Dec. 14, 1926. **1,610,674**

W. HAHNEMANN ET AL

SUBMARINE SOUND SIGNALING DEVICE

Filed Jan. 6, 1921

Fig. 1.

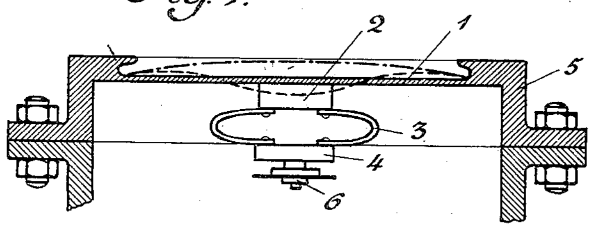


Fig. 2.

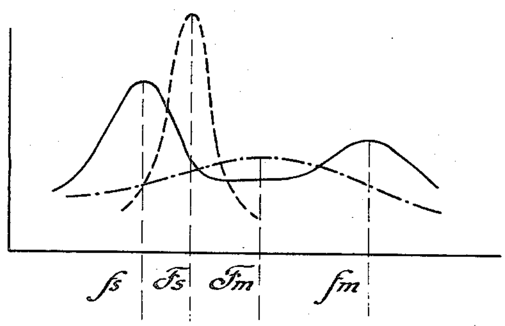
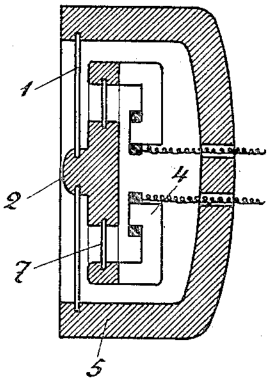


Fig. 3.



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SUBMARINE SOUND-SIGNALING DEVICE.

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This invention relates in general to submarine sound signaling devices, and more particularly to means in such devices for adjusting the magnitudes determined by the vibrations set up in the same and for establishing definite relationships between parts of different or equal tuning.

By the present invention a means is provided by which, while maintaining a proper ratio of transformation of the amplitudes of motion of the vibrations during the transfer of the vibrations between the sender or receiver proper and the sound propagating medium, the other factors or magnitudes that govern the character of the oscillations of the complete apparatus, such as the damping effect and tuning, can be made to assume a desired value. The invention has to do with signaling apparatus comprising two or more bodies or structures each capable of executing oscillations and all coupled together acoustically, one of these structures preferably acting chiefly as a sound radiating body, while another serves as an exciting or receiving member. An important feature of the invention consists in effecting such a close acoustic coupling of the vibratory structures that they affect each other in a considerable degree.

The term "acoustic coupling" has been selected to express the relation between the vibratory structures or units. The word "coupling" is used in an analogous sense in the wireless telephone art, where primary and secondary circuits are said to be closely or loosely coupled depending upon the degree of influence which one exerts upon the other, or on the amount of energy transferred from one to the other.

The structures to be coupled belong, as a rule, to two fundamentally different groups. The one group comprises the structures or bodies which perform the function of radiating the sound waves into the propagating medium (for example, water), or which take in the sound waves from this medium (i. e. the radiators), while the other group embodies special vibratory structures whose functions can be performed by detectors, microphones, electromagnets, etc., of a kind that comprises elastic members. When coupling such structures due consideration must be given to the fact that a certain amount of the mass or weight and of the elastic force of each structure operates to affect the rate of vibration of the other.

Now to obtain the close acoustic coupling contemplated by the invention it will generally not suffice to effect merely an intimate mechanical joint or connection of the two structures with each other, or to use relatively large masses that are common to both structures; but, in addition, their natural rates of vibration must be made approximately or precisely equal.

An obvious embodiment of the invention would be to make the fundamental frequencies of each of the two structures equal.

If this course is adopted where one of the vibratory structures is a diaphragm abutting against the water it will only be possible to operate with relatively low rates of vibration; since, as the frequency increases, the diaphragm becomes thicker, and its mass greater, and hence the damping of the entire apparatus decreases. As will be pointed out hereinafter a diaphragm having relatively large individual damping is desired, to balance off the relatively small individual damping generally possessed by the other vibratory structure or structures coupled thereto.

But instead of utilizing the fundamental rate of vibration of one of the vibratory structures, say the sound radiating diaphragm, for coupling purposes, it is possible to couple with a harmonic thereof. That is to say, the vibratory structure which (for example) is to cooperate with the diaphragm may be so tuned that its frequency or rate of vibration is equal or approximately equal to that of a harmonic of the diaphragm. An advantageous rate of vibration to use is one whereby the oscillations executed by the diaphragm take the form of alternating rises and depressions, or outward and inward bulgings, of an annular zone lying between the center and the periphery. That is to say, instead of the diaphragm being caused to execute a simple bulge first in the one direction and then in the other, whereby the greatest travel is performed by its centre and the travel executed by its other parts grows smaller as their distance from the centre increases, the greatest travel or amplitude of motion may be caused to be executed by points of the diaphragm lying in a circular zone between the center and the periphery. For the sake of brevity these oscillations of an annular portion of diaphragm will be referred to as "ring vibrations" of the same. As the fundamental rate of vibration of a diaphragm remains low when, in accordance with this invention, the ring vibrations are employed, its thickness is less than that of a diaphragm having a fundamental rate of vibration as high as that of the utilized harmonic of the thinner plate. Hence, on account of the smaller mass of the parts of maximum travel, a greater damping effect is obtained when the ring vibrations are used.

A feature of the invention, therefore, consists in using a radiator or diaphragm that is of uniform thickness throughout and whose area and thickness are such that it has a fundamental rate of vibration that is so low compared with that of the vibratory structure coupled to it, that the rate of vibration of this last-named vibratory structure is only approached or equalled by the natural periodic time of the ring vibration or harmonic of the diaphragm. A result accomplished by this measure is that as far as the fundamental vibration of the radiator is concerned no mutual acoustic interaction and hence no acoustic coupling between the special vibratory structure and the radiator takes place; whereas on account of the proximity between, or the equality of, the periodic time, of the ring vibration of the radiator and of the special vibratory structure, a strong acoustic coupling effect between these two bodies or structures is produced as far as the frequency or periodic time of the ring vibration of the radiator is concerned.

Two examples showing how the invention may be applied in practice will now be adduced.

If, for instance, a vibratory structure with a small intrinsic damping effect has to be used to obtain the proper ratio of transformation of the amplitudes of motion of the vibrations, while the apparatus as a whole shall be considerably damped, the preferred procedure according to the invention will be to couple to the said vibratory structure a radiating body with a large damping effect so as to thus obtain the desired total damping effect. It will then be possible to predetermine the size of each of the two individual damping effects, that is, the damping effect in each vibratory structure after coupling, this being done in accordance with the law that when unequally damped vibratory bodies or structures are acoustically coupled together the damping becomes equally distributed in each.

If a sound-producing or receiving apparatus with a particularly high frequency of resonance is desired, the two vibratory structures (the radiator and the special vibratory structure) will, in accordance with the invention, be acoustically coupled so closely that an apparatus with two frequencies of resonance will result, one of which will be very much higher and the other very much lower than either of the two individual frequencies of resonance of the individual structures. The closer the coupling is made the more the higher of the two frequencies of resonance will be shifted up, so that by this means the desired particularly high frequency of resonance can be obtained. This closeness of coupling may be secured in two ways; one, by bringing the individual frequencies of the vibratory structures closer together, and another by distributing the masses of the coupled structures so that the common mass becomes smaller than the others.

The invention will be elucidated by reference to the drawing in which

Fig. 1 shows a sound signaling receiving apparatus in which the individual structures that are to be regarded as being coupled to each other are, (1) a sound collecting or radiating diaphragm, and (2) a special vibratory structure formed of two masses connected by springs, the latter structure carrying a microphone.

Fig. 2 shows, in two separate curves, the amplitudes at different frequencies of the vibrations executed by the individual vibratory structures before coupling, and in a single curve the two frequencies of resonance that result from coupling the two individual structures.

Fig. 3 is a modification of the apparatus represented in Fig. 1, the chief difference being that the latter apparatus is equipped with an electromagnet and may be used both as a sound producer and as a sound receiver, the second or special vibratory structure that is coupled to the diaphragm operating either to produce or to receive sound waves.

Fig. 1 shows a receiving apparatus made up of two coupled vibratory bodies or structures; the one vibratory structure being the diaphragm 1 with its supporting or holding frame or border 5 formed from the same material and the mass 2 in its centre; and the other vibratory structure consisting of the weights or masses 2 and 4 and the elastic members 3 the mass 2 thus being common to both structures. Attached to the weight 4 is a microphone 6.

Let it be assumed that the damping in the vibratory structure 2, 3, 4 is very small, which might for instance be due to the fact that the microphone cannot be made large enough to present an opposing force great enough to sufficiently damp the vibrations of small amplitude that the energy of vibration causes the mass 2 of the structure to execute. In a case like this the diaphragm is made to have a large radiation damping, which can be done by making or arranging it in such manner that it is forced to execute ring vibrations of a kind that will result in the middle part of the diaphragm carrying out motions that are smaller than, and in phase with, the motions of the marginal parts nearer to the periphery of the diaphragm, or else much smaller motions that are out of phase with the motions of the marginal parts. Now if the further condition is fulfilled that the frequency of the ring vibrations of the diaphragm and the individual frequency of the structure 2, 3, 4 do not greatly differ, one of the two new frequencies of resonance of the coupled system will be higher, and the other will be lower, than the two original frequencies of resonance. By coupling closer or looser the proximity of the two resulting frequencies can be altered and the tuning of the finished signaling apparatus or system thus predetermined.

It has been found by experience that a specially simple arrangement to use for the radiating body or structure is that of the hereinbefore described ring vibration of a diaphragm. To make the radiation damping large it is only necessary to arrange the diaphragm in such a way that the volume pressed out by its marginal or annular portion into the sound propagating medium is large—especially in comparison to any volume that might be simultaneous pressed inward at the middle of the diaphragm—and that the mass of the vibrating annular portion is not too large. This may be accomplished, for example, with flat diaphragms by rigidly attaching to the diaphragm a second vibratory structure having the same natural rate of vibration as the ring vibrations of the diaphragm and consisting of separate masses connected by an elastic member or members, one of said masses being attached to the middle of the diaphragm, and this mass being made small in comparison with the other mass or masses.

In Fig. 2, in which the abscissæ represent frequencies and the ordinates the acoustic effect, F*s* indicates the individual frequency of resonance of the special vibratory structure 2, 3, 4; FM denotes the frequency of resonance of the ring vibration or harmonic of the diaphragm used for the purpose of coupling, the resonance curve of the fundamental vibrations of the diaphragm being omitted. When the two structures are acoustically coupled a single apparatus or system is formed having a resonance curve such as that indicated by the solid or unbroken graph with two crests. *fs* and *fm* are the frequencies of resonance after coupling and correspond to the frequencies F*s* and F*m* respectively.

Of course the relative positions of the frequencies of resonance of the radiator and the special vibratory structure could be just the reverse.

In Fig. 3 the two coupled devices of which the entire apparatus is composed comprise the casing 5 with the diaphragm 1 and the central mass 2 on the one hand, and the mass 2 with the spring plate 7 and the magnet 4 on the other. It is necessary in certain cases in accordance with this invention—especially in the cases of receiving apparatus consisting of two coupled structures (the radiator and the exciting or sound transferring member)—to make the acoustic coupling between the various vibratory structures of which the entire apparatus is composed so close that the higher of the two resulting frequencies of resonance is twice as high as the lower of these two frequencies. If, in apparatus having a mass 2 which is common to two structures, which structures are in turn each provided with their own unrestrained or freely vibratory masses 5 and 4, the condition is fulfilled that the free mass 5 of the one structure (the radiator) is large compared to the common mass 2 and the free mass 4 of the second structure, the required closeness of the coupling will be attained in a satisfactory degree by making the common mass 2 smaller than, or at the most as large as the second free mass 4. In practice the free mass 5 is therefore generally large in comparison with masses 2 and 4.

Other advantages of the invention are the following: It has not been possible with the acoustic structures hitherto employed—at least not in working with tuned sound signaling systems—to use the same apparatus for signaling at several different frequencies. To render this possible was an acoustic problem in connection with submarine sound signaling that was extremely difficult to solve, because, on account of the large elastic forces that have to be applied, it was not possible to bring about a change of tuning in a simple manner. Besides, the apparatus are always arranged in the water or at places that are difficult to get at, so that to alter their tuning after installation they would always have to be detached and removed. But with the novel method proposed herein it is possible to so arrange the apparatus that it is ready to respond at any moment to any one of at least two, and under certain circumstances of more, distinct tones. With apparatus of this kind it is only necessary, to change from one frequency to another where electrical energy is employed, to alter the speed of revolution of the electric generator so as to change the rate of vibration of the sound producer, or, in the case of a receiver, to change the tuning circuit of the same. By a suitable choice of the dimensions of the systems and proper coupling it would also be possible to obtain more than two frequencies of resonance.

Instead of two vibratory structures a larger number such as three may be used, the third structure being interposed between and coupled to the radiating vibratory structure or diaphragm and the vibratory structure that is associated with the sound receiver or exciter proper.

The term "means for coupling", as used in the claims, is intended to refer not simply to the mechanical connection between the coupled vibratory structures, but to this in combination with the tuning and mass relations of the said structures.

We claim:

1. In a sound signaling apparatus, a plurality of vibratory structures each individually tuned to a definite pitch, said structures being provided with means for coupling them together acoustically whereby the resulting frequencies of resonance of the structures in the coupled system are considerably different from the original frequencies.

2. In a sound signaling apparatus, a vibratory structure tuned to a definite pitch, and a second vibratory structure tuned to the same pitch, said vibratory structures being provided with means for coupling them together acoustically whereby one of the resulting frequencies of resonance of the structures in the coupled system is twice as great as the other.

3. In a sound signaling apparatus, a plurality of vibratory structures each individually tuned to a definite pitch and individually damped to a definite degree, said structures being provided with means for coupling them together acoustically whereby the resulting frequencies of resonance and dampings of the structures in the coupled system are considerably different from the original frequencies and dampings.

4. In a sound signaling apparatus, a vibratory structure tuned to a definite pitch and having relatively high damping, a second vibratory structure tuned to a definite pitch and having relatively low damping, said structures being provided with means for coupling them together acoustically whereby the damping at the resulting frequency of resonance of the coupled system corresponding to the vibratory structure of relatively low damping is increased, and the damping of the resulting frequency of resonance of the coupled system corresponding to the vibratory structure of relatively high damping is decreased, to a considerable extent.

5. In a sound signaling apparatus, a vibratory structure tuned to a definite pitch and having relatively high damping, a second vibratory structure tuned to a definite pitch and having relatively low damping, said structures being provided with means for coupling them together acoustically whereby the damping magnitudes are caused to become substantially equalized.

6. A device according to claim 4, in which the vibratory structure having relatively high damping is a sound radiating diaphragm having high radiation damping.

7. In a sound signaling apparatus, a plurality of vibratory structures each individually tuned to the same pitch, and provided with means for coupling them together acoustically including having the effective masses thereof proportioned relatively to each other, whereby the resulting frequencies of resonance of the structures in the coupled system are considerably different from the original frequencies.

8. In a sound signaling apparatus, a sound radiating diaphragm, and a vibratory structure coupled thereto tuned substantially to the frequency of an upper harmonic of the diaphragm to cause the diaphragm to vibrate in the latter frequency.

9. In a sound signaling apparatus, a sound radiating diaphragm having high radiation damping, and a vibratory structure coupled thereto tuned substantially to the frequency of an upper harmonic of the diaphragm to cause the diaphragm to vibrate in the latter frequency, the vibratory structure and the diaphragm being so related that a relative large portion of the diaphragm vibrates in phase when it is executing the said harmonic vibration.

In testimony whereof we affix our signatures.

HEINRICH HECHT.
WALTER HAHNEMANN.