March 3, 1931. H. CHIREIX 1,794,365

HETERODYNE RECEIVING APPARATUS

Filed March 27, 1926

Fig. 1

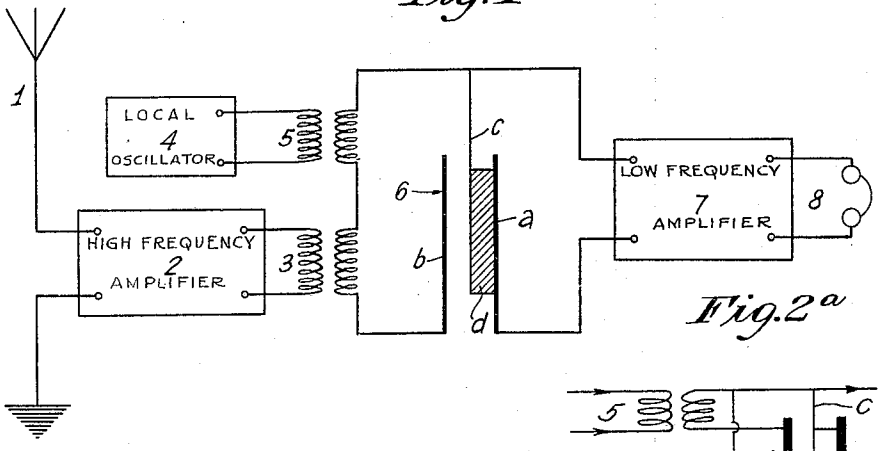



Fig. 2a

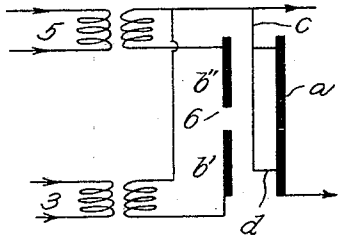
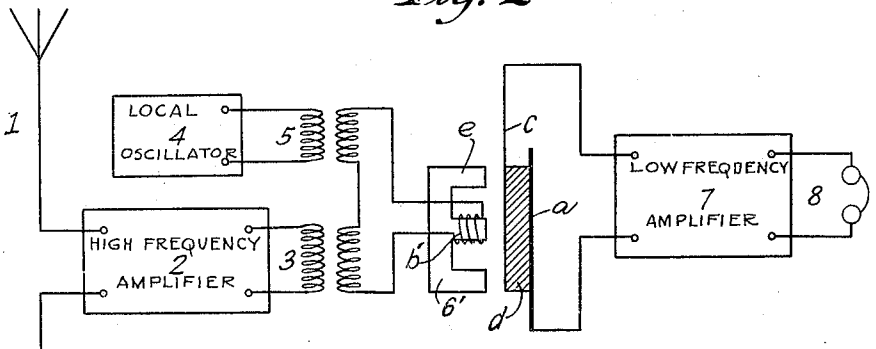



Fig. 2



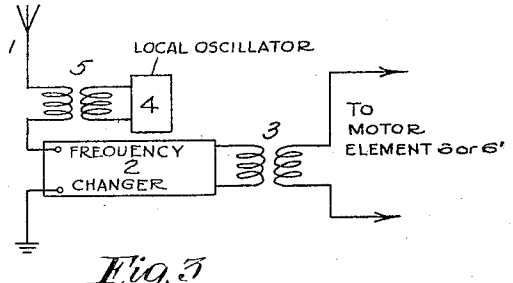




Fig. 3

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# UNITED STATES PATENT OFFICE

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## HETERODYNE RECEIVING APPARATUS

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The present invention has as its object the construction of a receiver for wireless telegraphy and telephony of a new type.

Receiving apparatus are already known of the kind wherein the frequency of the incoming waves is lowered by means of a change in frequency, with the end in view of amplifying them more readily, reducing the number of controls, and attaining sharper tuning. In all of the receivers of this type, the change in frequency is brought about by the aid of vacuum tubes, while tuning is accomplished by the aid of tuned electrical circuits.

The present invention consists in utilizing for the two operations, i. e., changing the frequency and tuning, one and the same element or means, namely, a motor, or moving, element acting upon a piece of piezo-electric quartz, or other substances, possessing piezo-electric properties. The motor element may consist, for example, of a condenser, one plate or armature of which is stationary, while the other one is affixed to the crystal. Again, there may be employed as a motor element an electromagnet whose mobile armature is affixed to the said crystal. The other plate of the crystal in either case, is rendered stationary or immobile by any convenient means.

If the sum of two high frequency potentials is applied to a condenser or to an electromagnet, the force of attraction naturally will be of a complex nature. Calculation shows that by resolving this force into a Fourier series, there is found, among others, a frequency component which is equal to the sum of the frequencies, and another component of frequency equal to the difference of the frequencies. If then, this force is applied to a piezo-electric piece of quartz, and if the frequency of one of said potentials be varied, the said piece of quartz will be subjected to vibrations of great amplitude whenever the total or the difference of the exciting frequencies coincides with its natural period (or with one of its harmonics). This vibration of the quartz may be impressed upon a pair of electrodes, and there will be procured, as a result, a wave having a frequency similar to the natural period of the piece of quartz, or to one of its harmonics. If one of the two frequencies applied to the motor driving element is modulated by Morse signals, or by speech, the vibration of the quartz will follow or respond to such modulation, provided that the damping is sufficient and the wave developed at the electrodes of the quartz itself will be modulated similarly to the former. Since the resonance curve of the quartz is very sharp, it will generally be necessary to provide for damping, or to give it a natural period sufficiently high whenever speech transmission is concerned; in this case, it will usually be preferable to provide for a raising of the frequency.

Hence, the receiving apparatus forming the subject-matter of the present invention comprises a resonator followed, if desired, by amplification, and tuned to the signal to be received, a local generator or controllable and variable frequency, the driving element (motor) acting upon the piezo-electric piece of quartz, and a periodic or aperiodic amplifier-detector connected across the electrodes of the quartz, and characterized by optimum operation at the natural frequency of the quartz.

It must be noted that the piezo-electric quartz thus used actually functions as a motor-generator receiving two frequencies at the motor end, and delivering a single frequency of invariable value at the generating end. It can thus be said that the connection between the elements preceding the piezo-electric quartz and those following it is a purely mechanical connection. In view of the character of this connection and the exceptionally high tuning properties of the quartz, the disturbance-precluding properties of the scheme are very marked.

The invention is shown by way of example in the accompanying drawing in which,

Fig. 1 is a diagrammatic arrangement according to the invention in which a condenser is used as the motor element of the piezo electric crystal,

Fig. 2 is a modification of the arrangement shown in Fig. 1 in which an electromagnetic motor element is used,

Fig. 2*a* is a modification of the motor element shown in Fig. 1,

Fig. 3 is a further modification in which the piezo electric crystal is used principally for sharpness of tuning.

In Figs. 1 and 2, 1 is an antenna connected with the assembly 2 comprising the resonator followed, if desired, by a high frequency amplification stage; 3 denotes a transformer, 4 the local generator of variable frequency, and 5 a transformer.

The secondaries of transformers 3 and 5 are connected to a motor element 6 acting upon the piezo-electric piece of quartz *d*, the two quartz armatures or plates being connected with the amplifier-detector 7 joined to telephone 8.

Referring more specifically to Fig. 1, element 6 consists of two fixed metallic armatures *a* and *b*, and a mobile metallic armature *c* which is movable conjointly with the quartz. The lamina of quartz *d* is cemented to the armatures *a* and *c*, and therefore armature *c* will be set into vibrations as the quartz vibrates.

Referring to Fig. 2, where the structure up to the motor element corresponds to Fig. 1, motor element 6′ consists of a laminated fixed core *e* made of magnetic material, and carrying a winding *b′*, a mobile magnetic armature *c* affixed, as by cementation, to the quartz lamina *d*, and a fixed armature *a* cemented, also, to the quartz lamina *d*. When the quartz vibrates, armature *c* will be set in motion conjointly with it.

Without departing from the spirit of the invention which consists essentially in imparting a resonant vibration to a piezo-electric crystal under the combined action of two high-frequency waves with a view to obtaining a selective change in frequency, it is, of course, possible to conceive other modifications, especially as regards the mode of action on the quartz. For instance, it would be possible to set the quartz in vibration by means of two pairs of electrodes to which the two high frequency waves are applied.

Thus, as shown in Fig. 2*a*, it being understood the structure preceding and following the motor element is the same as in Fig. 1, the quartz lamina *d* is cemented between the plates *c* and *a* while the pair of electrodes *b′*, *b″* correspond to the single condenser electrode *b* in Fig. 1.

It should be understood that while the above described arrangement is the preferred one it is quite feasible to use a piezo-electric resonator to increase the sharpness of tuning after a change in frequency by any of the well known methods.

In the case of such an arrangement, as will be readily understood, the quartz or crystal does not participate in the frequency-changing phenomena, and its use serves the sole purpose of imparting an exceptionally marked selectivity to the amplifier arrangement mounted next to the frequency changing means.

This particular modification of the invention is illustrated by way of example in Fig. 3 where the same numerals are used for denoting the same elements or parts as in Figs. 1 and 2. It will be noted that the local oscillator, instead of acting directly upon the circuit containing the piezo-electric motor element, acts on one of the preceding circuits. (In the example here chosen the oscillator 4 is coupled, as at 5, to the antenna-ground circuit, 1). The output from the frequency changer 2, which includes the high frequency amplifier shown in Figs. 1 and 2, is coupled, as at 3, to the motor element 6 as in Fig. 1, or to the element 6′ as in Fig. 2. The motor element assembly thus happens to be simply a part of the amplifier-detector 7 whose function is to amplify and render perceptible the signals whose frequency has been previously altered.

The use of piezo-electric resonators or tuned circuits of the kind here in question can be extended to cover all other types of receivers than those hereinbefore mentioned; in particular it will be of advantage whenever the point is to increase the sharpness of tuning after a change in frequency.

Having described my invention, I claim:

1. A high frequency signalling circuit, comprising means responsive to incoming signals, a motor member connected with said means and including a movable element, and a piezo-electric crystal mounted upon said movable element for changing the frequency of the incoming signals.

2. A high frequency signalling circuit, comprising means responsive to incoming signals, a local oscillator, a motor member connected to the oscillator and responsive means, the motor member including a movable element adapted to be vibrated by the combined oscillations of the local oscillator and the incoming signals, and a piezo-electric crystal mounted upon said movable element.

3. A high frequency signalling circuit, comprising, in combination, means for receiving signal oscillations, a capacitive motor element including a movable plate, a piezo-electric crystal mechanically coupled to said plate, and a local oscillation generator having a frequency equal to the difference of the signal frequency and the natural frequency of the piezo-electric crystal, the motor element being connected to the generator and receiving means.

4. A high frequency signalling circuit, comprising, in combination, means for receiving signal oscillations, a motor member including a movable plate connected to the receiving means, a piezo-electric crystal mechanically affixed to said plate, and a local oscillation generator connected to the motor

member having a frequency equal to the sum of the signal frequency and the natural frequency of the piezo-electric crystal, the combined signal and local oscillations acting upon said motor member.

5. A high frequency signalling circuit, comprising means for receiving signalling energy, a local oscillator, a capacitive motor member including a movable element, means responsive to the received energy and the local energy for energizing said movable element, a piezo-electric crystal mechanically mounted upon the movable element, and signal responsive means connected to said crystal.

6. A high frequency signalling circuit, comprising means responsive to incoming oscillations, a local oscillator, a capacitive motor element including a movable plate, means responsive to the resultant beat frequency between incoming and local oscillations for electrostatically energizing said movable plate, a piezo-electric crystal, having a natural frequency equal to said beat frequency, mounted upon the movable plate, and signal responsive means connected to said crystal.

7. A heterodyne receiving system having a circuit for combining incoming and local oscillations, a condenser motor element including a movable plate connected to said circuit, a piezo-electric crystal mechanically mounted upon said movable plate, and signal responsive means connected with the crystal.

8. A heterodyne receiving system, comprising means responsive to incoming oscillations, a source of local oscillations, means including a condenser for combining the incoming and local oscillations to produce a beat frequency, said condenser having a fixed plate and a movable plate, a piezo-electric crystal mounted on said movable plate, a second fixed plate mounted on the crystal, and electrical indicating means connected to the movable plate and to said second fixed plate.

9. A receiving system, comprising means responsive to incoming oscillations, a source of local oscillations, a motor means responsive to the beat frequency produced by superposing the incoming and local oscillations, said motor means including a fixed plate and a movable plate, a piezo-electric crystal mounted on said movable plate, a second fixed plate mounted on the crystal, and electrical indicating means connected to the movable plate and to said second fixed plate.

10. An arrangement for changing the frequency of received signal oscillations, comprising means responsive to said signal oscillations, a local source of oscillations, a circuit for combining said oscillations to produce a beat frequency, an electromechanical motor means including a vibrator connected with said combining circuit, and a piezo-electric crystal affixed to said vibrator for producing electrical oscillations of a frequency equal to said beat frequency.

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