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MEANS TO ALTER THE DIRECTIVITY PATTERN
OF ENERGY TRANSLATING DEVICES
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FIG. 1

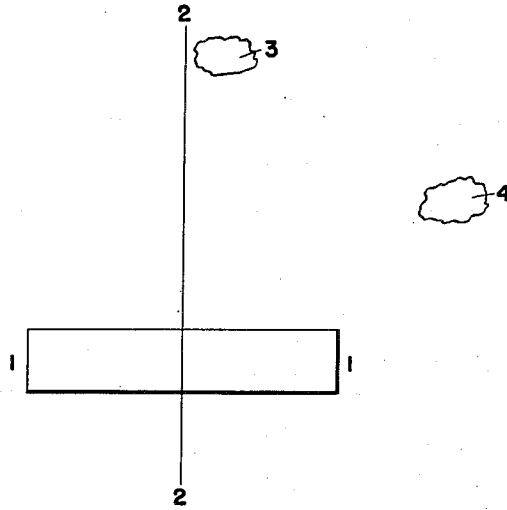


FIG. 2

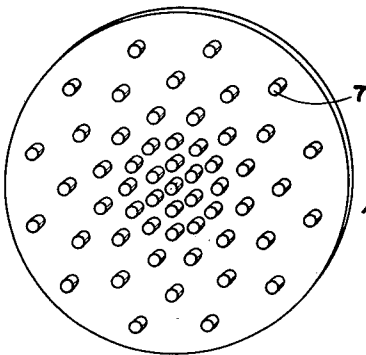
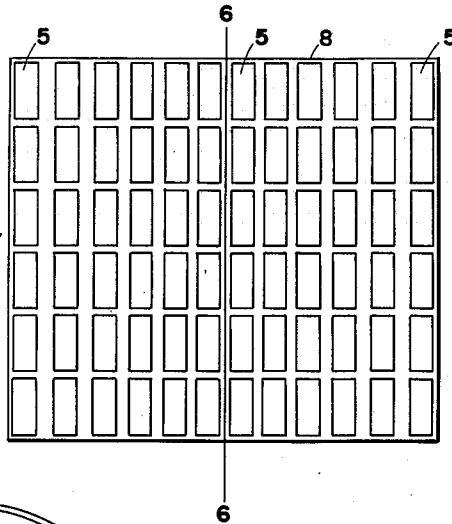


FIG. 3

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MEANS TO ALTER THE DIRECTIVITY PATTERN OF ENERGY TRANSLATING DEVICES

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4 Claims. (Cl. 340—9)

My invention relates to energy translating devices and more particularly to transducers for the projection of acoustic energy.

In the use of acoustic energy to determine the presence and direction of a reflecting object or for the purpose of communication, it is necessary to have a sharp, highly directive, beam of energy. To produce this beam, it is common practice to provide a plurality of transducer elements each of which converts electric energy to the desired acoustic energy. These elements are mounted as an array on a common support to give an effective output of acoustic energy in a direction normal to that support. For purposes of projecting a strong, sharply defined, energy beam, this method has been relatively successful. However, it is subject to an important disadvantage in that a number of minor lobes of energy are produced from the structure. These minor lobes, directed in position differing from that of the desired energy distribution, cause spurious undesired signals and detract from the effectiveness of the transducer as a whole.

It has heretofore been proposed to reduce these minor lobes in the directional transmission pattern of a transducer by several expedients. The most common method is to alter the energy supplied to the elements of the transducer; causing more energy per element to be transmitted at the center than at the side. This can be done in magnetostriction type transducers by reducing the number of ampere turns in the energizing windings on the outside elements with respect to the ampere turns used in the center elements. In piezoelectric crystal transducers the same effect may be accomplished by reducing the admittance of the outer elements relative to the admittance of the center elements. A second proposal has been to shade the mass loading on uniformly wound elements so that the effective diaphragm vibration is a result of uniform energy applied to a non-uniform diaphragm; resulting in greater motion at the center of the diaphragm than at the sides. A further method which has been used consists of a uniformly wound array of elements whose effective active face is covered with a shaded shield of pressure release or sound absorbent material. The transmission aperture of the shield is greater at the center of the array than at the sides so that an effectively greater proportion of the transmitted energy originates near the center.

These proposals all have disadvantages in one respect or another. If it is proposed to alter the energy supplied to the various elements of the transducer, the elements must comprise several different types, resulting in an increased problem of providing spare parts since these must be kept for all the different types of elements. Furthermore, repair of the unit is made more difficult by reason of the need to segregate properly the various elements when assembling the complete units. If diaphragm vibration is altered by use of a non-uniform diaphragm, the efficiency of the unit as a whole is reduced and greater driving power required than otherwise would be necessary. Furthermore, the non-uniform diaphragm requires

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careful mechanical design and construction and it is very difficult to manufacture diaphragms having predetermined characteristics of this type. The use of a covering over the face of a stack of laminations has the same disadvantages as those associated with the use of a non-uniform diaphragm, but the power loss involved is substantially greater than if the non-uniform diaphragm is used.

I have found that the above mentioned disadvantages of transducing devices may be avoided and at the same time a highly directive energy pattern with substantially no minor lobes obtained if the elementary transducers are spaced in accordance with the desired energy distribution. To accomplish this, I alter the distance between adjacent elementary transducers in accordance with their distance from the axis of the complete unit. In a specific instance, this spacing has been found most effective when the distance between adjacent elements was made proportional to the secant of $n\theta$ where θ equals 10° and n corresponds to the position of the element out from the center line of the projector. Having spaced the elements in accordance with this relation, I may often achieve even better performance by altering the position of the various elements and experimentally observing the resulting change in the energy pattern of the complete unit.

It is an object of my invention to provide an electrical transducer having a highly directive energy pattern having maximum energy in the desired direction and with minor lobes of minimum strength.

Also in accordance with my invention, efficiency is improved, maintenance simplified, and production facilitated, by the use of a uniform diaphragm having no intentionally introduced absorbing material in conjunction with elemental transducers of identical design.

In accordance with another aspect of my invention, initial design is simplified by spacing adjacent transducer elements in an array in proportion to a predetermined mathematical function of their position with respect to other elements of the array.

Other objects and aspects of this invention will be apparent from the appended drawings and claims.

In the drawings:

Figure 1 is an elemental cross-section diagram illustrating the principles of my invention.

Figure 2 is a plan view showing my invention as applied to a rectangular shaped underwater sound transducer.

Figure 3 illustrates my invention as applied to an underwater sound transducer of circular shape.

Referring in more detail to Figure 1, 1 represents a side view of the transducer which for purposes of this drawing may be either rectangular or circular in shape; 2 is the axis of the transducer; and 3 and 4 represent objects from which energy emanating from the transducer is reflected or at which it is desired to record this energy. Object 3 is close to the axis of the transducer, whereby object 4 is at a considerable angle to this axis.

It is desirable in the use of the projector to provide a strong signal along the transducer axis 2 so that objects such as 3 will be provided with an incident wave of high energy content. If it is desired to locate the position of object 3 by reflection, this provides a strong reflecting signal, thereby facilitating measurement.

If it is desired that a listener at position 3 receive intelligence from the transducer, concentrating energy along axis 2 provides maximum ease of listening. On the other hand, it is very undesirable to have any significant amount of energy pass from the transducer in the direction of object 4. If the transducer is used as an object locating device, the presence of an object such as 4 in the path of a spurious beam of energy will produce a false indication. If the equipment is used as a means of communication, a listener at position 4 may receive the intelligence transmitted when it is desired that listeners outside the

direct path of communication be ignorant of the intelligence.

I have found that the energy emanating from a transducer may be concentrated along its axis if the energy density in the center of the transducer exceeds that at the edges. Figure 2 shows a method of accomplishing this result with a transducer of rectangular shape. In the figure, 5 represents the elemental transducing devices which may be of the magnetostriction or of the piezo-electric crystal construction, secured to a support 8 and excited by electric energy of the proper frequency. It is along a central dividing plane perpendicular to the plane of the paper and indicated by line 6—6 and including the axis 2—2 of Fig. 1 that maximum energy is to be transmitted. As shown in the figure, the transducer elements nearest line 6—6 are closely spaced and the spacings of the elements further from line 6—6 are progressively greater.

In general, in obtaining the optimum distribution, I may first locate the elements so that spacing between them is in accordance with the relation:

$$(1) \quad \text{Spacing} = K \secant n\theta$$

Where:

N is the number of the element counted from the central axis.

θ is about 10 degrees.

K is a constant.

This leads to a construction in which the spacing in terms of wave-lengths of the radiation involves is as follows:

From projector center line to center line of unit No. 1-----	.2509λ
From center line of unit No. 1 to center line of unit No. 2-----	.2629λ
From center line of unit No. 2 to center line of unit No. 3-----	.2853λ
From center line of unit No. 3 to center line of unit No. 4-----	.3225λ
From center line of unit No. 4 to center line of unit No. 5-----	.3843λ
From center line of unit No. 5 to center line of unit No. 6-----	.4941λ

Having established initial spacing in this manner, I then alter spacing of individual elements and determine the resulting change in the amplitude of minor and major lobes. By this process, I obtain the desired results after a few trials. For some purposes, the distribution of equation 1 may give satisfactory performance without further adjustment.

While the secant spacing defined above is adequate for large transducer surfaces where a piezo-electric or magneto-stricture transducer element may be considered a point source, it may not produce optimum directional characteristics with smaller units because the dimensions of the transducer elements are not small with respect to the dimensions of the entire unit. It is therefore advantageous to further calculate the performance of the transducer by considering the vector addition of the wave energy from the several transducer elements in particular directions. Since the several transducer elements are similar, a polar radiation characteristic of a single element may be applied to each element of the transducer.

The electrical energy to be radiated is applied equally and simultaneously to all transducer elements, so that the phasing of the several wave trains from the transducer elements is determined by the angle from the central axis of the unit and the spacing of the transducer element from the axis of symmetry of the unit. Since such calculations are old and well-known to those skilled in the art, no further description is considered necessary. It will be apparent that laterally shifting a transducer element will vary the amplitude of the radiated wave energy by rein-

forcing or canceling portions of the wave energy from other elements.

As an example of the variations in spacing from the secant spacing of transducer elements, I have found the following spacings to be desirable in a transducer having twelve transducer elements in a transverse section thereof, each transducer having a width of 1 cm. and operating at a wave length in sea water of 61 millimeters:

	Mm.
10 From transducer center line to center line of the first transducer elements laterally therefrom-----	8.2
From center line of first transducer elements to the center line of the second transducer elements laterally therefrom-----	13.2
15 From center line of second transducer elements to the center line of the third transducer elements laterally therefrom-----	10.8
From center line of third transducer elements to the center line of the fourth transducer elements laterally therefrom-----	22.4
20 From center line of fourth transducer elements to the center line of the fifth transducer elements laterally therefrom-----	15.3
25 From center line of fifth transducer elements to the center line of the sixth transducer elements laterally therefrom-----	29.6

In general, the choice of spacing for the inner energy producing elements is dictated by the size of the elements themselves and the need for achieving maximum utilization of available space. I normally allow only such spacing between these elements as is necessary to separate them adequately for mechanical reasons. However, where space is not a factor and the energy producing elements are small with respect to one wave length, other spacing may be used.

The application of my invention to a transducer of the circular type is shown in Figure 3. In the figure, 7 indicates the separate elemental transducer utilized to make up the complete unit. In this case, I space the elemental transducers both radially and circumferentially in accordance with the radial distance from the center of the transducer unit. I thereby achieve a concentration of energy in the center of the unit and minimum energy in spurious beams in undesired directions.

The transducers shown in Figures 2 and 3 are enclosed in protective housings and structurally may follow any suitable form, as for example, that of crystal groups cemented to a steel plate having loading projections opposite each crystal. If desired, the rear of the steel projection can be covered with air filled rubber. The entire assembly may be immersed in an acoustically proper liquid such as castor oil. Loading coils for the crystals are mounted in the housing in any suitable manner and leads brought out for the connection to transmitting and/or receiving apparatus.

It will be apparent to those skilled in the art that my invention may be applied to a wide variety of uses. In particular, it may be used with transducers of all type of wave energy including, in particular, all varieties of acoustic energy whether in a liquid medium such as water, or in a gaseous medium such as air.

My invention may be realized in widely different embodiments within the scope of the claims.

I claim:

1. A wave projector comprising a plurality of transducer elements arranged to form a planar group having a longitudinal axis, said transducer elements being equally and simultaneously energized, the distance between adjacent elements in a direction perpendicular to said axis being substantially in proportion to secant $n\theta$ where n is the number of the element counted from the axis and θ is approximately 10 degrees.

2. A wave projector comprising a plurality of transducer elements arranged in a circular planar group having

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a center point, said transducer elements being equally and simultaneously energized, circumferential and radial spacing between adjacent elements being substantially in proportion to secant $n\theta$ where n is the number of the element counted from the center and θ is approximately 10 degrees.

3. A wave projector comprising a plurality of transducer elements arranged to form a rectangular planar group having a longitudinal axis, said transducer elements being symmetrically disposed about a central plane that includes said longitudinal axis, said transducer elements being equally and simultaneously energized, the distance between adjacent elements measured laterally of said plane being substantially in proportion to secant $n\theta$, where n is the number of the transducer element as counted from the longitudinal axis and θ is approximately 10 degrees.

4. A large acoustic transducer having a large transducer surface for the projection of acoustic energy, said transducer comprising, support means, a large number of identical transducer elements, each transducer element being substantially a point source in said large transducer, said transducer elements adapted to be identically energized at every instant, said transducer elements be-

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ing secured to said support means to form a rectangular planar group symmetrically arranged about a central dividing plane, perpendicular to said support means, each of said transducer elements being spaced from the next nearest one of said transducer elements, closer to the central dividing plane, by an amount equal to $.25$ (secant $n 10^\circ$) wavelengths of the transducer operating frequency where n is equal to the number of the transducer elements as counted from the central dividing plane, said transducer being adapted to project a highly directive beam of acoustic energy symmetrical about the dividing plane.

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