

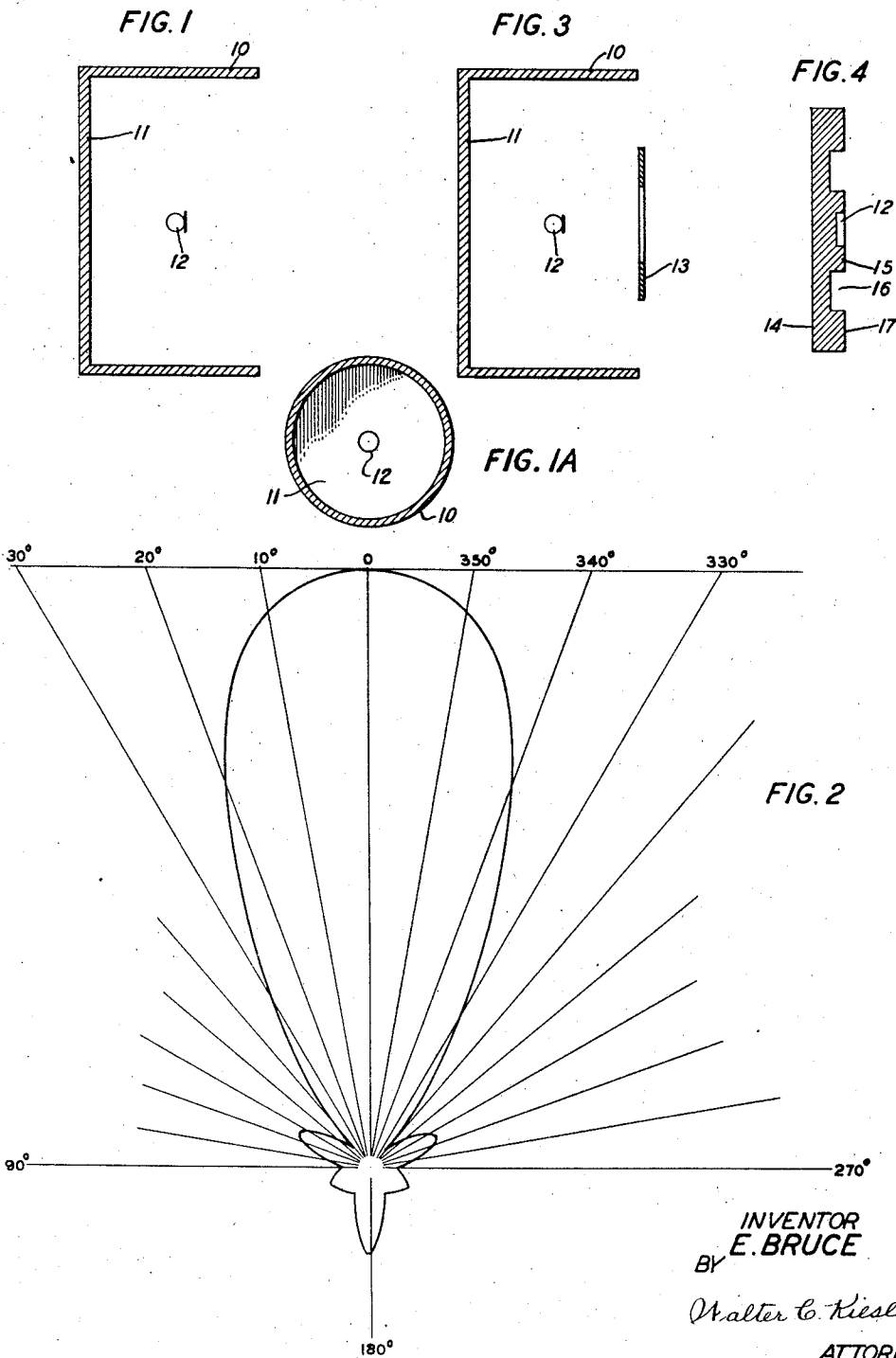
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ACOUSTIC DEVICE

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ACOUSTIC DEVICE

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This invention relates to acoustic devices and more particularly to acoustic receivers and transmitters having marked directional characteristics.

One object of this invention is to obtain a highly directional characteristic with a sound translating device of relatively simple construction and relatively small dimensions.

Another object of this invention is to obtain a high amplitude level of response or propagation for directional acoustic devices.

Directivity and amplitude of response or propagation of sound translating devices are basically a matter of superposition of amplitudes and their phases. Zonal theory of wave motion indicates that the amplitude of pressure at a point in space, due to a plane-wave of sound, is the sum of the effects of incremental pressures in a series of concentric interference zones located in a plane contained in any equiphase wave front, intermediate the point and the wave. The effect of each zone upon the point in question is dependent, in both amplitude and phase, upon the distance between the zone and the point. In general, the effect, in amplitude, decreases as this distance increases. As to phase, the zones may be considered as divided into two groups, the zones being spaced, from the point in question, distances a function of the length of the propagated wave such that at the point in question the pressures due to each group are in phase, with the pressures due to the zones in one group in phase opposition to the pressures due to the zones in the other group.

The amplitude of pressure at the point of interest, due to the central zone is greater than, theoretically twice as great as, the sum of the amplitude due to all the other zones, considering all zones to infinity. If this central zone is considered numerically as the first zone, the odd-numbered zones constitute useful zones, that is they add to the amplitude due to the central zone, whereas the even-numbered zones constitute harmful zones inasmuch as their effect at the point of interest is in opposition, i. e., out of phase with, the pressure due to the central and odd-numbered zones.

In accordance with a feature of this invention, a sound translating device is constructed as a zonal system with the receiver or transmitter mounted at the focal point of the system and means are provided for eliminating the effects of the harmful zones, whereby large amplitudes accompanied by marked directional characteristics are produced at the focal point. This means may be effective to block out the effects of the harmful zones, or effective to produce a phase reversal whereby these zones are self-canceling in effect.

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The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a sectional view of a sound translating device illustrative of one embodiment of this invention wherein the transmitter is subjected only to the effects of the central zone;

Fig. 1A is a front view, to a reduced scale, of the sound translating device illustrated in Fig. 1;

Fig. 2 is a graph illustrating the directional characteristic of the device shown in Fig. 1;

Fig. 3 is a side view in section of a device illustrative of another embodiment of this invention wherein a number of zones are employed and the second zone, a harmful zone, is blocked out; and

Fig. 4 is a sectional view of a device illustrative of another embodiment of this invention wherein a phase reversal of the pressures due to the harmful zones is produced whereby the harmful zones are self-canceling in effect.

Referring now to the drawing, the sound translating device illustrated in Fig. 1 comprises a circular cylindrical drum or shield 10, for example of metal, having a plane reflecting base 11. Within the drum 10 is an acoustic transmitter or microphone 12, which is mounted on the axis of the drum and mid-way between the base 11 and the open end thereof. The drum or shield is dimensioned so that the transmitter or microphone is subjected only to the effects of the first or central diffraction zone and of the corresponding reflection zone. Specifically, the device being adapted to translate signals within a band of frequencies, the shield or drum is of a diameter of substantially 1.73λ , where λ is the mean wave-length of the signals in the band to be translated, and is of a depth or length of approximately λ . The diameter, it will be noted, corresponds to that of the first or central zone. The distance between any point in the plane of the open end of the drum and the microphone, considering the depth of the drum or shield as λ , lies between

$$\frac{\lambda}{2}$$

and λ so that the effect of the incremental pressures at all those points is cumulative upon the microphone. The surface of the base wall 11 toward the microphone constitutes a second equiphase wave front and the effects of all points thereon upon the microphone also are cumulative and in phase with those of the equiphase wave front in the plane of the open end of the drum. The total pressure at the focal point, at which

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the microphone is mounted, is several times that which would be produced in the absence of the shield or drum.

Theoretically, the depth or length of the drum should be exactly 1 wave-length. However, practically, because of edge effects, a departure from the theoretical value is necessary for optimum operation. In a particular construction, a depth or length of $\frac{3}{4}$ wave-length was found to be satisfactory.

The microphone 12 may face either way, that is toward the base 11 or toward the open end of the shield or drum 10. Also, it may be of any one of a number of types and in general should be of small dimensions. A moving coil type microphone of substantially spherical configuration has been found particularly satisfactory.

A typical directional pattern for an actual device such as illustrated in Fig. 1 constructed in accordance with this invention is shown in Fig. 2, wherein the response is plotted against the angle between the axis of the device and the direction of the sound source. It will be noted from Fig. 2 that the device is highly responsive to waves traveling toward the open end of the drum 10 and substantially parallel to the axis of the device and within an angle of approximately 25 degrees to this axis on both sides thereof but is only slightly responsive to waves approaching the device in directions outside of the angular range noted.

The device illustrated in Fig. 3 is similar to that shown in Fig. 1 and described hereinabove but is of such construction that the microphone 12 is subjected to the effects of two useful zones, namely the central and third zones, and the second zone is blocked out. The circular, cylindrical drum wall 10 is of a diameter of approximately 3.87 wave-lengths of the mean frequency in the band of signals to be translated and the drum length or depth is approximately 1 wave-length, the microphone 12 being mounted mid-way between the base 11 and the open end of the drum. Mounted in the plane of the open end of the drum or shield is an annular masking or diffraction member 13, the inner diameter of which is substantially 1.73λ and the outer diameter of which is substantially 2.82λ . This diffraction member 13, it will be noted, blocks out the second zone in the plane of the open end of the drum 10 and blocks out also the corresponding reflecting zone on the inner surface of the base 11. The opening in the member 13 corresponds to the central zone and the opening between the outer edge of the member 13 and the drum 10 corresponds to the third zone. The distance to the focal point, at which the microphone is mounted, from any point in the central zone is, for a depth of the drum or shield of λ , between $\frac{1}{2}\lambda$ and λ and the distance between the focal point and any point in the third zone is between $\frac{3}{2}\lambda$ and 2λ so that the effects of these zones and also the corresponding reflecting zones on the wall 11, are additive upon the microphone and a high amplitude level at the microphone together with a marked directional characteristic are realized.

Although the device shown in Fig. 3 is a three-zone device it will be understood that a greater number of zones can be employed, the even-numbered zones being blocked out by annular masking or diffraction members.

In Figs. 1 and 3, described above, the focal length has been considered as $\lambda/2$. However, the distance from the microphone 12 to the center of the central zone may be any integral mul-

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tipole of $\lambda/2$. For such distances of other than the particular value of $\lambda/2$ in the specific devices considered hereinabove, the diameters of the several zones will differ from the particular values, e. g., approximately 1.7λ for the central zone and approximately 2.8 for the second zone, given for the case where the distance is approximately $\lambda/2$. The general condition to be fulfilled in any case is that the difference between the distance from the boundary of the central zone to the microphone and the distance between the microphone and the center of this zone be approximately $\lambda/2$ and the difference in the distances between the microphone and the boundaries of any other zone also be $\lambda/2$. Thus, for example, if the microphone is spaced

$$\frac{n\lambda}{2}$$

from the center of the central zone, the distance from the microphone to the boundary of this zone, i. e., to the boundary of the aperture in the plate 13 in Fig. 3 and to the edge boundary of the open end of the shield or drum 10 in Fig. 1, should be approximately $(n+1)\lambda/2$ and the diameter of the central zone, then, should be approximately

$$\sqrt{2n+1}\lambda$$

In the devices illustrated in Figs. 1 and 3 it will be noted that both diffraction and reflection zone means are employed. The invention may be embodied also in devices where only diffraction zone plates or only reflection zone plates are utilized. In such cases, the restrictions on focal length present in devices employing both reflection and diffraction zone members, occasioned by the requisite phase relation between the effects of the two, are not present. Thus, in devices employing either only diffraction or reflection zone members any focal length, i. e., distance between the microphone and the center of the central zone may be used. If this focal length is designated as F, the distance between the focal point to the inner and outer boundaries of the second zone would be, respectively, $F+\lambda/2$ and $F+\lambda$ and the distance from the focal point to the outer boundary of the third zone would be $F+3\lambda/2$.

In the embodiment of this invention illustrated in Fig. 4, the microphone 12, which in this case preferably has a planar front, is mounted at the center of a circular reflecting member 14, for example of metal. The reflecting member is provided with a central circular face 15 of 1 wave-length in diameter, an annular recess 16, $\frac{1}{4}$ wave-length deep and $\frac{1}{2}$ wave-length wide, and an outer annular surface 17 also $\frac{1}{2}$ wave-length wide, the surfaces 15 and 17 and the recess 16 being coaxial. The effects of the central zone 15 and the third zone 17 upon the microphone 12 are in phase. The recess 16 corresponds to the second zone and because of its $\frac{1}{4}$ wave-length depth produces a phase reversal of the waves entering thereto so that in the plane of the surfaces 15 and 17 the resultant pressure due to the second zone is zero. Hence, the second zone is effectively self-canceling with respect to its effect upon the microphone.

Although in the construction illustrated in Fig. 4, three zones are involved, it will be understood that a greater number may be employed, the even-numbered zones being recesses $\frac{1}{4}$ wave-length deep and $\frac{1}{2}$ wave-length wide and the odd-numbered zones being $\frac{1}{2}$ wave-length wide.

Although the invention has been described with

particular reference to microphone devices, it may be embodied also in receivers, in which case a suitable telephone receiver would be employed in place of the microphone 12. Also, it will be understood that the invention may be embodied in devices suitable for submarine signaling as well as for sound propagation and reception in air. It will be understood further that the several devices disclosed and described are illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An acoustic device for translating signals within a band of frequencies comprising means defining a reflecting surface of a diameter sufficient to embrace several concentric interference zones corresponding to the mean wave-length of frequencies in said band, a sound translating device mounted at substantially the focal point of said zones, and means for substantially preventing the second interference zone from affecting said translating device.

2. An acoustic device in accordance with claim 1 wherein said preventing means comprises an annular masking member lying in a plane parallel to said surface and opposite said second interference zone thereof.

3. An acoustic device in accordance with claim 1 wherein said sound translating device is mounted at substantially the center of said surface and which comprises means bounding an annular recess conforming to said second interference zone and having a depth of substantially $\frac{1}{4}$ the mean wave-length of signals in said band.

4. An acoustic device for translating signals within a band of frequencies comprising means bounding a circular plane area of a diameter sufficient to include several concentric interference zones corresponding to the mean wave-length of frequencies in said band, a sound translating device mounted at substantially the focal point of said zones and to one side of said plane, and means masking said sound translating device from the second interference zone, said sound translating device being exposed to at least the central and third interference zones.

5. An acoustic device for translating signals within a band of frequencies comprising means bounding a circular opening, and a sound translating device mounted to one side of and coaxial with said opening, said sound translating device being spaced from the center of said opening a distance substantially equal to

$$\frac{n\lambda}{2}$$

where λ is the mean wave-length in said band and n is an integer, said opening having a diameter of substantially

$$\sqrt{2n+1}\lambda$$

6. An acoustic device for translating signals within a band of frequencies comprising a sound translating device, zone plate means in coaxial relation with said sound translating device, and means for substantially preventing wave pressures at the second interference zone from affecting said sound translating device.

7. An acoustic device for translating signals within a band of frequencies having a mean wave-length comprising means bounding a circular plane including several concentric circular zonal areas, a sound translating device coaxial with said areas and so positioned with respect

thereto that the distance between said sound translating device and any point in the central zonal area is between substantially said wave-length and substantially $\frac{1}{2}$ said wave-length, the zonal area next adjacent said central area having such width that the distance between said sound translating device and any point in said next adjacent area is between substantially said wave-length and substantially $\frac{3}{2}$ said wave-length, and means for preventing pressures at said next adjacent area from affecting said sound translating device.

8. An acoustic device for translating signals within a band of frequencies having a mean wave-length comprising a cylindrical member having at one end a circular opening coaxial therewith and of a diameter of substantially 1.7 times said wave-length, and a sound translating device within said cylindrical member in axial alignment with said opening and spaced effectively $\frac{1}{2}$ said wave-length from the center of said opening.

9. An acoustic device for translating signals within a band of frequencies comprising a cylindrical member closed at one end by a substantially plane reflecting surface and having at the other end an opening coaxial therewith and of a diameter of substantially

$$\sqrt{2n+1}\lambda$$

where λ is the mean wave-length of the frequencies in said band and n is an integer, said member having a depth of substantially

$$\frac{n\lambda}{2}$$

and a sound translating device within said member, coaxial therewith and mid-way between the ends thereof.

10. An acoustic device for translating signals within a band of frequencies having a mean wave-length comprising a cylindrical member closed at one end by a substantially plane reflecting surface and having at the other end an opening coaxial therewith and of a diameter substantially 1.7 times said wave-length, said member having a depth approximately equal to said wave-length, and a sound translating device within said member, substantially mid-way between the ends thereof and coaxial with said opening.

11. An acoustic device for translating signals within a band of frequencies having a mean wave-length comprising a reflecting member having a surface divided into a series of concentric zonal areas, the central zonal area having a diameter substantially equal to said wave-length and each of the other of said zonal areas being of a width substantially equal to $\frac{1}{2}$ said wave-length, the zonal area next adjacent said central area being recessed and having a depth of substantially $\frac{1}{4}$ said wave-length, and a sound translating device mounted at substantially the center of said central zonal area.

12. An acoustic device for translating signals within a band of frequencies having a mean wave-length comprising a sound translating device, reflecting zone plate means adjacent and coaxial with said sound translating device and having a diameter sufficient to include several interference zones corresponding to said wave-length, and means masking said sound translating device from both the second diffraction and second reflecting interference zones.

13. An acoustic device for translating signals

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within a band of frequencies comprising a cylindrical member of a diameter sufficient to include several interference zones corresponding to the mean wave-length in said band of frequencies, said member being closed at one end and open at the other and having a depth substantially equal to

$$\frac{n}{2}$$

times said wave-length, n being an integer, a sound translating device within said member, on the axis thereof and substantially mid-way between the ends thereof, and an annular masking member coaxial with said cylindrical member and substantially in the plane of the open end thereof, said annular member having an inner diameter of substantially

$$\sqrt{2n+1}$$

times said wave-length and an outer diameter of substantially

$$2\sqrt{n+1}$$

times said wave-length.

14. An acoustic device for translating signals within a band of frequencies having a mean wave-length comprising a cylindrical member of a diameter sufficient to include several interference zones corresponding to said wave-length, said member being closed at one end and open at the other and having a length approximately equal to said wave-length, a sound translating device within said member, on the axis thereof and substantially mid-way between the ends thereof, and an annular masking member coaxial with said cylindrical member and mounted substantially in the plane of the open end thereof, said annular member having an inner diameter of approximately 1.7 times said wave-length and an outer diameter of approximately 2.8 times said wave-length.

15. An acoustic device for translating signals within a band of frequencies having a mean

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wave-length comprising a zonal system including a reflecting member of a diameter sufficient to include several interference zones corresponding to said wave-length, an annular imperforate member parallel to and coaxial with said reflecting member and corresponding to the second interference zone, and a sound translating device mounted at substantially the focal point of said system.

16. An acoustic device for translating signals within a band of frequencies comprising an annular zone plate, a sound translating device coaxial with and to one side of said zone plate, said zone plate being so constructed and arranged that the distance between said sound translating device and the inner edge of said zone plate is substantially

$$F \times \frac{\lambda}{2}$$

and the distance between said sound translating device and the outer edge of said zone plate is substantially $F + \lambda$, where F is the distance between said sound translating device and the center of said zone plate and λ is the mean wave-length of frequencies in said band.

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