Dec. 27, 1938. F. E. NICKEL 2,141,277

INTERFERENCE ELIMINATOR

Filed Oct. 16, 1936 2 Sheets-Sheet 1

Fig. 1

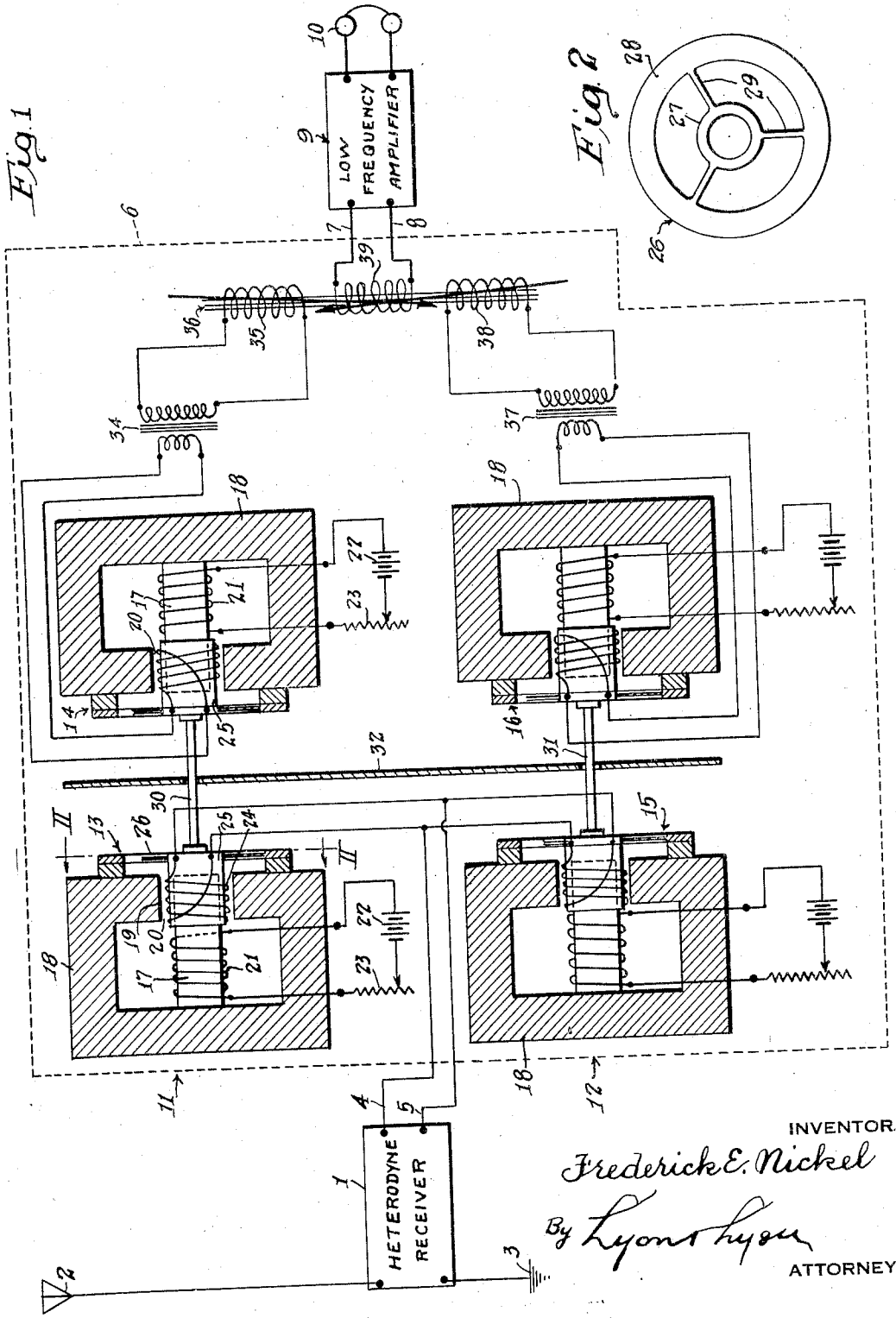


Fig. 2

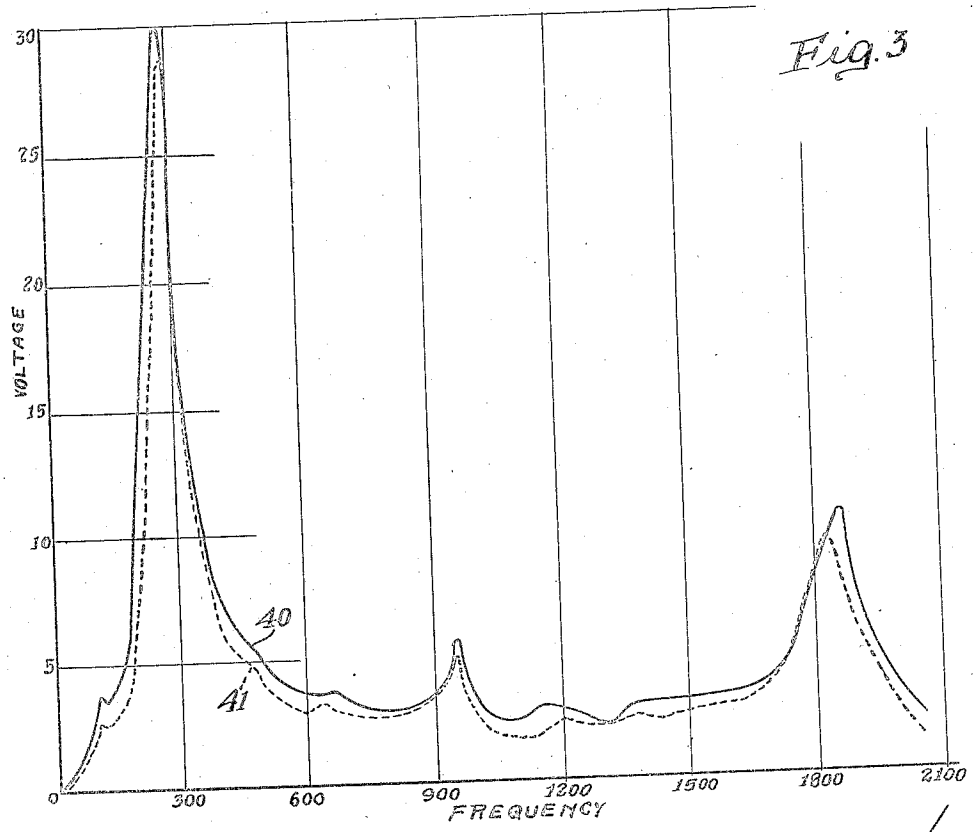
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Fig. 3



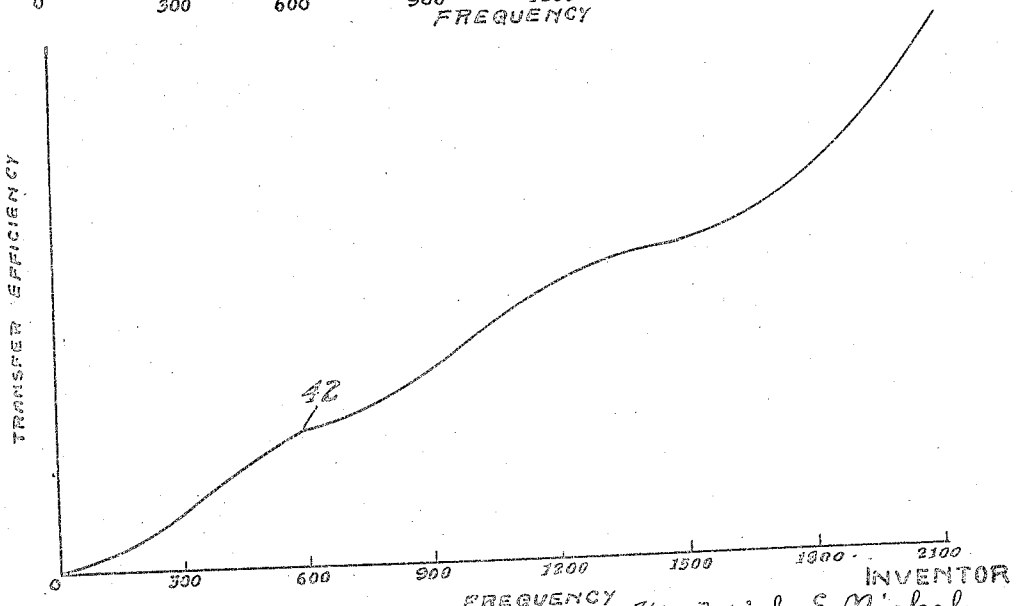


Fig. 4

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UNITED STATES PATENT OFFICE

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INTERFERENCE ELIMINATOR

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7 Claims. (Cl. 178—44)

This invention relates to electrical communication, particularly radio telegraph communication, in which extraneous currents resulting from various causes are superimposed on desired signal currents, masking the latter and often making it impossible to intelligibly receive the signal currents.

A broad object of the invention is to provide a practicable filtering system capable of passing persisting electric current of desired frequency while attenuating currents of other frequencies to a marked degree.

Another object is to provide a filtering system capable of passing persisting currents of a desired frequency that is relatively inefficient in the production of currents of such frequency when shock excited.

Various more specific objects and features of the invention will become apparent from the detailed description of one embodiment of the invention as employed in a C. W. (continuous wave) radio telegraph receiving system.

As is well known, radio interference results from natural static and also from local disturbances caused by electrical machinery, power circuits, etc., all of which produce in the output circuit of the radio receiver noise currents of various frequencies, most of which lie in that portion of the audio frequency band to which the ear is highly sensitive. Attempts have been made to reduce interference in C. W. telegraphy by making the signal note of relatively high frequency and tuning the audio circuit of the receiver sharply to the signal frequency whereby noise currents of frequencies other than the signal frequency are discriminated against. The results are less favorable than might be expected, however, apparently for the reason that the tuned circuits were shock excited by the interference currents to produce relatively strong interfering currents at the signal frequency.

In accordance with the present invention, I have discovered that relatively simple filters can be constructed having sharp resonance in the upper audio range so that they pass currents of a single frequency or very narrow band of frequency within this range with good efficiency while attenuating currents of other frequencies adjacent thereto. I have further found that such filters are relatively immune to shock excitation at this frequency. The particular filters constructed, however, also have the characteristic of resonating strongly at lower frequencies. In brief, they seem to resonate at a fundamental frequency relatively low in the audio range and at higher frequencies which are near but usually not exactly at multiples or harmonics of the fundamental. In general, I have found that if two filters of this type are constructed as nearly identical as possible, they will usually resonate at substantially the same fundamental frequency but at slightly different higher frequencies. In accordance with this invention, I impress the signal currents, which may be contaminated with interfering currents, equally on the input circuits of two such filters and connect the output circuits of the filters in opposition to a signal responsive device, and adjust the signal note to the higher resonant frequency of one of the filters. The signal currents therefore appear in the output circuit of the one filter with greater intensity than in the output circuit of the other filter; they do not balance out, and therefore actuate the signal responsive device. However, because of the fact that the two filters have substantially uniform response at most frequencies, and particularly at their fundamental resonance points, the interfering currents are largely balanced out.

Heretofore I have employed electro-mechanical filters having the above mentioned characteristics because I have found them simple, easy and inexpensive to construct and successful in operation. However, it is quite possible that equally good or better results might be obtained with purely electrical filters having the same general attenuation characteristics. The invention in its broad aspects is not limited to any particular type of filter but rather to the particular combination in a circuit of filters having certain over-all attenuation characteristics regardless of the internal construction of such filters.

Referring now to the drawings:

Fig. 1 is a schematic diagram of a complete C. W. radio telegraph receiving system incorporating the invention;

Fig. 2 is a detailed view taken in the plane II—II of Fig. 1, showing details of construction of one of the electromagnetic units employed;

Fig. 3 is a graph illustrating the propagation characteristics of the filters employed in the circuit of Fig. 1 at different frequencies; and

Fig. 4 is a graph illustrating the transfer efficiency of a balancing transformer that may be employed in the circuit of Fig. 1.

Referring to Fig. 1, I have shown a heterodyne radio receiver 1 having its input terminals connected between an antenna 2 and ground 3 and having an output line consisting of a pair of conductors 4 and 5 which extend into a filter unit enclosed within the dotted line 6. The fil-

tering unit has a pair of output conductors 7 and 8 which connect through a low frequency amplifier 9 to a head telephone 10.

Aside from the use of the filtering system enclosed within the dotted line 6, the circuit of Fig. 1 is in accordance with standard radio practice, the heterodyne receiver 1 producing, in response to continuous wave telegraph signals impressed upon the antenna 2, trains of waves of an audible frequency which are amplified in the low frequency amplifier 9 and impressed upon the headphones 10 where they are converted into sound waves of corresponding frequency which appear as short and long impulses, representing dots and dashes, respectively, of a single musical note corresponding to the frequency of the current applied thereto. It is well known that by the use of a heterodyne receiver, which includes a local oscillator producing an oscillation that beats with the received oscillations, the frequency of the audible note produced in the headphones 10 may be varied from zero to frequencies above audibility and adjusted to a point most satisfactory to the listener.

However, interfering currents, whether produced by natural static or by nearby electrical circuits, produce noise currents in a heterodyne receiver and these currents may be of sufficient intensity in many instances to completely mask the desired signal currents. However, these noise currents differ in general from the signal currents in that they have no particular frequency characteristics but contain many components of different frequencies scattered throughout the audible range but in general concentrated to a substantial extent in the lower portion of the audio range. By inserting a filter of the construction next to be described between the output circuit of the receiver and the headphones, I have found it possible to greatly attenuate the noise currents, which are heterogeneous in their frequency characteristics, from the signal note which may be of a single desired frequency.

Referring again to Fig. 1, the filter enclosed within the dotted line 6 comprises two filter units 11 and 12, respectively, each of which units in turn consists of a pair of dynamic speaker elements 13 and 14, and 15 and 16, respectively. All of the units 13, 14, 15 and 16 may be identical and it will suffice to describe in detail one of them.

Thus the unit 13 consists of a field magnet having a central core 17, the outer end of which forms one pole, and an annular portion 18 surrounding the core 17 and connected thereto at one end and defining an annular pole 19 juxtaposed to the end of the core 17 but spaced therefrom by a small air gap 20. A field winding 21 is positioned about the core 17 and is energized by a suitable source of direct current indicated as a battery 22 connected to the winding 21 in series with a variable adjusting resistance 23. Current flowing in the winding 21 produces a strong magnetic flux in the field magnet and an intense radial magnetic field within the air gap 20.

Mounted in the air gap 20 is a movable coil 24, which coil may be wound on a cylindrical shell 25 which supports it. The shell 25 is in turn connected to a supporting spider 26, the outer edge of which is rigidly attached to the field magnet. This construction is similar or identical to that commonly employed in dynamic speakers. As shown in Fig. 2, the spider 26 consists of a central portion 27 secured to the cylindrical shell 25 and an outer portion 28 anchored to the magnets with radial portions 29 interconnecting the central and outer portions. The purpose of this spider mounting is to permit free longitudinal motion of the shell 25 and coil 24 while maintaining the shell and coil out of contact with the pole pieces of the field magnet.

The shell 25 of unit 13 is rigidly connected by a rod 30 to the shell 25 of unit 14 and likewise the shell 25 of unit 15 is rigidly connected by a rod 31 to the shell 25 of the unit 16. To prevent any electromagnetic coupling between the units 13, 15 and the units 14, 16, a shield 32 of iron or other paramagnetic material is positioned between the units, suitable apertures being provided in the shield 32 for the passage of the mechanical connecting rods 30 and 31.

The movable coils 24 of the units 13 and 15 are connected in parallel across the conductors 4 and 5 extending from the output terminals of the receiver 1. The moving coil of unit 14 is connected through a matching transformer 34 to a winding 35 of a balancing transformer 36 and the moving coil of unit 16 is connected through a matching transformer 37 to a separate winding 38 on the balancing transformer 36. Transformer 36 has a third or tertiary winding 39 magnetically coupled to both the windings 35 and 38 and electrically connected to the conductors 7 and 8 leading to the low frequency amplifier 9. The windings 35 and 38 can be shifted with respect to the tertiary winding 39 to vary the couplings between each of windings 35 and 38 and the winding 39. By suitably positioning the windings 35 and 38, they can be made to induce substantially equal and opposite potentials in the tertiary winding 39 so that if equal currents are flowing in windings 35 and 38 they can be made to induce equal and opposite potentials in winding 39, thereby neutralizing each other and producing no resultant current in the winding 39.

As a result of the fact that the moving coil 24 of each filter unit is suspended in a strong magnetic field, mechanical forces tending to vibrate the coil will be produced if alternating current is impressed on the moving coil and alternating currents will likewise be developed in the moving coil if the latter is vibrated within its associated magnetic field by some external cause. Hence if alternating currents are applied to the moving coil 24 of either unit 13 or unit 15, the moving coil and associated shell will be caused to vibrate and the vibration transferred by the rod 30 or the rod 31 to the moving coil of unit 14 or 16, thereby setting up alternating currents in the moving coil of unit 14 or 16, which alternating currents are applied through the matching transformers 34 and 37 to the associated winding of the balancing transformer 36.

As a result of the fact that the moving elements of each filter unit 11 and 12 comprising the shells 25, coils 24, spiders 26 and the connecting rod 30 or 31, as the case may be, have mass and resilience, they tend to vibrate with increased amplitude at certain resonant frequencies and when the windings 24 of the units 13 and 15 are energized with alternating currents of such frequencies the moving systems vibrate with increased amplitude to develop currents of correspondingly increased magnitude in the coils 24 of the unit 14 and 16.

In Fig. 3 the resonance characteristics of the filters 11 and 12, respectively, are indicated by the curves 40 and 41, respectively, the curve 40 being shown in full lines and the curve 41 in dotted lines. The curves of Fig. 3 were prepared by applying alternating currents of equal in-

tensity but successively varying frequencies to the windings 24 of the filter units 13 and 15, measuring the resultant potentials developed in the windings 24 of the filter units 14 and 16 and plotting the latter voltages against frequency, the ordinates in Fig. 3 representing the voltages developed in the windings 24 of units 14 and 16 and the abscissa representing the different frequencies.

It will be observed from Fig. 3 that each of the units 11 and 12 responds strongly at a frequency slightly less than 300 cycles and at frequencies above 1800 cycles. A slight peak is also noted at a frequency above 900 cycles. It will also be observed that the peaks in curves 40 and 41 in the neighborhood of 300 cycles occur at very nearly the same frequency but that as the frequency increases the peaks in curves 40 occur at slightly higher frequencies than the peaks in curve 41. This difference is particularly noticeable in the peaks above 1800 cycles.

The four filter units 13, 14, 15 and 16 are all substantially identical and differ from each other only as the result of minute unavoidable variations in dimensions during manufacture. It appears that these unavoidable variations in the dimensions of the parts account for the differences in the frequencies of maximum response in the region above 1800 cycles. On the other hand, the differences in dimensions are insufficient to produce any appreciable difference in the frequencies of fundamental response below 900 cycles. The probable explanation for this phenomenon is that the moving elements vibrate as a complete unit at the lower resonant frequency below 900 cycles whereas at the higher frequencies above 1800 cycles the resonance peaks result from secondary or nodal vibrations in the spiders supporting the moving elements. In other words, although two vibrating systems may have the same fundamental resonance frequencies, they will not have the same harmonic frequencies unless their constants are uniformly distributed. The vibrating systems of the units 11 and 12 may be analogous to vibrating strings having weights thereon, the supporting spiders being the equivalent of the string and the coils 24 and the driving pins or rods 30 and 31 constituting the equivalent of the weight on the string. In the case of two such strings having weights thereon, both might vibrate at the same fundamental frequency although the tension of one string might be less than the other and the weight on that string correspondingly less than the weight on the other. However, such strings would not have the same upper resonant frequencies. Considering further the present invention, the spring constant of one set of spiders and the effective weight of the coils and driving pins might both be less on one unit than on the other, under which conditions the fundamental natural periods would be the same but the upper or harmonic periods different.

Whatever the specific explanation may be, I have found that in assembling two filter units 11 and 12 as shown in Fig. 1 from four similar units 13, 14, 15, and 16 the two systems will in almost every case have different frequencies of response in the upper range although they may respond at substantially the same fundamental frequency.

Assume now that a continuous wave telegraph signal is received on the antenna 2 along with static and/or miscellaneous interference from various local sources. Assume further that the heterodyne receiver 1 is adjusted to deliver signal pulses of frequency corresponding exactly to the peak in the curve 40 above 1800 cycles, this adjustment being readily effected by adjusting the frequency of the local oscillator in the receiver 1.

The signal impulses will be transmitted through the filter unit 11 with greater efficiency than through the filter unit 12 by virtue of the fact that the signal occurs at exactly the upper resonant frequency of filter unit 11 whereas this frequency is substantially removed from the corresponding resonant peak of the unit 12. Assuming that the windings 35 and 38 of the balancing transformer 36 are adjusted to balance out equal currents therein, the stronger current produced in the winding 35 in response to the signal will not be completely balanced out by the current in the winding 38 and a resultant current will be induced in the tertiary winding 39 and applied through the low frequency amplifier 9 to the receiver 10, producing an audible signal therein.

However, currents in the output of the receiver 1 resulting from static or other interference will have no particular frequency characteristic and will contain components distributed over the entire audible frequency band but concentrated to a large extent in the lower portion of the band. These extraneous and undesired currents will in general produce strong currents in the windings 35 and 38 at the lower resonant frequencies of the two filter units below 900 cycles but, since both units resonate at substantially the same frequency in this region, the currents of these frequencies produced in the windings 37 and 38 will be substantially equal and will be balanced out so that they will appear to a very slight extent in the winding 39 and headphones 10.

Because of the fact that most of the undesired extraneous currents appear in the lower portion of the audible frequency range, the system can be made even more selective for currents of the signal frequency by so designing the balancing transformer 36 and/or the matching transformers 34 and 37 as to cause them to transmit more efficiently in the range of the signal frequencies than at lower frequencies. Thus as shown in Fig. 4 the transformers 34, 37 and 36 can be designed to have a rising characteristic as indicated by the curve 42, thereby attenuating the currents in the lower audible range to a greater extent than those in the vicinity of 1800 cycles.

It is to be understood that although in the system of Fig. 1 the signals are shown applied through the low frequency amplifier 9 to a pair of headphones 10, other types of signal responsive devices may be employed. Thus a loud speaker might be substituted for the headphones 10 or if desired these signals can be rectified and used to actuate relays for automatic recording. Such devices are well known in the art and do not constitute a part of the present invention.

It is not essential that the filter units 11 and 12 have equal average transmission efficiencies over the frequency range nor that the balancing transformer 36 be adjusted exactly to neutral position although it is possible to vary the transmission efficiencies of the units 11 and 12 independently by varying the resistances 23 in the field magnet circuits. As a matter of fact, the curves 40 and 41 represent the actual transmission efficiencies of two units 11 and 12 when they are adjusted for most efficient operation with respect to the elimination of interference. It will be observed, however, that the curve 40 is above the curve 41 substantially throughout the range. The plausible explanation for this phenomenon is that the balancing transformer 36 was not ad-

justed to exactly neutral position so that in order to secure maximum suppression of interfering currents it was necessary to adjust the unit 11 to have a slightly higher transfer efficiency at all frequencies than the unit 12.

It is not essential that the exact circuit arrangement shown in Fig. 1 be employed in order to utilize the advantages of the invention. Thus instead of connecting the moving coils 24 of units 13 and 15 in parallel across the output of the receiver 1, these coils may be connected if desired in series with each other and with the output circuit 7. Of course, the impedances of the windings 24 should be properly matched to the impedance of the output circuit of the receiver 1 and it may often be desirable to insert a suitable matching transformer or other network in the output circuit of the receiver. Such expedients are well known in the art.

The system as described has been found to be unusually immune to shock excitation at the signal frequencies corresponding to the peaks above 1800 cycles in the curves 40 and 41. Although this fact has been definitely established by experiment, the reason for such action is not fully known to me at present. It may be that by virtue of the relatively great response of the filter elements 11 and 12 at the fundamental resonance frequency below 900 cycles, the energy of the undesired currents of no particular frequency characteristics is largely absorbed by the filter units and converted into currents of this lower resonant frequency which are then balanced out in the balancing transformer 36.

As previously indicated, many variations can be made in the particular circuit disclosed, especially with reference to the specific construction of the filter units, without departing from the invention and the latter is therefore to be limited only to the extent set forth in the appended claims.

I claim:

1. A system of the type described for transmitting with relatively high efficiency electric waves of a predetermined frequency while attenuating waves of other frequencies, comprising an input line and an output line, a pair of filter elements having input circuits connected to said input line and having output circuits, means for applying waves in the output circuits of said filter elements to said output line in opposing relation whereby waves of the same frequency and predetermined relative intensities in the output circuits of said filter elements neutralize each other and produce no waves in the output line but whereby waves of relative intensities other than said predetermined relative intensities in the output circuits of said filter elements produce a resultant wave in the output line, said filter elements having high transfer efficiencies at relatively low substantially identical frequencies and also at relatively high dissimilar frequencies and the upper frequency of high transfer efficiency of one of said filter elements being substantially identical with said predetermined frequency.

2. A system of the type described for transmitting with relatively high efficiency electric waves of a predetermined frequency while attenuating waves of other frequencies, comprising an input line and an output line, a pair of filter elements having input circuits connected to said input line and having output circuits, means for applying waves in the output circuits of said filter elements to said output line in opposing relation whereby waves of the same frequency and predetermined relative intensities in the output circuits of said filter elements neutralize each other and produce no waves in the output line but whereby waves of relative intensities other than said predetermined relative intensities in the output circuits of said filter elements produce a resultant wave in the output line, said filter elements resonating at substantially identical fundamental frequencies low in the audible range and also resonating at higher frequencies in the audio range adjacent to multiple frequencies of the fundamental frequency, at least one of the upper resonating points of one filter element being substantially removed in frequency from the nearest resonating point of the other filter element and the said upper frequency at which one of said filters resonates being substantially identical with said predetermined frequency.

3. A system of the type described for transmitting with relatively high efficiency electric waves of a predetermined frequency while attenuating waves of other frequencies, comprising an input line and an output line, a pair of filter elements having input circuits connected to said input line and having output circuits, means for applying waves in the output circuits of said filter elements to said output line in opposing relation whereby waves of the same frequency and predetermined relative intensities in the output circuits of said filter elements neutralize each other and produce no waves in the output line but whereby waves of relative intensities other than said predetermined relative intensities in the output circuits of said filter elements produce a resultant wave in the output line; said filter elements comprising vibratory electrodynamic devices including mechanical elements having natural periods of vibration with means responsive to electric waves applied to said input circuits for vibrating said mechanical elements, and means responsive to vibration of said mechanical elements for generating electric waves of corresponding frequencies in said output circuits, one of said filter elements having a natural period of vibration at said predetermined frequency and the other filter element having a corresponding natural period of vibration displaced from said predetermined frequency.

4. A system of the type described for transmitting with relatively high efficiency electric waves of a predetermined frequency while attenuating waves of other frequencies, comprising an input line and an output line, a pair of filter elements having input circuits connected to said input line and having output circuits, means for applying waves in the output circuits of said filter elements to said output line in opposing relation whereby waves of the same frequency and predetermined relative intensities in the output circuits of said filter elements neutralize each other and produce no waves in the output line but whereby waves of relative intensities other than said predetermined relative intensities in the output circuits of said filter elements produce a resultant wave in the output line; said filter elements comprising vibratory electrodynamic devices including mechanical elements having natural periods of vibration with means responsive to electric waves applied to said input circuits for vibrating said mechanical elements, and means responsive to vibration of said mechanical elements for generating electric

waves of corresponding frequencies in said output circuits, said filter elements also including means for independently varying the amplitude of vibration of said mechanical vibratory elements in response to electric waves of given amplitude in said input circuits and one of said filter elements having a natural period of vibration at said predetermined frequency and the other filter element having a natural period of vibration displaced from said predetermined frequency.

5. A system of the type described for transmitting with relatively high efficiency electric waves of a predetermined frequency while attenuating waves of other frequencies, comprising an input line and an output line, a pair of filter elements having input circuits connected to said input line and having output circuits, means for applying waves in the output circuits of said filter elements to said output line in opposing relation whereby waves of the same frequency and predetermined relative intensities in the output circuits of said filter elements neutralize each other and produce no waves in the output line but whereby waves of relative intensities other than said predetermined relative intensities in the output circuits of said filter elements produce a resultant wave in the output line, in which said filter elements comprise vibratory electrodynamic devices including mechanical elements having natural periods of vibration with means responsive to electric waves applied to said input circuits for vibrating said mechanical elements, and means responsive to vibration of said mechanical elements for generating electric waves of corresponding frequencies in said output circuits, said filter elements also including means for independently varying the amplitude of electric waves generated in said output circuits in response to vibration of given amplitudes in said mechanical vibratory elements, and one of said filter elements having a natural period of vibration at said predetermined frequency and the other having a natural period of vibration displaced from said predetermined frequency.

6. A system of the type described for transmitting with relatively high efficiency electric waves of a predetermined frequency while attenuating waves of other frequencies, comprising an input line and an output line, a pair of filter elements having input circuits connected to said input line and having output circuits, means for applying waves in the output circuits of said filter elements to said output line in opposing relation whereby waves of the same frequency and predetermined relative intensities in the output circuits of said filter elements neutralize each other and produce no waves in the output line but whereby waves of relative intensities other than said predetermined relative intensities in the output circuits of said filter elements produce a resultant wave in the output line, said filter elements having high transfer efficiencies at relatively low substantially identical frequencies and also at relatively high dissimilar frequencies and the upper frequency of high transfer efficiency of one of said filter elements being substantially identical with said predetermined frequency, and means for varying the relative coupling between said two output circuits of said filter elements and said output line.

7. A system of the type described for transmitting with relatively high efficiency electric waves of predetermined frequency in the upper portion of the audio range while attenuating waves of other frequencies, said system comprising an input line and an output line, a pair of filter elements having input circuits connected to said input line and having output circuits, means for applying waves in the output circuits of said filter elements to said output line in opposing relation whereby waves of the same intensity and frequency in the output circuits of said filters neutralize each other and produce no waves in the output line but whereas waves of the same frequency but unequal intensity produce a resultant wave of the same frequency in the output line, one of said filter elements being adapted to pass waves of said predetermined frequency more efficiently than the other filter, said filter elements having at least approximately the same attenuation characteristics in the lower portion of the audio range and having corresponding resonance points of substantial amplitude within said lower range, and said means for applying waves in the output circuits of said filter elements to said output line in opposing relation having a transfer efficiency which increases with frequency up to said predetermined frequency.

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