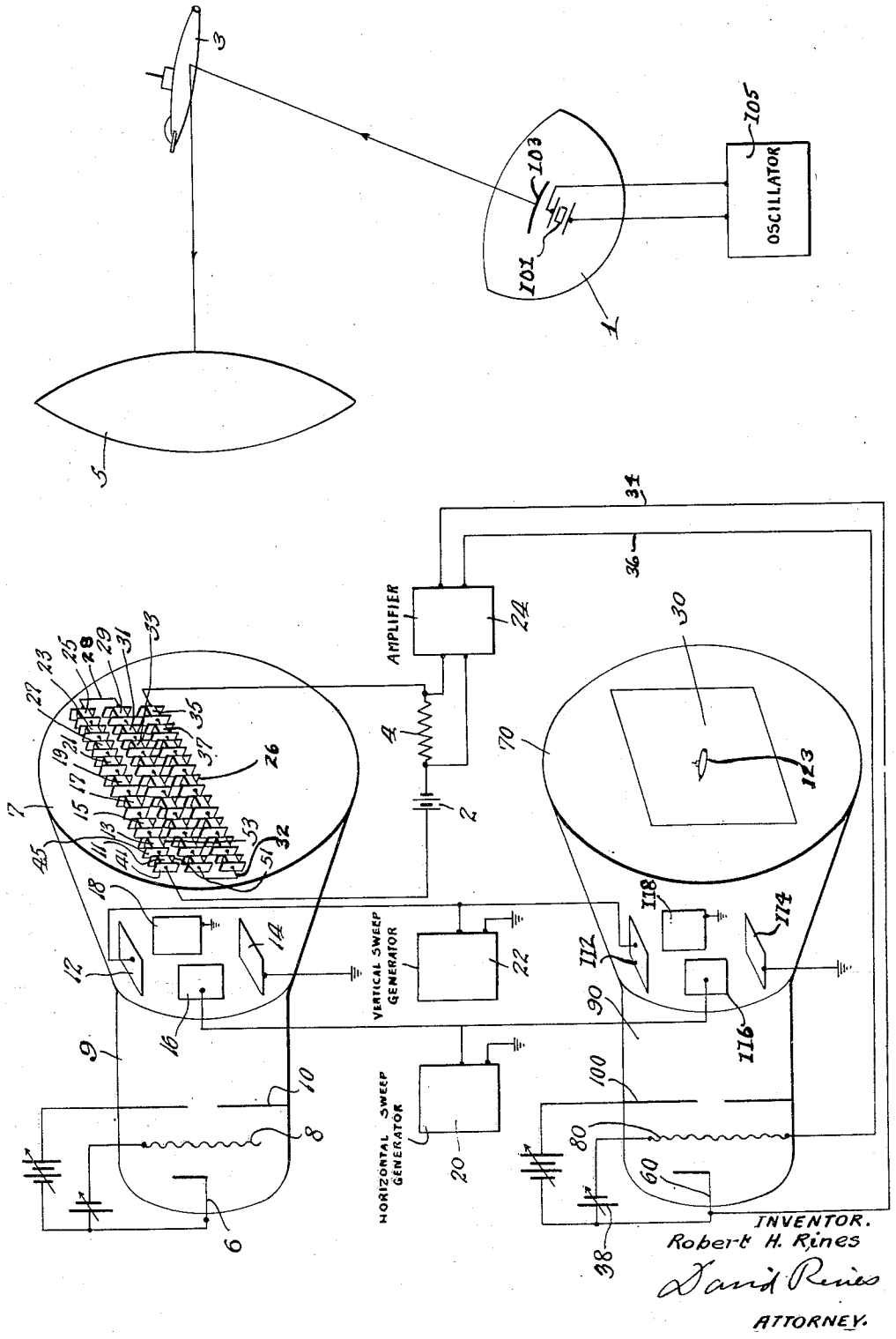
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ELECTRIC SYSTEM

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ELECTRIC SYSTEM

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6 Claims. (Cl. 250—164)

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The present invention relates to electric systems, and more particularly to receiving systems using sound waves as the agency of communication. The term "sound" will be employed hereinafter, in the specification and the claims, to include not only the audible part of the sound spectrum, but also, and more particularly, the ultrasonic spectrum, and to include also all kinds of elastic vibrations. This present application is a division of application, Serial Number 597,281, filed June 2, 1945.

An object of the invention is to provide a new and improved sound-receiving system embodying a novel cathode-ray-tube member.

Other and further objects will be explained hereinafter and will be more particularly pointed out in the appended claims.

The invention will now be more fully explained in connection with the accompanying drawing, the single figure of which is a diagrammatic view of circuits and apparatus arranged and constructed in accordance with a preferred embodiment thereof.

A directive ultrasonic transmitter is shown comprising an ultrasonic oscillator 105 for exciting a piezo-electric crystal 101 and an auxiliary reflector 103 for reflecting the energy emitted by the piezo-electric crystal 101 upon a parabolic sound reflector 1. Ultrasonic waves are thus propagated toward an object 3, illustrated as an underwater submarine. The sound waves are reflected and scattered from the surface of the object 3 toward a sound-receiving station. The invention is operable also with objects 3 that emit, as well as reflect or scatter, sound waves.

At the receiving station, the sound waves thus reflected and scattered from the object 3 may be focused, converged or directed by a sound lens 5 upon a bank or array 26, comprising a plurality of sound-receiving pick-up unit elements, mechanically vibratory in response to the sound energy impinged thereon. The sound lens 5 may be replaced by any other type of well-known lens, mirror or other directive system for focusing the sound waves scattered and reflected from the object 3 on the bank or array 26 of pick-up elements. The sound lens may, for example, be constituted of a collodion balloon filled with carbon dioxide or sulphur dioxide; or any other substance for refracting the sound waves.

The vibratile pick-up elements of the bank or array 26 are illustratively shown as piezo-electric-crystal receiver elements embedded in the insulating screen, face or wall 7 of a cathode-ray-oscilloscope-like member 9. They may, for example, be constituted of Rochelle salt, dihydrogen potassium phosphate, or any other suitable substance, including quartz. The front surface of each crystal element projects forward beyond the screen, face or wall 7 of the member 9 outside the cathode-ray member, exposed in the direction of the incoming sound waves, but the rear surface of each crystal element is exposed within the evacuated cathode-ray-tube member 9 along the inside surface of the screen, face or wall 7.

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The crystal pick-up units are shown arranged in the form of rows and columns, in the proximity of the focal plane of the lens 5. The first or uppermost row of the bank is illustrated as comprising the group of crystals 25, 23, 27, 21, 19, 17, 15, 13 and 11, shown as equally spaced horizontally. The second row from the top is shown constituted of a group of similarly disposed crystals, respectively disposed directly below the corresponding crystals of the first row; several of these are illustrated at 29, 31, and 33. The third or next-lower row is similarly constituted, several of the crystals being illustrated at 35 and 37. Though only a small number of pick-up units is shown in each row, and though only three rows are shown, this is merely for illustrative purposes, in order not to confuse the disclosure. It will be understood that, in practice, a large number of pick-up units will be employed in each row.

The crystal elements 25, 29, 35, etc., are shown equally spaced vertically in the first or right-hand column. The crystal elements 23, 31, 37, etc., are disposed in the second column from the right. The crystal elements 27, 33, etc., are disposed in the third column from the right, and so on. There may, or may not, be as many columns as there are pick-up units in each row. Though each column is shown as comprising only a few pick-up units, this is again in order not to complicate the drawing.

The pick-up units will, of course, all receive the reflected or scattered sound waves through the lens 5 simultaneously. There will be focused on the front surface of each pick-up unit a sound-wave intensity corresponding to the intensity of the sound energy reflected or scattered from a corresponding component part, portion or area of the object 3. Each pick-up unit will vibrate individually and separately in response to the sound waves impinged upon it. Voltages will thus be translated, produced or generated across the pick-up elements corresponding to the different field strengths of sound-wave energy thus received by them, and proportional to the

intensity of the sound-wave energy reflected or scattered or otherwise emanating from the various parts of the object 3 and converged upon the array 26 of pick-up elements by the lens 5 since the piezo-electric effect is linear. The sound lens 5 or its equivalent will thus focus upon the array 26 the sound waves reflected or scattered from the various parts of the object 3 in various energy strengths dependent on the reflecting properties of the component parts of the object 3, thus to produce a faithful sound image of this distribution of the sound waves in approximately the focal plane of the lens 5. The same result may be attained, as first pointed out by Lord Rayleigh, with the aid of a circular disc (not shown); the sound waves from the object will become diffracted about the periphery of the disc to produce a similar sound image of the object 3.

It has heretofore been proposed to convert a sound-energy picture of this character into a visible-picture likeness 123 of the object 3 upon the fluorescent viewing screen 30 of a display cathode-ray oscilloscope tube 90. The tube 90, as well as the cathode-ray-oscilloscope-like member 9, is shown operating on the electrostatic principle, but, of course, a magnetic deflector, or a combination of magnetic and electrostatic forces, may equally well be employed in both the tube 90 and the tube 9.

According to a feature of the present invention, improved results are obtained with the aid of the novel cathode-ray apparatus sound-receiving mosaic adapted to be scanned by an electron stream.

The crystals 11, 13, 15, etc. may be held in metallic crystal holders. The crystal 11, for example, is illustrated as disposed between a pair of metal electrodes 41 and 51, and the crystal 13, between a pair of metal electrodes 45 and 53. Adjacently disposed electrodes of adjacently disposed crystals are shown electrically connected together. The electrode 51 of the crystal 11, for example, is shown electrically connected to the adjacently disposed electrode 45 of the adjacently disposed crystal 13. The terminal electrode of the end crystal of each row, moreover, is shown electrically connected, as at 28 and 32, to the terminal electrode of the corresponding crystal of the next row. The crystals are thus all connected together in series relation with a source of energy, shown as a battery 2, and an impedance 4.

There will thus be produced across the impedance 4 a voltage dependent upon the sum of the alternating current voltages produced across the individual crystals by the incident sound waves and the direct current biasing voltage of battery 2. Provision is made, however, for short-circuiting successively disposed crystals, thus to produce successively across the impedance 4 indications corresponding to the voltage drops across the successively disposed crystals and, therefore, of the corresponding strengths of sound-wave energy received by the crystals.

According to the preferred embodiment of the present invention, this short-circuiting process is carried out with the aid of a scanning electron stream in the cathode-ray-oscilloscope-like member 9, which is shown provided with a vacuum-tube electron gun comprising a cathode 6, a control-grid electrode 8 and an anode 10. Electrons emitted from the cathode 6 will become accelerated, in response to proper stimulation of the grid 8, so as to pass by the grid 8 to the anode 10 of the member 9. The electrons will continue to travel in a stream from the anode 10, between a pair of vertically disposed deflector plates 16 and 18, of which the plate 18 is shown grounded, and between a pair of horizontally disposed deflector plates 12 and 14, of which the plate 14 is shown grounded, directed to impinge finally on the disc 7 of the member 9. A horizontal-sweep-time base, applied to the vertically disposed deflector plates 16 and 18, will cause the electron stream from the cathode 6 to become deflected horizontally as many times as there are rows of pick-up elements. After each horizontal sweep or scan of the cathode-ray or oscilloscope-like member 9 has been completed, a successively larger voltage will be applied to the horizontally disposed deflector plates 12 and 14 of the member 9, by a vertical-sweep-time base causing the electron stream to become deflected vertically, and causing each of the horizontal sweeps to appear at successively lower levels on the face 7 corresponding to successively lower vertically disposed levels of the rows of elements. The rows of crystals may be positioned along the successive paths of the electron stream, as the electron stream successively sweeps or scans the successive rows of the array on the disc 7. After the last such horizontal sweep, the horizontally disposed plates of the member 9 will become restored to their starting voltage. The next horizontal sweep, therefore, will start again at the first or top row. Sweep generators 20 and 22 may be employed to produce the horizontal-time-base sweep and the vertical sweep, according to conventional and well-known television techniques.

The distance or spacing between the electrodes of each crystal, such as the electrodes 41 and 51 of the crystal 11, may be made of value necessary to give a desired capacitance to provide a circuit resonant to the frequency of the received sound waves, and the anode 10 may be adusted so that the distance between the pair of electrodes of each crystal shall be equal to the width of the electron stream. The electron stream will thus become enabled to fill the gap between the electrodes of each crystal, thereby discharging the capacity between these electrodes.

As the electron stream produced from the cathode 6, in response to appropriate horizontal sweep-time-base voltages applied to the vertically disposed deflector plates 16 and 18 of the cathode-ray-like member 9, travels across between the crystal electrodes, the voltages built up across the crystal electrodes of each crystal become successively discharged to effect the short-circuiting of the crystals, thus affording successive indications of the intensity of the sound energy impinged upon the particular crystals. These indications will be made evident across the impedance 4, and may be amplified in a preferably linear amplifier 24.

This amplifier 24 is operated at a high point on its characteristic curve by virtue of the bias battery 2 in series with the small alternating voltages from the crystals across the input of the amplifier. The positive swings of the alternating voltages from the crystals drive the tube 24 into the saturation region, while the negative swings are amplified on the linear characteristic, thus producing positive pulses at the plate or anode of the amplifier 24. Operating, in this manner, as an overdriven amplifier, it serves, therefore, as a rectifier. The amplifier 24 could, of course, be operated to amplify the alternating voltages of frequency corresponding to the frequency of

the sound waves and could be followed by a separate rectifier (not shown) to rectify the voltages, as is well-known in the art.

Upon the successive short-circuiting of each crystal-condenser element by the electron stream, as discussed above, the alternating voltage across the impedance 4 is diminished by the small voltage from the particular crystal element representative of the intensity of the sound wave impinged on that element. The amplified positive pulses occuring in the output of the amplifier 24, during the scanning of a crystal, therefore, will have a peak amplitude that is less than before by an amount equal to the amplification of the tube multiplied by the voltage appearing across the particular crystal element. The output of the amplifier 24 will thus obviously vary, at successive instants, in accordance with the discharge or short-circuiting of the successive crystals, which discharge, as before stated, is a measure of the strength of the sound energy received by the corresponding pick-up elements.

Means is provided, controlled by the discharge or short-circuiting of the crystal electrodes, for producing, upon the screen 30 of the display oscilloscope 90, images 123 corresponding to the sound energy received by the corresponding pick-up elements. Successively disposed parts, portions, regions or areas of the screen 30, that correspond to the similarly disposed pick-up elements, are energized by an electron stream in the oscilloscope 90 to illuminate them. This electron stream is synchronized to travel with the electron stream of the cathode-ray-like member 9. The horizontal sweep circuit 20 is shown connected to the horizontal-deflector plate 116 of the oscilloscope 90, and to the horizontal deflector plate 16 of the oscilloscope-like member 9. The vertical-sweep circuit 22 is shown connected to the vertical-deflector plate 112 of the oscilloscope 90 and to the vertical-deflector plate 12 of the oscilloscope-like member 9. The other horizontal-deflector plate 118 and the other vertical-deflector plate 114 of the oscilloscope 90 are shown grounded.

Since the cathode-ray tubes 9 and 90 are subjected to the same scanning voltages, the electron stream in the tube 90 will impinge on the fluorescent screen 30 in synchronism with the electron stream impinging on the crystals on the face 7 of the oscilloscope-like member 9 during the voltage-discharging or scanning process. The signals amplified by the amplifier 24, and fed between the cathode 60 and the control electrode 80, will produce intensity modulation of the beam impinging on the screen 30.

Prior to the discharging process, the positive swings or pulse outputs of the amplifier 24 would make the cathode 60 periodically positive with respect to the grid 80. In conjunction with the bias of a battery 38 disposed between the cathode 60 and the grid 80, this would permit the passage of but few of the electrons of the electron stream beyond the grid 80. Since, during the discharge of a crystal element, however, the positive swings or pulses in the output of the amplifier 24 are of a peak amplitude less than the original pulses by an amount proportional to the voltage produced by the sound waves across the particular crystal element, the cathode 60 is periodically driven less positive with respect to the grid 80. A larger quantity of electrons are thus permitted to travel periodically past the anode 100, during the train of pulses produced by a crystal-condenser discharge, to impinge finally on the fluorescent

screen 30. The quantity of electrons that reach the screen 30 to produce intensity modulation during the scanning of a particular crystal, therefore, depends on the decrease in the output of the amplifier 24, and this, in turn, depends upon the voltage produced across the crystal by the sound-wave intensity impinged thereon. The illumination resulting from the intensity modulation on the screen 30 will be such that the intensity of illumination of parts of the screen 30 corresponding to parts of the crystal bank 26 will correspond to the sound-wave image on the rows and columns of the bank 26; this sound-wave image, in turn, corresponding to correspondingly disposed parts of the object 3.

The sound waves received successively by the crystal units along the successive rows and columns as the units are rendered successively effective in the display circuit, will thus become converted into successive portions of the visual likeness, along correspondingly disposed rows and columns thereof, along the successive time bases. The visual picture 123 of the object 3 on the oscilloscope screen 30 will accordingly correspond to the sound-energy-frequency picture on the array 26 of pick-up elements which, in turn, corresponds to the actual object 3. A visual image 123 of the object 3 is thus produced on the screen 30.

The crystals of the bank 26 may be wafer thin in order to make possible the use of a sufficiently large number of them in the array 26 to provide for good definition. The frequency of the sound waves, for example, may be 100 megacycles, corresponding to a wavelength of approximately 5×10^{-5} feet, in water, and produced, for example, by an oscillating quartz crystal, as described, for example, in an article by W. P. Mason and I. E. Fair, entitled "A New Direct Crystal-Controlled Oscillator for Ultra-Short-Wave Frequencies," Proceedings of the Institute of Radio Engineers, October, 1942, vol. 30, No. 11, pages 464 to 472. Lower-frequencied crystal oscillators may also be used, as described, for example, in an article by G. W. Pierce, entitled "Piezoelectric Crystal Oscillators Applied to the Precision Measurement of the Velocity of Sound in Air and CO_2 at High Frequencies," Proceedings of the American Academy of Arts and Sciences, October, 1925, vol. 60, No. 5, pages 275 to 295. Reference may be made also to W. G. Cady, Piezoelectricity, McGraw-Hill, 1946, pages 501 to 506 and 682, and Kamayachi and Watanabe, Electrotechnical Journal of Japan, vol. 5, No. 1, 1941, pages 19 and 20.

Although the invention has been described in connection with pick-up elements arranged in rows and columns, it will be understood that this is not essential, for other arrangements are also possible. Pick-up elements arranged along concentric circles covering the field, or along a continuous spiral, will also serve, though the oscilloscope arrangement would, of course, be correspondingly modified.

Further modifications will occur to persons skilled in the art, and all such are considered to fall within the spirit and scope of the invention, as defined in the appended claims.

What is claimed is:

1. In an evacuated cathode-ray apparatus provided with means for producing an electron stream, a mosaic upon which the electron stream may impinge provided with a plurality of groups of piezo-electric elements having front and rear surfaces and substantially equally spaced along a predetermined dimension, with the piezo-elec-

tric elements of each group substantially equally spaced along a second predetermined dimension, the front surfaces of the elements being exposed through the front surface of the screen to receive sound waves and the rear surfaces of the elements being exposed through the rear surface of the screen within the evacuated cathode-ray apparatus, and means for directing the electron stream upon the rear surfaces of the elements.

2. An electric system having, in combination, an evacuated cathode-ray member having means for producing electrons, a plurality of sound-wave receiving elements mounted along a wall of the cathode-ray member and capable of responding electrically when mechanically vibrated by sound waves impinged thereupon, one surface of each sound-wave receiving element being exposed at the surface of the said wall outside the cathode-ray member to receive sound waves and another surface of each element being exposed at the surface of the said wall within the evacuated cathode-ray member to the electrons, and means for directing the electrons upon the said other surfaces of the elements.

3. An electric system having, in combination, an evacauted cathode-ray member having means for producing electrons, a two-dimensional array of sound-wave receiving elements mounted along a wall of the cathode-ray member and capable of responding electrically when mechanically vibrated by sound waves impinged thereupon, one surface of each sound-wave receiving element being exposed at the surface of the said wall outside the cathode-ray member to receive sound waves and another surface of each element being exposed at the surface of the said wall within the evacuated cathode-ray member to the electrons, and means for directing the electrons upon the said other surfaces of the elements.

4. An electric system having, in combination, an evacuated cathode-ray member having means for producing electrons, a plurality of piezo-electric sound-wave receiving elements mounted along a wall of the cathode-ray member and capable of responding electrically when mechanically vibrated by sound waves impinged thereupon, one surface of each sound-wave receiving element being exposed at the surface of the said wall outside the cathode-ray member to receive sound waves and another surface of each element being exposed at the surface of the said wall within the evacuated cathode-ray member to the electrons, and means for directing the electrons upon the said other surfaces of the elements.

5. An electric system having, in combination, an evacuated cathode-ray member having means for producing electrons, a plurality of sound-wave receiving elements embedded in an insulating wall of the cathode-ray member and capable of responding electrically when mechanically vibrated by sound waves impinged thereupon, one surface of each sound-wave receiving element being exposed at the surface of the said insulating wall outside the cathode-ray member to receive sound waves and another surface of each element being exposed at the surface of the said insulating wall within the evacuated cathode-ray member to the electrons, and means for directing the electrons upon the said other surfaces of the elements.

6. An electric system having, in combination, an evacuated cathode-ray member having means for producing electrons, a plurality of series-connected sound-wave receiving elements mounted along a wall of the cathode-ray member and capable of responding electrically when mechanically vibrated by sound waves impinged thereupon, one surface of each sound-wave receiving element being exposed at the surface of the said wall outside the cathode-ray member to receive sound waves and another surface of each element being exposed at the surface of the said wall within the evacuated cathode-ray member to the electrons, and means for directing the electrons upon the said other surfaces of the elements.

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