March 3, 1931. E. I. GREEN 1,794,847

FREQUENCY ELIMINATOR

Filed March 18, 1927

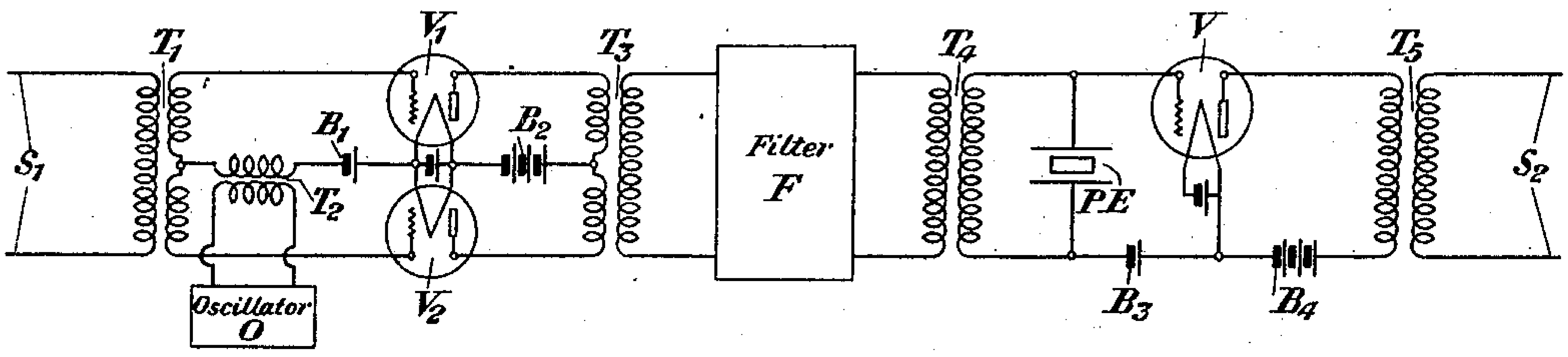

Fig. 1

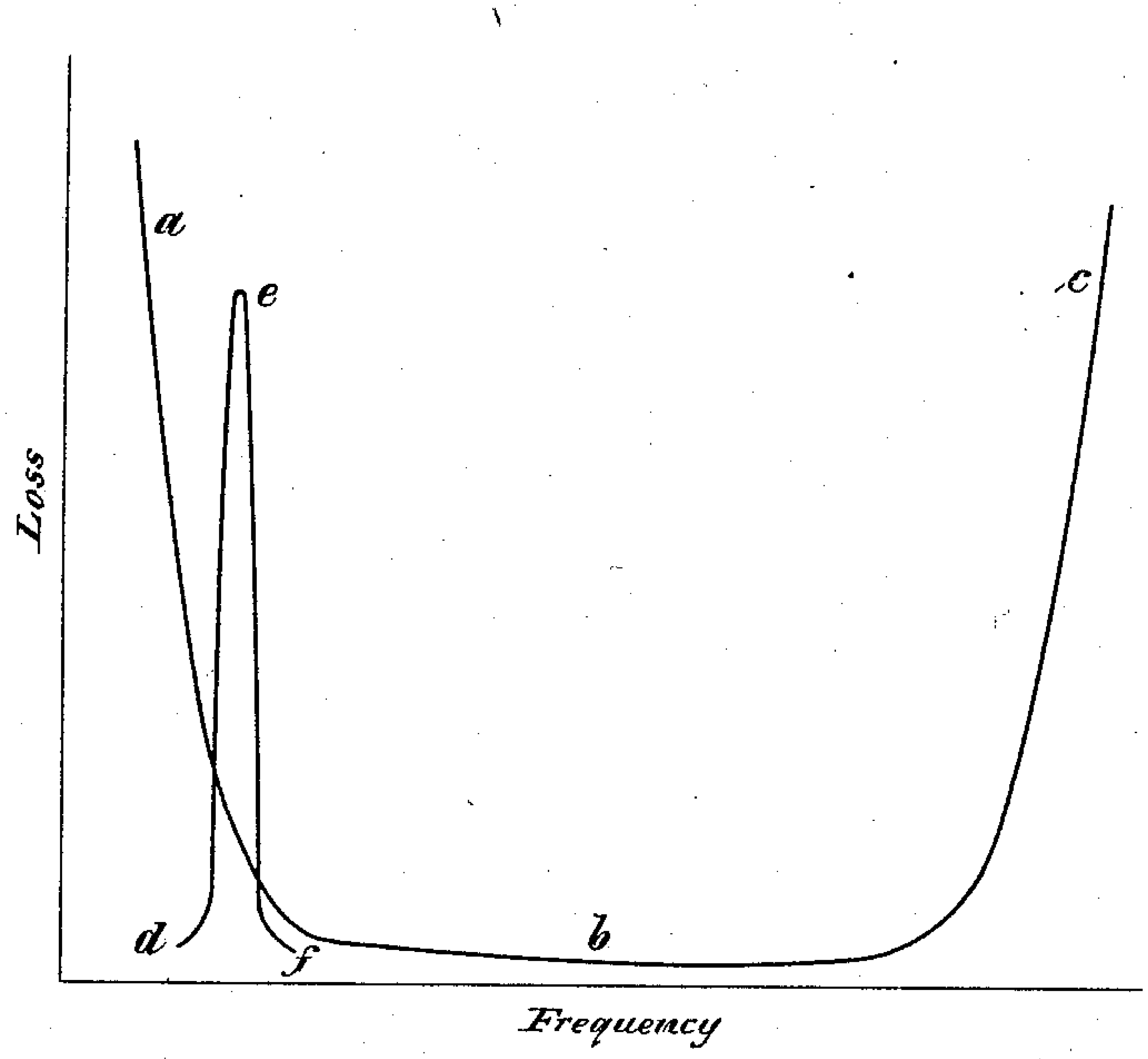

Fig. 2

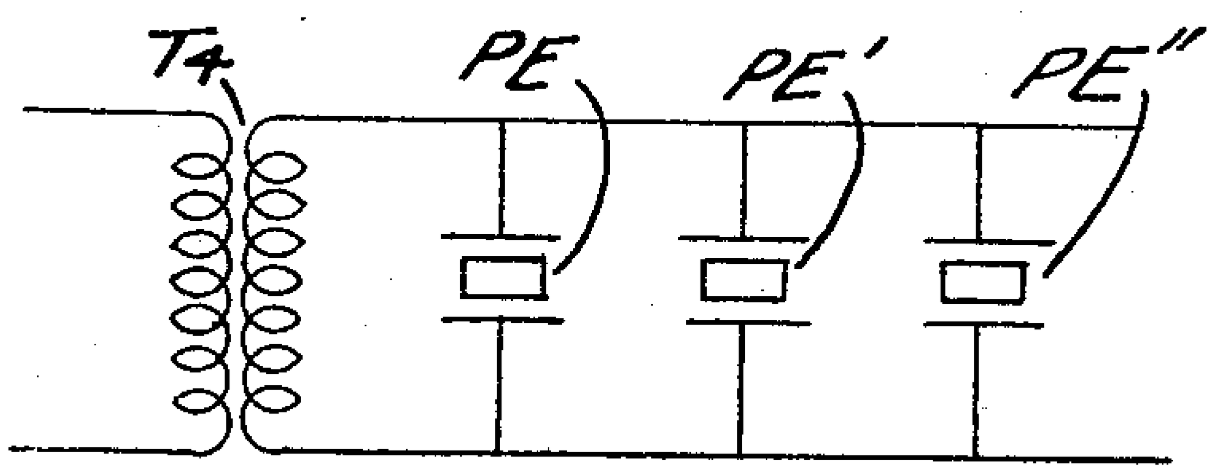

Fig. 1a.

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UNITED STATES PATENT OFFICE

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FREQUENCY ELIMINATOR

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This invention relates to signaling systems, and particularly to arrangements in such systems for eliminating currents of definite frequencies.

In systems in which current of a carrier frequency is modulated by voice frequency signals so as to produce side bands of the carrier frequency corresponding to the voice frequency signals, it is frequently the practice to employ an electrical wave filter to suppress one of the side bands and to freely transmit the other of the side bands. In such systems, the elimination of certain frequencies of the undesired side band, particularly of those frequencies that are closely adjacent to the carrier frequency in their position in the frequency spectrum, has been extremely difficult of accomplishment with the ordinary designs of electrical wave filters. If any of the component frequencies of the undesired side band are transmitted through the electrical wave filter, such transmitted frequencies will become demodulated at the receiving terminal of the system, and thereby constitute a source of interference, the seriousness of which will depend largely upon the magnitudes of such transmitted frequencies and upon the phase relationship existent between the current of carrier frequency at the receiving terminal and the current of carrier frequency at the transmitting terminal.

Accordingly, it is an object of this invention to employ a piezo-electric structure to act as a means of suppressing undesirable frequencies at or near the cut-off point of an electrical wave filter.

It is another object of this invention to associate a piezo-electric structure with a device exhibiting attenuation which is variable with frequency, the piezo-electric structure being operated so as to provide very high attenuation for a number of frequencies or for all frequencies within a small region of the frequency spectrum.

While this invention will be pointed out with particularity in the appended claims, the invention itself, both as to its further objects and features, will be better understood from the detailed description hereinafter following, when read in connection with the accompanying drawing, in which Figure 1 represents a signaling system embodying the principles of this invention, Fig. 1*a* represents a portion of the signaling system shown in Fig. 1 in modified form, and Fig. 2 represents curves characteristic of the elements of the invention.

Referring to Fig. 1 of the drawing, there is shown a source of signals S_1 connected to the primary winding of the transformer T_1. The secondary windings of the transformer T_1 are connected to a duplex modulating system having two three-element thermionic tubes V_1 and V_2, the filaments of which are heated to electron-emitting temperatures by a common battery. These thermionic tubes are preferably similar and equal in their structure and characteristics, and may be replaced by a single duplex tube having a single filament, two grids and two plates. The input circuits of these thermionic tubes are arranged in parallel with respect to the secondary winding of the transformer T_2, which winding is in series with a battery B_1 in the conductor common to the input circuits of these tubes. The output circuits of these tubes are connected through the primary windings of a transformer T_3 in parallel with respect to a common plate battery B_2. The secondary winding of the transformer T_3 is connected to an electrical wave filter which may be of any well-known type, preferably of the type disclosed in the patent to G. A. Campbell, No. 1,227,113, dated May 22, 1917.

The output terminals of the filter F are connected to the primary winding of the transformer T_4. The secondary winding of the transformer T_4 is connected to the input terminals of a translating device, such as a three-element thermionic tube V, the input circuit of which includes the grid and filament of the thermionic tube V, a battery B_3 and the secondary winding of the transformer T_4. The filament of the thermionic tube V is also heated to an electron-emitting temperature by a local battery, which may, in this illustration, be the same as the battery which heats the filaments of the thermionic tubes V_1 and V_2 to electron-emitting temperatures. The output circuit of the thermionic tube V includes the filament and plate of the thermionic tube V, the primary winding of transformer T_5 and a battery B_4. The secondary winding of the transformer T_5 is connected to an output circuit S_2. A piezo-electric device PE is connected in shunt with the input circuit of the thermionic tube V, the piezo-electric device being shown bridging the secondary winding of the transformer T_4.

An oscillator O, which may be of any well-known type, preferably of the vacuum tube type, is connected to the primary winding of the transformer T_2. This oscillator generates current of the carrier frequency to be employed in the process of modulation in the system. By virtue of the connection of the oscillator O and the transformer T_2 in the duplex translating system, the grids of the tubes V_1 and V_2 are both in phase with respect to current of the carrier frequency transmitted by this oscillator. Oscillations of the carrier frequency are thus impressed in the same direction on the input circuits of these tubes, the grids usually becoming equally biased negatively by the battery B_1. Under ordinary conditions, equal currents of the carrier frequency will flow in the output circuits of the tubes V_1 and V_2, which may be oppositely directed by the primary windings of the transformer T_3, so that these currents may effectively balance and neutralize each other.

Signaling currents originating in the source S_1, when impressed upon the input circuits of the tubes V_1 and V_2, modulate current of the carrier frequency transmitted by the oscillator O, so that side bands of the carrier frequency, known as the upper and lower side bands, may appear in the output circuits of these tubes and may be transmitted through transformer T_3 to the filter F, current of the carrier frequency being effectively suppressed by virtue of the balanced arrangement of the duplex system. This electrical wave filter F may, of course, be either a high-pass filter, a low-pass filter or a band-pass filter. Yet, for illustrative purposes, it may be assumed that this filter is of the band-pass type, freely transmitting one of the side bands resulting from modulation, and substantially suppressing the other side band. For illustrative purposes, it may also be assumed that the electrical wave filter F substantially suppresses the lower side band, while freely transmitting the upper side band. In systems similar to the one illustrated, it has been discovered that if any of the frequencies of the undesired side band, i. e., the lower side band, are transmitted through the filter F, the frequencies of the undesired side band, which are thus transmitted, will become demodulated at the receiving terminal of the system when beaten with current of the carrier frequency which is supplied at that terminal. The presence of the frequencies within the undesired side band will constitute a source of interference tending to distort the signals. The effect of these transmitted frequencies in causing interference will depend largely upon the amplitudes of these transmitted frequencies and upon the degree of synchronism between the carrier currents supplied at the transmitting terminal and at the receiving terminal of the system.

The piezo-electric device PE is designed to have a resonant period such that it may present in the input circuit of the thermionic tube V a path of very low impedance for frequencies at or near the cut-off point of the electrical wave filter F. When viewed from a different angle, the piezo-electric device may be considered one which exhibits very high attenuations for a number of frequencies, or for all frequencies within a narrow range of the frequency spectrum, at or near the cut-off point of the electrical wave filter. In the particular system illustrated herein, the vibratory period of the piezo-electric device may, if desired, be substantially equal to the period of the current of carrier frequency. In other words, the vibratory period of the piezo-electric device may be the same, or almost the same, as the period of the current of carrier frequency. At frequencies very close to the natural frequency of the piezo-electric device PE, there will be high attenuations, these attenuations additively increasing the attenuations of the electrical wave filter F for all frequencies within a narrow range.

In Fig. 2 of the drawing, *abc* represents a curve characteristic of an electrical wave filter of the band-pass type, in which the ordinates represent loss or attenuation and the abscissæ represent frequency. This curve indicates that the electrical wave filter exhibits a low and substantially uniform attenuation within a range of frequencies somewhat well-defined in the frequency spectrum. The curve *def* represents a curve characteristic of a piezo-electric device, from which it will be apparent that there is very high attenuation for each frequency within a small band also somewhat well-defined in the frequency spectrum. It will be apparent from the drawing that the band-pass filter will transmit freely and uniformly all frequencies within a desired side band and effectively suppress frequencies within the undesired side band very remote from the frequency of the carrier current. The magnitudes of the loss or attenuation presented by the filter in the range of the undesired side band which is immediately adjacent to the frequency of the carrier current, may, however, be insufficient to prevent interference and distortion of the signals if some of the frequencies in the undesired side band do become transmitted to the receiving terminal. The employment of a piezo-electrical crystal designed to have a suitable vibratory period will, however, provide a material improvement in the suppression of frequencies of the undesired side band closely adjacent to the frequency of the carrier current. The curve *def* shows the amount of attenuation introduced by the piezo-electric device, and shows also how important such a device may be for providing additional attenuation in the range of frequencies at which the filter provides insufficient attenuation.

It will be obvious that if the band of frequencies intended for suppression in accordance with the principles of this invention, is too wide for elimination with a single piezo-electric device, two or more of such piezo-electric devices may be suitably combined to provide sufficient attenuation for all frequencies within that band. In the illustrated system of Fig. 1*a*, additional piezo-electric devices PE′ and PE″ having different vibratory periods are shown connected in shunt across the secondary winding of the transformer T_4.

It will be also understood that while the piezo-electric device has been shown herein related to an electrical wave filter, it may be similarly related to any other device, especially one which may exhibit attenuation which is variable with frequency.

While this invention has been shown and described in one particular embodiment, merely for the purpose of illustration, 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. The combination of an electrical wave filter having a flat transmission characteristic for frequencies above a predetermined frequency and a variable attenuation characteristic for frequencies below said predetermined frequency, and a piezo-electric device coupled to said electrical wave filter having a natural frequency of vibration adjacent to said predetermined frequency.

2. The combination of an electrical wave filter having an attenuation characteristic which varies with frequency immediately adjacent to the cut-off point of said filter, and a piezo-electric structure having a vibratory frequency close to the cut-off point of said filter, and means whereby said piezo-electric structure may exhibit a high attenuation for all frequencies within a narrow region of the frequency spectrum adjacent to its vibratory frequency.

3. The combination of an electrical wave filter having a cut-off point well defined in the frequency spectrum, and means coupled to said electrical wave filter including a piezo-electric structure having a vibratory period such that it provides high attenuation for a range of frequencies immediately adjacent to the cut-off point of said electrical wave filter.

4. In a signaling system, the combination of a source of high frequency current, a source of signals, means for beating the current of said high frequency source with the current of said signaling source so as to produce two side bands of the high frequency current each characteristic of said signals, an electrical wave filter for freely transmitting one of the side bands and for substantially suppressing the other of the side bands, and means including a piezo-electric structure vibrated at a frequency substantially equal to the frequency of the current of the first-mentioned source, said piezo-electric structure effectively sharpening the cut-off of said electrical wave filter in the region near the side band to be suppressed.

5. In a signaling system, the combination of a source of signals, a source of carrier current, a duplex translating circuit for beating the carrier current with said signals in order to provide a pair of side bands of the carrier current each characteristic of the signals, an electrical wave filter for suppressing one of the side bands and for transmitting the other of the side bands, and a piezo-electric structure connected to said electrical wave filter which may be vibrated at a frequency substantially equal to the cut-off frequency of said wave filter adjacent to the frequency of the carrier current, said piezo-electric structure effectively sharpening the cut-off of said electrical wave filter at the frequency or frequencies at which it is vibrated.

6. The combination of an electrical wave filter having a substantially uniform transmission characteristic over a band of frequencies and having a non-uniform attenuation characteristic for a range of frequencies immediately adjacent to said band, and piezo-electric means connected to said electrical wave filter to substantially increase the attenuation characteristic of said filter for all frequencies within a narrow band immediately adjacent to the first-mentioned band.

7. The combination of a band-pass filter and a piezo-electric device coupled to said filter having a frequency of vibration substantially equal to one of the cut-off frequencies of said filter.

8. A band filter comprising a plurality of piezo-electric devices of different vibratory periods connected in parallel relationship, the vibratory period of each device being within the limits of the band, each piezo-electric device suppressing currents of frequencies within a narrow portion of said band, the portions of said band suppressed by the various piezo-electric devices being adjacent to each other.

9. A band filter comprising a plurality of

piezo-electric devices connected in parallel relationship and having closely spaced natural vibratory frequencies so that the various piezo-electric devices may suppress currents having frequencies within adjacent portions of the band to be eliminated.

10. The combination of a band-pass filter and a plurality of piezo-electric devices coupled to said filter having different vibratory frequencies, the vibratory frequency of each device being near a selected cut-off frequency of said filter.

In testimony whereof, I have signed my name to this specification this 17th day of March, 1927.

ESTILL I. GREEN.