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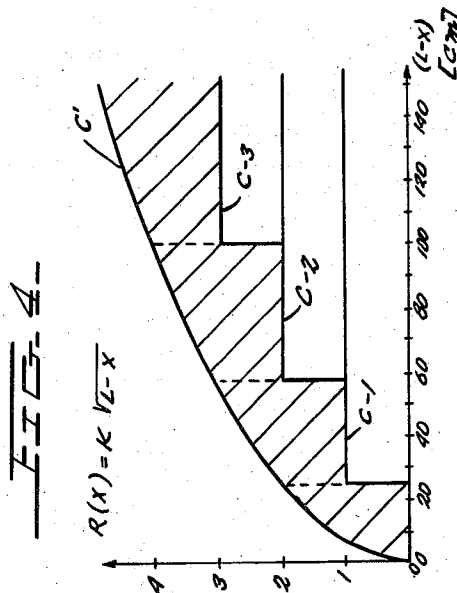
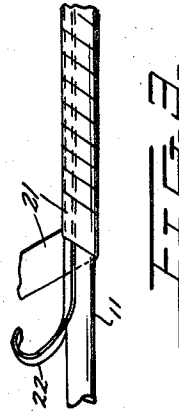
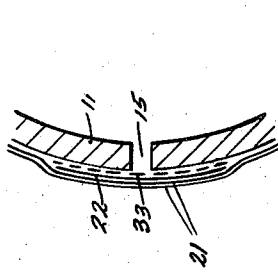
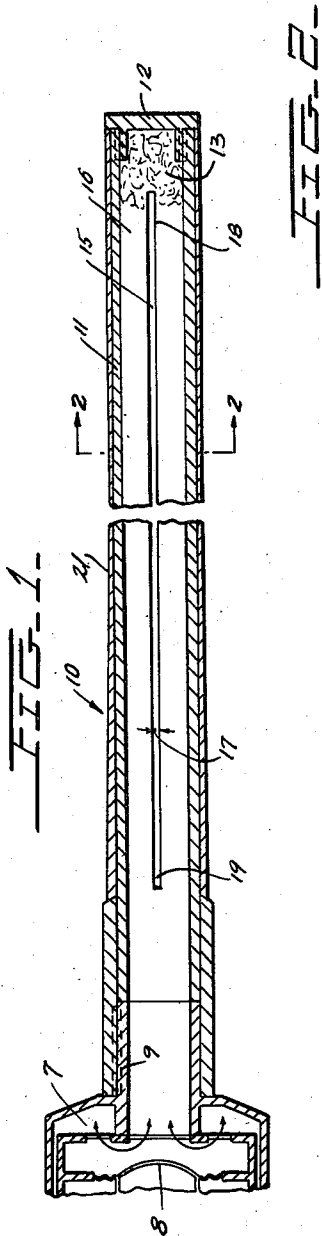
G. KURTZE ET AL

2,856,022

DIRECTIONAL ACOUSTIC SIGNAL TRANSDUCER

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2 Sheets-Sheet 1



INVENTORS
GUNTHER KURTZE
KONRAD TAMM

BY

Greene, Pinckney & Dunn
ATTORNEYS

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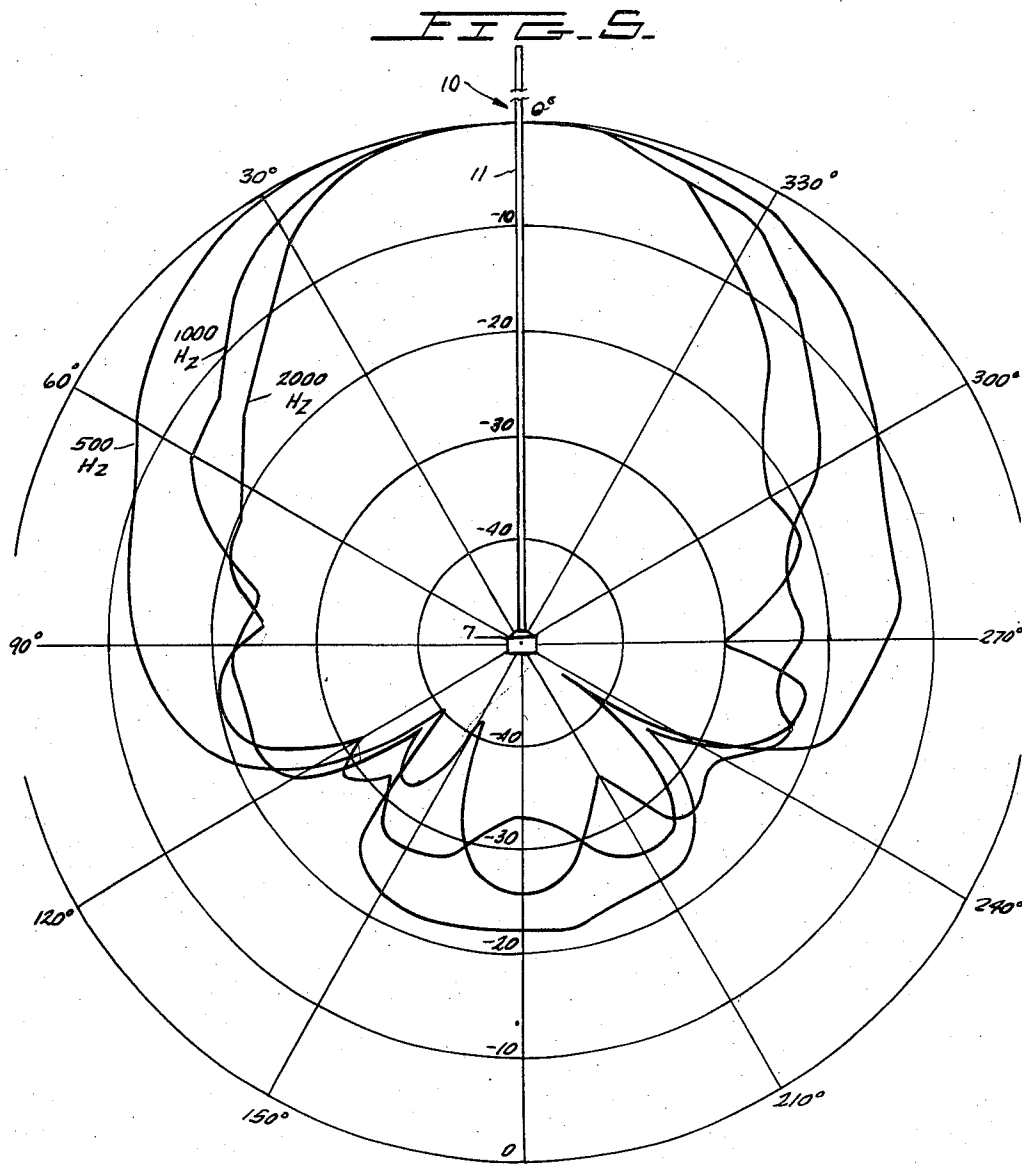
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DIRECTIONAL ACOUSTIC SIGNAL TRANSDUCER

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2 Sheets-Sheet 2



INVENTORS
GUNTHER KURTZE
KONRAD TAMM

BY

Greene, Pinckles & Burr
ATTORNEYS

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DIRECTIONAL ACOUSTIC SIGNAL TRANSDUCER

Gunther Kurtze and Konrad Tamm, Gottingen, Germany, assignors to Electro-Sonic Laboratories, Inc., Long Island City, N. Y., a corporation of New York

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6 Claims. (Cl. 181—5)

This invention relates to acoustic signal transducers such as microphones and more particularly to directional acoustic signal transducers.

U. S. Mason Patent No. 2,225,312 discloses an effective directionally selective or discriminating sound transducing device wherein the directional discrimination is obtained by an acoustic impedance formed of a large number of adjacent sound transmitting tubes or ducts extending parallel to a common cluster axis, the different ducts varying in a predetermined progressive relation in both length and also in their cross-sectional areas so that the sensitivity of this acoustic impedance is a maximum for sound waves reaching or incident upon the ducts in directions parallel to the cluster axis. The ends of the ducts nearest the microphone or transmitter are coplanar and equally spaced from the diaphragm or other vibratory elements of the transmitter. The different ducts are of increasing length so that the longest duct has a length substantially equal to the longest wave length or lowest frequency and the shortest duct has a length equal to the shortest wave length or the lowest frequency of the sound waves to which the device is to respond, requiring 49 ducts for a typical practical microphone.

The present invention is based on the discovery that a sound transducing device or microphone having a directional discrimination at least as high as that obtainable with the multitube device of the Mason patent may be achieved with a much simpler device using only a single duct coupled to the sound transducer, the single duct having a wall region with an acoustical perviousness which increases gradually along the duct so that all sound waves reaching the transducer undergo the same attenuation irrespective of the length of the duct path through which they travel.

The foregoing and other objects of the invention will be best understood from the following description of various exemplifications of the features of the invention, reference being had to the accompanying drawings, wherein:

Fig. 1 is a vertical cross sectional and partially diagrammatic view of a directional microphone exemplifying one form of the invention;

Fig. 2 is a cross-sectional view along lines 2—2 of Fig. 1;

Fig. 3 is an elevational view of a portion of the directional duct of Figs. 1 and 2 showing how the damping strip is applied to the duct in accordance with the principles exemplifying one form of the invention;

Fig. 4 is a curve diagram explanatory of the relationship of the thickness of applied damping material to the directional discrimination of the duct forming part of a transducer exemplifying the invention.

Fig. 5 is a polar diagram plot of the directional sound discrimination obtained with an electrostatic microphone provided with the discriminating impedance duct of the invention.

According to the invention the desired large directional discrimination for sound waves reaching the sound

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transducer is achieved with only a single long duct structure having an elongated acoustically pervious region of successively different acoustic perviousness. The sound transducer element is connected to one end of the duct.

The acoustic perviousness of different longitudinal portions of the longitudinal sound pervious duct region is graduated and so chosen that duct portions farther away from the transducer element subject the sound waves to smaller attenuation than duct portions which are nearer to the transducer element for causing all sound waves reaching the transducer element from different longitudinal portions of the duct to undergo substantially the same degree of attenuation irrespective of the length of the duct paths through which they travel. In other words, the different longitudinal portions of the longitudinal sound pervious duct region have such different graduated degrees of predetermined sound perviousness as to cause all sound waves which reach the sound transducer to undergo the same degree of attenuation irrespective of the length of the duct paths along which they travel to the transducer element.

The directional discrimination achieved by giving such graduated sound perviousness to different longitudinal portions of the duct varies with the frequency in that the discrimination increases in sharpness the greater the length L of the duct in relation to the wave length λ of the transmitted sound waves.

In accordance with the invention, the directional discriminating characteristics of the impedance of the invention are made independent of the frequency of the sound waves by providing the directionally discriminating duct with a longitudinal region of graduated acoustic perviousness so proportioned and designed as to compensate for the frequency discrimination of its directional discriminating characteristics while also securing the full desired directional discrimination. This is achieved by proportioning the longitudinally graduated perviousness of the duct region to cause the effective duct length L to decrease with increasing frequency so that the relation of the effective duct length L to the wave length λ of the sound waves or L/λ remains substantially constant over a certain frequency range.

The duct may be provided with the desired predetermined different acoustic perviousness in a variety of ways, as by providing it with a series of openings or pores of different size and length, with or without different wall thicknesses along its different longitudinal portions, and/or by combining such openings or pores with longitudinally graduated or ungraduated damping means. A simple directionally discriminating acoustic impedance structure is obtained by forming the duct with a slit the width and/or depth of which varies along its length to provide it with the desired differential acoustic perviousness or by combining such duct slit with a damping means which provides for the desired predetermined different acoustic perviousness along different portions of the slit length.

According to the invention, a highly effective directionally selective impedance is obtained with an extremely simple structure by providing an elongated duct with a long narrow longitudinal slit and spirally winding in a graduated way around the duct and over the duct slit a ribbon of damping material so that successive longitudinal portions of the duct slit have thereon successively larger numbers of winding turns of the damping ribbon giving a continuously graduated increase in the acoustic damping to successive longitudinal portions of the duct slit.

As stated above, the directional discrimination of the longitudinal duct region having gradually varying perviousness to provide the same attenuation for all sound

waves reaching the transducer from different longitudinal portions of the duct varies with the frequency of the sound waves, the discrimination increasing the greater the duct length L is in relation to the wave length λ . According to the invention, the directional discriminating characteristics are made substantially independent of the wave frequencies by providing the duct slit with frequency discriminating damping means arranged so as to provide the desired directional discrimination without introducing any frequency discrimination. In other words, in accordance with the invention, the damping of the duct slit is so controlled that the effective duct length L decreases with an increase of the frequency of the sound waves, this being achieved by choosing and dimensioning the damping so as to give a constant value for the ratio of the duct length L to the wave length λ or L/λ for the entire length of the duct slit.

According to a further phase of the invention, an acoustic transducer with inverse directional characteristics, i.e. a transducer which discriminates against reception of sound waves from one predetermined direction only, is obtained by coupling a directionally discriminating impedance of the type described above with an impedance having uniform sensitivity to all directions, both being suitably coupled to the sound transducer such as the microphone.

Figs. 1 to 3 illustrate one form of a practical directional microphone exemplifying the invention. It comprises an electro-acoustic transducing device or element such as the microphone 7 which may be of the electrostatic, electro-dynamic or any other type, having a vibratory member 8 and a coupler member 9, shown in the form of a hollow duct, by means of which the transducer device 7 is coupled to a directionally discriminating impedance generally designated 10.

The directionally discriminating impedance 10 comprises an elongated duct or duct structure 11 of substantial length corresponding to the wave length at the lowest frequency for which directivity is wanted.

The duct 11 may be of metal and its two opposite ends closed by or have connected thereto a matching impedance. In the form shown, one end portion of the duct structure 11 is closed by or has connected thereto the microphone device 7. The other or remote end portion of the duct 11 is closed by a cover 12, of metal, for instance, having at its inner side a body portion of acoustic damping material 13 such as a cotton for absorbing sound energy reaching the remote end region of the duct 11.

The duct 11 is provided with an elongated sound-pervious duct region in the form of slit 15 extending substantially throughout the entire length of the duct, the slit 15 providing acoustic coupling between the exterior space and the interior duct space 16 for causing sound from the exterior space to be propagated by way of the duct 15 into the interior duct space and therethrough to the microphone 7 and excite it to produce a corresponding electric output.

In the form shown, the elongated duct 11 has a duct slit 15 of uniform width 17 extending substantially over its entire length between its outer end 18 and its inner end 19 which is nearest to the microphone 7. In order to give the duct slit the desired graduated acoustic perviousness which decreases from the outer slit end 18 towards the inner slit end 19, the slit is combined with correspondingly graduated damping means which causes all sound waves reaching the transducer microphone 7 from different longitudinal portions of the duct slit 15 to undergo the same degree of attenuation irrespective of length of the duct paths through which they travel. In other words, the different longitudinal portions of the duct slit 15 are provided with such graduated amounts of acoustic damping means as to cause all sound waves which reach the sound transducer 7 through different portions of the duct slit 15 to undergo the same degree

of attenuation irrespective of the length of the duct path along which they travel to the transducer element.

According to the invention, the desired continuously graduated damping for the duct slit 15 of uniform width 17 is provided by spirally winding around the duct a ribbon 21 of damping material or damping element such as woven fabric, so that the spirally wound layers increase in number in a substantially uniform graduated manner from the outer slit end 18 to inner slit end 19 and provide gradually increasing attenuation for the duct slit portions nearer to the microphone 7.

In order to make the directional discrimination independent of the wave frequencies, either the damping material of the ribbon 21 or additional material within the duct is so chosen that the damping effect automatically compensates for any frequency discrimination in that the damping material or the damping elements thereof provide a frequency discrimination which results substantially in or approaches a constant ratio of the effective duct length L to the wave length λ for the transmitted sound waves or a constant ratio for L/λ .

Without in any way thereby limiting the scope of the invention, but in order to enable more ready practice of the same, there are given below specific data of a practical construction of a microphone of the type shown in Figs. 1 and 2 which has extremely desirable qualities.

The duct 11 is formed of a tube of metal one meter long having a slit 15 about 95 cm. long and about 1 millimeter in width. The specific duct 11 shown was made of aluminum tube with a circular cross-section 1 centimeter (cm.) in diameter, 1.5 millimeter (mm.) thick and 1 meter (m.) long. The longitudinal duct slit 15 was about 97 cm. long and about 1 mm. wide.

The damping was provided by a woven ribbon of cotton threads about 22 mm. wide spirally wound around the tube 11 with the number of overlapping spiral ribbon turns increasing toward the microphone 7, and giving the frequency compensated attenuation increasing gradually from the outer slit end 18 to the inner slit end 19 as explained above. In the practical construction of the microphone, good results have been obtained by placing a continuous length of a cotton ribbon 22 over longitudinal portions of the slit 15 before winding around the tube the spiral ribbon turns 21.

In Fig. 4, the ordinates of curve C represent the values of the damping resistance of the duct slit 15 for successive elements of the duct slit, the damping resistance being proportional to the square root of $(L-x)$ where L represents the total length of the slit and x the increments of the slit from the outer slit end 18 in the direction toward the microphone. The curve C represents the desired damping to secure maximum directional discrimination. In Fig. 4, the step-like curve elements C-1, C-2, C-3 show the damping secured by successively larger number of spiral turns or layers of a cotton damping ribbon placed upon the slit indicating that such damping material approaches in its damping action the desired damping action. Commercially available cotton fabric ribbons may be readily used to provide frequency compensation and graduated damping required to secure the desired large directional discrimination.

Fig. 5 is a polar diagram plot of the directional sound discrimination obtained with an electrostatic microphone provided with the specific directionally discriminating impedance duct shown and described above in connection with Figs. 1-3 for sound waves of different frequencies.

In the form shown in Figs. 1 to 3, the duct 11 with the damping ribbon wound thereon may be enclosed in an outer enclosure 21 of plastic material having a wide elongated gap 32 through which the duct slit 15 is exposed to sound waves in the surrounding space. A protective screen 33 of wire for instance is placed along

the enclosure gap 32 to protect the underlying damping material 21.

In the polar diagram of Fig. 5, the duct 11 is indicated at the center or zero point of the diagram with the slit 15 defining the discrimination axis along which sound reaching the duct 11 will be propagated by the duct 11 with the greatest sensitivity.

The features and principles underlying the invention described above in connection with specific exemplifications, will suggest to those skilled in the art many other modifications thereof. It is accordingly desired that the appended claims be construed broadly and that they shall not be limited to the specific details shown and described in connection with exemplifications thereof.

We claim:

1. In a signal transducer for directionally discriminating in the transmission of acoustic signals between an electro-acoustic transducer element and exterior space, an elongated axially directed duct structure confining an elongated interior space having a transducer end portion coupled to said transducer element for generating therein signals in response to sound waves transmitted in said interior space, said duct structure having a sound-absorbing closure body closing a remote end portion thereof, said duct structure having a substantially continuous elongated sound-pervious duct region extending from near the transducer end portion to near the remote end portion of said duct structure for coupling said interior duct space to the exterior space and causing sound waves from the exterior space to be propagated through said interior space to said transducer element, the length of said pervious duct region being at least ten times greater than the maximum width of said duct and corresponding in length to the lowest frequency for which directional discrimination is effective, successive longitudinal elements of said pervious duct region having attenuation means of successively different attenuation characteristics which increase in the direction toward said transducer end portion for gradually increasing attenuation of sound waves transmitted from the exterior space through portions of said sound-pervious region which are successively nearer to said transducer element, and thereby causing sound waves transmitted from said exterior space to said transducer element by way of said interior space to undergo substantially the same degree of attenuation irrespective of the length of said interior space through which said sound waves pass before reaching said transducer element.

2. In a signal transducer for directionally discriminating in the transmission of acoustic signals between an electro-acoustic transducer element and exterior space, an elongated axially directed duct structure confining an elongated interior space having a transducer end portion

coupled to said transducer element for generating therein signals in response to sound waves transmitted to said interior space, said duct structure having a sound-absorbing closure body closing a remote end portion of said duct, said duct structure having a substantially continuous elongated slit-like opening extending from near the transducer end portion to near the remote end portion of said duct structure for coupling said interior duct space to the exterior space and causing sound waves from the exterior space to be propagated through said interior space to said transducer element, the length of said slit-like opening being at least ten times greater than the maximum width of said duct and corresponding in length to the lowest frequency for which directional discrimination is effective, successive longitudinal elements of said slit-like opening having attenuation means of successively different attenuation characteristics which increase in the direction toward said transducer element for gradually increasing attenuation of sound waves transmitted from the exterior space through portions of said slit-like opening which are successively nearer to said transducer element and thereby causing sound waves transmitted from said exterior space to said transducer element by way of said interior space to undergo substantially the same degree of attenuation irrespective of the length of said interior space through which said sound waves pass before reaching said transducer element.

3. In a signal transducer as claimed in claim 2, said attenuating means including flexible sheet material placed over said slit-like opening.

4. In a signal transducer as claimed in claim 2, said attenuating means including a strip of damping material placed over said slit-like opening.

5. In a signal transducer as claimed in claim 2, said attenuating means including a strip of attenuating material spirally wound over at least a major portion of the length of said slit-like opening.

6. In a signal transducer as claimed in claim 2, said attenuating means including a strip of damping material spirally wound over at least a major portion of the length of said slit-like opening, said strip being wound with a pitch which is increasingly shorter in the direction toward said transducer end portion.

References Cited in the file of this patent

UNITED STATES PATENTS

2,210,415	Kellogg	Aug. 6, 1940
2,228,886	Olson	Jan. 14, 1941
2,406,391	Mason	Aug. 27, 1946
2,739,659	Daniels	Mar. 27, 1956