Sept. 24, 1946. L. BATCHELDER 2,408,028

MEANS FOR SENDING AND RECEIVING COMPRESSIONAL WAVES

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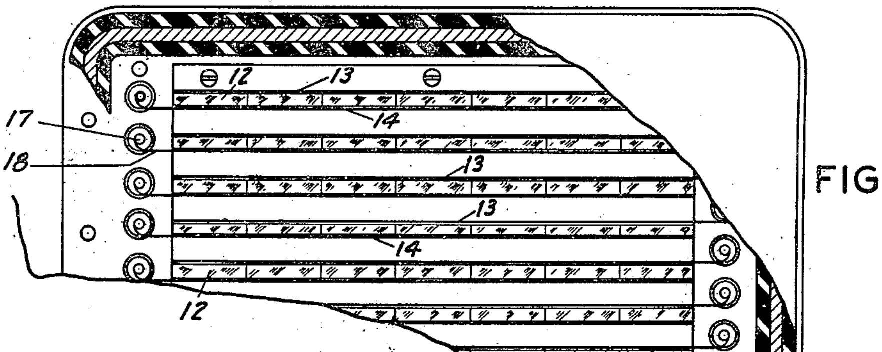
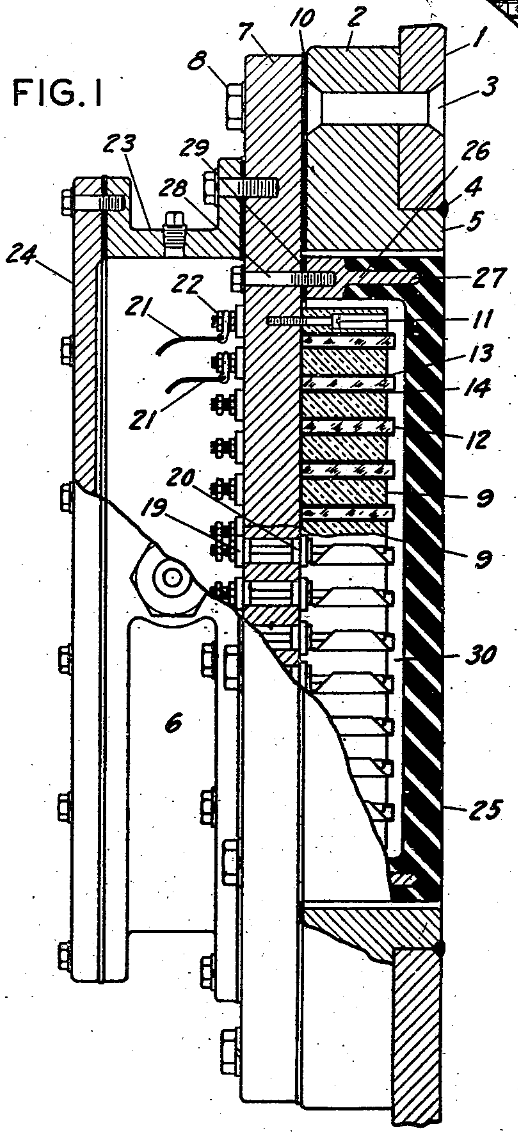


FIG. 2

FIG. 1



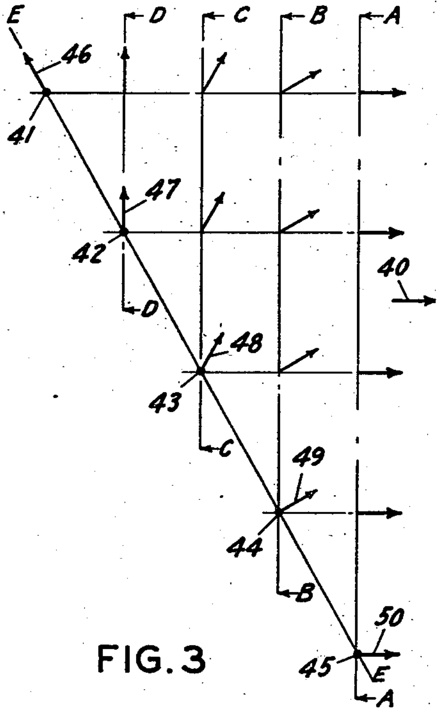


FIG. 3

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Fig. 5.

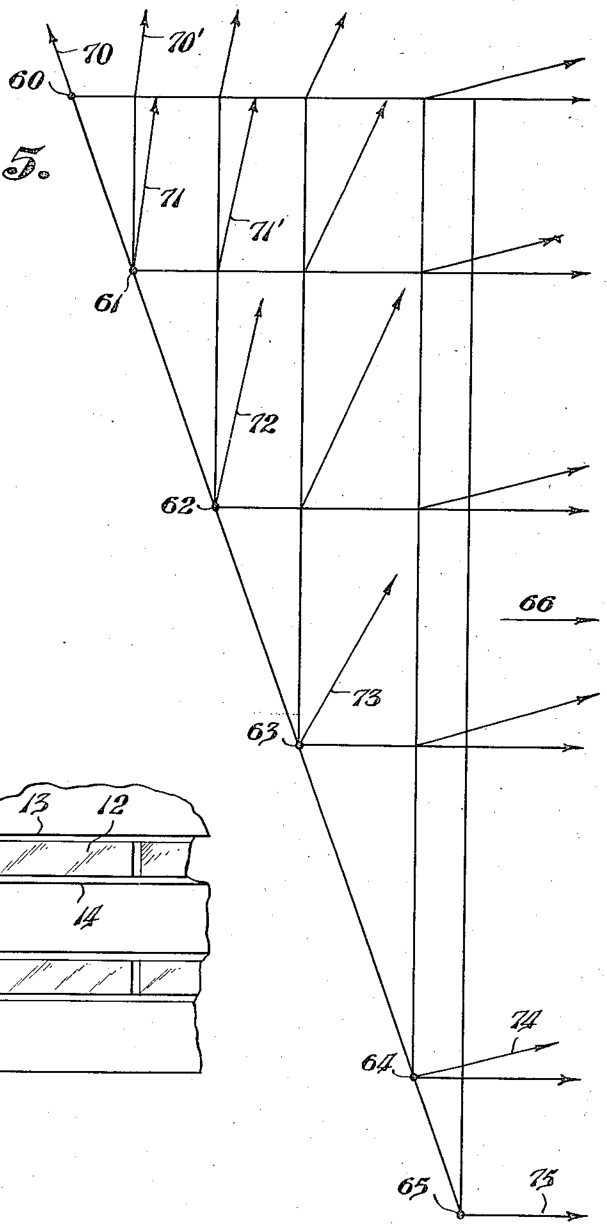
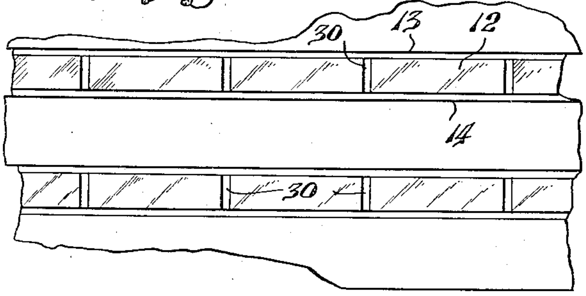


Fig. 4.



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UNITED STATES PATENT OFFICE

2,408,028

MEANS FOR SENDING AND RECEIVING COMPRESSIONAL WAVES

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Application January 19, 1934, Serial No. 707,284

7 Claims. (Cl. 177—386)

The present invention relates to a device for transmitting and receiving compressional waves from a desired direction without the rotation of the device. Such a device has already been described in my patent application filed April 1, 1933, Serial No. 663,963.

In the present invention the transmitter is of a considerably different construction from that shown in my previous application. It is to be used, however, in substantially the same relation in transmitting compressional waves in a desired direction. In the present invention the individual oscillatory elements are of the crystal type and these are arranged preferably in rows which are spaced apart center to center slightly less than one-half wave length of the compressional wave to be transmitted. The individual row tends to concentrate a sound wave in a plane perpendicular to the row, and the group of rows, when bearing the proper phase relation to one another, narrow the transmission from that of the plane perpendicular to the rows to a beam in that plane.

In the present system the oscillatory crystals which preferably are of the Rochelle-salt type, but other types may be used, have a natural tuning much higher than the frequency at which the device is to be operated. For instance, the crystal itself may have a natural tuning as high as 100 kilocycles whereas the frequency for the operation of the device may be in the neighborhood of 30 kilocycles.

In using the crystals in this manner it is possible to have the electrical energy and the acoustical energy correspond identical in character and phase throughout its vibration so that when a phase difference is established between two adjacent crystal rows by the impressed electrical potential, this phase difference will be preserved in the produced compressional waves. In the present invention this is an important feature, since by this means it is possible to be certain of the acoustic phase between successive rows of oscillatory crystals. The acoustic phase in the present invention establishes the direction of the beam as will appear from the description given below.

The invention will be better understood from a consideration of the drawings in which Fig. 1 shows a view of the transmitter with parts broken away to illustrate some of the details of construction; Fig. 2 shows a fragmentary face view looking from the right in Fig. 1 with part of the casing removed; Fig. 3 illustrates the relation of successive phases of the rows of crystals; Fig. 4 shows a fragmentary view illustrating a modification of the crystal arrangement shown in Fig. 2; and Fig. 5 shows schematically the relation of successive phases of rows of crystals spaced an unequal distance apart.

As illustrated in Fig. 1 the transmitter may be mounted in the skin of a vessel as shown by 1. In the usual method of mounting a heavy inertia ring 2 may be riveted to the vessel by means of the rivets 3 and be made tight to the skin by a weld 4 between the skin and a projecting flange 5 of the ring 2.

The oscillator or transmitter which is designated as 6 may be mounted upon the ring 2 through the projecting plate 7 through which the bolts 8 may pass to hold the oscillator rigidly to the ring. A gasket 10 of suitable material may be provided between the plate 7 and the ring 2 to make a watertight joint. Upon the plate 7 are mounted suitable insulating strips 9, 9, etc., which may be "bakelite" or material of any such nature. These strips may be held to the plate 7 by means of the small screws 11, 11, etc. Between the strips of Bakelite or other such material there are positioned the crystals 12, 12, etc. These, as indicated in Fig. 1, are spaced apart a definite and equal distance by means of the strips 9 and, as indicated in Fig. 2, they are arranged in rows, the crystals abutting one another at their end to form a continuous crystal surface. While this manner of construction is preferably employed, a slight space 30 may be left between the crystals in their rows, as indicated in Fig. 4, so that each crystal is separated from the rest in the row. The crystals, as will be noted, are preferably used as pressure type crystals as contrasted with tortional or bending crystals.

The electrodes are provided at both sides of the rows as shown by 13 and 14. The electrodes on one side of the row 13, for instance, are connected to the terminal posts 15 to the right of the oscillator as indicated in Fig. 2 by means of the conductors 16 which may be conducting strips or small bars, whichever is preferable. At the left a similar set of binding posts 17 are provided to which the electrodes 14 are connected by means of the conducting strips 18.

These terminals, as indicated in Fig. 1, are mounted in the plate 7, being insulated therefrom by insulating discs 19 and 20 which space the terminal away from the plate 7 which might be, and preferably is, made of metal. The external conductors are connected to the terminal posts at the left side of the plate 7 as indicated in Fig. 1, by the conductor 21 which is shown connected to the binding post 22 forming an extension of the terminals to which the electrodes are connected. Individual terminal conductors are employed in the present invention for each group of crystals since each group, which in the present case comprises a row, must be excited separately in order that the desired direction of the compressional wave beam may be obtained.

The plate 7 may be covered by means of a casing 23 which is provided with a removable plate 24 so that easy access may be had to the terminal binding posts. The front of the plate 7 is covered by means of a rubber cover 25 which is preferably molded to a ring 26 which has a projecting tongue 27 to which the rubber cover may snugly adhere. The ring 26 may be metallic or any other suitable hard material capable of holding the cover closely to the plate 7. In Fig. 1 this is obtained by means of the screws 28 passing through the plate 7 from the left or rear and threading into the ring 26. A gasket 29 may be provided between the surfaces to make the joint watertight.

Between the rubber cover 25 and the crystals 12 there may be a space 30 left which might be filled with a suitable liquid in which the crystals are not soluble for making a good sound conducting medium from the crystals to the water surface. The rubber itself may be of the sound transparent type so as to provide good transmission into the operating medium.

The present invention is more particularly applied to submarine signaling and signaling in liquids where the oscillator or transmitter has relatively a fixed position, as indicated in Fig. 1 where the oscillator is mounted in the skin of the vessel.

In Fig. 3 the rows of crystals are indicated as having positions 41, 42, 43, 44 and 45. In order to produce compressional waves in the medium in the direction of the arrow 40 it is necessary that the vectors along the wave front lie in the same direction. In order to satisfy this condition each of the vectors 46, 47, 48, 49 and 50, positioned at the crystals, will have an angular displacement proportioned to the perpendicular distance to the wave front A—A. In this way the vectors along the line B—B, C—C and D—D, parallel to the line A—A, will all have, respectively, the same direction, that is all the vectors on the line B—B will be in the direction of the arrow 49, those along C—C in the direction of the arrow 48 and those along D—D in the direction of the arrow 47.

It will be noted that in order to obtain a desired direction for the propagation of the compressional waves, as indicated by the arrow 40, each vector at the source, that is at the oscillators, must have a definitely established phase. If, therefore, any uncontrollable factors come between the impressed electrical power and the radiated acoustic power, although the impressed power may be definitely established and correct, it might follow that the acoustic power will have phase variations so that the vector compressional waves will not be right for the production of the beam in the desired direction. This happens frequently in transient conditions as, for instance, when employing the transmitter for the purpose of voice transmission. If the signals or the variations in the signals are of short duration, there may be a certain phase difference between the building up of the electrical potential and the generation of the acoustic vibration. This is avoided in the present invention due to the use of substantially non-resonant sources so that the vectors of the compressional waves which are produced at the sources always bear the same phase relation to the vectors of the impressed electrical potential.

It should also be noted that as a rule it is impossible to construct a group of resonance structures which will be exactly alike and which will respond identically at the same frequency and have the same point of resonance. In most apparatus of the present type the resonant frequencies are sufficiently far apart so that the attempt to operate at resonance usually brings about a condition where some structures are being operated before the resonant point is reached and some after.

For instance, if one structure is resonant at 18,000 cycles and another at 18,500 cycles, if the system is operated at 18,200 cycles, the first structure will be operated beyond resonance and the second not quite at resonance. Under these conditions it frequently happens, as shown by the reactance curve, that a reversal of phase actually occurs and that with the same impressed voltage one structure will be 180 degrees out of phase with the other. By using resonant structures in which the point of resonance is far beyond the operating range, this is avoided and there is no chance of a reversal in phase as there is when the structures are being operated at their resonant frequencies. In ordinary mechanical systems it has been found very difficult to obtain sufficient energy or efficiency in acoustic oscillators without operating them at or near their resonant frequencies, but in the case of the present invention with the use of crystal structures, particularly that of Rochelle salts, it is possible to obtain a substantial acoustic efficiency even though the structure is operated far from the point of resonance.

The electrical potential for energizing the crystals and translating the electrical energy to compressional wave energy is impressed across the electrodes 13 and 14 as indicated in Fig. 1. The potential established across these surfaces of the crystal produces a contraction and elongation of the crystal in the longitudinal direction, that is horizontally as shown in Fig. 1. This directly impresses the compressional wave energy into the medium through the space 30 and the cover 25.

The crystals, as has been mentioned above, are operated in the desired phase by any suitable means and preferably in the manner described in my application Serial No. 663,963 mentioned above.

In the description above it is stated that the crystals should be arranged in rows spaced apart center to center slightly less than one-half wave length of the wave generated or received. Although I prefer this spacing, others may be used, but if the spacing is greater than one-half wave length the distances between rows may not be equal. If a longer base is desired, unequal spacings greater than one-half wave length of the wave to be generated or received may be employed. In such cases the phase differences between any two rows must be proportional to the distances between those rows. In this manner the beam will have a definite and unique direction for the wave length chosen and likewise the frequency received.

Several advantages may be gained by unequally spacing the rows and energizing the crystals in proportionately different phases. One of these advantages is that most any type of surface can be accommodated as, for instance, the side of a vessel where beams and girders can not well be cut or removed. In addition to this, the directive effect can be controlled by exciting the rows of crystals in a predetermined phase relationship. This relationship may be such as to either produce a broad or narrow beam and to provide or eliminate some of the secondary maxima that produce limited directive waves in other than the normal direction of the beam itself, particularly where the sound produced or received is not purely of a single frequency.

Figure 5 shows the relationship of unequal spacing of units and the necessary phase compensation to have all of the units act in the same direction. In this figure the units are indicated as 60, 61, 62, 63, 64 and 65, the arrows 70, 71, 72, 73, 74 and 75 being the initial vector direction necessary to produce the ultimate horizontal direction indicated by the arrow 66. In this case the rotation of the vector 70 to the position 70' corresponds to the time lag necessary with respect to the relative position of the units 60 and 61, and similarly the time lag between 71' and 71 corresponds to the relative position of the units 60 and 61. If the units were equally spaced, the angle increment of the vectors between successive units would be equal, but where the spacing of units is not equal, this must vary as indicated in the figure. It will, of course, be understood that the vector diagrams of Figs. 3 and 5 refer to vectors of a single frequency. Vectors for waves of other frequencies will be differently phased and therefore will not combine in the same manner as indicated in these diagrams.

In receiving waves by the device just described, the same means as described for the generator in my copending application may be used as the phase receiving circuit. In such a case, a selective filter is used tuned to the frequency for which the phase shifting device is calibrated. By using different calibrations, different frequencies may be listened to and in this manner within the listening range the most favorable frequency may be used.

Having now described my invention, I claim:

1. In a means for sending or receiving a beam of compressional waves of a chosen high frequency in a desired direction, a transmitter comprising a plurality of rows of oscillatory crystals including oscillatory surfaces having long and short dimensions, means spacing apart said rows and insulating them from each other, said crystals presenting oscillatory surfaces having their long dimension aligned in the direction of the row and their short dimension transverse thereof, said rows being spaced apart a distance slightly less than a half wave length of the compressional wave desired to be received and having a width smaller than the half wave length.

2. In a means for sending or receiving a beam of compressional waves of a chosen high frequency in a desired direction, a transmitter comprising a plurality of rows of oscillatory crystals having oscillatory surfaces and forming in each row a substantially continuous surface, means unequally spacing said rows apart, said spacing

conforming to the proportional phase differences at which said crystals are to be energized and means acoustically coupling the surfaces of said crystals with a propagating medium.

3. In a means for sending or receiving a beam of compressional waves of a chosen high frequency in a desired direction, a transmitter comprising a plurality of rows of oscillatory crystals having oscillatory surfaces extending substantially continuous throughout the individual rows, said crystals being cut in rectangular prismatic shape and having a long dimension in the direction of the row and a short dimension forming the width thereof, means spacing said rows apart with unequal spacing proportional to the phase differences with which successive rows are to be energized, the width of said rows being smaller than one-half wave length of the compressional wave in the propagating medium used to energize the crystals.

4. Means for sending a beam of compressional waves in a desired direction having a casing, a plurality of oscillatory crystals having comparatively small end faces and positioned end on end to form a plurality of parallel rows, means positioned between said crystals for spacing said rows of crystals from each other a distance further apart than the width of the crystals and means providing an acoustic transmitting medium from the face of the crystals to the external progagating medium.

5. Means for sending a beam of compressional waves in a desired direction comprising a casing having a back plate, a plurality of spacing elements mounted to form parallel rows over said plate, means holding said spacing element rigidly to said plate, a plurality of oscillatory crystals having comparatively small end faces positioned end on in said rows and forming a continuous crystal surface for the length of the row and means acoustically coupling the crystal surfaces with the propagating medium.

6. Means for sending a beam of compressional waves in a desired direction having a plurality of rows of oscillatory crystals, means spacing said rows apart and holding said oscillatory crystals adjacent to one another to form a continuous crystal surface in each row, said means spacing said rows apart a distance somewhat less than one-half wave length of the beam to be transmitted and means acoustically coupling said crystal surfaces with the medium in which the beam is to be propagated.

7. Means for sending a beam of compressional waves in a desired direction having a casing and a plate contained therein, a plurality of oscillatory crystals, means mounting said oscillatory crystals on said plate in rows having said crystals positioned end on and forming a continuous crystal surface for the row, said mounting means spacing said rows apart from one another, said crystals being provided with electrodes positioned against said mounting means on either side of said rows of crystals and having terminals taken out at opposite ends of the rows.

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