Nov. 10, 1925. 1,561,278

M. I. PUPIN

WAVE SIGNALING SYSTEM

Original Filed Feb. 4, 1918

Fig. 1.

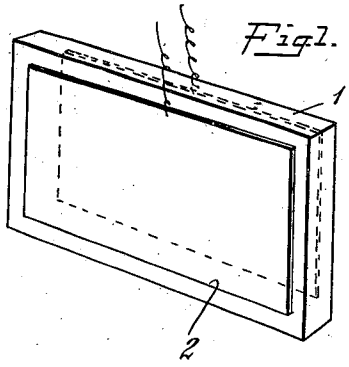


Fig. 2.

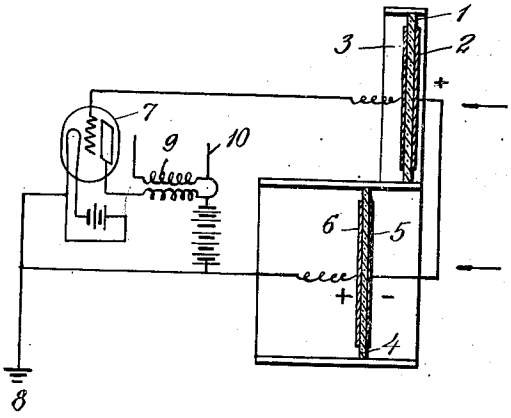
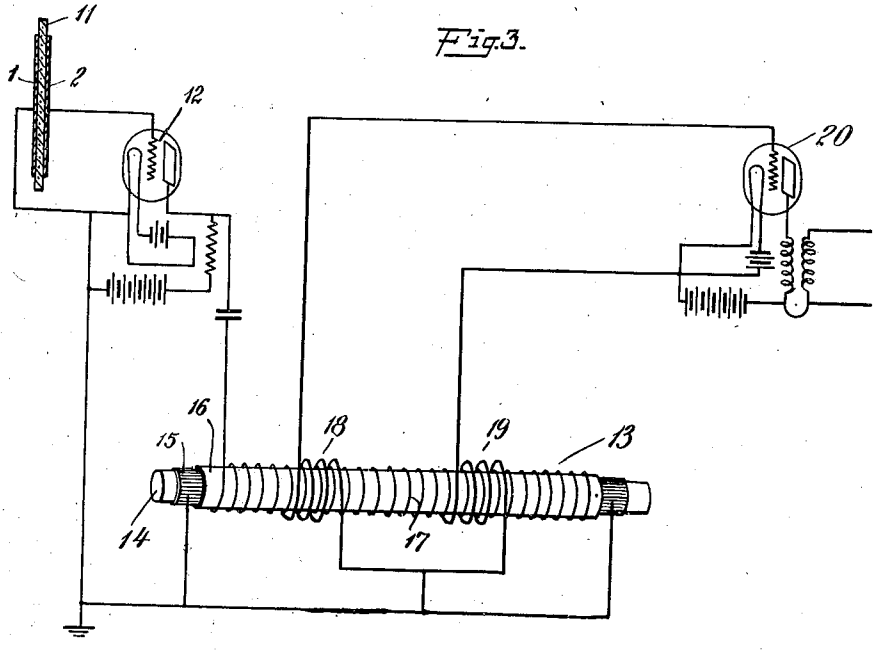


Fig. 3.



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Patented Nov. 10, 1925. 1,561,278

UNITED STATES PATENT OFFICE.

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WAVE SIGNALING SYSTEM.

Application filed February 4, 1918, Serial No. 215,294. Renewed January 26, 1921. Serial No. 440,225.

To all whom it may concern:

Be it known that I, MICHAEL I. PUPIN, a citizen of the United States, residing at Norfolk, in the county of Litchfield, State of Connecticut, have invented certain new and useful Improvements in Wave Signaling Systems; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention is a receiver of high frequency waves in which the phase distribution of the electrical forces produced by the action of the received waves is so utilized that the receiver is rendered insensitive for long waves without impairing its efficiency for the reception of the short signaling waves.

In the accompanying drawing, Figure 1 is a diagrammatic representation of the essential elements in the construction of a crystal plate piezo-electric receiver. Fig. 2 is a diagram representing two piezo-electric receivers electrically connected to each other and to a vacuum tube amplifier, in accordance with the present invention. Fig. 3 is a diagram of a receiving system in which the electrical waves produced by the action of the sound waves on a piezo-electric receiver or the like, are led through a phase distributing device properly connected to a vacuum tube amplifier, in accordance with this invention.

It is well known that when a piezo-electric crystal is subjected to changes of pressure corresponding changes of electrical potential will be produced on opposite faces of the crystal. The phenomenon, which is known as the piezo-electric effect, has been made use of in the detection of sound waves by causing the received sound waves to vary the pressure upon the crystals, and observing the electrical potential variations produced. Such receivers have practically no natural period of oscillation and are therefore aperiodic or dead beat in character. In order to arrive at the simplest explanation of the present invention, it will be assumed that such dead beat receiving devices are employed, although, as will be understood by those skilled in the art, the invention is of general application in connection with all sorts of sound receiving devices wherein the received waves produce corresponding variations in electric forces within the receiving circuits.

Referring now particularly to Figure 1, in which there is illustrated a suitable form of piezo-electric receiver, 1 is a quartz plate cut out of a quartz crystal in such a way that its flat faces are parallel to the optical axis and perpendicular to an electrical axis. 2 and 3 are two electrically conducting sheets, as of tin foil, attached to these two flat faces as indicated. When a pressure is applied perpendicularly to these flat faces by the piezo-electric effect a difference of potential between the two metal plates is produced, and when a tension is applied to the same two faces then a difference of potential is produced which is opposite to that produced by a pressure. A simple harmonic sound wave acting upon the face of the plate will, therefore, produce a simple harmonic variation of the electrical potential between the two faces, as is well known. This difference of potential is indicated by a vacuum tube repeater to which the metal plates are connected, and may be amplified and detected by vacuum tube amplifiers and detector circuits in several well known ways. It will be observed, however, that such a receiver is sensitive to sound waves of all frequencies.

In Fig. 2, an arrangement, in accordance with this invention, by which the receiver may be made selective with respect to signaling waves of high frequency, is shown. In this figure, there are two equal receivers 1 and 4, of which 1 is provided with the two metal plates 2, 3, and 4 is provided with the like metal plates 5, 6. By suitable electric connections the homologous metal plates 2 and 5 are connected to each other and the other two homologous metal plates are connected respectively to the grid and to the wing of a vacuum tube repeater 7 of the usual construction, the wing circuit being grounded at 8, and being associated, as through the transformer 9, with a circuit 10 leading to amplifying or detecting devices. Assume that plain sound waves reach the receiver in the direction indicated by the arrows. It is obvious that if the two receivers 1 and 4 are homologously placed with respect to the incoming plain sound waves, then the homologous faces 2 and 5 will both develop, at any given instant, electrical

charges of like sign, so that such homologously placed receivers so connected would give no difference of potential between plates 1 and 4 and therefore no electrical excitation in the vacuum tube repeater. If, however, the two receivers are not placed homologously with respect to the incoming plain sound waves, but are displaced with respect to one another by a distance equal to one-half of a wave length of the incoming waves, or equal to any odd multiple of one-half a wave length of the incoming waves, as indicated in Fig. 2, then the face 2 of the receiver 1 will be positively charged at the instant when the face 5 of receiver 4 is negatively charged and consequently there will be a difference of potential between 1 and 4 equal to twice the difference of potential produced in each of them. In a signaling system employing sound waves of a frequency of the order of 100,000 periods per second, a slight displacement of one receiver with respect to the other will place the receivers at a distance of half a wave length apart, whereas the external noises which commonly occur in the medium in which the device is employed, that is in the air or in water, are of such low frequency, probably not exceeding with any substantial amount of energy a frequency of the order of 3,000 periods per second, that with respect to such waves the receivers thus displaced will still be practically homologous and will not show any appreciable difference of potential between 1 and 4 produced by the action of these long waves. As a result of this differential reaction of the parts of the receiver to the action of long and short waves, the presence of the long waves will not be felt in the receiving system, whereas the short waves will produce considerable excitation in the receiving circuit and can readily be detected. The receiver eliminates, therefore, the low frequency noises which reach it without impairing the efficient reception of the high frequency signaling sound waves.

It will be observed that in the foregoing arrangement, the receiving devices, which transform the energy of the sound waves into electrical waves, are physically displaced to produce the desired effe t. It is obvious, however, that the same result may be obtained by using a suitable receiving device which transforms all of the sound waves into electrical waves, and electrically displacing the phase of the resultant waves within the receiving system. A suitable arrangement for this purpose is illustrated in Fig. 3. In this diagram, 11 represents a suitable receiver, such as the dead beat crystal receiver above described, capable of transforming the energy of received sound waves into electrical waves within the receiving system. A vacuum tube repeater 12 has its grid and plate circuits respectively connected to the opposite faces of the crystal receiver and transmits the potential variations thereof to a wave conductor 13 which consists of a glass tube 14 on which is pasted tin-foil 15 which is covered with a suitable insulation 16. On this insulating layer is wound a helix of copper wire 17. This helix with the tin-foil 15 forms a conductor having uniformly distributed inductance, resistance and capacity. Its constants can, as is well known, be so arranged that for the high signaling frequency there will be several wave lengths of the electrical waves within the full length of the helix. 18 and 19 are two secondary coils wound about this conductor and connected respectively to the grid and to the wing circuit of a vacuum repeater 20. These coils are connected to one another and to the ground as shown, and for obvious reasons the tin-foil 15 and the vacuum repeater 12 are grounded. Let the distance between the centers of the two secondary coils 18 and 19 be one-half wave length of the waves to be received, then for the signaling frequency there will be a difference of potential between the grid and the plate of the vacuum repeater 20 approximately equal to twice the electromotive force developed in each of the secondary coils, whereas for the lower frequencies produced by the surrounding noises there will be no appreciable difference of potential between the grid and the plate of the vacuum repeater. Several wave conductors of this type with half wave length displacements may be employed, connecting the secondary winding of one to the primary of the next in order to increase the weeding out of the low frequencies.

It is obvious from the foregoing that the elimination of the long waves by suitable phase displacement of the various elements of the receiving apparatus with respect to the incoming signaling sound waves can be carried out in many ways. I have selected the methods described above as the simplest for the sake of clearness of presentation.

What I claim is:

1. A receiver for a signaling system employing high frequency sound waves in which the signaling sound waves produce electrical variations differing in phase, a local electrical repeater, and circuit connections for applying the electrical forces to the repeater, the connections being so related to the phase distribution of the generated electrical forces that the points of the receiver connected to the repeater differ in phase by an odd multiple of one-half wave length of the waves which are to be received.

2. A receiver for a signaling system employing high frequency sound waves in which the received sound waves produce electromotive forces of corresponding frequency, a local electrical responsive device,

and circuit connections so arranged that the electromotive forces produced by the signaling sound waves are additively applied to the responsive device and the electromotive forces produced by all sound waves of substantially different frequency are differentially applied thereto.

3. A receiver for a signaling system employing high frequency sound waves comprising a crystal supported in the path of the sound waves for producing an electromotive force of corresponding frequency, means for producing a corresponding electromotive force differing in phase from said first electromotive force, an electrical responsive device and connections for additively applying thereto the said electromotive forces.

4. The combination with an input circuit carrying received currents of a predetermined frequency and other currents differing in frequency, of a helix having one terminal connected to one terminal of said input circuit, a condenser element connected to the other terminal of said input circuit and constituting, with said helix, a conductor having distributed inductance and capacity, whereby there are one or more half-waves of the predetermined frequency within the full length of the helix, a pair of coupling means in operative relation to said conductor and spaced by substantially an odd multiple of one-half wave-length of the predetermined frequency, and an output circuit operatively associated with said pair of coupling means.

5. The combination with an input circuit carrying received currents of a predetermined frequency and other currents differing in frequency, of a helix having one terminal connected to one terminal of said input circuit, a condenser element connected to the other terminal of said input circuit and constituting, with said helix, a conductor having distributed inductance and capacity, whereby there are one or more half-waves of the predetermined frequency within the full length of the helix, a pair of secondary coils surrounding portions of said helix spaced substantially an integral number of half wave-lengths of the predetermined frequency on said helix, and an output circuit associated with said coils whereby the energy received from said currents of predetermined frequency is additive and the energy received from said other currents is differentially applied in said output circuit.

6. Means for selectively receiving compressional waves of a predetermined high frequency in a material medium, comprising a transmitter for converting said compressional waves into electrical waves, an input circuit responsive to said transmitter, a helix having one terminal connected to one terminal of said input circuit, a condenser element connected to the other terminal of said input circuit and constituting, with said helix, a conductor having distributed inductance and capacity, whereby there are one or more half-waves of the predetermined frequency within the full length of the helix, a pair of secondary coils surrounding portions of said helix spaced substantially an odd number of half wave-lengths of the predetermined frequency on said helix, and an output circuit including said coils in series whereby the secondary electromotive forces resulting from said high-frequency compressional waves are additive in said output circuit whereas the secondary electromotive-forces resulting from sound waves of ordinary frequency in said material medium are substantially oppositely applied in said output circuit.

In testimony whereof I affix my signature.

MICHAEL I. PUPIN.