Oct. 20, 1931. E. I. GREEN 1,827,843

PIEZO ELECTRIC FREQUENCY ELIMINATOR

Filed March 18, 1927

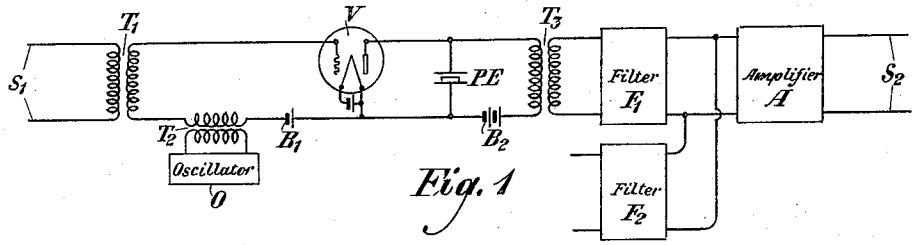


Fig. 1

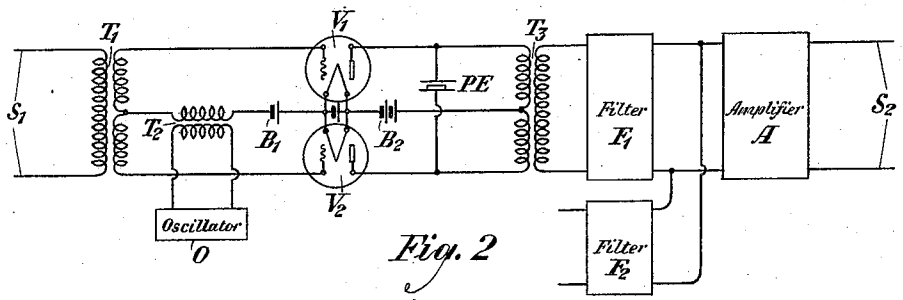


Fig. 2

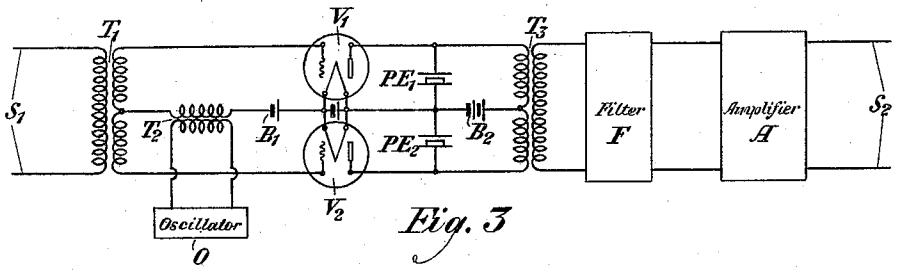


Fig. 3

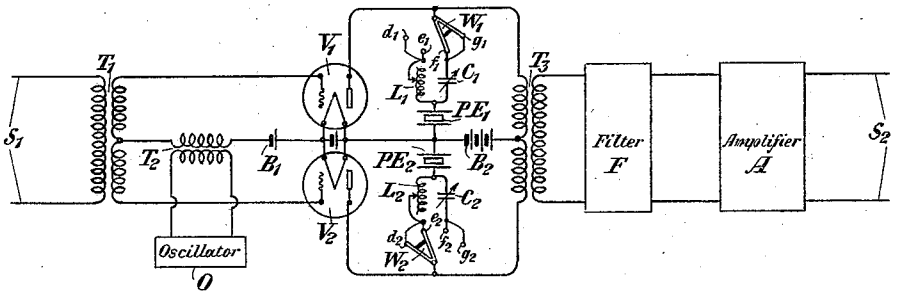


Fig. 4

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UNITED STATES PATENT OFFICE

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PIEZO ELECTRIC FREQUENCY ELIMINATOR

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

In signaling systems of the carrier suppression type, it is common practice to use modulators or translating devices of the push-pull type in order to balance out the carrier supply. In such devices the balance between the circuits is usually not perfect, so that generally some residual energy of the carrier frequency is transmitted along with side bands of the carrier frequency, these side bands corresponding to signaling currents. It has been the practice heretofore to connect balancing condensers or resistances, or both, to the translating circuits in order to produce a better balance, yet there was ordinarily a certain amount of leakage of carrier current which was obviously undesirable. This leakage of carrier current produced, inter alia, crosstalk and tones in the channels of adjoining carrier systems having somewhat different frequency allocations. It, therefore, becomes apparent that it is esesntial to provide the most efficient means to suppress this carrier current leakage.

It is therefore an object of this invention to provide a piezo-electric structure in connection with carrier signaling systems so that the piezo-electric structure may act as a means for suppressing energy of a definite frequency such, for example, as the carrier frequency.

It is another object of this invention to provide a piezo-electric structure to supplement, or even to supplant, the circuit elements heretofore employed to produce balance between duplex translating circuits, the piezo-electric structure acting as a resonator to suppress energy of the carrier frequency.

It is another object of this invention to provide a piezo-electric structure for definitely fixing the location of the carrier frequency so that, as energy of the carrier frequency is impressed upon the piezo-electric structure, there will be a high degree of absorption of the carrier frequency energy.

While this invention will be pointed out with particularity in the appended claims, the invention, 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 drawings, in which Figure 1 represents a simple modulating system including a piezo-electric device for suppressing carrier frequency energy; Fig. 2 shows a duplex translating system to which a piezo-electric element is connected to supplement the balancing properties of the duplex arrangement for the suppression of carrier energy; Fig. 3 shows a duplex arrangement similar to Fig. 2, in which two substantially similar piezo-electric structures are employed, one being connected to each translating circuit; and Fig. 4 shows another duplex translating system to which piezo-electric elements are connected, including means for modifying the electrical properties of these piezo-electric devices.

Referring to Fig. 1 of the drawings, a source of signals S_1 is shown, arranged in a series circuit with the primary winding of a transformer T_1. The transformer T_1 connects the source of signals to a modulating system having a three-element thermionic tube V, including a filament, a grid and a plate, the filament being heated to an electron-emitting temperature by a local battery. The input circuit of the thermionic tube V includes the grid and the filament of the tube V, a battery B_1, the secondary winding of a transformer T_2 and the secondary winding of the transformer T_1, the battery B_1 providing a suitable bias for the grid of the tube V.

The primary winding of the transformer T_2 is connected to an oscillator O which may be of any well-known type, preferably of the vacuum tube type, this oscillator supplying to the input circuit of the vacuum tube V current of a definite frequency, as, for example, the carrier frequency. The output circuit of the thermionic tube V comprises the plate and filament of the tube V, a battery B_2 and the primary winding of the transformer T_3, the battery B_2 providing the necessary potential for the plate of this output circuit.

The transformer T_3 connects the output circuit of the thermionic tube V with a filter

F_1 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 filter F_1 is connected to an amplifier A which may also be of any well-known type, preferably of the vacuum tube type. The amplifier is connected to an output circuit S_2. Bridged across the output terminals of the filter F_1 and across the input terminals of the amplifier A is another filter F_2 which is connected to a modulating system similar to the one shown and described herein above.

A piezo-electric device is connected between the plate and filament of the thermionic tube V, in shunt with the output circuit of the tube. In this system energy of the carrier frequency transmitted by the oscillator O is impressed upon the input circuit of the vacuum tube V along with signals originating in the source S_1. The thermionic tube V acts as a modulator and transmits to its output circuit current of the carrier frequency as well as side bands of the carrier frequency corresponding to the signaling currents originating in the source S_1.

Inasmuch as the piezo-electric device is connected across the output circuit of the thermionic tube V and inasmuch as this device is arranged to have a resonant frequency approximating that of the carrier frequency, the piezo-electric device will present a path of low impedance for current of the carrier frequency, as compared with the impedance in the output circuit of the tube V for current of this frequency, while at all other frequencies, the impedance of the piezo-electric device will be very high in comparison with the impedance of the output circuit of the tube. Accordingly, the piezo-electric device will absorb substantially all of the energy of the carrier frequency which would otherwise be present in the output circuit and remain unsuppressed.

The very low decrement of a piezo-electric device is particularly desirable for the suppression of current of a definite frequency, because electrically tuned circuits which might be employed for this purpose are inherently of such high decrement that a considerable range of frequencies on either side of the undesirable frequency are also substantially suppressed. Inasmuch as the side bands of the carrier frequency are very close to the carrier wave in their position in the frequency spectrum, ordinary electrical circuits would suppress some of the energy of the side band or side bands of the carrier wave as well as the energy of the carrier wave itself, and would likewise have an undesirable effect on the output circuit impedance at the side band frequencies.

If it is desired to employ the piezo-electric device as a means for definitely fixing the position of the carrier wave, then it may be necessary to incorporate in the oscillator O means for varying the frequency of oscillations sustained, so that the frequency of these oscillations may approximate within extremely narrow limits the natural vibratory period of the piezo-electric device. On the other hand, if the frequency of oscillations sustained by the oscillator O is substantially constant normally, means may be provided for varying the vibratory period of the piezo-electric device so that the vibratory period of this device may closely approximate the frequency of the sustained oscillations. Well known means for varying the frequency of vibration of a piezo-electric device may involve an adjustment of the distance between one or both of the electrodes of the piezo-electric device with respect to the active faces of the device. In other words, a variation of one or both of the air gaps of the piezo-electric device may be employed to correspondingly vary the frequency of vibration of the device.

Fig. 2 shows a source of signals S_1 connected to the primary winding of the transformer T_1. The secondary winding of the transformer T_1 is 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 tubes are preferably similar and equal in structure and characteristics and may obviously be replaced by a single duplex tube having a single filament, two grids and two plates. The input circuits of these tubes are arranged in parallel with respect to the secondary winding of transformer T_2, which winding is in series with battery B_1 in the common conductor of the input circuits of these tubes. The output circuits of these tubes are connected through the primary of the transformer T_3 in parallel with respect to the common plate battery B_2. The secondary winding of the transformer T_3 is connected to a filter F_1. The filter F_1 is connected to an amplifier A, and the amplifier A is connected to the output circuit S_2.

The oscillator O which is connected to the primary winding of the transformer T_2 generates the carrier frequency to be employed in the system. By virtue of the connection between the oscillator O and the transformer T_2, the grids of the devices V_1 and V_2 are both in phase with respect to the carrier frequency transmitted by the oscillator O. Oscillations of the carrier frequency are therefore impressed in the same direction on the input circuits of these tubes. The grids of these tubes are equally biased negatively by the battery B_1. Under ideal conditions, equal currents of the carrier frequency will also flow in the output circuits of the tubes V_1 and V_2, which will be oppositely directed by the primary windings of the transformer T_3, so

that these currents effectively balance and neutralize each other.

In practice, however, it is very difficult to get two tubes which are substantially alike in their structure. Nor can the two windings of the output transformer which are connected to the tubes be made identical in all respects. Balancing condensers of resistances, or both, are, accordingly in practice, connected to these tubes to aid in producing a more perfectly balanced condition between the tubes. When, for instance, the filament supply or the plate battery supply varies, however, the balance between the tubes is upset and, consequently, the carrier frequency is not completely suppressed. Accordingly, a piezo-electric device PE having a natural vibratory period substantially equal to the period of sustained oscillations, is connected between the plates of the vacuum tubes V_1 and V_2. As has been explained hereinabove, this piezo-electric device will present a path of low impedance for energy of the carrier frequency, and will, accordingly, efficiently suppress any of the carrier frequency which would otherwise be transmitted to the output circuit.

Fig. 3 shows an arrangement similar to the arrangement of Fig. 2 in which two piezo-electric devices PE_1 and PE_2 are employed, one connected between the plate and filament of one of the thermionic tubes V_1 and the other connected between the plate and filament of the other thermionic tube V_2. Each piezo-electric device is vibrated at a frequency substantially equal to the frequency of oscillations sustained by the oscillator O. At the frequency of these sustained oscillations, each piezo-electric device will present a path of extremely low impedance and will accordingly prevent the transmission of current of this frequency. It will be apparent that these piezo-electric devices are vibrated at the same or at substantially the same frequencies. It will be also apparent that these piezo-electric devices supplement the hitherto well-known balancing property of oppositely directed output circuits of a push-pull system, these piezo-electric devices suppressing current of the frequency of the sustained oscillations of carrier frequency, which would ordinarily be transmitted because of any unbalances in the circuit or circuits of the push-pull arrangement.

Fig. 4 shows an arrangement similar to the arrangement shown in Fig. 3 in which suitable reactance elements are associated with each piezo-electric device in order to modify the electrical properties of each such device. In the arrangement shown, inductive or capacitative reactance may be added in series with each piezo-electric device. Piezo-electric devices PE_1 and PE_2 are connected between the plates and filaments of the vacuum tubes V_1 and V_2, through the reactances L_1 or/and C_1 and through the reactances L_2 or/and C_2, by means of switches W_1 and W_2, respectively. By rotating one of the switches, W_1, for instance, any two of the contacts d_1, e_1, f_1 and g_1 may be closed. By closing any pair of these contacts, the inductance L_1, the capacity C_1, or a parallel arrangement of inductance L_1 and capacity C_1 may be connected in series with the piezo-electric device PE_1. When the blades of switch W_1 close contacts f_1 and g_1, the condenser C_1 is connected in series with the device PE_1 and the magnitude of the capacity may be adjusted to any desired value. When the blades of switch W_1 close contacts e_1 and f_1, the inductance L_1 and the capacity C_1 are connected in a parallel circuit which is in series with the piezo-electric device PE_1. When the contacts d_1 and e_1 are closed at the switch S_1, the inductance L_1 is connected in series with the piezo-electric device PE_1 and the magnitude of the inductance may be changed to any desired value. Similarly, the magnitude of the reactance in series with the piezo-electric device PE_2 may be modified by the manipulation of the switch W_2.

By rendering the reactance in the circuit of the piezo-electric device slightly capacitative or slightly inductive at the frequency of the oscillations sustained by the oscillator O, it will be clear that the impedance in the series path may be considerably lowered, so that this path may conveniently short-circuit current of the frequency of these sustained oscillations. Accordingly, a current of the frequency of the sustained oscillations will be substantially suppressed and, due to the sharpness of the transmission characteristic of the piezo-electric device, the effect of current of this frequency upon the side band or side bands will be negligible.

It is well to note that the insertion of reactance in series with a piezo-electric device modifies the region of positive reactance exhibited by the device, the region increasing with the insertion of inductance and decreasing with the insertion of capacity. With the insertion of inductance in series with the piezo-electric device, not only is the region of positive reactance increased in width, but the maximum attainable inductive reactance is also increased and the maximum attainable capacitative reactance is decreased. By the insertion of capacity in series with the piezo-electric device, not only is the region of positive reactance exhibited by the piezo electric device decreased in width, but the maximum attainable inductive reactance is also decreased and the maximum attainable capacitative reactance is increased. Obviously, the impedance in the respective paths of these piezo-electric devices may be made very low at a desired frequency by the addition of these series reactance elements and, moreover, the

impedances of these paths may be rendered substantially equal.

While this invention has been shown and described in certain particular arrangements merely for the purpose of illustration, it will be obvious 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 a source of signals, a source of carrier frequency, means for modulating said carrier frequency with said signals so as to produce an unmodulated carrier wave and side bands of said carrier wave corresponding to said signals, and a plurality of piezo-electric devices shunting said modulating means vibrated at a common frequency substantially equal to the frequency of the carrier wave in order to cause its suppression.

2. In a carrier suppression system, the combination of a pair of three-element vacuum tubes each having an input circuit connected to its grid and cathode and an output circuit connected to its anode and cathode, a source of oscillations of carrier frequency, a source of signals, means for impressing said signals and said oscillations of carrier frequency upon the input circuits of said vacuum tubes so that oscillations of the carrier frequency and energy of equally high frequency corresponding to said signals may appear in the output circuits of said vacuum tubes, and a mechanically vibrating body connected between the plate electrodes of said vacuum tubes for substantially suppressing the oscillations of carrier frequency.

3. In a signaling system having a carrier wave and superposed signals, the combination of a pair of piezo-electric devices connected in series relationship, and means for rendering their reactive values substantially equal at the frequency of the carrier wave.

4. A modulating system comprising a pair of translating devices, a source of high frequency energy symmetrically connected to said devices, a source of modulating energy oppositely connected to said devices, an output circuit differentially connected to said devices, and a pair of piezo-electric devices connected to said output circuit vibrating at substantially the same frequencies.

5. A signaling system comprising a generator of a high frequency wave, a source of low frequency signals, means for modulating the high frequency wave by the low frequency signals, and a plurality of piezo-electric devices each having a frequency of resonance substantially the same as the frequency of said generator, said piezo-electric devices being connected in series relationship and shunting said modulating means and presenting a path which is absorbent to energy of the high frequency wave.

6. The combination of a pair of vacuum tubes in push-pull relationship, and a pair of substantially similar piezo-electric devices connected respectively to said vacuum tubes, said piezo-electric devices operating in synchronism.

7. The combination of a pair of space discharge devices in push-pull relationship, a pair of substantially similar piezo-electric devices one connected to each space discharge device, and means for rendering the resonant frequencies of said piezo-electric devices substantially equal.

8. In a signaling system, a pair of mechanically vibrating bodies, and a pair of reactances one in series with each mechanically vibrating body, and means for rendering the impedance of one mechanically vibrating body and the corresponding reactance substantially equal to the impedance of the other mechanically vibrating body and its corresponding reactance so that both of said bodies may simultaneously act to suppress current of a particular frequency.

9. A pair of space discharge tubes in push-pull relationship each having an input circuit and an output circuit, a pair of piezo-electric devices one connected to each output circuit, said piezo-electric devices resonating at the same frequency, said piezo-electric devices presenting paths of low impedance in the vicinity of the common resonant frequency.

10. A pair of space discharge tubes in push-pull relationship each having an input circuit and an output circuit, a pair of piezo-electric devices one connected in shunt with each output circuit, the impedance of each piezo-electric device at a particular frequency of vibration being low as compared to the impedance of the output circuit to which it is connected.

11. The combination of a piezo-electric device of a vibratory period constant within very narrow limits, a duplex vacuum tube system, and an oscillator coupled to the piezo-electric device through said vacuum tube system, the current of said oscillator being varied in frequency so as to equal the vibratory frequency of the piezo-electric device, whereupon the piezo-electric device may be rendered absorbent to the energy of said oscillator.

12. In a carrier suppression system, a source of signals, an oscillator the frequency of which may be varied as desired, a pair of three-element vacuum tubes each having an input circuit and an output circuit, and a pair of piezo-electric devices each having a natural vibratory period constant within exceedingly narrow limits, both of said piezo-electric devices having substantially the same natural vibratory period, the frequency of

said oscillator being varied to be substantially equal to the natural frequency of said piezo-electric devices, said source of signals and said oscillator being connected to the input circuits of said vacuum tubes, each of said piezo-electric devices being connected in shunt across the output circuit of one of said vacuum tubes.

13. The combination of a pair of sources of currents of equally high frequency coupled to each other and a pair of piezo-electric devices respectively shunting said sources and naturally and independently resonant at periods corresponding to the frequency of the currents transmitted by said sources.

14. The combination of a pair of coupled circuits, each circuit transmitting a plurality of frequencies, and a pair of independently operated piezo-electric devices both resonant at substantially the same period, said devices respectively shunting said circuits and suppressing currents of resonant frequencies.

15. The combination of a modulating circuit including a pair of vacuum tubes in push-pull relationship, and a piezo-electric device shunting the output circuit of said vacuum tubes, said piezo-electric device having a vibratory frequency equal to the frequency of the carrier current and substantially suppressing transmitted carrier current.

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

ESTILL I. GREEN.