Nov. 24, 1925. **1,562,950**

R. A. FESSENDEN

SIGNALING BY ULTRA AUDIBLE SOUND WAVES

Filed Dec. 14, 1918 2 Sheets-Sheet 1

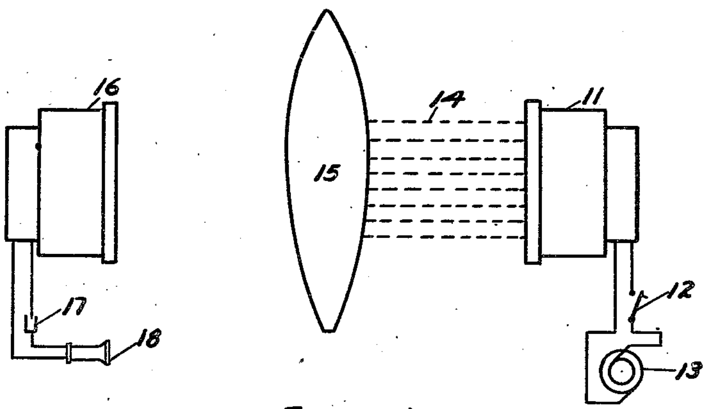

FIGURE 1

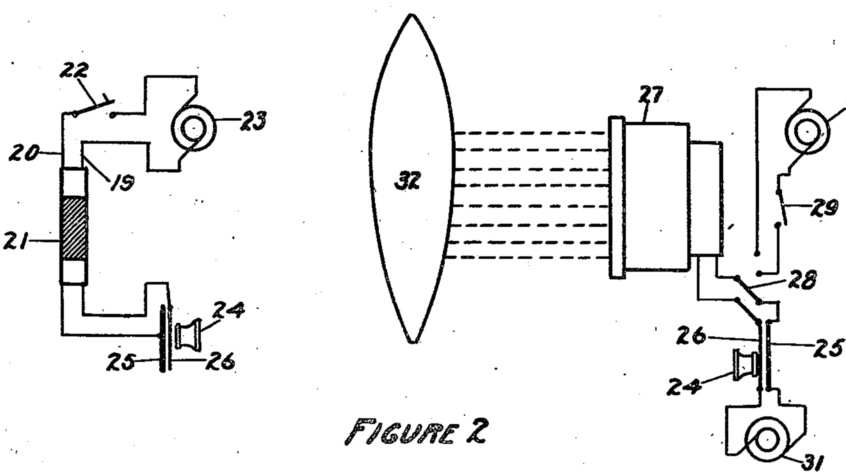

FIGURE 2

WITNESS:

INVENTOR.

Reginald A. Fessenden

BY

Nov. 24, 1925.

1,562,950

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2 Sheets-Sheet 2

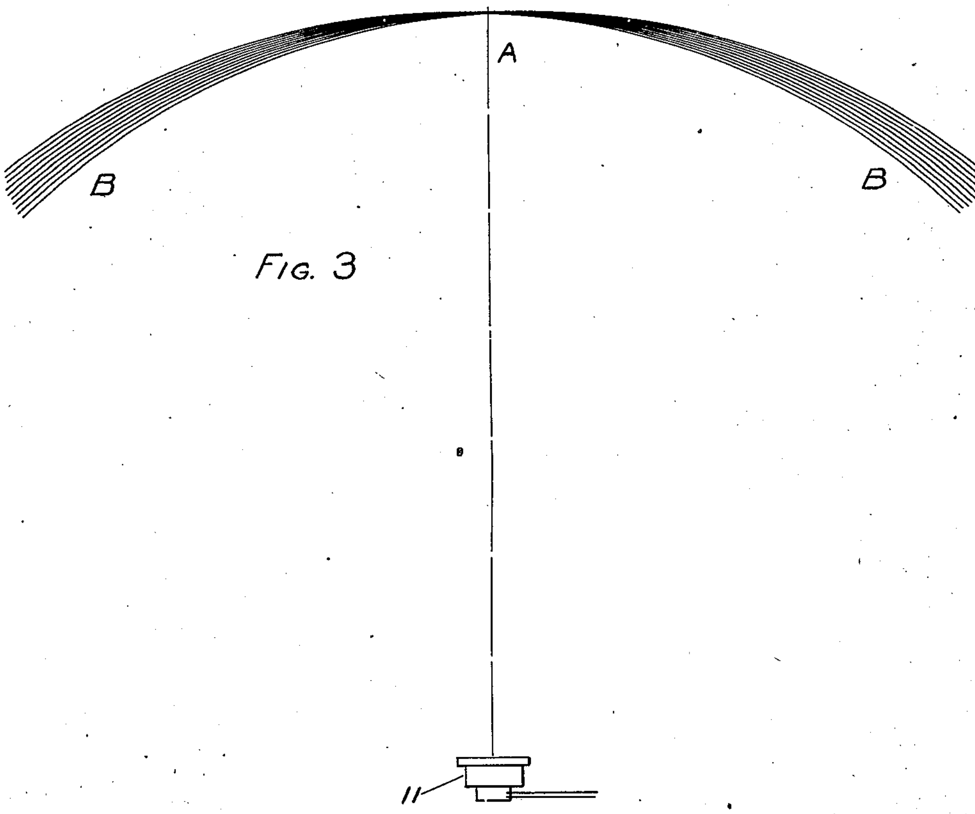

FIG. 3

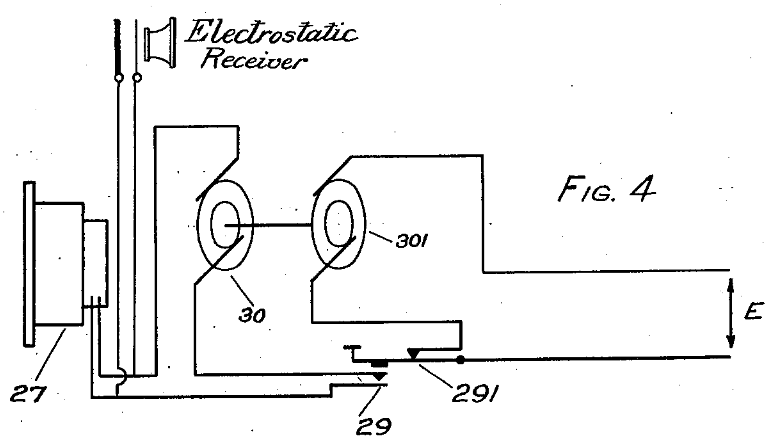

FIG. 4

Inventor:
Reginald A. Fessenden
per
[signature]
Attorney.

Patented Nov. 24, 1925. **1,562,950**

UNITED STATES PATENT OFFICE.

REGINALD A. FESSENDEN, OF BROOKLINE, MASSACHUSETTS, ASSIGNOR TO SUBMARINE SIGNAL COMPANY, OF PORTLAND, MAINE, A CORPORATION OF MAINE.

SIGNALING BY ULTRA-AUDIBLE SOUND WAVES.

Application filed December 14, 1918. Serial No. 266,711.

To all whom it may concern:

Be it known that I, Reginald A. Fessenden, of Brookline, in the county of Norfolk and State of Massachusetts, a citizen of the United States, have invented certain new and useful Improvements in Signaling by Ultra-Audible Sound Waves, of which the following is the specification.

My invention relates to the transmission and receipt of anacysms or sound waves above the limit of audibility, and more especially to signaling and detecting by means of said anacysms.

My invention has for its object the more efficient generation, reception and utilization of said anacysms, and the transmssion of said anacysms in the form of a beam.

The accompanying drawings, Figures 1 and 2, show partly diagrammatically, means adapted for carrying out my invention.

The present application is in part a continuation of U. S. application Serial No. 35,957 filed June 23, 1915, so far as it relates to those parts which are common to the two specifications, more particularly the description on page 31 of said application 35,957. This application, Serial No. 35,957, contained a number of inventions a patent on one of which was issued No. 1,265,776, May 14, 1918.

Applicant in 1912 designed and built the type of apparatus called an oscillator, and described in U. S. Patent No. 1167366 (issued Jan. 4, 1916) for submarine telegraphy and telephony over long distances.

In the course of the experimental work, applicant applied one of his 500 cycle wireless generating sets, of the type shown in U. S. Patent No. 918,306 (issued April 13, 1909), and giving a frequency of approximately 50,000 cycles per second, to one of these oscillators, and discovered that when so connected the oscillator radiated an intense stream of ultra-audible sound waves, and that the radiation took the form of a beam like that of a search light.

As no scientific name has as yet been given to such ultra-audible sounds, applicant in his Report, Navy Department, No. 22, December 11, 1912, has termed these anacysms, and the term is used with this meaning in the present application.

Figure 1 is a diagrammatic view illustrating means for generating anacysms.

Figure 2 is a similar view illustrating one of the methods.

Figure 3 is a diagrammatic view illustrating the theory of the subject involved in part of this invention.

Figure 4 is a modification of part of Figure 2.

11 is an oscillator, 13 is one of applicant's high frequency alternators, for example, of the type described in U. S. Patent No. 706,737, (issued August 12, 1902), and U. S. Patent No. 962,018 (issued June 21, 1910), having a frequency of the order of 50,000 per second, though frequencies of 200,000 or higher may be used.

When the key, 12, is pressed down, the high frequency current flowing through the oscillator causes anacysms of a frequency of 50,000 per second to be emitted in the form of a beam, as shown at 14.

The reason that the anacysms are emitted in the form of a beam applicant has found to be due to the fact that the quarter wave length of the anacysms is of a different and lower order of magnitude than that of the diameter of the oscillator. For example, the oscillator diaphragm may have a diameter of twenty inches, while the quarter wave length of compressional waves of a frequency of 50,000 per second will be, in water, only about one-fourth of an inch, i. e., the diameter will be eighty times the quarter wave length.

Applicant has found that the larger the ratio of the diameter of the oscillator to the quarter wave length of the anacysms, the more definite will be the beam, and the spread of the beam may be varied by varying the frequency.

Referring to Figure 3, if a line be laid off representing the diaphragm of an oscillator 11, and say forty points at equal distances from each other be laid off on that line and from each point a circle be struck say ten times the diameter of the ascillator and also circles having radii longer than the first named radii by the distance between said points and therefore representing waves of half a wave length difference, there will be a complete interference with the exception of a few narrow zones of interference fringes except in that portion directly in front of the line indicating the oscillator diaphragm. In other words, sound waves emtted from a source, large compared with a quarter of a wave length of the sound waves, annul each other except directly in front of the source and so produce the effect of a beam. For obvious reasons this cannot be fully illustrated in a drawing of the size required by the rules, but it is approximately indicated in Figure 3 where it will be noted that at the point A directly in front of the diaphragm of the oscillator 11 the circles B all cross showing a path of slight interference.

A convenient method of receiving the anacysms is shown on the left hand of Figure 1, where 16 is an oscillator, 17 a rectifier of any suitable type, for example, a crystal rectifier, and 18 is a telephone receiver.

On the beam of anacysms falling on the diaphragm of 16, high frequency oscillations of a periodicity of 50,000 will be generated by the oscillator, and these being rectified by the rectifier 17, will produce a current in the receiver 18, and if the beam of anacysms is rendered discontinuous by means of the key, 12, a sound will be heard in the receiver, 18.

Such a beam of anacysms may be used to detect the passage of a submarine, 15, between the oscillator, 11, and the oscillator, 16, as so long as the beam 14 reaches 16, signals made by the key 12, or any suitable conducting device will be heard on the receiver 18, but if the submarine 15, passing down a channel, comes between the oscillators 11 and 16, the beam will be interrupted and no sound will be heard on the receiver 18, thereby indicating the presence of the submarine, 15.

In Figure 2 is shown the application of a beam of anacysms to the detection of a submarine, 32, by means of reflection, as described in Report to U. S. Navy Department No. 83, Feb. 19, 1917.

As therein described, on throwing the switch 28 upwards so as to connect the oscillator 27 with the high frequency generator, 30, and depressing the key 29, for a short time, for example, one second, a beam of anacysms will be thrown out as shown. On this beam striking the submarine 32, which may be a mile away, it will be reflected back, if the surface is smooth, as a continuous reflected beam, or if the surface is rough, or the medium turbid as interference fringes of sound i. e., discontinuous trains of sound waves, as described in applicant's U. S. Patent No. 1,217,585 (filed April 2, 1914, and issued Feb. 27, 1917).

If the submarine 32 is a mile away from the oscillator 27, the emission from the oscillator 27 will have ceased before the beam strikes the submarine 32, and if immediately after opening the key 29, the switch 28 is thrown down into the position shown, the beam or sound diffraction fringes reflected from the submarine 32 will, on returning and striking the diaphragm of the oscillator 27, generate high frequency currents in the oscillator windings of a frequency corresponding to that of the generator 30, which may be 50,000 per second.

These high frequency oscillations generated by the oscillator 27 may be detected by attaching the terminals of the oscillator, by throwing the switch 28, to the fixed plate 25, and movable plate 26 of the condenser telephone receiver 24, as shown, and at the same time connecting the condenser telephone terminals to another high frequency generator, 31, giving a frequency of, for example, 51,000 per second.

If this is done, then beats will be produced between the two sets of oscillations, and an audible sound will be emitted, this method of receiving being known as applicant's heterodyne method.

If desired, the second high frequency generator 31, and the switch 28 may be omitted, and the terminals of the dynamo, 30, permanently connected to the terminals of the oscillator 27, and the motor 301 driving the dynamo 30 disconnected as at 291 from the source of power E at the instant of depressing the key 29, so that the speed of the dynamo 30 gradually falls, while the key 29 is being held down. This construction is shown in Figure 4.

Applicant has discovered that when this is the case, the frequency of the anacysms reflected from 32 will be higher than the frequency of the oscillations which are being generated by the dynamo 30 at the instant when the reflected anacysms come back again and strike the diaphragm of the oscillator 27, and generate oscillations in the oscillator windings, and therefore on the terminals of the electrostatic telephone receiver 24, and hence beats will be produced in this case also.

Applicant has also discovered that the greater the distance the submarine 32 is away from the oscillator 27, the higher will be the pitch of the beats produced by the reflected anacysms, and that in this way the distance of the submarine from the oscillator 27 can be determined by noting the rate at which the high frequency dynamo 30 is slowing down, and the frequency of the beats in the electrostatic telephone receiver 24.

Still another method of sending and receiving these anacysms is shown in the left hand of Figure 2, where 19 and 20 are the terminals, and 21 the dielectric of a condenser receiver of the type shown in applicant's U. S. Patent No. 1,182,843 (issued May 9, 1916), 22 is a key, and 25, 26, the fixed and movable plates of a condenser receiver 24, of the type shown in applicant's U. S. Patent No. 793,649, (issued July 4, 1905).

On depessing the key 22, anacysms will be sent out from the condenser 19, 20, 21, or if the key 22 is held down and anacysms of a different frequency from that generated by the high frequency dynamo 23 impinge upon the condenser 19, 20, 21, heterodyne beats will be created, and a musical note will be produced in the condenser receiver 24.

The methods and apparatus described in the present application were disclosed to the U. S. Navy in 1914, especially their use in connection with detecting submarines (see Report, U. S. Navy Department No. 22, December 11, 1912, also No. 83, Feb. 19, 1917), and instructions were issued to construct the apparatus and test it out, and favorable results have been obtained by the Navy Department.

It is to be noted that detection by means of interference fringes and detection by means of scattering are fundamentally different. Scattering occurs when a sound of short duration, such as a short impulse or a group consisting of a few waves, strikes an irregular object whose dimensions are larger than the quarter wave length of the waves. See Rayleigh's "Theory of Sound" and Rayleigh's collected papers, article "Polish".

Detection by scattering has been described by other inventors; for example, Richardson British Patent 9423/1912, page 3, lines 17–33; also Richardson's British Patent 11,125/1912, page 4, line 55 and page 5, lines 17 and 18.

Applicant, however, does not use scattering, but prefers to use interference. Interference does not occur with short impulses, but long trains of waves are required. For example, in the method described in this application the trains preferably consist of thousands of waves and a train of 100 waves is necessary in order to produce a single beat or interference fringe.

On actual tests applicant has found a great difference between the results obtained from scattering and from interference. For example, when a sound of short duration (as for example Richardson's British Patent 11,125/1912) was sent out against an iceberg or ship in very few cases was any echo observed, in fact an echo was substantially non-existent. On the other hand when a prolonged train of waves was sent out the waves reflected from the body of the iceberg and probably reflected again from the surface of the water formed interference fringes and in every single case—i. e. 100% of the singnals sent—a series of short sounds were received back, due to interference fringes. This also held without exception even when the reflecting object was the smooth side of a ship. As Richardson points out (British Patent 11,125/1912, page 5, lines 17 and 18) an echo cannot be expected from a smooth body like the side of a ship when scattering methods are used, but with applicant's interference method echoes were received on every occasion because the energy must go somewhere and with the prolonged trains of waves sooner or later interference fringes are formed which affect the receiver.

It is also to be noted that the heterodyne method of reception performs a new and useful function in connection with anacysms from what it does in the methods disclosed in applicant's original heterodyne patents. This if for the reason that in wireless telegraphy the motion of the stations is negligible in comparison with the velocity of transmission and consequently there is no Doeppler effect and the received frequency remains constant. On the other hand with anacysms the sources are generally in motion and there is a very pronounced Doeppler effect and it would be impossible to tell what frequency to listen in on unless the direction and velocity of the object were known, but with the heterodyne method used in connection with anacysms, as described in the specification, it does not matter what the received frequency may be as this will merely vary the number of beats per second, which is a second new and useful function.

The invention herein described my be applied to signaling in air as well as through water, for example, from or to aeroplanes.

What I claim is—

1. In a system of signaling by high frequency sound vibrations the method of producing a beam of sound by generating ultra audible sound vibrations by the motion of a surface having a large ratio of the diameter of the surface to the wave length of said sound vibrations at an ultra-audible frequency and having all of said surface vibrating in substantially the same phase.

2. In a system of signaling by high frequency sound vibrations, the method of producing a beam of sound by generating ultra-audible sound vibrations by the motion of a surface having its diameter of a larger and different order of magnitude than the quarter wave length of said sound vibrations at an ultra-audible frequency, and having all of said surface vibrating in substantially the same phase.

3. In a system of signaling by high frequency sound vibrations, the method of producing a beam of sound by generating ultra-audible sound vibrations by the motion of a surface having its diameter of a larger and different order of magnitude than the quarter wave length of said sound vibrations at an ultra-audible frequency, and having all of said surface vibrating in substantially the same phase, and varying the spread of said sound beam by varying the frequency of said ultra-audible sound vibrations.

4. The method of detecting by ultra-audi-

ble sound vibrations, objects submerged in the sound carrying medium, said objects having surface irregularities of a size, large in comparison with a quarter wave length of the sound vibrations, which consists in emitting continuous trains of said ultra-audible sound vibrations in the direction of said object thereby producing reflections of discontinuous ultra-audible sound vibrations whose discontinuity corresponds to audible frequencies and receiving said discontinuous ultra-audible sound vibrations whereby the discontinuity of said discontinuous ultra-audible sound vibrations allows an audible sound.

5. The method of detecting submarines and other submerged objects which comprises the emission of a long train of ultra-audible vibrations against such object whereby the reflected train of ultra-audible vibrations interfering with the emitted train produce beats of an audible frequency by the interference fringes and causing the response of an indicator to said beats.

6. The method of determining the distance of submerged objects and surfaces which consists in emitting a high frequency sound wave, receiving the emitted sound waves when reflected from the object, causing beats to be formed by heterodyne action, the frequency of the beats indicating the distance of the object or surface.

7. The method of determining the distance of submerged objects and surfaces which consists in emitting a high frequency compressional wave, receiving the emitted compressional wave when reflected from the object, causing beats to be formed by the heterodyne action of a varying frequency wave, whereby the frequency of the beats indicate the distance of the object.

8. Apparatus of the kind described comprising means for producing a source of high frequency compressional waves, a high frequency generator, a motor driving said high frequency generator, a double contact key normally closing said motor circuit and opening said generator circuit, and closing said generator circuit when the apparatus is in operation.

9. The method of generating a beam of compressional waves which consists in emitting high frequency compressional waves from a source, said source having a substantially plane radiating surface, large in comparison to a quarter wave length of the compressional wave transmitted.

10. The method of varying the spread of a beam of compressional waves which consists in emitting high frequency compressional waves from a source, said source having a substantially plane radiating surface, large in comparison to a quarter wave length of the compressional wave, changing the frequency of the source whereby the spread of said beam is changed.

11. The method of generating a beam of compressional waves which consists in emitting high frequency compressional waves from a source, said source having a substantially plane radiating surface large in comparison to the wave length of the compressional wave transmitted.

12. The method of detecting ultra-audible sound vibrations which consists in utilizing at a receiving station the received ultra-audible sound vibrations to generate electrical vibrations of ultra-audible frequency, generating, from an independent source, electrical vibrations of a frequency slightly different from the frequency of the vibrations to be detected, producing beats between the electrical vibrations produced by the ultra-audible sound vibrations to be detected and the electrical vibrations produced by the independent source, said beats being of audible frequency, and producing an indication by said beats.

REGINALD A. FESSENDEN.