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ELECTRICAL SYSTEM

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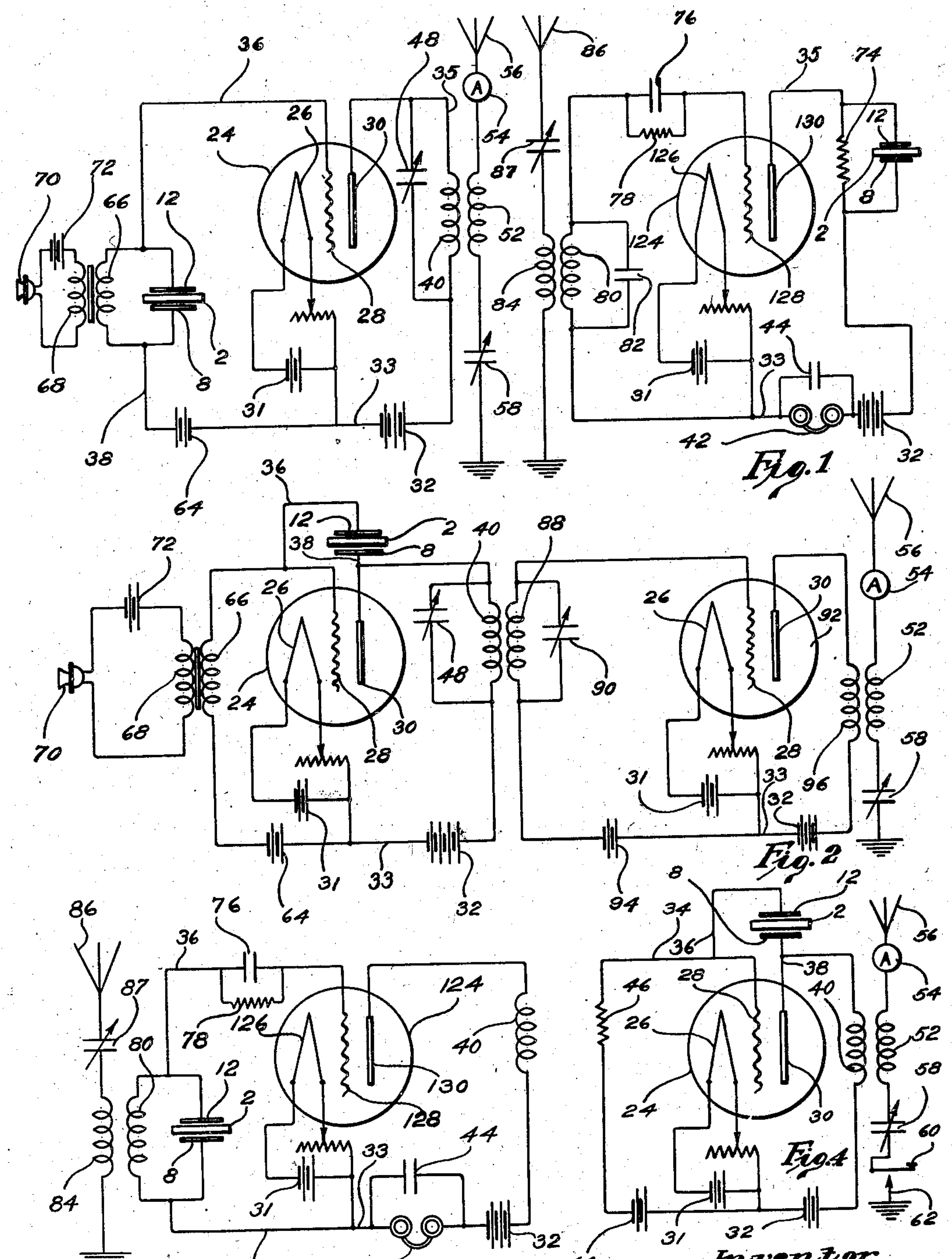

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ELECTRICAL SYSTEM

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The present invention relates to the transmission and reception of intelligence.

In radio telegraphy, it is customary to transmit signals by means of electric waves with a frequency that is desired to be constant. In the reception of such signals, a receiving system is often employed comprising an electric circuit traversed by an oscillatory current of frequency such as to give audible beats with the received signal frequency. For this purpose, particularly when high-frequency waves are employed, it is important to keep constant the frequency of the receiving circuit. In the reception of radio-telephone signals, too, it is useful to maintain a constant-frequency oscillation at the receiving station to beat superaudibly with the incoming signals for superheterodyne reception. In radio telephony and radio telegraphy, and in carrier-current systems where transmitting or receiving is effected by means of a carrier wave, also, the carrier frequency may be suppressed at the sending station, the side bands only being transmitted, and these must be supplied again with great accuracy at the receiving station.

The present invention has for its chief objects to provide an improved method of and systems and apparatus for transmitting and receiving electrical signals and to reduce interference to a minimum; also, to provide for an accurate control of the receiving-station frequency, and for a cooperation of frequency control at the transmitting station with control at the receiving station.

Other and further objects of the invention will be explained hereinafter and will be pointed out in the appended claims, it being understood that it is intended to cover in the appended claims all the novelty that the invention may possess.

In the accompanying drawings, Fig. 1 is a diagram of circuits and apparatus illustrating the present invention in its preferred form; Fig. 2 is a similar diagram of a modified radio-telephonic transmitting system and apparatus, using power amplification; Fig. 3 is a similar diagram of a modified receiving system; and Fig. 4 is a similar diagram of a radio-telegraphic transmitting system and apparatus.

A complete transmitting-and-receiving system is diagrammatically shown in Fig. 1. In order to simplify the drawings, and to render the description more easily understood, the complete transmitting-and-receiving system is omitted from the other figures, which, therefore, show separate transmitting systems and receiving systems. The system of Fig. 1 is more particularly designed for radio-telephone work, but corresponding connections for transmitting or receiving by radio telegraph or by telegraph or telephone over line wires will be obvious to those skilled in the art.

The constant frequency of the transmitting and receiving circuits, according to a preferred embodiment of the present invention, is attained by the interaction upon the system of electromechanical vibrators, like piezo-electric crystals. Such vibrators have the property of executing mechanical vibrations under vibratory electrical stimulus and, conversely, of developing electrical potentials as a result of their mechanical vibrations, as is now well known, and as is explained in a co-pending application, Serial No. 695,094, filed February 25, 1924, of which the present application is a division. For convenience, the action of the electric forces to cause mechanical deformation will be termed "stimulation" and the development of electromotive force by the displacement will be termed "response."

The electromechanical vibrator, shown as a piezo-electric body 2, is differently disposed in the different diagrams, so as to illustrate a few of the many different ways in which the vibrator may be employed. It is to be understood, however, that the vibrator disposition, in a particular diagram, is not specific to that diagram, but that the vibrator may be similarly disposed in the other diagrams. The oppositely disposed surfaces of the vibrator 2 are provided with opposed electrodes 8 and 12. One of the electric axes of the crystal 2 is assumed, for concreteness, to be in the direction of the thickness of the crystal plate.

A vacuum tube 24 is diagrammatically

shown in the transmitting system provided with three sensitive elements or electrodes, namely, a filament 26, a grid 28 and an anode or plate 30. The filament 26 is connected with a filament-heating battery 31. A plate battery 32 is connected with the filament 26 by a conductor 33, and with the plate 30 by a conductor 35. A load 40, shown in the form of an inductance coil having a distributed capacity resistance, is connected between the battery 32 and the plate 30. A tuning condenser 48 may be connected in parallel with the load, or the power of the system may, for some purposes, be increased by electrically tuning some other element.

In the transmitting system shown in the left-hand portion of the diagram of Fig. 1, and in Figs. 2, 3 and 4, the electrode 12 of the electromechanical vibrator is shown connected by a conductor 36 with the grid. The other electrode 8 is connected in Figs. 1 and 3 by a conductor 38 with the filament 26, and in Figs. 2 and 4, to some point in the circuit of the plate 30. The vibrator is thus connected, in the transmitting-system portion of the diagram of Fig. 1 and in Fig. 3, between the filament and the grid of the vacuum tube; and in Figs. 2 and 4, between the grid and the plate. Other connections, too, may be used. Thus, in the right-hand or receiving-system portion of the diagram of Fig. 1, the vibrator is shown connected between the filament and the plate, in the plate circuit of the vacuum tube.

An impedance element 66 (Figs. 1 and 2), 80 (Fig. 3), or 46 (Fig. 4) may be connected in the grid circuit. In Figs. 1 and 3, the impedance element 66 is disposed in parallel with the vibrator. If desired, a biasing battery 64 may be employed to bias the grid 28 to a predetermined potential, so that the potential of the grid may fluctuate about the biased value.

The system will oscillate with a frequency determined by the frequency of some normal mode of mechanical vibration of the vibrator and independent of the electrical parameters of the circuits.

With this setting, the invention of the present application will now be explained, though it will be understood that the invention is not, in its broader aspects, limited to any particular arrangement of circuits and vibrator connections.

In order to adapt the invention for transmission, the coil 40 is coupled to a coil 52 in the usual manner, as illustrated in Fig. 1. The coil 52 is connected, through a hot-wire ammeter 54, to an antenna 56, and through a tuning condenser 58, to the ground. These connections serve admirably for radio-telephone transmission. If the transmission is to be applied to a telephone line, the antenna and ground connection may be replaced by the well known connections to line wires. The same remark applies to reception along line wires as alternative to reception by an antenna. The coils 40 and 52 are so adjusted as to tune the system for the maximum current, as observable in the ammeter 54. The impedance element 66 may take the form of the secondary winding of a modulation transformer, as in Figs. 1 and 2. The primary winding 68 of the transformer may be connected to a microphone 70, in circuit with a source of energy, shown as a battery 72. The variations produced by the microphone will modulate the carrier oscillations of the system. The operation will be understood by persons skilled in the art without further description. The winding 66 of the modulation transformer may be replaced by a resistor of high resistance, with a new disposition of the microphone. Corresponding connections for transmitting by telegraph, or (as will presently appear) for receiving, will be obvious to those skilled in the art, as illustrated in Fig. 4. The freqeuncy of a transmitting station so designed is very nearly constant and stable.

In the receiving system, too, as shown in Fig. 3, the vibrator 2 may be connected in the input circuit, between the filament 126 and the grid 128 of the receiving tube 124, the same as in the transmitting system of Fig. 1. In order to illustrate some of the many different ways in which the vibrator may be connected into circuit, however, it is illustrated in the receiving system at the right of Fig. 1 as connected in the output circuit, between the filament 126 and the plate 130, shunted by a bypass 74 for direct current. The bypass 74 may be a radio choke, an inductance winding, a resistor, or a combination of these. The bypass 74 is preferably so chosen that the circuits shall have parameters such as to make the system stably non-oscillatory when the crystal is removed or restrained from vibrating. A blocking condenser 76, shunted by a leak resistor 78, and a winding 80, shunted by a condenser 82, are shown in Fig. 1 connected in the grid circuit, between the filament and the grid. The winding 80 is coupled to a winding 84 in series with a receiving antenna 86 and a condenser 87, and is grounded or connected with a counterpoise. The antenna 86 will receive the radio signals transmitted from the antenna 56. A telephone receiver 42, with or without a bypass condenser 44, may be disposed in the plate circuit of the receiving tube 124. Where the telephone is not needed, it may be replaced by an inductance, the primary winding of a transformer, or the input terminals of an amplifier, or it may be wholly short-circuited. The locally generated oscillations of the circuits of the tube 124 will beat with the oscillations received by the antenna 86, according to well-known principles, rendering the received signal audible in the telephone 42, or giving them any required superaudible frequency for superheterodyne reception. These locally generated oscillations may also be employed to supply a suppressed carrier frequency if desired.

A system of this character is adapted to receive high-frequency radiations, to which the electrical tuning elements are adjusted, and to superimpose upon them the frequency of mechanical vibration of the vibrator. The two frequencies are thus coexistent at the same time, permitting beats to be produced.

A tunable transmitting system and a tunable receiving system such, for example, as are illustrated together in Fig. 1, each supplied with a suitable vibrator, may, the one transmit, and the other receive, constant oscillations of very high frequency. This has been done by me over considerable distances. Variations in frequency arise from many sources, for all the circuit constants or parameters are continuously varying. For example, the mere running down of the battery, thus changing its voltage, the variation of inductance, the aging of a condenser, deterioration of the vacuum tubes, or a mere change in temperature—these and many other factors each introduces changes in the circuit constants and produces a different frequency from the frequency intended. No such difficulties are encountered in accordance with the present invention. The frequency is maintained constant irrespective of the parameter variations. The constancy of the beat note and the consequent certainty of being always in adjustment to receive the given signals is found to be of great value, rendering possible the use of very high frequencies.

The beats render audible unmodulated telegraph signals. Superaudible beats may also be produced, in the case of telephone and telegraph reception, and these may be used for amplifying purposes, as in superheterodyne apparatus. The superposed frequencies may also be used to supply a carrier wave in a radio telephone system where the system operates by suppressed carriers. These results may be effected both in space-communication systems and in wire-communication systems. The invention is particularly useful where constant-frequency sources are used at the transmitting station and also at the receiving station.

The function performed by the piezo-electric crystal may be performed also by other vibrators similarly operating by internal stresses, such as the tuned magnetostriction vibrator of application Serial No. 158,452, filed January 3, 1927, and all such vibrators will be included in the claims under the generic term "electromechanical vibrator" or its equivalent.

The invention is readily adapted to power-amplifying systems, as by a plurality of vacuum tubes; and one such system, adapted for transmission, is illustrated in Fig. 2. The connections are very much as in the transmitting system of Fig. 1, except that the winding 40, instead of being directly coupled to the winding 52 of the antenna circuit, is coupled to a winding 88 that is shunted by a condenser 90. The elements 88 and 90 may be tuned so as to pick off one of the many harmonics from the plate circuit of the master oscillating tube 24. The winding 88 is connected in the grid circuit of an oscillating vacuum tube 92, and that is biased by a battery 94. A winding 96 is connected in the plate circuit of the vacuum tube 92, and is coupled to the winding 52. The vibrator 2 determines the frequency of oscillation of the master oscillating circuit comprising the vacuum tube 24. The master oscillator, which may be of, say, 5 watts, controls, through power amplification of the fundamental or a harmonic, the tube 92 that is adapted to yield an output of much higher power, say 50 watts, and so forth. The frequency of the master oscillator 24 may be caused to beat with the fundamental or the harmonics of the circuits of the tube 92; and the beat may be reduced to zero by suitably tuning the circuits of the tube 92; so that a large number of frequencies may thus be obtained. Such a system has been successfully operated by me, in practice, over a considerable distance. I have utilized harmonics of the device at frequencies of 20,000 kilocycles per second, corresponding to an electric wave of fifteen meters wave length. This range may undoubtedly be extended in both directions. Any desired number of such amplifying units may be interposed in cascade, without in any way departing from the present invention.

A telegraphic transmitting apparatus according to the present invention is illustrated in Fig. 4. The coil 40 is coupled to the coil 52 in the usual manner, as before described. The coil 52 is connected, as before, through a hot-wire ammeter 54, to an antenna 56, and through a variable condenser 58, to a sending key 60. The key 60 is adapted to make and break contact with a grounded contact member 62. The method of telegraphing will be obvious to persons skilled in the art, and need not be further described. The grid is connected with the filament by a conductor 34 having the impedance element 46, which may be used to give the grid a suitable potential about which its fluctuations occur about a zero value. If desired, however, the biasing battery 64 may be employed, as before described, in which event the fluctuations will taken place about the biased value.

Both in telegraphy and in telephony, the oscillations of the system will be kept at practically constant frequency by the vibrators, making it possible, for example, to use a very high frequency, with all the advantages flowing therefrom. For example, consider a frequency of 50,000,000 cycles, corresponding to 6-meter wave length. A control of the frequency to within one tenth of one percent would obviously involve a difference in variation of 50,000 cycles. With a variation in frequency as great as 50,000 cycles, the signal is continually running off the setting of the receiving system, with the result that the operator has to shift continuously, trying to catch it here and catch it there. A part of the signal is detected, but a large part is often lost. According to the present invention, on the other hand, it is possible to maintain the frequency to within 1/100,000 of one percent. This involves a variation of only five cycles on a frequency of 50,000,000. Indeed, by proper care, it is possible to keep the variation within only one cycle.

The importance of this for beat reception will be realized when it is reflected that the local oscillator used for voice modulation may have a frequency of 1,000 cycles. A variation of 50,000 cycles or, for that matter, a variation of only 500 cycles, is a serious problem for beat reception under such circumstances. A variation of only five cycles, on the other hand, or, for that matter, as much as 50 cycles, could readily be handled.

These oscillations may also be employed, with or without amplification, to serve as sources in carrier-wave systems, or to aid in the receiving apparatus of a carrier-wave system. At the receiving station, the local oscillator will replace the suppressed carrier wave and this, with the received side band, will give the complete signal.

The vibrations of the electro-mechanical vibrator may also, in accordance with the present invention, be communicated to air or to some other elastic medium, as water, to produce sound for intercommunication or any other desired purposes.

The use of the Pierce oscillator,—as it is termed in the art,—in the present invention is particularly advantageous, because the system is always certain to oscillate at the frequency determined by the crystal, and at no other frequency. Using some crystal-controlled oscillators heretofore proposed, for example, a comparatively slight variation of the circuit parameters, such as might be caused by running down of the battery voltage, will cause the system to oscillate at a frequency different from the crystal frequency, leaving the crystal inert and out of operation altogether. The circuits continue to oscillate, but at a different frequency from ~~the~~ crystal frequency. This happens without the operator even becoming aware of that fact. The system continues to oscillate without the crystal, and the operator's work becomes entirely vitiated. The transmitting end, for example, may keep on transmitting without the operator knowing that, at the receiving end, it becomes necessary to shift and hunt for the signals, merely because the system at the transmitting end is oscillating without control by the crystal. This is impossible with the Pierce oscillator. The Pierce oscillator can not oscillate except with the aid of the crystal, and at any other than the crystal frequency. When the crystal is disconnected from the system, there are no oscillations. On the other hand, with the crystal in circuit, any variation in the parameters of the system, no matter how great, is automatically compensated for by the crystal itself. As the circuit is thus always under the control of the crystal, the frequency of its oscillations is always constant. Once the system starts oscillating, it is impossible for the frequency of the oscillations to drift out of control by variations in the parameters of the system, or for any other reason.

The Pierce oscillator,—crystal and all,—comprises a periodic system,—that is, a closed system in which any energy liberated in the system must swing periodically from the kinetic or motional form to the potential or stored form and back again, until dissipated. The period or frequency of these swings is a constant of the system, called its "natural frequency" or "natural period."

Other uses and applications and other modifications within the scope of the present invention will also readily occur to persons skilled in the art. It is therefore desired that the above-described embodiments of the invention shall be regarded as illustrative of the invention, and not restrictive, and that the appended claims shall be construed broadly, except insofar as it may be necessary to impose limitations in view of the prior art.

What is claimed is:

1. A transmitting and receiving system having, in combination, means for transmitting signal waves, means for receiving the signal waves, a local oscillating system comprising an amplifying relay having an inherent regenerative coupling, a source of energy, a piezo-electric body, and means connecting the relay, the source and the body together, the connecting means being such that the local system can not oscillate through the inherent regenerative coupling when the body is disconnected from the system, whereby the frequency of the waves of the local oscillating system is maintained substantially constant, and means for combining the received waves with the local waves.

2. A transmitting and receiving system having, in combination, means for transmitting signal waves, means for receiving the signal waves, each of the said means comprising a source of electric energy, a tube

having a plurality of electrodes, an electromechanical vibrator having two electric terminals respectively connected with two of the electrodes, means substantially non-periodically connecting the source, the tube, and the vibrator together to maintain the vibrator in vibration and the system in oscillation with a frequency widely independent of the electrical constants of the system and determined by a mode of mechanical vibration of the vibrator, the electrical parameters of the system being such that the system will not oscillate in the absence of the vibrator, the terminals being adapted to act conjointly both for electric stimulation and electric response to effect the oscillation of the system, and means for evidencing beats.

3. A transmitting-and-receiving system having, in combination, a transmitting system for transmitting electric waves, an electromechanical vibrator connected with the system for maintaining the frequency of the transmitting system substantially constant, the connections being such as to prevent the operation of the transmitting system at other than the said substantially constant frequency, a receiving system for receiving the electric waves, the receiving system being traversed by local oscillations, and an electro-mechanical vibrator connected with the receiving system for maintaining the frequency of the local oscillations substantially constant, the connections of the second-named electromechanical vibrator with the receiving system being such as to prevent the local oscillations at other than the second-named substantially constant frequency.

In testimony whereof, I have hereunto subscribed my name.

GEORGE W. PIERCE.