

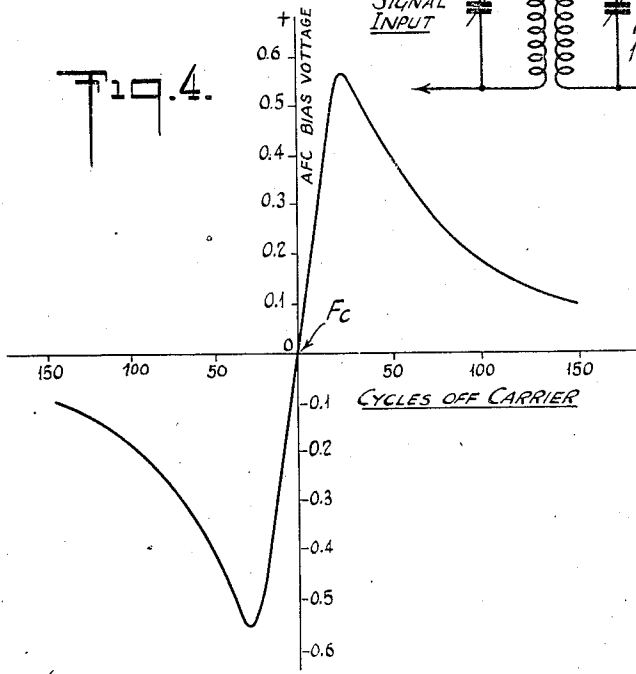
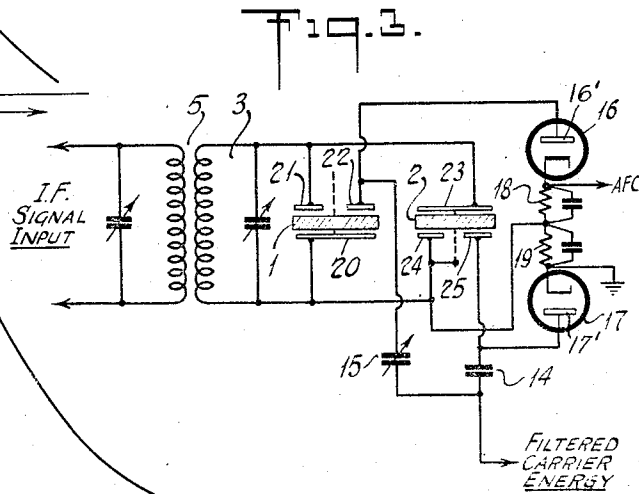
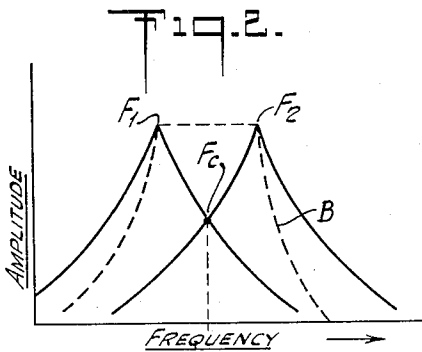
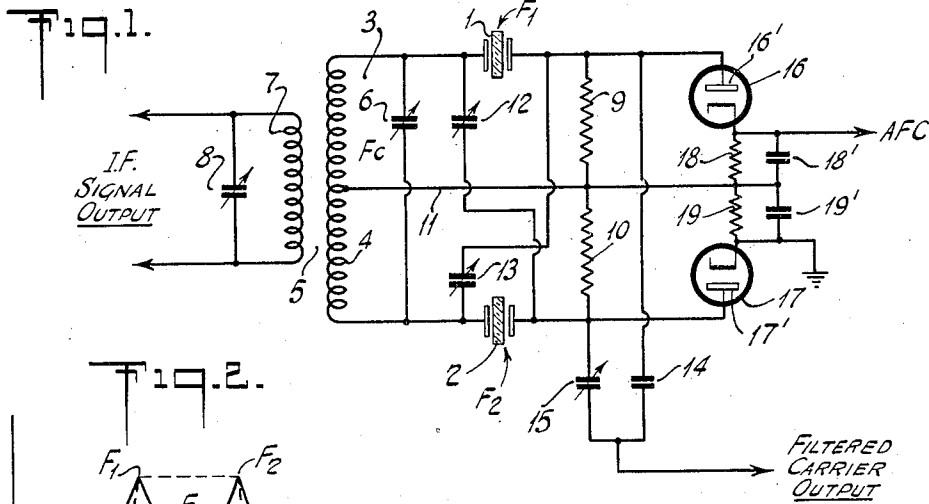
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2,374,735

COMBINED DISCRIMINATOR AND CARRIER FILTER CIRCUIT

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COMBINED DISCRIMINATOR AND CARRIER
FILTER CIRCUITSMurray G. Crosby, Riverhead, N. Y., assignor to
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My present invention relates to combined frequency discriminator and carrier energy filter networks, and more especially to an improvement in a piezo-electric crystal discriminator and carrier filter.

One of the main objects of my present invention is to provide a carrier filter network of the piezo-electric crystal type which has a substantially flat-topped band pass response characteristic at its output terminals whereby pure carrier energy may be effectively supplied to the demodulator of a carrier-exalted receiver; the same network additionally functioning as a sharp discriminator for an automatic frequency control (AFC) system of the same receiver.

Another important object of my invention is to provide a crystal detection circuit for phase modulated ("PM" hereinafter for brevity) carrier waves, or amplitude modulated ("AM" hereinafter for brevity) carrier waves, the detection circuit having a relatively sharp "frequency deviation-rectified output" characteristic; the crystal discriminator section of the detection circuit being constructed to have a flat-topped response characteristic at its output terminals whereby filtered carrier energy may be supplied with uniform response over a range of frequency shift.

Another object of my invention is to improve the action of carrier exaltation receivers by constructing the carrier supply source as a filter network having a pair of piezo-electric crystals equally mistuned to opposite sides of a predetermined reference frequency whereby the response characteristic at the filter output terminals is band pass with a substantially flat top.

Still other objects of my invention are to improve the reception of carrier-exalted receivers, and to provide improved circuits capable of economical and ready manufacture and assembly.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description, taken in connection with the drawing, in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows an embodiment of the invention.

Fig. 2 illustrates the response characteristics of the carrier filter network.

Fig. 3 shows a modified form of circuit,

Figure 4 illustrates the AFC characteristic provided by either of the circuits of Figs. 1 and 3.

Referring now to the accompanying drawing, wherein like reference characters in the different figures designate similar circuit elements, there is shown in Fig. 1 that portion of a combined carrier filter network and AFC circuit which is sufficient for an understanding of my invention. It is first pointed out that in the reception of either PM carrier wave energy or AM carrier wave energy, it is often desirable to provide carrier exaltation. As those skilled in the art fully know, carrier exaltation is employed to overcome the effects of selective fading. In a carrier-exalted receiver, and at some point in the receiving system prior to the demodulator, a certain portion of the modulated carrier wave energy is subjected to a filter action so that the modulation side bands can be removed, and the resulting filtered carrier energy is employed.

The resulting relatively pure carrier energy is usually injected into the demodulator circuit in such a manner that any relative change in amplitude which may exist between the carrier and modulation side bands is effectively overcome by the injected pure carrier energy. This process has been generically indicated as "carrier exaltation." It is important that the selective characteristics of the carrier filter be such as to adequately reject the side bands. The system of the present invention makes use of a pair of piezo-electric crystals to produce a band pass filter having a greater degree of side band rejection than prior single crystal circuits.

Accordingly, there is provided, in accordance with my invention, a piezo-electric crystal filter network which is capable of substantially removing all modulation side bands from the carrier, but which filter has a substantially flat-topped band pass characteristic at the output terminals thereof. Referring to Fig. 1, the piezo-electric crystal elements of the carrier filter network are indicated by numerals 1 and 2. Each of these crystals is mounted between the usual pair of electrodes. A common resonant input circuit 3 feeds the modulated carrier wave energy to these crystals. Hence, the input electrode of crystal 1 is connected to one side of the input circuit 3, while the input electrode of the crystal 2 is connected to the opposite side of the resonant input circuit.

The input circuit 3 employs the secondary winding 4 of input transformer 5. The tuning condenser 6 is connected in shunt with the winding 4 so as to tune the input circuit 3 to a desired

predetermined operating frequency. The aforesaid predetermined operating frequency, in the case of a superheterodyne receiver, will be the intermediate frequency (I. F.). The primary winding 7 is shunted by its own tuning condenser 8, and the circuit 7-8 is also tuned to the I. F. value. It is not necessary to disclose the circuits of a superheterodyne receiver between the usual signal collector device and the primary circuit of transformer 5. Those skilled in the art are fully acquainted with superheterodyne receiver construction. Where the received signal energy is AM carrier wave energy, there will be provided a branch connection from the circuit 7-8 to a demodulator network of any well known type, such as that shown in my U. S. Patent No. 2,063,588, issued December 8, 1936. In such case the filtered carrier output of crystals 1 and 2 will be fed to such amplitude modulation detector. Where the received signal energy is PM carrier wave energy, then the circuit 8-7 may be preceded by an amplitude modulation limiter so as to suppress any amplitude modulation effects. Here, again, a branch circuit will lead from the circuit 7-8 to a demodulator which may take the form of any well known PM detector circuit. In this case, also, the filtered output energy of the crystals 1 and 2 will be injected into the PM detector circuit to secure the advantages of carrier-exalted reception.

In the case of AM wave reception, or PM wave reception, the circuits 7-8 and 4-6 are each tuned to the mean, or carrier, frequency F_c of the applied signal energy. Since it is desirable to provide AFC voltage as well from the network the crystal filter is additionally constructed in the manner of a frequency discriminator. Hence, it will be responsive to frequency shifts of the signal energy with respect to the predetermined frequency of input circuit 3. Accordingly, crystal 1 is ground so as to be tuned to a frequency F_1 which is located a predetermined frequency distance from the above-mentioned center, or mean, frequency F_c . The crystal 2 will then be ground so as to be tuned to a frequency F_2 located on the opposite side of F_c by an equal frequency spacing from the mean frequency.

In Fig. 2 there is shown by solid line curves the "frequency-amplitude" characteristics of crystals 1 and 2. It will be seen that they have sharp peaks at their resonant frequencies F_1 and F_2 . The cross-over frequency of the two characteristics is F_c . The dotted line curve B in Fig. 2 illustrates the over-all response characteristic at the output terminals of the crystals 1 and 2. The output electrodes of the crystals 1 and 2 are connected together by resistors 9 and 10. The junction of these two resistors is connected by lead 11 to the midpoint of winding 4.

The capacity existing between the electrodes of each crystal is neutralized by voltage fed through a respective neutralizing condenser. Thus, the numeral 12 indicates the neutralizing condenser for the inter-electrode capacity of crystal 2. One terminal of condenser 12 is connected to the output electrode of crystal 2, while the opposite terminal is connected to the upper end of winding 4. The neutralizing condenser 13 for the inter-electrode capacity of crystal 1 is connected between the output electrode of crystal 1 and the lower end of winding 4. The condenser 14 is connected to the output electrode of crystal 1, while the condenser 15 is connected to the output electrode of crystal 2. The junction of condensers 14 and 15 is the point from which the substantially pure

carrier energy is derived from the crystal filter network. It is this filtered carrier energy which is supplied to the receiver modulator (not shown) for carrier exaltation. At the output terminals of the crystal filter network the frequency-amplitude characteristic is the dotted line characteristic B of Fig. 2. It will be seen that the amplitude of the pure carrier energy will be substantially uniform between the limiting frequencies F_1 and F_2 . By locating these limiting frequency values at a reasonable frequency spacing from F_c , the filtered carrier energy may shift in frequency without any substantial change in amplitude thereof. Furthermore, the band pass action produced effects a high degree of side band rejection as is evident from the flanks of curve B.

Since the crystals 1 and 2 are equally and oppositely mistuned with respect to the mean frequency F_c of the applied signal energy, AFC voltage is readily supplied by connecting a pair of opposed rectifiers to the output terminals of the crystals. These opposed rectifiers are diodes, and are designated by numerals 16 and 17 respectively. The anode 16' of rectifier 16 is connected to the output electrode of crystal 1, while the anode 17' of rectifier 17 is connected to the output electrode of crystal 2. The cathodes of both rectifiers are connected together by the series-arranged load resistors 18 and 19. The junction of resistors 18 and 19 is connected to the junction of the return resistors 9 and 10. Condensers 18' and 19' respectively shunt the load resistors 18 and 19 to bypass intermediate frequency currents. The cathode of rectifier 17 is grounded, and the AFC bias is taken off from the cathode end of resistor 18.

The functioning of the crystal network as a discriminator will be readily understood by those skilled in the art. Since the two crystals are respectively tuned to frequencies equally and oppositely displaced from the center frequency of the applied signal waves, it follows that a shift of the mean frequency of the applied signal waves from the predetermined center frequency F_c will result in the development of relatively increased rectified voltage across the load resistor of that rectifier which is connected to the crystal whose resonant frequency is located in the direction of the aforesaid frequency shift. In other words, if the mean frequency of the applied signal waves shifts in the direction of F_1 , then the rectified voltage developed across load resistor 18 will be greater than that developed across load resistor 19. Hence, the AFC bias will be the differential resultant of the two voltages, and will be essentially positive with respect to ground.

Furthermore, the magnitude of the positive potential will be a function of the extent of frequency shift. On the other hand, if the frequency shift is in the direction F_2 then the rectified voltage across resistor 19 will be greater, and the AFC bias will be essentially negative relative to ground. In Fig. 4 I have shown a calculated discriminator characteristic. It will be seen that the peak rectified voltage is developed for each rectifier substantially 25 cycles off the carrier frequency. In other words, the peak frequencies of the crystals 1 and 2 may be spaced 50 cycles apart. There would be developed linear AFC bias over the range of 50 cycles. Beyond these peak frequencies the AFC bias decreases very sharply. It will be clear that the type of characteristic shown in Fig. 4 is sharp, and will tend to control the local oscillator of the receiver quite rigorously.

Any frequency shift from F_c will result in AFC bias which will be applied to the local oscillator in the usual manner to overcome the frequency shift. It will, also, be appreciated that if the frequency spacing between F_1 and F_2 is 50 cycles, then the filtered carrier energy derived from condensers 14 and 15 will be capable of shifting over a range of 50 cycles without change in amplitude. Of course, my invention contemplates any frequency spacing between the peak frequencies of crystals 1 and 2. Furthermore, the condensers 14 and 15 are adjusted to give equal output from each crystal. This would make them approximately equal in magnitude, but if there were amplitude differences in the crystal filters compensation would be possible with these condensers. The two crystal filters are separately neutralized, as previously explained. In this respect the circuit has an advantage over the usual band pass circuit in that line-up is simplified; that is, there is a separate detector connected to each filter section to indicate when proper neutralization is achieved.

In Fig. 3 I have shown a modification wherein the neutralizing condensers 12 and 13 may be dispensed with. In this case, the crystals are positioned between crystal holders of the three-electrode type. Thus, the crystal 1 has on one face thereof a single electrode 20 which is connected to the low potential side of input circuit 3. The opposite face of the crystal is provided with a pair of spaced electrodes 21 and 22. Electrode 21 is connected to the high potential side of input circuit 3. The second electrode 22 is connected to the anode 16' of rectifier 16. An electrostatic shield is provided between the electrodes 21 and 22, as indicated by the vertical dotted line extending from the grounded electrode 20 of crystal 1. Electrode 22 is the output electrode. The crystal 2 has its single electrode on one face thereof designated by numeral 23, and the latter is connected to the high potential side of input circuit 3. The opposite face of crystal 2 is provided with the spaced electrodes 24 and 25.

The electrode 24 is connected to the low potential side of input circuit 3. The electrode 25 is the output electrode of the crystal, and is connected to the anode 17' of diode 17. Crystal 2 is, also, provided with an electrostatic shield which is indicated by the dotted line. The output condensers 14 and 15 are connected to the crystal output electrodes 25 and 22 respectively. The essential difference between the circuit of Fig. 3 and that of Fig. 1 resides in the fact that neutralization of the crystal inter-electrode capacities is provided by means of the specific three-electrode construction. Otherwise, the functioning of this circuit is precisely the same as has been explained in connection with Fig. 1. In other words, in the system of Fig. 3 the crystal 1 feeds its filtered output to rectifier 16, while the crystal 2 feeds its filtered output to rectifier 17. Any frequency shift of the carrier relative to F_c will be quickly compensated for by the AFC bias.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In combination with a source of high frequency signal energy, a resonant input circuit tuned to a predetermined reference frequency, a first piezo-electric crystal element provided with input and output electrodes having an input electrode connected to one side of the input circuit, a second piezo-electric crystal element provided with input and output electrodes, said second crystal input electrode being connected to the opposite side of said input circuit, said crystal elements being respectively tuned to frequency values spaced by relatively small amounts on opposite sides of said reference frequency, means for deriving from the output electrodes of said crystal elements filtered energy of said reference frequency, a first rectifier in circuit with said first crystal element to rectify solely the filtered output energy thereof, a second rectifier in circuit with the second crystal element to rectify solely the filtered output energy thereof, and a common output circuit connecting said rectifiers in polarity opposition thereby to provide a differential rectified output voltage whose polarity and magnitude depend respectively upon the direction and extent of the frequency shift of said applied signal energy from the said reference frequency.

2. In combination with a source of phase modulated carrier wave energy, a crystal filtered network for providing substantially pure carrier energy, said network including a pair of piezo-electric crystal elements provided with respective input and output electrodes, said crystal elements having peak frequencies respectively equally mistuned with respect to a predetermined reference frequency equal to the center frequency of applied phase modulated carrier waves, means coupled to the output electrodes of said crystal elements for deriving therefrom said substantially pure carrier energy, and said peak frequencies being sufficiently close together to provide a response characteristic at the output electrodes of said crystal elements which is a substantially flat-topped, band pass characteristic whereby the substantially pure carrier energy may reasonably shift in frequency without change in amplitude and whereby, in addition, there may be effected a high degree of side band rejection.

3. In combination with a source of phase modulated carrier wave energy, a crystal filter network for providing filtered carrier energy, said network including a pair of piezo-electric crystal elements whose peak frequencies are respectively equally mistuned with respect to the center frequency of applied phase modulated carrier waves, means coupled to the output electrodes of said crystal elements for deriving therefrom said filtered carrier energy, said peak frequencies being spaced by a slight amount thereby to provide a response characteristic at the output electrodes of said crystal elements which is a substantially flat-topped, band pass characteristic whereby the filtered carrier energy may reasonably shift in frequency without change in amplitude, a first rectifier connected in circuit with one of said crystal elements to rectify solely the filtered carrier output energy thereof, a second rectifier connected in circuit with the second crystal element to rectify solely the filtered carrier output energy thereof, said rectifiers being connected in opposition, and a common rectified voltage output circuit connected to said opposed rectifiers to provide a differential rectified voltage whose magnitude and polarity are dependent respectively

upon the extent and direction of frequency shift of the center frequency of the applied modulated wave energy from the mean frequency of said crystal peak frequencies.

4. In combination with a source of amplitude modulated carrier energy, a resonant input circuit tuned to the carrier frequency of applied energy, a first piezo-electric crystal provided with an input electrode connected to the input circuit, a second piezo-electric crystal provided with an input electrode connected to said input circuit, said crystals being respectively tuned to frequency values equally spaced by a relatively small amount on opposite sides of said carrier frequency, a first rectifier in circuit with said first crystal to rectify solely the filtered output energy thereof, a second rectifier in circuit with the second crystal to rectify solely the filtered output energy thereof, and a common output circuit connecting said rectifiers in polarity opposition.

5. In combination with a source of modulated carrier wave energy, a network including a pair of piezo-electric crystal elements whose peak frequencies are respectively equally mistuned by slight frequency values with respect to the center frequency of applied modulated carrier waves, each of said crystal elements having a respective pair of input and output electrodes, means coupled to the output electrodes of said crystal elements for deriving therefrom substantially pure carrier energy, the response characteristic at the output electrodes of said crystal elements being a substantially flat-topped, band pass char-

acteristic, a separate rectifier coupled to a respective crystal element to rectify solely the filtered carrier energy thereof, and a common rectified voltage output circuit connecting the rectifiers in opposition.

6. In combination with a source of amplitude modulated carrier wave energy, a crystal filter network for providing substantially pure carrier energy, said network including a pair of piezo-electric crystal elements whose peak frequencies are respectively relatively slightly mistuned with respect to the mean frequency of applied modulated carrier waves, means coupled to the output electrodes of said crystal elements for deriving therefrom said substantially pure carrier energy, the response characteristic at the output electrodes of said crystal elements being a band pass characteristic whereby the pure carrier energy may reasonably shift in frequency without substantial change in amplitude, a first rectifier connected in circuit with one of said crystal elements to rectify solely the filtered output energy thereof, a second rectifier connected in circuit with the second crystal element to rectify solely filtered output energy thereof, said rectifiers being connected in opposition, and a common rectified voltage output circuit connected to said opposed rectifiers to provide a differential rectified voltage whose magnitude and polarity are respectively dependent upon the extent and direction of frequency shift of the mean frequency of the applied modulated wave energy from the mean frequency of said crystal peak frequencies.

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