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SIGNALING SYSTEM INCLUDING ADJUSTABLE WAVE FILTER

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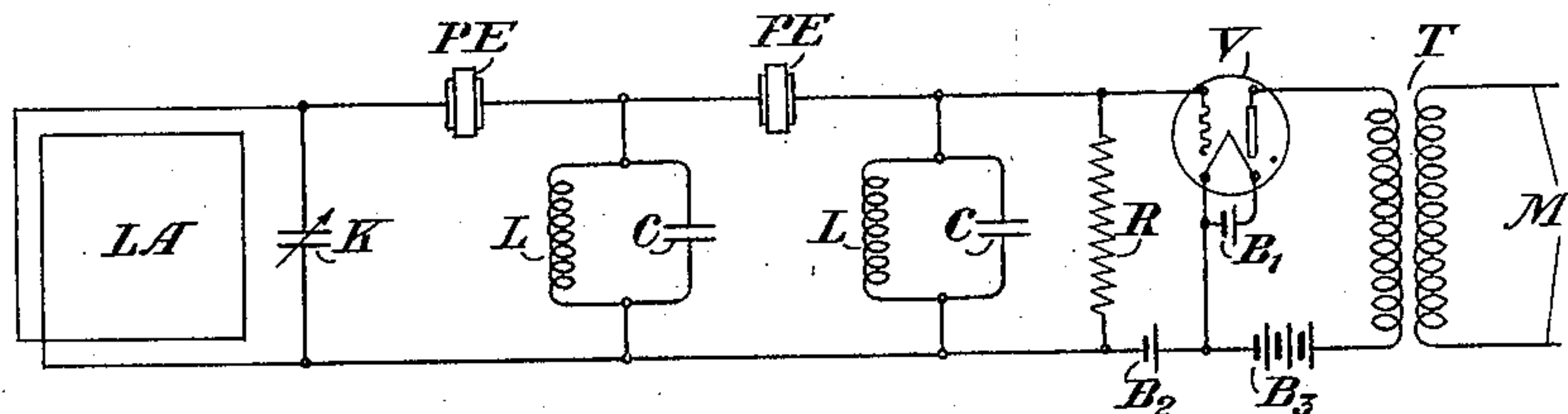


Fig. 1

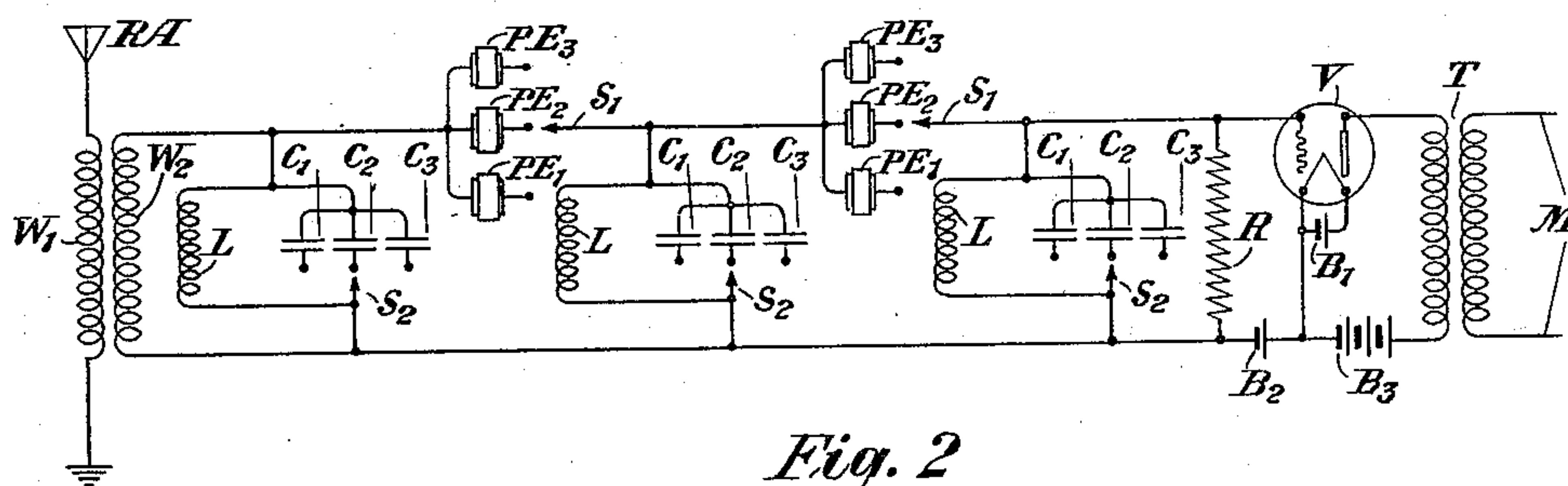


Fig. 2

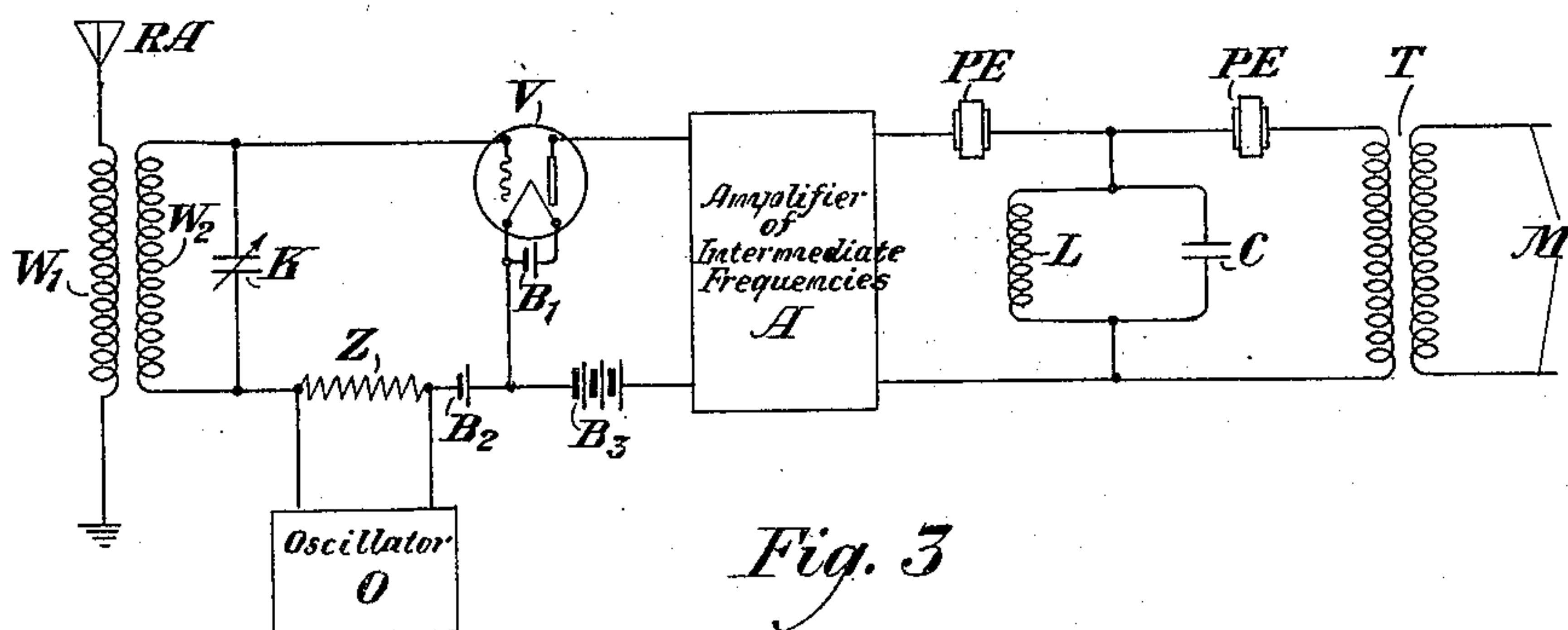


Fig. 3

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SIGNALING SYSTEM INCLUDING ADJUSTABLE WAVE FILTER

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This invention relates to signaling systems, and more particularly to signaling systems employing piezo-electric crystals arranged so that one band of signals may be received to the exclusion of all signals lying outside the band.

This invention is also related to electrical wave filters adapted to transmit, with small or negligible attenuation, currents of all frequencies lying within a desired, particular range of frequencies, while attenuating and substantially suppressing currents of all frequencies lying outside of the limits of the desired, particular range.

This invention may find expression in an electrical wave filter involving a plurality of piezo-electric structures having a plurality of impedance elements so arranged that any one of these elements, or a plurality of these elements of the same magnitudes, may be connected in series with a line, and a plurality of impedance elements any one of which, or several of which having the same magnitudes, may be connected in shunt across the line, the values of the series impedance elements being so proportioned with respect to the values of the shunt impedance elements, that the arrangement will transmit, with small or negligible attenuation, currents of all frequencies lying within a desired, predetermined band while attenuating and substantially suppressing currents of all frequencies lying outside that band.

As is well-known in the art, a simple electrical wave filter may consist of an electrical circuit network which has a negligible transmission loss over one range, while the loss may be appreciable and may become very high over different ranges. If it be attempted to design an electrical wave filter for high impedance circuits with the elements heretofore employed therefor, it will be found that the inductances required become impracticably large and that the capacities become very small, especially when the frequencies involved are high. It is an established fact that it is exceedingly difficult to wind a large inductance which will have an inductive reactance over a wide range of frequencies, due to the distributive capacities of the induc-

tance. Furthermore, the electrical resistance of practicable coils having high inductance tends to greatly reduce the sharpness of the cut-off obtainable in the simple electrical wave filter, and therefore introduce another serious difficulty. These difficulties, as well as others not mentioned, may in part be avoided by the introduction of step-up and step-down transformers, in order that the impedances may be adjusted to the requirements of established filter design. Even such transformers, however, introduce difficulties, especially when the impedance ratio is large, or if a wide frequency range is to be covered, for the same reasons as stated hereinabove.

In order to overcome these difficulties, it is proposed herein to replace some or all of the circuit elements of the simple and well-known electrical wave filter by piezo-electric structures, or by a plurality of similar piezo-electric structures. Such a replacement may become apparent from the partial equivalence of the piezo-electric crystal to some form of electrical network consisting of suitable reactance elements. That this partial equivalence exists, will readily be apparent if a piezo-electric crystal be connected in parallel relationship with a tuned circuit of series inductance and capacity and the arrangement be fed with current from a source of variable frequency. If the current in the tuned circuit may be read on a meter, and the frequency of the source is varied, it will be found that the current therethrough reaches a maximum value at the frequency at resonance of the tuned circuit. If the tuned circuit be so adjusted that its resonant frequency lies very close to the resonant frequency of natural vibration of the piezo-electric crystal, and if the current in this tuned circuit be plotted as a function of frequency, it will be found that at the natural vibratory period of the piezo-electric crystal the current in the tuned circuit will drop to a very low value, rising sharply thereafter as the resonant frequency of the crystal is past. In other words, the crystal acts in some respects like a series resonant circuit of exceedingly low decrement at its resonant frequency. At frequencies somewhat above the frequency at which current

through the crystal is a maximum, the piezo-electric crystal acts like an anti-resonant circuit. Moreover, the crystal will be found to include the equivalent of a resistance element
 5 representing dissipation due to its viscosity.

It is an object of this invention to provide an improved form of electrical wave filter which may comprise a plurality of recurrent sections, each section including a plurality
 10 of piezo-electric devices and a plurality of corresponding reactive elements, whereby a desired piezo-electric device in each section, and a corresponding reactive element, may be selected in order to permit the free trans-
 15 mission of currents having frequencies lying within a band of predetermined limits, currents of all other frequencies being substantially suppressed. It will be apparent that with a suitable selection of piezo-electric de-
 20 vices in each recurrent section, the electrical wave filter may be adjusted to freely transmit currents of any one of a plurality of bands of frequencies.

It is another object of this invention to provide a signaling system capable of receiving a plurality of bands of frequencies with which
 25 piezo-electric means, or a piezo-electric wave filter of adjustable characteristic, may be associated for freely transmitting only one desired band of frequencies, currents of all other frequencies becoming greatly sup-
 30 pressed.

And it is another object of this invention to incorporate in a receiving system for receiv-
 35 ing any one of a plurality of bands of frequencies, each lying within a definite position of the spectrum, a plurality of sets of piezo-electric devices, the various sets being equally graded and having substantially the same
 40 frequencies, one piezo-electric device in one set corresponding to a similar piezo-electric device in each of the other sets, a particular piezo-electric device in each of the various sets being selected and interconnected in order
 45 that currents of frequencies lying within a particular, predetermined band may become freely transmitted. It will be apparent that this invention embodies a novel method for changing the receptivity from one band of
 50 frequencies to another band of frequencies, the transmission characteristic of the interconnected circuit being considerably flatter within the selected transmitting band than has heretofore been possible with electrical
 55 wave filters, and its attenuation characteristic being considerably steeper.

While this invention will be pointed out with particularity in the appended claims, the invention itself, both as to its further
 60 objects and features, will be better understood from the detailed description hereinafter following, when read in connection with the accompanying drawings, in which Figure 1 shows how an electrical wave filter, including
 65 piezo-electric elements, may be embodied in

a radio circuit to freely transmit the radio frequencies, it being practically impossible to use ordinary and well-known reactance elements in electrical wave filters therefor;
 70 Fig. 2 shows how it is possible to change the band of transmission of an electrical wave filter of the piezo-electric type so as to select one or another of a plurality of bands of frequencies, the selected band being freely
 75 transmitted; and Fig. 3 shows a piezo-electric wave filter employed in a lower impedance circuit, as is obtained in the case of an intermediate frequency stage of certain radio receiving systems.

Referring to Fig. 1 of the drawings, a loop
 80 antenna LA is shown, connected to a variable condenser K, these being tuned so as to receive the radio frequencies composed in a band of radio signals as well as the corre-
 85 sponding carrier frequency. The impressed signals are transmitted through a wave filter including piezo-electric elements, the details of which are to be described hereinafter, and are impressed upon the grid and filament
 90 electrodes of a three-element vacuum tube V, which may be employed to act as a demodulator. The filament of this vacuum tube is maintained at a suitable electron-emitting temperature by means of a battery B₁.
 95 The grid electrode is connected to the filament through a resistance R and a battery B₂, whereby a suitable negative potential is maintained at the grid electrode with respect to the filament. The plate electrode of the
 100 vacuum tube V is connected to the filament through the primary winding of the transformer T and a battery B₃, the battery B₃ providing the required operating positive potential for the plate electrode. The sec-
 105 ondary winding of the transformer T couples the output circuit of the vacuum tube V with a wired circuit M. It will be apparent that while the transformer T is represented to
 110 interconnect the output circuit of the vacuum tube V with the wired circuit M, any other well known coupling arrangement may be employed instead thereof, preferably one in-
 115 cluding a pair of suitable reactance elements.

The electrical wave filter interconnecting the loop antenna circuit and the grid and fila-
 120 ment electrodes of the vacuum tube V, may be composed of identical or substantially identical sections each including suitably selected series elements and suitably selected shunt elements. Thus, in Fig. 1 of the drawings,
 125 two sections of a plurality are shown, each including a piezo-electric crystal PE as the series element and an anti-resonant circuit including a winding L and a condenser C as the shunt element. The piezo-electric crystals PE are preferably identical or substan-
 130 tially identical in their structure and characteristics, and accordingly, vibrate at the same or at substantially the same frequencies.

If a piezo-electric crystal such as the one 135

employed herein and designated as PE were connected to a source of alternating current, the frequency of which was adjustable, the piezo-electric crystal would exhibit a capacitative reactance below some frequency such as f_1 , the magnitude of the capacitative reactance decreasing as the frequency f_1 is approached. Beyond the frequency f_1 the reactance would become inductive rather gradually, and as another frequency f_2 is approached, the inductive reactance would decrease very suddenly, becoming a capacitative reactance at and beyond the frequency f_2 . The change from a high inductive reactance to a high capacitative reactance usually takes place within a narrow range of the frequency spectrum. Thereafter, the capacitative reactance decreases in magnitude with increase in frequency. It will be understood that any particular piezo-electric device may undergo these changes, i. e., from capacitative reactance to inductive reactance, and then again from inductive reactance to capacitative reactance, at a number of different frequencies within the spectrum. In the arrangement shown in Fig. 1 of the drawings, the piezo-electric devices PE are selected so that these changes in the character of the reactances are substantially the same and take place at substantially the same frequencies.

By assigning suitable values to the elements employed in the various sections of the electrical wave filter shown interconnecting the loop antenna circuit and the grid and filament electrodes of the vacuum tube V, a system can be provided which will transmit sinusoidal currents having frequencies lying within a preassigned range, which may include, for example, a carrier frequency to which the range is related, while at the same time effectively suppressing the transmission of currents lying outside of the preassigned range as well as the corresponding carrier frequency.

Fig. 2 of the drawings shows a radio receiving system for receiving any one of a plurality of bands of signals and the corresponding carrier frequency. A receiving antenna RA is shown connected to ground through a winding W_1 . This receiving antenna circuit may thus become impressed with a plurality of bands of signals of high frequency components as well as with the corresponding carrier frequencies, these carrier frequencies being necessarily present for the proper demodulation of the various bands. The arrangement of Fig. 2 is designed to freely transmit only one of these bands of signals as well as the corresponding carrier frequency, to the exclusion of all other bands as well as all other carrier frequencies.

Winding W_2 is coupled to winding W_1 . Winding W_2 is connected to the grid and filament electrodes of vacuum tube V through a novel form of electrical wave

filter including piezo-electric elements, this wave filter being one which is capable of adjustment in order that one or another of a plurality of bands composed of high frequency components may become freely transmitted.

The electrical wave filter shown in Fig. 2 of the drawings may be composed of identical or substantially identical sections, each of which may include a group of piezo-electric elements and a group of corresponding reactance elements. Here two groups of piezo-electric crystals and three groups of reactance elements are shown, yet it will be understood that this arrangement may include a third group of piezo-electric crystals and that it may include, in addition, still other groups of piezo-electric crystals and corresponding groups of reactance elements.

Each group of crystals may be graded in accordance with frequencies. Thus, the natural vibratory periods of the crystals PE_1 , PE_2 , and PE_3 , may be arranged in ascending or descending order. As has already been stated, the piezo-electric crystal in one section are the same or substantially the same as the piezo-electric crystals in each of the other sections. Thus, the natural vibratory periods of the crystals designated PE_1 may be the same or substantially the same, and the natural vibratory periods of the crystals designated PE_2 and those designated PE_3 may be the same or substantially the same, respectively.

A switch S_1 may be associated with the crystals of each section so as to connect one or another of these into circuit. Thus, switch S_1 may be manipulated so as to interconnect the various crystals designated as PE_1 . When so connected these crystals are set into vibration, their operation being in synchronism. Similarly, when the piezo-electric crystals PE_2 or PE_3 are connected into circuit, they are also rendered vibratory, operating in synchronism at different frequencies, respectively. The manipulation of the switches designated as S_1 serves to interconnect the series elements of the electrical wave filter.

The shunt elements of the disclosed filter may each be composed of an inductance L in parallel relationship with any one of a plurality of condensers designated in the drawings as C_1 , C_2 , and C_3 . A switch S_2 is present in each shunt element in order to selectively connect any one of the condensers in parallel relationship with the winding L. The various condensers may correspond to the piezo-electric devices representing each group. Thus, condenser C_1 may be of a value designed to function properly when crystals PE_1 become interconnected, condensers C_2 and C_3 being designed to operate in association with piezo-electric devices PE_2 and PE_3 , respectively. By manipulation of the

switches S_2 in the various sections, the shunt elements may be brought into operation, each exhibiting anti-resonance at a frequency of predetermined value corresponding to the particular piezo-electric devices interconnected as series elements.

Fig. 3 represents another embodiment of the invention in which one of the bands of signals composed of radio frequencies, as well as the corresponding carrier frequency, may be selected by manipulation of a condenser K connected across the winding W_2 . An oscillator O is shown transmitting current of a definite frequency to be employed in beating the selected band, as well as the corresponding carrier frequency, to produce a band of intermediate frequencies and a corresponding carrier frequency considerably lowered in the frequency spectrum. The oscillator O is terminated in a resistance Z, the resistance Z and battery B_2 being connected in series with winding W_2 between the grid and filament electrodes of the vacuum tube V. It will be understood that the oscillator O may be any arrangement for producing sustained oscillations, preferably one of the vacuum tube type. Current of the oscillator O is beaten with the selected band of signals in the input circuit of the vacuum tube V acting as a modulator to produce a band of intermediate frequencies and a correspondingly lowered carrier frequency. These are transmitted through an amplifier A and are substantially impressed upon an electrical wave filter which preferably includes piezo-electric elements. Devices PE represent two of a plurality of series elements, while winding L and condenser C are interconnected in shunt relationship to provide an anti-resonant circuit and these represent one of a plurality of shunt elements. This electrical wave filter of the piezo-electric type freely transmits to the circuit M through transformer T the intermediate band of frequencies and the corresponding carrier frequency. Apparatus may be connected to the circuit M to permit the beating of the intermediate band of frequencies and the corresponding carrier frequency in order that the original signals may become reproduced.

It will be understood that suitable impedance elements may be added to the filter structure or structures shown herein to bring about any desirable transmission characteristics therefor, the values of these additional elements being determined from convenience of design or may be made to satisfy some specified requirement such as, for example, that the system shall have a definite and predetermined impedance at some certain frequency or at some certain range or band of frequencies.

It will be further understood that while the filter structure or structures shown in the

drawings may be of the band pass class, any desired electrical wave filter for any range of frequencies or for any circuit network may be designed with suitably selected combinations of piezo-electric devices, within the scope of this invention.

It will be apparent that the principles of this invention are clearly suitable to provide an electrical wave filter composed of groups of piezo-electric elements whereby certain selected piezo-electric elements may become interconnected and rendered vibratory in order that any predetermined band of frequencies may become freely transmitted thereby.

It will also be understood that the number of sections required for a particular wave filter will depend upon the degree to which it is desired to extinguish currents to be filtered out. If the number of sections is increased, the ratio of the magnitude of the current of any particular frequency entering the filter to the magnitude of the current of that frequency leaving the filter may be greatly increased.

While this invention has been pointed out in certain particular arrangement merely for the purpose of illustration, it will be understood that the general principles of this invention may be applied to other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. In a signaling system, the combination of means for receiving a plurality of bands of frequencies, a piezo-electric wave filter having a network of contiguous recurrent sections, and means to adjust said filter to selectively and freely transmit any desired band of frequencies while greatly suppressing the frequencies within all other bands.

2. In a signaling system, the combination of a circuit upon which are impressed bands of modulated signals, an electrical wave filter including a plurality of piezo-electric devices, certain of which may be selected and interconnected in a definite relationship, and means whereby only one band of modulated signals may become transmitted through said electrical wave filter very freely while all other bands become greatly suppressed.

3. In a receiving system for receiving any one of a plurality of bands of frequencies each lying within definite limits of the spectrum, including a plurality of sets of piezo-electric devices, the various sets being equally graded at substantially the same frequencies, one piezo-electric device of one set corresponding to a similar piezo-electric device in each of the other sets, the method of changing the receptivity from one band of frequencies to another band, which consists in selecting the same piezo-electric device in the various sets and transmitting currents of frequencies lying within a predetermined band,

the selected devices being brought into vibration.

4. In a receiving system for receiving any one of a plurality of bands of frequencies each lying within definite limits of the spectrum, the system including a plurality of sets of piezo-electric devices graded equally and with substantially the same frequencies, a piezo-electric device of one set corresponding to a similar piezo-electric device in each of the other sets, the method of changing the receptivity from one band of frequencies to another, which consists in selecting and interconnecting in definite relationship certain similar piezo-electric devices of the various sets corresponding to the band to be received, transmitting the currents of the band to be received, and vibrating the selected and interconnected piezo-electric devices.

5. The combination of a plurality of recurrent sections each having a plurality of piezo-electric devices graded in accordance with frequencies, the piezo-electric devices in one recurrent section being substantially the same as the piezo-electric devices in every other recurrent section, an anti-resonant circuit the natural period of which may be changed as desired, and means for selecting corresponding piezo-electric devices in the various recurrent sections and interconnecting those selected in a definite relationship with the anti-resonant circuit.

6. A receiving system comprising a three-element vacuum tube, input and output circuits for said vacuum tube, said input circuit including a plurality of recurrent sections, each recurrent section including a plurality of piezo-electric devices of different natural frequencies and a plurality of reactances one corresponding to each piezo-electric device, and means for selecting a desired piezo-electric device in each recurrent section to the exclusion of all other piezo-electric devices in that section, the plurality of piezo-electric devices in one section having natural frequencies which are substantially the same as the plurality of piezo-electric devices in each of the other sections.

7. A receiving system comprising a three-element vacuum tube, input and output circuits for said vacuum tube, said input circuit including a plurality of recurrent sections, each section including a plurality of piezo-electric devices and a plurality of corresponding reactive elements, and means in each of the various sections for selecting and operatively associating any desired piezo-electric device and the corresponding reactive element.

8. The combination of a plurality of groups of piezo-electric devices, the piezo-electric devices of one group having natural frequencies different from each other and the same natural frequencies respectively as the piezo-electric devices in each of the other

groups, and means for selecting and vibrating a particular piezo-electric device in each of the various groups, the selected piezo-electric devices being vibrated in synchronism.

9. The combination of a plurality of groups of piezo-electric devices, the piezo-electric devices in one group having natural frequencies which are different from each other and which are respectively equal to the natural frequencies of the piezo-electric devices in any other group, means for selecting a particular piezo-electric device in each of the groups having the same natural frequency, and means for vibrating the selected piezo-electric devices in synchronism.

10. The combination of a plurality of groups of piezo-electric devices, those piezo-electric devices in any one group having substantially different natural frequencies, the natural frequencies of the piezo-electric devices in one group being substantially the same as the natural frequencies of the piezo-electric devices in any other group, a plurality of reactive elements one corresponding to each different natural frequency, a vacuum tube system, and means for selecting and associating the piezo-electric devices of the various groups corresponding to a particular natural frequency and the corresponding reactive element with said vacuum tube system.

11. An electrical wave filter comprising a plurality of recurrent sections, each section including a plurality of piezo-electric devices and a plurality of corresponding reactive elements, and means for selecting the desired piezo-electric device in each section and the corresponding reactive element and interconnecting the selected piezo-electric devices.

12. An electrical system including a plurality of sections, each section having a plurality of piezo-electric elements and a plurality of corresponding reactive elements, and means for selecting any desired piezo-electric element and the corresponding reactive element in each of the various sections, the selected piezo-electric devices being interconnected in series relationship, the selected reactive elements being interconnected in shunt relationship.

13. In an electrical wave filter, the combination of a plurality of groups of piezo-electric elements, the piezo-electric elements of each group having substantially different frequency characteristics, the frequency characteristics of the piezo-electric devices of one group being substantially the same as the frequency characteristics of the piezo-electric devices in any other group, and means for selecting and interconnecting a particular piezo-electric element in each of the various groups and vibrating the selected piezo-electric elements in synchronism.

14. The combination of a radio frequency

circuit, a vacuum tube system, and an electrical wave filter including a plurality of contiguous recurrent sections arranged to freely transmit any desired band of radio signals from the radio frequency circuit to the vacuum tube system, each section of said electrical wave filter including a piezo-electric device.

15. The combination of a radio frequency circuit, a vacuum tube system, an electrical wave filter including a plurality of similar contiguous recurrent sections which are interconnected and couple the radio frequency circuit with the vacuum tube system, each section of said electrical wave filter including a piezo-electric device, and means to adjust the electrical wave filter to permit the free transmission of any one of a plurality of bands of radio signals which may be impressed on the radio frequency circuit to said vacuum tube system, to the exclusion of all signals having frequencies lying outside the selected band.

16. The combination of a wave collecting device capable of collecting radio frequency signals, a vacuum tube system, a piezo-electric structure coupling the wave collecting device with the vacuum tube system, said piezo-electric structure including a plurality of contiguous recurrent sections each of which comprises a piezo-electric device, the various piezo-electric devices being interconnected in tandem, and means whereby the piezo-electric structure may freely transmit only those currents of radio frequencies lying within any one of a plurality of bands each occupying a predetermined portion of the frequency spectrum to the exclusion of currents of all other frequencies.

In testimony whereof, I have signed my name to this specification this 28th day of December 1927.

CHARLES H. FETTER.

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