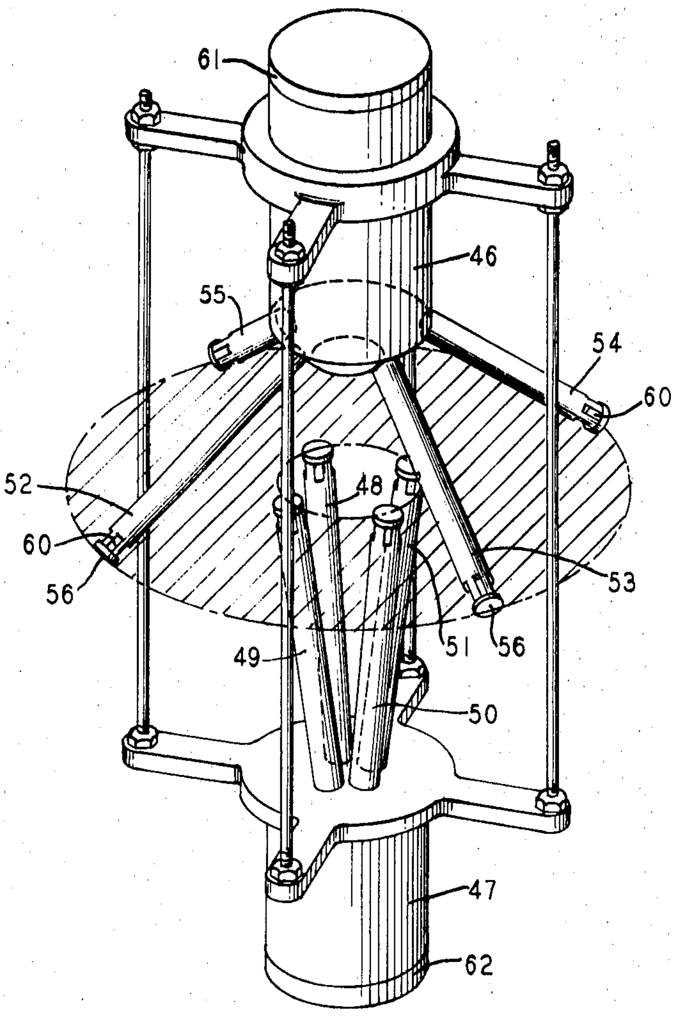
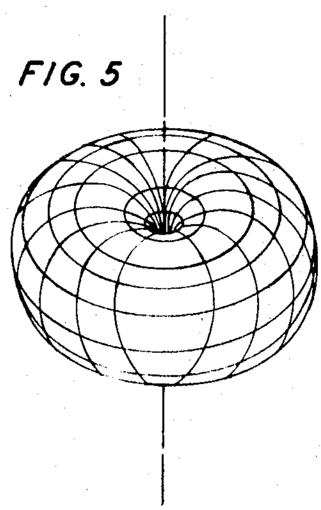


FIG. 5



DIRECTIONAL MICROPHONE

This relates to electroacoustic transducers and more particularly to a directional electroacoustic microphone with a toroidal sensitivity pattern which can be selectively distorted.

BACKGROUND OF THE INVENTION

1. Field of the Invention

Directional microphones are commonly employed in a great variety of audio communications systems; frequently to emphasize weak signals in a noisy environment and to reduce the effects of reverberation. Microphones for these purposes are currently available with numerous diverse sensitivity patterns ranging from the omnidirectional pattern to the long range unidirectional beam type pattern. One such microphone which is becoming more and more important in a great variety of recurrent communication situations is the microphone with toroidal sensitivity characteristics; that is, a microphone which is highly sensitive to acoustic signals impinging approximately from within a single plane and which rejects acoustic signals impinging from a direction normal to that plane. Such toroidal microphones are valuable, for example, in sound studio recording situations or in conference room telephone arrangements where many talkers located around a single conference table use a single telephone channel for two-way communication to a distant point.

2. Prior Art

Prior toroidal microphones have been constructed with a pair of mutually perpendicular pressure gradient receivers, the electrical outputs of which are combined after a 90° phase shift. Such a toroidal microphone is disclosed in Olson, Pat. No. 2,539,671 issued Jan. 30, 1951. Olson shows two perpendicular ribbon microphones with their outputs combined in a network including a pair of broadband phase shifters. This arrangement has the following properties which may be significant shortcomings in certain situations: Firstly, as the angle of incidence of the impinging sound wave increases away from the plane of maximum sensitivity, the sensitivity decreases in proportion to the cosine of the angle of incidence. Secondly, in the Olson arrangement the phase response in the plane of maximum sensitivity is a function of the angle of incidence of the sound wave in that plane. And finally, the broadband phase shifter which is required by the Olson arrangement is cumbersome, and an unnecessary source of potential malfunction of the system.

A different arrangement which is claimed to provide a toroidal sensitivity pattern is shown in Weingartner Pat. No. 3,201,516 issued Aug. 17, 1965. In this arrangement, an encased transducer is exposed to an acoustic field through a number of selected acoustic channels. However, this system does not achieve full toroidal sensitivity and has substantial sensitivity for signals impinging from its underside. Additionally, it provides only one nonadjustable sensitivity pattern and is highly frequency sensitive. That is, its sensitivity decreases in proportion to the square of the frequency of the impinging acoustic signal.

Thus, it is an object of the present invention to overcome the faults of prior microphone arrangements in a simple, compact electroacoustic transducer with toroidal sensitivity characteristics.

SUMMARY OF THE INVENTION

In accomplishing this and other objects and in accordance with the invention, a directional second order microphone with toroidal sensitivity characteristics is constructed with an arrangement of exposed acoustic tubes positioned to sample a sound field at a plurality of points on an inner circle and at a plurality of points on a concentric outer circle. The acoustic signals gathered from the inner points are summed in a first acoustic chamber and the signals from the outer points are summed in a second acoustic chamber, with the signal in the first chamber being subtracted from the signal in the second either mechanically by exposing the two sides of a microphone membrane to the two signals or electrically in a differential amplifier. In accordance with two prominent features of the invention, the length of several of the acoustic tubes may be varied to adjust the sensitivity pattern of the microphone to specific conference situations, and the dimensions of the acoustic chambers are established to emphasize preselected frequency components of the received signal and thus reduce the frequency dependence of the sensitivity of the system. In addition, higher even order systems may be arranged by adding additional rings of sampling points.

BRIEF DESCRIPTION OF THE DRAWING

The invention will be more fully understood from the following theoretical considerations and detailed description of a preferred embodiment thereof taken in conjunction with the appended drawings wherein:

FIG. **1** graphically depicts an array of eight pressure microphone point sensors arranged in accordance with the invention;

Fig. **2** is a perspective view of a directional transducer utilizing a single transducer element constructed in accordance with the invention;

FIG. **3** shows a partially sectioned view of the transducer depicted in FIG. **2**;

FIG. **4** is a microphone constructed in accordance with an alternative embodiment of the invention employing two separated cavities and a pair of transducer elements with the electrical outputs of the two transducer elements being electrically combined in accordance with the invention; and

FIG. **5** shows the shape of the sensitivity pattern of a microphone constructed in accordance with the invention.

THEORETICAL CONSIDERATIONS

Fig. **1** graphically portrays an arrangement of eight pressure responsive acoustic point sensing elements located in accordance with one embodiment of the invention so as to be highly sensitive to sounds impinging from the x, y plane and to reject sounds impinging normal to this plane. Such sampling elements, represented in FIG. **1** by circles **10** through **17**, may be open ends of acoustically conductive tubes arranged in a manner to be described more fully in conjunction with the detailed description of an illustrative embodiment of the invention that follows. The arrangement shown in FIG. **1** samples a sound field at eight points in a plane, four inner points **14**, **15**, **16** and **17** on a circle of radius r and four outer points **10**, **11**, **12** and **13** on a circle of radius R: the circles r and R are concentric. It is to be understood that more or less than eight sensors may be arranged in accordance with the description that follows, for example 16 sensors may be employed, eight located on the outer circle and eight on the inner circle. The analysis which follows is directed to the embodiment shown in FIG. **1** and is intended as an example only. It is also to be understood that higher even order toroidal microphones may be constructed by sampling the sound field on additional concentric rings of radius greater than R. In processing the acoustic signals received at each point in accordance with the invention, the sound pressures at the outer points are added together by circuitry or acoustic apparatus, now shown, and their sum is subtracted from the sum of the sound pressure at the inner points. The resulting received total sound pressure may be designated $p(\alpha, \Phi)$ where α is the angle between an arbitrarily selected line in the plane of the eight sensing elements, in this case the line through circles **12** and **15** corresponding to the x axis, and the direction defined by the projection into this plane of the propagation vector of an acoustic wave shown as path A in FIG. **1**. Φ represents the angle of the elevation of the impinging sound wave above the plane defined by the x and y axis.

For sound waves impinging in the plane defined by the x and y axis, that is the plane in which $\Phi=0$, the sound pressure at the outer sensors adds up to,

$$p_{out}(\alpha, 0)=\frac{1}{4}p_0 \exp(-i\omega t)\,[\exp(-ikR\sin\alpha) + \exp(ikR\cos\alpha)+\exp(ikR\sin\alpha)+\exp(ikR\cos\alpha)]$$
$$=\frac{1}{2}p_0\exp(-i\omega t)\,[\cos(kR\sin\alpha)+\cos(kR\cos\alpha)] \qquad (1)$$

where p_0 represents the phase and amplitude of the pressure of the undisturbed sound field at the center of the system and k is the wave number. Using a similar relation for the sum of the sound pressures at the inner points, there is obtained for the received sound pressure $p(\alpha, 0)=p_{in}(\alpha, 0)-p_{out}(\alpha, 0)$,

$$p(\alpha,0)/p_0=\frac{1}{2}[\cos\ (kr\sin\alpha)+\cos\ (kr\cos\alpha]$$
$$-\frac{1}{2}[\cos\ (kR\sin\alpha)+\cos\ (kR\cos\alpha)] \quad (2)$$

where the common factor $\exp(-i\omega t)$ has been suppressed. For sound waves impinging at an angle Φ above the plane of the sampling points, k must be replaced by $k'=k\cos\Phi$. Thus, equation (2) yields,

$$p(\alpha,\varphi)/p_0=\frac{1}{2}[\cos\ (kr\sin\alpha\cos\varphi)+\cos\ (kr\cos\alpha\cos\varphi)$$
$$-\cos\ (kR\sin\alpha\cos\varphi)-\cos\ (kR\cos\alpha\cos\varphi)] \quad (3)$$

This equation shows that the phase of the received sound pressure is either equal or opposite to that of the undisturbed sound pressure at the center of the system.

Using a series expansion for the terms in Equation (3) there is obtained for $kR\cos\Phi$ less than or approximately equal to 1,

$$p(\alpha,\varphi)/p_0\approx\left(\frac{1}{2}k\cos\varphi\right)^2(R^2-r^2)$$
$$\left[1-\frac{1}{12}(k\cos\varphi)^2(R^2+r^2)(\sin^4\alpha+\cos^4\alpha)\right] \quad (4)$$

If $kR\cos\Phi<<$ $p(\alpha, \Phi)$ is approximately given by

$$p(\alpha,\varphi)/p0\approx\left(\frac{1}{2}k\cos\varphi\right)^2(R^2-r^2). \quad (5)$$

At low frequencies, the received sound pressure is therefore proportional to,

$$k^2=(\omega/c)^2, \quad (6)$$

and to $(\cos\Phi)^2$ as expected for a second order gradient microphone. In this range, the amplitude of the sound pressure is independent of α, and the phase is independent of α and Φ and equal to the phase of the undisturbed sound pressure.

Thus, point sensors arranged as shown in FIG. **1** provide an electroacoustic transducer with toroidal sensitivity characteristics in which the sensitivity decreases in proportion to the square of the cosine of the angle between the direction of incidence of a sound wave and the plane of the sensors. The microphone is uniformly sensitive for sound waves impinging in the plane of the sensors and the phase is constant in all directions. Note, however, that the microphone described above is very frequency dependent; that is, the sensitivity increases in proportion to the square of the frequency of the signal being received (Equation 6). While this response is to be expected in a second order pressure gradient microphone, it would be preferable if this effect were eliminated.

In accordance with a feature of the present invention, this frequency dependence can be substantially reduced by selectively dimensioning the various elements of the acoustic system designed to implement the principles discussed above. Thus, in one alternative implementation, the sound field is sampled at eight points, as indicated above, by eight acoustic tubes, such as tubes **20** through **27** in FIG. **2**. In this arrangement, the acoustic signals received at the four outer tubes are directed to a first acoustic cavity and the signals received at the four inner tubes are directed to a second acoustic cavity. This entire acoustic system preferably is selectively dimensioned to be acoustically inversely frequency dependent thus to counteract the normal frequency dependency of the microphone.

In order to achieve this acoustic inverse frequency dependence, each acoustic cavity and its associated tubes are made to form a Helmholtz resonator or an acoustic low pass filter. An analysis of such systems based on well known electrical analogies will be found in Morse, Vibration and Sound, 2nd edition, McGraw Hill Book Company, 1948 at pages 233 to 237. As indicated by Morse, the pressure in the cavity of a tube-cavity system is maximum at the Helmholtz resonance frequency given by $\omega_0=c(S/\lambda V)^{1/2}$, where λ and S are the length and cross section of the tube, V is the volume of the cavity, and c is the velocity of sound. The pressure drops off in proportion to ω^{12} at higher frequencies. By adjusting the dimensions of the system so as to place the resonance frequency at the lower end of the frequency range of interest, the normal frequency dependency of the microphone is counteracted. At the same time, the overall signal to noise ratio of the system is improved since the signal is increased at low frequencies, in the vicinity of the resonance frequency, where electronic noise is highest.

In order to achieve the required equal resonance frequencies, in a two cavity system, such as that shown in FIGS. **2** and **3**, the two cavities with their tubes must form acoustically equivalent systems over the entire frequency range of interest. To ensure this condition, the tubes feeding both cavities are preferably of equal length and the cavities are preferably of the same volume. A preferred manner of accomplishing these conditions will be described in conjunction with the detailed description of a preferred embodiment below.

In accordance with a second feature of the invention, a system having a distorted toroidal sensitivity pattern, for example a pattern with greater sensitivity for $\alpha=0$ and $\alpha=\pi$ than for

$$\alpha=\frac{\pi}{2}\text{ and }\alpha=\frac{3\pi}{2},$$

may be obtained by changing the position of the two outer sensors **10** and **12**. If the distance between the sensors **10** and **12** is extended from $2R$ to $2R$, where R is greater than R, then Equation (3) assumes the form;

$$p(\alpha,\varphi)/p_0=1/2[\cos\ (kr\sin\alpha\cos\varphi)+\cos\ (kr\cos\alpha\cos\varphi)$$
$$-\cos\ (kR\sin\alpha\cos\varphi)-\cos\ (k\overline{R}\cos\alpha\cos\varphi)] \quad (7)$$

Series expansion yields for $kR\cos\Phi<<$

$$p(\alpha,\varphi)/p_0\approx\left(\frac{1}{2}k\cos\varphi\right)^2[R^2-r^2+(\overline{R}^2-R^2)(\cos\alpha)^2] \quad (8)$$

This equation is equivalent to Equation (5)

$$\alpha=\frac{\pi}{2}\text{ and }\alpha=\frac{3\pi}{2}.$$

For all other azimuth angles, $p(\alpha, \Phi)/p_0$ from Equation (8) is greater than the values obtained from Equation (5) and reaches maximum for $\alpha=0$ and $\alpha=\pi$. For each angle α, the dependence on $(\cos\Phi)$**2** is, however, preserved.

DETAILED DESCRIPTION

Referring to the drawing, the microphone shown in FIG. **2** embodies the principles of the invention in a compact, durable device which is suitable for use in a conference room telephone arrangement. The microphone samples the surrounding sound field at eight selected points in the same plane, four on an inner circle and four on a concentric outer circle in accordance with the theoretical discussion above.

The sampling is accomplished with eight radially extending acoustic tubes, **20** through **27**, which feed acoustic signals into a cylindrical body member **28**. The tubes **20** through **27** are all of equal length. However, an upper set of tubes, including tubes **20**, **21**, **22** and **23** are secured through apertures in the upper half of the lateral portion of the cylindrical casing **28** so that only a selected relatively short segment of the tube protrudes from the cylindrical casing. These upper tubes are orthogonally positioned with regard to the central axis of the casing 28 are are secured to the casing by an acoustically tight connection. The tubes of the upper set may be angled downward slightly so that their ends fall in a single plane. As will be described in more detail in conjunction with FIG. 3, tubes 20, 21, 22 and 23 feed acoustic signals to a first selectively dimensioned acoustic cavity within the casing 28.

The lower set of tubes 24, 25 26 and 27 are secured through apertures in the lower portion of the cylindrical casing 28 so that a relatively long segment of each tube is exposed beyond the wall of casing 28. These tubes are also orthogonally disposed about the central axis of the cylindrical casing. In the case shown in FIG. 2, the longer tubes are positioned in holes directly above the shorter tubes. Thus, tube 20 is positioned above tube 25, and so forth. It is to be understood, however, that either set of tubes could be rotated, say by 45°, about the central axis of the cylinder and still produce a toroidal sensitivity pattern in accordance with the invention. Tubes 24, 25, 26 and 27 are angled slightly upward so that their free ends fall in the plane defined by the ends of tubes 20, 21, 22 and 23.

In accordance with a feature of the invention, a number of tubes may be adjusted to alter the points at which they sample the sound field. Thus, for example, tubes 24 and 26 may include a threaded portion 29 which is mated with threading on the interior of the appropriate aperture. The length of threaded portion 29 is selected according to the degree of variation in the sensitivity pattern desired. To adjust the pattern, tubes 26 and 24 are rotated so that they are advanced into or withdrawn from the cylindrical body 28, thus altering the distance between the exposed ends of tubes 26 and 24. The effective alteration of the toroidal sensitivity pattern caused by this variation is identical to the result achieved by altering the position of receivers 10 and 12 in FIG. 1, which has already been described in conjunction with the theoretical discussion above.

FIG. 3 shows the microphone assembly of FIG. 2 in partially sectional view exposing the interior of casing 28. The casing includes two acoustic cavities 31 and 32 separated by an electroacoustic transducer element 33. The casing 28 comprises a cylindrical upper section 34 mated to a cylindrical lower section 35. The upper cylindrical section is enclosed by a contiguous circular top element 36 which may be formed with the upper cylindrical section 34 from a single homogeneous piece of material. The lower cylindrical section 35 is enclosed by a threaded circular bottom plate 38 which mates with a threaded portion 40 of the cylindrical lower section. These threads are preferably very fine so that as the bottom plate is rotated it advances slowly into the lower cylindrical section 35 reducing the size of the lower acoustic cavity 32. Plate 38 is equipped with a slotted disc 45 to facilitate rotation. This adjustment permits the volume of the upper and lower acoustic cavities to be equalized so as to provide a low pass filtering effect and thus reduce the frequency dependence of the system in accordance with the theoretical considerations discussed above.

Tubes 20, 21, 22 and 23, which open into the upper cavity 31, are secured to the upper cylindrical section 34 with only a relatively short length extending out beyond the wall of the casing. Thus, these tubes sample the sound field at four selected points on an inner circle as shown in FIG. 2. Since, as indicated in the theoretical discussion above, it is desirable that all tubes entering the cylindrical casing be of equal length, a substantial portion of each of the tubes 20, 21, 22 and 23 remain in the interior of cavity 31. These tubes tubes may preferably be arranged as shown, with tubes 21 and 23 lying adjacent to plate 36, tube 23 being forward of tube 21, and tubes 20 and 22 being located below tubes 21 and 23.

Tubes 24, 25, 26 and 27 open into the lower cavity 32 with their interior ends approximately abutting the interior wall of cylindrical section 35. As indicated above, tubes 24 and 26 include a threaded portion 29 which permits them to be advanced into cavity 32 thus altering the position at which the sound field is sampled and hence the sensitivity characteristic of the microphone.

The circular electroacoustic transducer element 33 may be any one of many such transducers which are well known in the microphone arts. However, it has been found that an electrostatic transducer of the foil electret type described in Pat. No. 3,118,022 issued Jan. 14, 1964 to G. M. Sessler and J. E. West is particularly desirable. A transducer of this type comprises a thin foil layer 37 superimposed upon a solid sheet of dielectric material 39 which is prepolarized in an electrostatic field at an elevated temperature. The foil and dielectric layer is stretched across a perforated backplate 41 which is insulated from the casing by an annular section of electrical insulating material 45.

Casing 28 may be specifically designed to accommodate such a foil electret transducer. Thus, the lower extremity of the cylindrical upper section 34 of the casing is found to include an annular channel 42 and the upper extremity of the cylindrical lower section 35 includes an arced annular nub 43. The two sections are held tightly together, e.g., by adhesive bonding or by mechanical means. Additionally, the cylindrical upper section includes an annular ledge 44 positioned slightly away from the annular channel so that the circular backplate 41 can be fitted below the ledge 44 with the foil and dielectric 37 and 39 stretched over the backplate to be retained between the annular channel 42 and the annular nub 43. The microphone's electrical output is then taken between the cylindrical casing 28 and the perforated backplate 41. This arrangement permits simple assembly of the entire microphone unit.

A toroidal microphone, constructed in accordance with a second embodiment of the invention is shown in FIG. 4. The principle of this microphone is theoretically identical to that of the microphone described above. The physical embodiment differs in that two separated acoustic chambers 46 and 47 are employed in conjunction with a pair of electroacoustic transducer elements 61 and 62, one associated with each cavity. The electrical output of the first transducer 61 is subtractively combined with the output of the second transducer 62 in an appropriate differential amplifier, now shown, of a type well-known in the electronic art. Alternatively, oppositely polarized air gap condensers or electret transducers may be employed in which case their outputs will be added. Like the prior embodiment, the present system comprises eight acoustic tubes 48 through 55 arranged in sets of four. Again in this arrangement, all tubes are of equal length. The first set of tubes, comprising tubes 48, 49, 50 and 51, are angled sufficiently away from the vertical to sample the sound field at four points on an inner circle, while the second set including tubes 52, 53, 54 and 55, are angled to sample the field at four points on an outer circle.

Unlike the prior arrangement, however, the acoustic tubes 48 through 55 are closed off at their ends by small circular plates 56 and sound energy is permitted to enter the tubes only through a plurality of ports 60 cut in the lateral portion of each tube at its outer extremity. This arrangement is required since the first set of tubes are directed generally upward and the second set of tubes are directed generally downward so that, with simple open tubes, one or the other microphone is always more directly exposed to the transmitting sound source. The present arrangement eliminates this difficulty by requiring sound pressure from all directions to enter the tubes approximately uniformly.

FIG. 5 shows the toroidal form of the sensitivity pattern of a microphone constructed in accordance with the invention. As indicated in the course of the discussion above, this pattern may be altered by rearranging the points at which the sound field is sampled.

It is to be understood that the above described arrangements are merely illustrative of application of the principles of the invention. Other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention. For example, the arrangement shown in FIG. 2 may be altered so that the two acoustic cavities are contained within an annular ring shaped casing. The first set of acoustic tubes then protrude outward from the ring's exterior and the second set extend into the open space in the ring's center.

We claim:

1. A directional transducer comprising, first and second selectively dimensioned acoustic chambers, electroacoustic transducer means for converting the acoustic signals in said acoustic chambers into electrical signals, a first plurality of exposed acoustic tubes opening into said first acoustic chamber and extending radially outward therefrom to sample a sound field at a plurality of points on a first circle exterior to said chambers, and a second plurality of exposed acoustic tubes opening into said second acoustic chamber and extending radially outward therefrom to sample a sound field at a plurality of points on a second circle exterior to said chambers, said first and said second circles being concentric and having different radii.

2. A directional electroacoustic transducer which comprises, a first selectively dimensioned acoustic chamber, a second selectively dimensioned acoustic chamber, at least one electroacoustic transducing element associated with said first and second acoustic chambers for converting the acoustic energy in said chambers into electrical signals, a first group of acoustically conductive tubes with exposed ends opening into said first acoustic chamber and extending outward from said first acoustic chamber a first selected distance to reception points on a first circle of radius *r*, and a second group of acoustically conductive tubes with exposed ends opening into said second acoustic chamber and extending outward from said second acoustic chamber a second selected distance to reception points on a second circle of radius *R*, where *R* is greater than *r* and where said first and second circles are concentric and lie in the same plane.

3. A directional electroacoustic transducer as defined in claim 2 wherein a selected number of said acoustic tubes are of variable length so as to permit adjustment of the shape of said directional sensitivity pattern.

4. A directional electroacoustic transducer as defined in claim 2 wherein said first and second selectively dimensioned acoustic chambers and said first and second groups of tubes are dimensioned such that the chamber-tube systems from a Helmholtz resonator with a resonance frequency positioned at the lower end of the frequency range of interest.

5. A directional electroacoustic transducer as defined in claim 4 wherein said first group of acoustically conductive tubes comprise four tubes orthogonally positioned with respect to a central axis and wherein said second group of acoustically conductive tubes comprise four tubes orthogonally positioned with respect to a central axis.

6. A directional transducer comprising, an enclosed cylindrical casing containing an electroacoustic transducer positioned to divide said casing into first and second selectively dimensioned acoustic cavities, means sampling the sound field exterior to said casing at a plurality of selected points in the same plane for supplying acoustic signals to said cavities, said

means including a first plurality of acoustic tubes opening into said first acoustic cavity and extending radially outward from said casing, and a second plurality of acoustic tubes opening into said second acoustic cavity and extending radially outward from said casing.

7. A directional microphone as defined in claim 6 wherein said first and second plurality of acoustic tubes each comprise four tubes orthogonally positioned about the central axis of said cylindrical casing.

8. A directional microphone comprising, a cylindrical casing enclosed at both ends, a circular electroacoustic transducer element coextensive with the internal cross section of said cylindrical casing and located so as to separate said cylindrical casing into two selectively dimensioned acoustic chambers, a first group of four open acoustic tubes of equal length extending radially outward from the sides of said cylindrical casing, the tubes of said first group being mated to said casing so as to open into a first of said selectively dimensioned acoustic chambers and extending outward to a plurality of selected reception points located on a first circle, a second group of four open acoustic tubes of equal length extending radially outward from the sides of said cylindrical casing, the tubes of said second group being mated to said casing so as to open into a second of said selectively dimensioned acoustic chambers and extending outward to a plurality of selected reception points located on a second circle, said second circle being concentric with said first circle and having a radius greater than the radius of said first circle.

9. A directional microphone comprising first and second selectively dimensioned acoustic chambers spaced apart by a selected distance, first and second electroacoustic transducers, said first transducer being associated with said first cavity and said second transducer being associated with said second cavity, a first plurality of equal length acoustically conductive tubes opening into said first acoustic chamber and extending outward to a plurality of reception points located on a first circle in a reception plane intermediate said first and said second chambers, a second plurality of equal length acoustically conductive tubes opening into said second acoustic chamber and extending outward to a plurality of reception points located on a second circle in said reception plane, said first and second circles being concentric, and subtractive circuit means for electrically interconnecting said first and second electroacoustic transducers.

10. A directional transducer as defined in claim 6 wherein the acoustic tubes of said first plurality of tubes and the acoustic tubes of said second plurality of tubes are of equal length and equal length and e!ual cross section, and wherein said first and second acoustic cavities are dimensioned to be of equal volume, thus to achieve for said directional transducer a substantially toroidal sensitivity pattern.