Dec. 31, 1929. E. I. GREEN 1,741,363

PIEZO ELECTRIC INTERFERENCE ELIMINATOR

Filed July 17, 1926

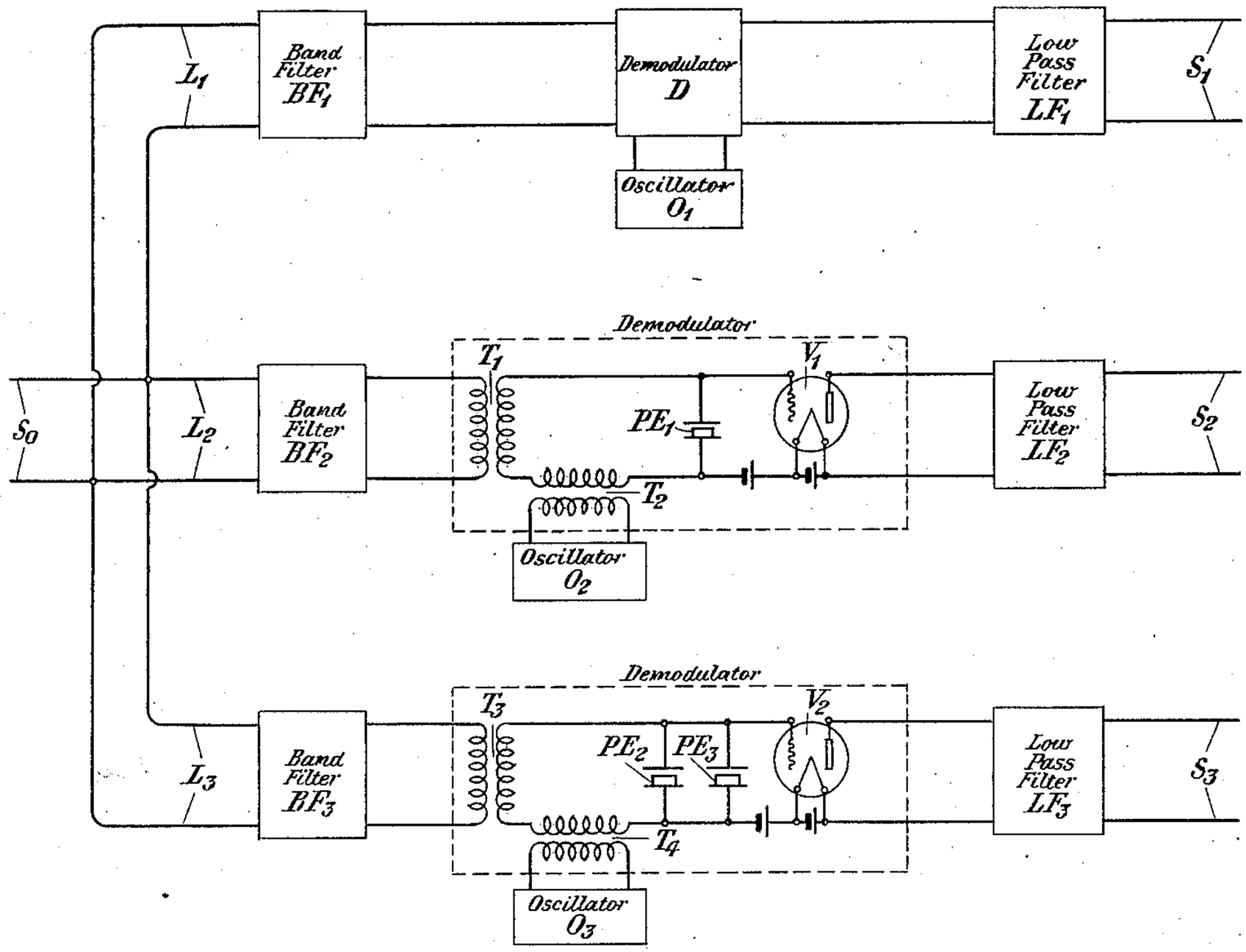

Fig. 1

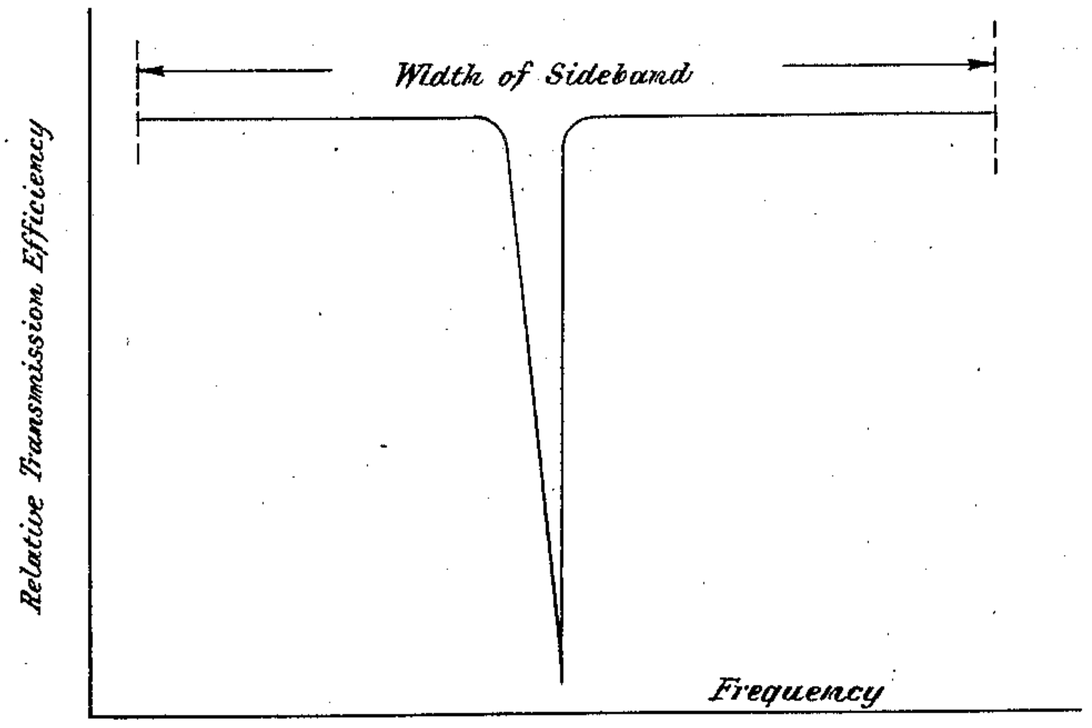

Fig. 2

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PIEZO-ELECTRIC INTERFERENCE ELIMINATOR

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This invention relates to transmission systems, and particularly to arrangements in such systems for eliminating interference.

In connection with carrier and radio and other signaling systems, it is desirable to prevent the interference caused by the superimposition of foreign waves upon a band of signals to be transmitted by the particular system. These interfering waves, which may, for example, emanate from radio telegraph stations, may be present in the system in frequencies which are within the limits of the band to be transmitted. Special circuits have been developed for balancing this interference out, but these are only partly successful in practice because they require very frequent adjustments to compensate for changes in the phase and in the magnitude of the balancing or interfering current. Moreover, the absorption of interfering waves by, for example, resonant circuits tuned to the interfering frequencies is very difficult. An unsurmountable objection to the use of tuned circuits as absorbing elements is apparent from the frequency characteristics of tuned circuits, which are so broad as to absorb an appreciable part of the signal band along with the interfering waves.

Accordingly, it is an object of this invention to provide a quartz crystal, or other device of piezo-electric character, which will furnish an absorbing circuit sufficiently sharp in its frequency characteristic as to have a comparatively small or negligible effect on the band of signals to be transmitted. Moreover, if there are two or more interfering frequencies within the limits of a band of signals, it is an object of this invention to provide two or more of such piezo-electric devices to act as absorbing bodies, one corresponding to each of the interfering waves, these piezo-electric devices being mutually non-reactive. Furthermore, it is to be understood that it is within the scope of this invention to employ a single piezo-electric device which has a plurality of natural frequencies which are substantially different from each other, so that each of these natural frequencies may be used to suppress a single interfering wave.

While the 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 one embodiment of the invention, shown merely for the purpose of illustration, and Fig. 2 shows a curve of the relative transmission efficiency that might be obtained when a crystal is used, in accordance with this invention, to absorb a single interfering frequency in a carrier frequency signaling band.

A plurality of bands of signals may be originated by a corresponding plurality of devices, such as telephone transmitters (not shown), which bands of signals may be modulated upon a plurality of carrier frequencies, one carrier frequency corresponding to each band of signals. Referring to Fig. 1, these bands of signals, each raised in the frequency spectrum as a result of modulation with the carrier wave (which carrier wave may or may not be transmitted), are transmitted over a medium in which interfering waves may be present, and then impressed upon a receiving circuit S_0. Transmission circuits L_1 to L_3, inclusive, connect the input or receiving circuit S_0 to band filters BF_1 to BF_3, inclusive, which band filters separate the bands of signals from each other in order that each may be transmitted through its corresponding demodulation circuit. In each of these transmission circuits the band filter transmits the corresponding band of signals, suppressing all frequencies above and below the limits of the band. In these transmission circuits there are demodulators, one corre-

sponding to each transmission circuit. Oscillators O_1 to O_3, inclusive, supply the carrier wave to each of these demodulators, respectively, for the purpose of demodulation, as is well known in the art, it being assumed in this case that the carrier frequency is not to be transmitted to the receiving end of the system. It will be understood that these oscillators may be of any well known type, preferably of the vacuum tube type. The products resulting from demodulation include the original voice frequency bands of signals which are transmitted through low pass filters LF_1 to LF_3, inclusive, these low pass filters freely transmitting the original bands of signals, while substantially suppressing all intermodulation components above the upper limits of the corresponding bands of signals. These bands of signals, returned to their original positions in the frequency spectrum, are transmitted to the output circuits S_1 to S_3, inclusive, respectively.

A wave or waves may interfere with one or more of these bands of signals, which wave or waves may be within the limits of said band or bands. In accordance with this invention, an arrangement is provided whereby these interfering waves may be substantially suppressed so that their effect upon the bands of signals will be substantially eliminated. For the purpose of illustration it has been assumed that one interfering wave is superimposed on the band of signals transmitted by the band filter BF_2, and that two interfering waves have been superimposed upon the band of signals transmitted by the band filter BF_3. It is to be understood that these conditions may vary in practice so as to necessitate different arrangements.

The band of signals transmitted by the band filter BF_2, which includes an interfering wave having a frequency within the limits of the band, is transmitted through a transformer T_1 to the input circuit of a vacuum tube V_1, a piezo-electric device PE_1 being connected in said input circuit. The piezo-electric device PE_1 is connected through conductive plates between the grid and cathode of the vacuum tube V_1. It is so arranged that it may freely vibrate therebetween, at one or perhaps more of its natural frequencies. The crystal may be made of quartz, or other piezo-electric material, cut along an axis of symmetry. It is a well known property of a crystal so cut that when subjected to a physical stress from the sides of the crystal, plus and minus charges appear on the faces of the crystal. Conversely, when the crystal is subjected to an electrostatic field a physical deformation occurs along the axis of the crystal. The signs of the charges produced in the first case depend upon the character of the stress, that is, whether the stress is tension or compression, whereas in the second case the physical deformation is due to the direction of the electrostatic field. If the physical stress changes from compression to tension, or vice versa, the signs of the electric charges on the faces of the crystal are reversed. On the other hand, if the direction of the electrostatic field is alternately reversed, the crystal undergoes contraction and elongation alternately in the direction of the axis. In other words, the crystal vibrates in an electrostatic field in which the charge is alternately reversed.

At any frequency different from a natural frequency of the piezo-electric device PE_1, the impedance of this device is very high compared to the impedance between the grid and the cathode of the vacuum tube V_1. Yet, at substantially the frequency of resonance the impedance of the piezo-electric device drops considerably so that its impedance is small as compared to the impedance of the grid and cathode of the vacuum tube V_1.

In accordance with this invention, the current of the interfering wave is shunted through the circuit including the piezo-electric device PE_1, which piezo-electric device has a natural frequency of vibration substantially equal to that of the interfering wave. Thus, the magnitude of the interfering wave is substantially reduced, and this is accomplished, as is indicated in Fig. 2, without appreciably affecting any of the frequencies in the signal band, except a very narrow range adjacent to the interfering frequency.

A similar arrangement is shown in connection with the transmission circuit L_3, the demodulator of this transmission circuit comprising a vacuum tube V_2, in the input circuit of which there are two piezo-electric crystals PE_2 and PE_3. These piezo-electric crystals may be employed to suppress at least two interfering waves. Moreover, the vibrations of these piezo-electric crystals are mutually non-reactive.

It is to be understood that it is within the scope of this invention to employ a single piezo-electric device having a plurality of natural frequencies so that each of these natural frequencies may be used to suppress one of the interfering waves.

It is also to be understood that in systems in which there are a plurality of interfering waves superimposed upon a band of signals, these interfering waves having frequencies within the limits of the band of signals, a plurality of piezo-electric devices may be employed within the scope of this invention, one piezo-electric device corresponding to each of these interfering waves so that the distortion effect of the interfering waves upon the band of signals will be substantially eliminated.

It will further be understood that although the piezo-electric device has been illustrated as connected between the grid and cathode of a demodulator tube, the object of

this invention may be carried out by connecting the said device at other points in the circuit, as, for example, between the anode and cathode of a tube used to amplify the side band arriving at the receiving station.

The term "piezo-electric" as employed herein refers to that property of a body or substance by which an electromotive force results from pressure, and vice versa.

It will be understood that 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 varied organizations without departing from the spirit of the invention or the scope of the appended claims.

What is claimed is:

1. The combination of a circuit passing a band of signals having definite limits in the frequency spectrum, a plurality of unmodulated waves having frequencies within the same limits of the frequency spectrum being superposed upon said circuit, and a plurality of piezo-electric resonators of different frequency characteristics each corresponding to one of the unmodulated waves, each piezo-electric resonator being vibrated when the corresponding unmodulated wave is impressed thereon to substantially suppress the corresponding unmodulated wave.

2. The combination of a source of signals, means for transmitting said signals, a frequency interfering with the faithful transmission of said signals being also transmitted with said signals, a piezo-electric device having a natural period corresponding to that of the interfering frequency, said piezo-electric device being connected to said transmitting means, and means for setting the piezo-electric device into mechanical vibration for substantially suppressing the interfering frequency as it becomes impressed on said device.

3. The combination of a circuit transmitting a band of signals within predetermined limits in the frequency spectrum, a plurality of interfering frequencies within said limits being present in said circuit, means of a piezo-electric character connected to said circuit transmitting the band of signals, and means for sustaining the piezo-electric means in vibration for substantially suppressing said interfering frequencies.

4. The combination of a circuit transmitting a band of signals upon which are superposed a plurality of waves having frequencies within the limits of the band, a plurality of bodies of piezo-electric character having vibratory periods corresponding to the various superposed frequencies, said bodies being connected to the circuit transmitting the band of signals, and means whereby each body of piezo-electric character may absorb one of the superposed waves.

5. A system for substantially eliminating the effect of a plurality of interfering frequencies which lie within the limits of a band of signals corresponding to speech, comprising a plurality of electro-mechanically vibrating bodies of frequency characteristics different from each other and corresponding respectively to the various interfering frequencies, and means whereby each vibrating body may be sustained in vibration for substantially absorbing the current of one of the interfering frequencies.

6. A system for substantially eliminating the effect of a plurality of interfering frequencies which lie within the limits of a band of signals, said interfering frequencies being superposed on said band of signals, comprising piezo-electric means suitable for by-passing the interfering frequencies, and means including a vacuum tube system for rendering said piezo-electric means active to suppress said interfering frequencies.

7. A system for substantially eliminating a plurality of frequencies which are superposed upon a circuit transmitting a band of frequencies corresponding to speech signals, comprising a plurality of piezo-electric bodies of frequency characteristics different from each other and corresponding to the various superposed frequencies, one piezo-electric body being provided for each superposed frequency, and means for rendering each piezo-electric body absorbent to the energy of the corresponding interfering frequency.

8. The combination of a circuit transmitting a band of signals, energy interfering with said band of signals being induced into said circuit, and means including a piezo-electric structure connected to said circuit which may be activated for absorbing said interfering energy.

9. The method of substantially suppressing the effect of a plurality of interfering frequencies which lie within the limits of a transmitted band of signals corresponding to speech and which are superposed on said band, with a plurality of mutually non-reactive piezo-electric bodies of vibratory characteristics different from each other, which consists in setting those piezo-electric bodies into mechanical vibration which have vibratory characteristics corresponding to the various transmitted interfering frequencies and passing these interfering frequencies independently through the corresponding piezo-electric bodies in vibration so as to suppress their effect without changing the nature of the transmitted band of signals.

10. In a signaling system including a plurality of mutually non-reactive piezo-electric bodies capable of independent vibration, the method of transmitting a band of signals substantially free from the effect of a plurality of interfering currents superposed on said band and having frequencies lying within the

limits of said band, which consists in independently vibrating those bodies having frequencies substantially the same as those of the interfering currents, one body being vibrated in response to interfering current of each frequency, and substantially decreasing the magnitude of the reactance of each body in vibration in order to bypass the corresponding interfering current.

In testimony whereof, I have signed my name to this specification this 16th day of July 1926.

ESTILL I. GREEN.