

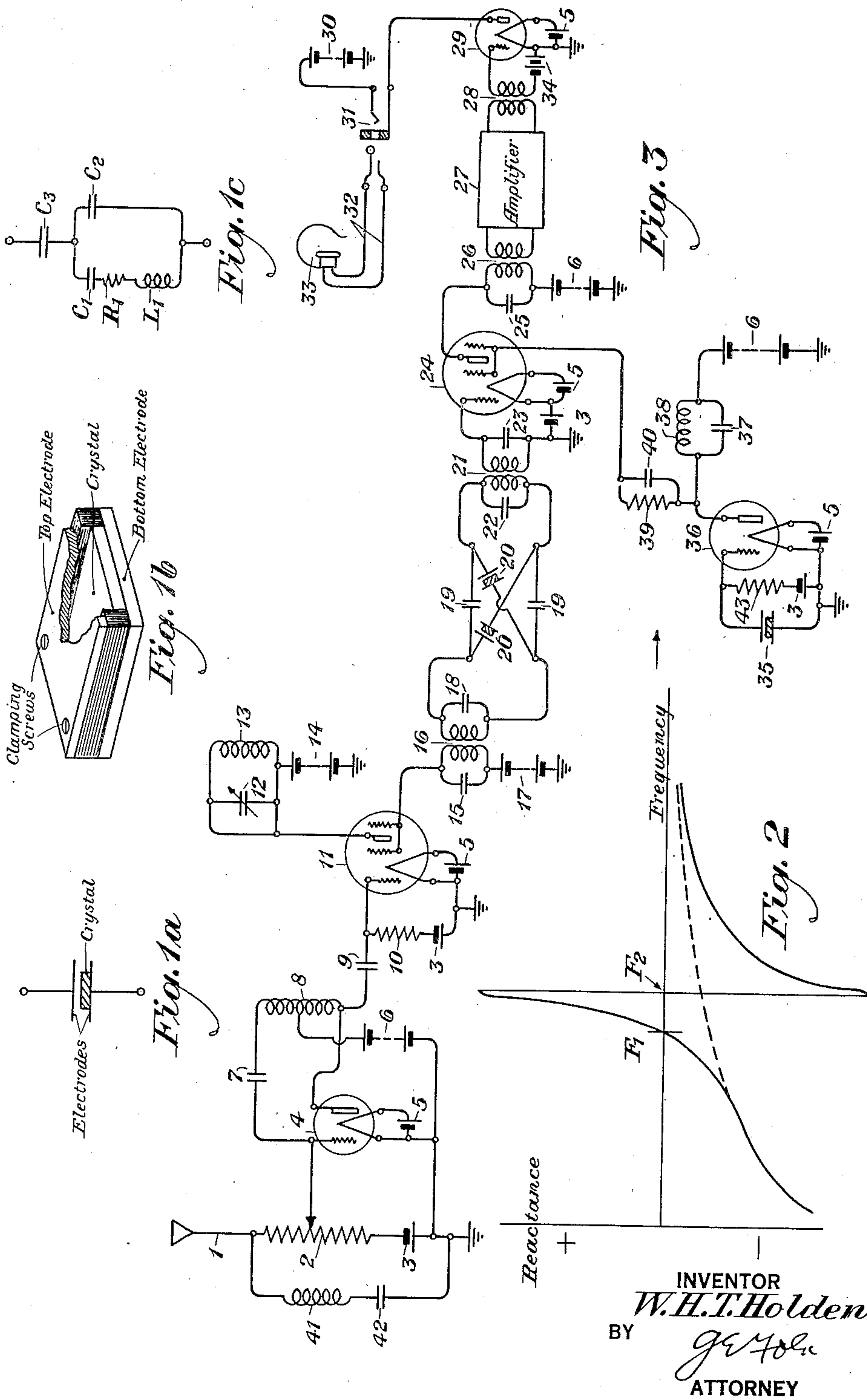
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RADIO RECEIVING SYSTEM

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RADIO RECEIVING SYSTEM

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This invention relates to electrical circuits and, more particularly, to those used for the reception of carrier or radio telephone signals, of the type in which the incoming signal is changed by combination with a locally generated current to a frequency adapted for selection and amplification. Such receivers have been termed superheterodynes.

where

$$C' = \frac{C_1 C_2}{C_1 C_2}$$

Now since $C_2 = 140C_1$, for X-cut crystals, vibrating along the electric axis, we have

$$C' = \frac{140C_1^2}{141C_1} = 0.99291C_1$$

and, therefore,

$$F_2 = 1.00354F_1.$$

The region of positive reactance, i. e. the region between F_1 and F_2 , as shown in Fig. 2, which is a typical reactance-frequency curve for a crystal is, therefore, approximately 0.35 per cent of F_1 in width. Now such a narrow band is not ordinarily regarded as useful and is in fact too narrow to pass intelligible speech, if the frequency F_1 be of the order of a few hundred kilocycles or less. While intelligible speech may be obtained from certain circuit arrangements using crystals as a selective element in low-frequency ranges of the order of a few hundred kilocycles, this can only be done by applying equalization to the crystal output, and to such an extent that much of the crystal selectivity is sacrificed. It is one of the objects of this invention to avoid the necessity for such equalization by operating the crystal selective element at a frequency high enough so that satisfactory transmission of speech can be obtained within a band width of 0.35 per cent of the mid-band.

The capacity C_3 , shown in Fig. 1c, represents the electrical effect of the air gap. The effect is to narrow the region of positive reactance, and this effect may be reduced to a negligible amount by providing very small air gaps or electrodes plated directly on to the crystal.

Referring now to Fig. 3, it will be apparent how the objects of this invention are accomplished. Signals picked up on antenna 1 are applied to the grid of tube 4 from potentiometer 2. Reference numbers 3, 5, 6 indicate, respectively, grid biasing battery, filament heating battery and plate supply battery, respectively, these batteries having values appropriate for amplifier or oscillator operation. While the invention has been explained with reference to a battery operated circuit, it is, of course, to be understood that the same arrangements might be applied to vacuum tube circuits energized from A. C. source, in accordance with well known methods.

Vacuum tube amplifier 4, which is to be operated as a substantially linear amplifier and which should be a tube of relatively large power ca-

It is an object of this invention to utilize the high selectivity and low damping associated with the use of a piezo-electric crystal of quartz or other suitable material in order to obtain a high degree of selectivity against unwanted signals. Such methods proposed heretofore have suffered from serious disadvantage owing to the narrow band of frequencies which is passed by a quartz crystal or other piezo-electric crystal, so that corrective networks or equalizers were required in the output circuits. Unfortunately, such networks greatly reduce the effective selectivity of the arrangement used. A further object of this invention is to apply the piezo-electric crystal in such a manner that little or no equalization is necessary, while at the same time acceptable fidelity can be obtained.

The invention may be more fully understood by reference to the attached drawing in which Figures 1a, 1b, 1c, 2 and 3 illustrate the various features of the invention.

Fig. 1a is the representation of a piezo-electric crystal ordinarily adopted, in which the crystal is placed between two electrodes; Fig. 1b is the crystal as it appears in its holder. In Fig. 1b the electrodes are held together by clamping screws and the crystal is located between the electrodes. Fig. 1c is the equivalent electrical circuit of a piezo-electric crystal.

It can be shown that the electrical equivalents are related to the mechanical properties of the crystal, (as, for example, in "Quartz resonators and oscillators" by P. Vigoreux, His Majesty's Stationery Office, London, 1931) and that the ratio of capacity C_2 and C_1 , of Fig. 1c, is approximately 140 to 1. It can also be seen that the frequency F_1 , at which series resonance occurs, neglecting C_3 , is given by

$$F_1 = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

while the frequency of parallel resonance is given by

$$F_2 = \frac{1}{2\pi\sqrt{L_1 C'}}$$

capacity to avoid cross modulation, is coupled to the grid of the first detector 11 by means of inductance 8 and capacity 9. Neutralizing condenser 7 prevents any tendency of tube 4 to oscillate and ensures its action as a one-way linear amplifier.

The signals amplified in tube 4 are applied to the grid of first detector 11, and it may be noted that thus far no selection has occurred, all signals received on antenna 1 being so applied. The first detector 11 is a tube of the screen-grid type, having a higher potential, from battery 17, applied to the screen than that applied to the plate from battery 14 through the resonant circuit consisting of capacity 12 and inductance 13. Such a combination of potentials will result in sustained oscillation at the frequency of resonance of capacity 12 and inductance 13, by virtue of the negative resistance of the plate circuit thus resulting, as is well-known in the art. It is a property of such dynatron oscillators that beats between the oscillatory frequency produced in the plate circuit and frequencies applied to the control grid are produced in the screen-grid lead. This oscillating first detector 11, in accordance with the objects of this invention, is so arranged that the beat frequency selected by transformer 16, which is tuned by condensers 15 and 18, is the sum of the frequency of the desired signal and the frequency of oscillation of the circuit consisting of capacity 12 and 13, if the signal received is below the frequency selected by the network made up of condensers 19 and crystals 20, as hereinafter described. Capacity 12 is variable, and, in fact, constitutes the sole variable element in the receiver. A rejector circuit consisting of inductance 41 and capacity 42 may be provided across the input potentiometer 2, to prevent signals, which the receiver is not expected to receive but which may lie close to the frequency passed by transformer 16, from causing noise or beat notes in the output. If it is desired to receive signals of frequency above that passed by the selective network, the difference beat frequency will be utilized in the output of first detector 11.

Transformer 16 transmits this additional beat frequency between the desired signal and the frequency generated by tube 11 to the selective network consisting of condensers 19 and piezo-electric crystals 20. (Each of the devices designated 19 and 20 is identical.) The selective network is of the lattice type and it is a well-known property of such a network to transmit only those frequencies for which the series and lattice elements are reactances of opposite sign. This network will, therefore, only pass the frequencies lying within the region of positive reactance of crystal elements 20.

The piezo-electric elements 20 may be sections of a quartz crystal or of any other piezo-electric substance having suitable properties, but crystals of tourmaline which are better adapted than quartz at very high frequencies are preferable in carrying out the principles of the invention.

This network is terminated in transformer 21, the primary and secondary of which are tuned by condensers 22 and 23, and which transmits the signal selected in the condenser and crystal network into the second detector 24, which is also a tube of the screen-grid type. While this tube might be operated as a dynatron oscillator as in the case of the first detector 11, I have preferred the use at this point of a separate oscillator 36, the frequency of which is controlled

by piezo-electric crystal 35. In this circuit, resistance 43 permits grid bias from battery 3 to reach the grid of tube 36, while a resonant circuit consisting of condenser 37 and inductance 38 in the plate circuit of tube 36 provides a proper reactance therein to cause oscillations controlled by crystal 35 to be generated in tube 36. This frequency, superposed on a positive bias, is applied to the screen of second detector 24 through resistance 39 and capacity 40. The frequency of the signal previously selected as described is thus heterodyned down from the high value used in passing through the selective circuits in tube 24 to a lower value convenient for amplification in the intermediate frequency amplifier 27, being applied thereto through transformer 26, the primary of which is tuned by condenser 25.

After amplification, the signal is applied through transformer 28 to the third detector 29. Grid battery 34 supplies a bias to this tube suitable to detector operation. Battery 30 supplies a suitable plate voltage, the circuit being completed through telephone receiver 33, cord 32 and jack 31. If desired, audio-frequency amplification may be provided between the third detector 29 and telephone receiver 33, especially if the latter be of the loud-speaking type.

The reason for the stepping up of signal frequencies in the first detector 11 may be seen when it is considered that the band passed by selective elements 19 and 20 will not exceed 0.35 per cent of mid-band frequency in width. A band 5000 cycles wide is ordinarily required for intelligible speech if an upper frequency limit of 2500 cycles is sufficient in the audio-frequency output. To obtain reasonably good quality this band should be increased to a width of 5000 cycles in the audio-frequency output or a band width of 10,000 cycles in the selective element.

For 2500 cycles maximum audio-frequency, we get

$$500 \times \frac{10,000}{35} = 1400 \text{ kilocycles,}$$

while for 5000 cycles maximum audio-frequency this becomes 2800 kilocycles. Such frequencies are difficult to amplify effectively and on this account the use of a fixed frequency translator, consisting of the oscillator 36 and the second detector 24, is desirable to bring these frequencies down to a few hundred kilocycles at which amplification may be more easily accomplished.

In the preceding description, it has been assumed that the frequencies of the signals received are less than the mid-band frequency of the selective circuit and it has therefore been necessary to raise the frequencies of the incoming signals. This is not necessarily the case as signals may be transmitted thru space at frequencies above that of the selective circuit. In the latter case, the first detector 11 will be employed to reduce the frequencies of incoming signals to the frequencies freely passed by the selective circuit.

While the invention has been described with respect to a specific form, it is to be understood that it is not limited thereto, but includes other and varied arrangements within the scope and spirit of the appended claims:

What is claimed is:

1. In a radio receiver, the combination of a heterodyne detector for raising the frequencies of an incoming band of signals to a higher level, a lattice type of wave filter having as its lattice elements a plurality of similar piezo-electric crystals and as its series elements equal condensers

for freely transmitting the raised band of signal frequencies, the crystals of said filter exhibiting positive reactance only at the frequencies within the band transmitted therethrough, the band of frequencies transmitted by said filter being of a width which is a small fraction of the frequency at the middle of said band, a second heterodyne detector for lowering the frequencies of the signals selected and transmitted by said selective circuit, an amplifier for amplifying the reduced frequencies of the signals, and a detector to convert the signals of reduced frequency into a corresponding band of audio-frequencies.

2. In a receiver for receiving radio signals, the combination of a heterodyne detector adapted to lower the frequencies of incoming signals to a desired level, a piezo-electric selective circuit having as its lattice elements only a pair of piezo-electric crystals and as its series elements only a pair of condensers for freely transmitting the frequencies of the signals lowered in the frequency spectrum, each crystal of said selective circuit exhibiting positive reactance only at the frequencies transmitted therethrough, the band of frequencies transmitted by said selective circuit being of a width which is a small fraction of the median frequency of said band, a second heterodyne detector for further lowering the frequencies of the signals selected and transmitted by the piezo-electric selective circuit, and a detector for converting the latter signals into audio-frequency currents.

3. In a radio receiving system, the combination of a lattice type of wave filter having as its lattice elements a plurality of piezo-electric crystals of similar vibratory frequencies and as its series elements, a plurality of similar condensers freely transmitting high frequencies representing signals, the band transmitted by said filter being relatively narrow as compared with the median frequency of said band, a local oscillator having a piezo-electric device for controlling the frequency of the locally produced oscillations, a detector including a four element vacuum tube, one of the elements of which is a grid and another of which is a screen grid, means for applying the high frequencies transmitted by said wave filter to the grid of the four element tube, means for applying the locally produced oscillations to the screen grid of the four element tube, and means for rendering the output of said detector audible.

4. The method of transmitting a band of speech signals through a band filter including a piezo-electric crystal of high natural period which consists in raising the frequency components of the speech signals to such a high range that the raised high frequencies will all

correspond to the frequencies at which the piezo-electric crystal of the filter exhibits a positive reactance, all of said raised frequencies being substantially freely transmitted, and transmitting only these raised frequency components through the filter.

5. The method of transmitting a broad band of frequencies through a band filter circuit including a piezo-electric crystal which has a high natural vibratory frequency, which consists in raising the frequencies of the band so that the limits of the band are within the region of positive reactance of the piezo-electric crystal and substantially equally transmitting only the raised frequencies through said filter circuit, whereby all frequencies outside of the region of positive reactance of the crystal will be substantially suppressed.

6. A lattice type of filter comprising only two equal series capacitances and only two piezo-electric crystals forming the diagonal elements, said piezo-electric crystals having substantially equal vibratory periods, the limits of the region of positive reactance of said piezo-electric crystals being the limits of free transmission of the filter.

7. A filter for freely transmitting a predetermined range of frequencies comprising means including a piezo-electric crystal having a region of inductive reactance which coincides with and limits the predetermined range of frequencies to be freely transmitted, all of the frequencies within said region being substantially equally freely transmitted.

8. A lattice type of filter comprising means including diagonal elements formed only by piezo-electric crystals which have substantially equal regions of inductive reactance at all of the frequencies at which free transmission will occur, all of the frequencies within said regions of inductive reactance being substantially equally transmitted.

9. A symmetrical filter of the lattice type comprising four impedance branches equal in pairs, one of said pairs of branches including only similar piezo-electric crystal elements, and the other of said branches including similar condensive elements, the impedances of said crystal elements being adapted in combination with the impedances of said condensive elements to pass only a band of frequencies equal in width to the region of positive reactance of the crystal elements.

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