Aug. 20, 1929. L. O. MARSTELLER 1,725,154

WAVE FILTER

Filed Aug. 9, 1924

Fig. 1.

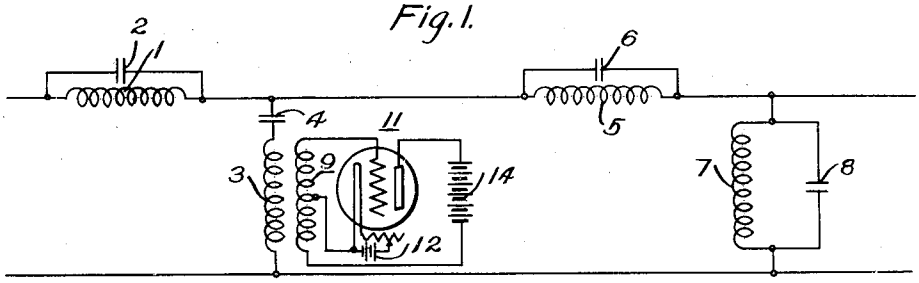


Fig. 2.

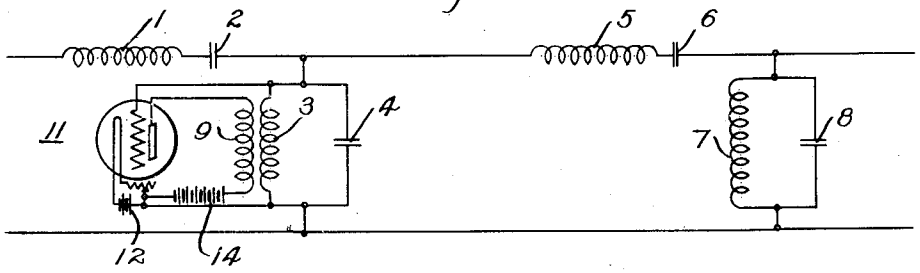


Fig. 3.

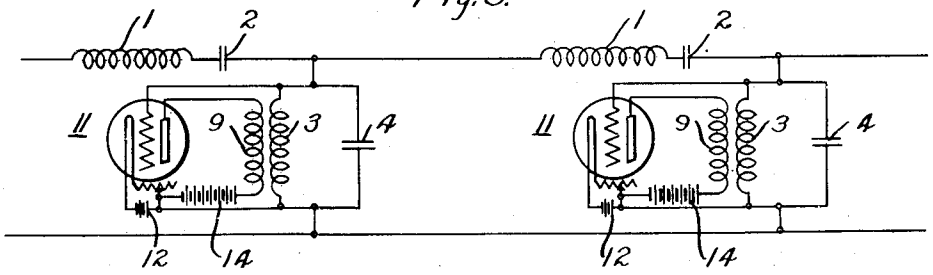
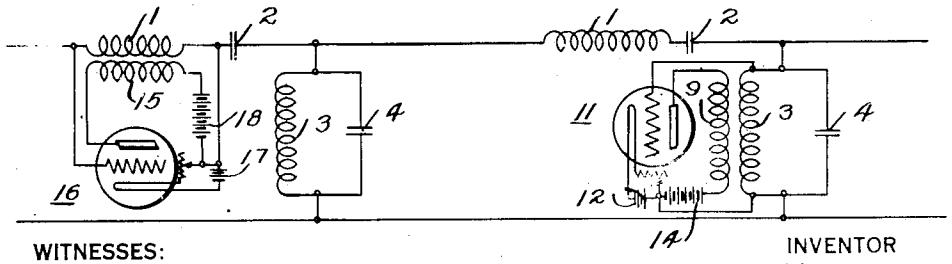


Fig. 4.



WITNESSES:

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UNITED STATES PATENT OFFICE.

LESTER O. MARSTELLER, OF PITTSBURGH, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA.

WAVE FILTER.

Application filed August 9, 1924. Serial No. 731,085.

My invention relates to electrical frequency traps or wave filters, and more particularly to means operative therewith whereby the attenuation of predetermined frequencies may be increased.

An object of my invention is to provide a selective conductor system in which the line of demarkation between frequencies conducted and frequencies not conducted is of maximum sharpness.

Another object of my invention is to reduce the effective resistance of the elements of a filter trap system.

Another object of my invention is to provide regenerative means in connection with a wave filter trap system.

In the prior art of the separation of various frequencies of electric current, it has been customary to employ for that purpose a selective conductor comprising suitably arranged values of inductance and capacitance as described in Patent No. 1,227,113 to Campbell. By the means described therein, it has been found possible to transmit substantially any desired band of frequencies at an amplitude which is only slightly diminished, and to attenuate greatly all other frequencies. The structure, as described, is known in the art as a band filter.

Theoretical considerations of wave filters indicate that the inductance and capacitance connected therein are the essential elements. Practical operation of the devices indicates that the resistance of both capacitances and inductances are important elements in determining the completeness of transmission and the completeness of attenuation of the predetermined frequencies. The lower the resistance is made, the more complete are both transmission and attenuation of the respective desired and undesired frequencies and the sharper is the dividing line therebetween.

Experimental study of the effect of resistance upon the attenuation of a filter section shows that it depends upon the ratio

$$\frac{2\pi fL}{R}$$

in which f is the frequency, L the impedance and R the resistance. It is, therefore, evident that decreasing R increases the degree of attenuation per filter unit.

In the consideration of such wave filter systems, limits are placed upon the conductance of both the inductance and the capacitance by the limitations of structural size as well as the limitations of available materials. For this reason, it has not been possible in the prior art to attain entirely satisfactory conduction and attenuation of the desired frequencies nor wholly satisfactory separations therebetween.

My invention provides means whereby the effective resistance of the impedances in a filter trap circuit may be substantially reduced; conversely, means whereby the effective conductance thereof may be substantially increased and, thereby, the conductance of the desired frequencies and the attenuation of the undesired frequencies substantially increased. Likewise, a substantial gain in sharpness of separation between conducted and attenuated frequencies is obtained.

This result my invention secures by means of a regenerative triode system applied to the filter system. Regenerative energy may be applied to a single filter section and influence a plurality of sections, or it may be applied to a plurality of sections.

Other objects and structural details of my invention will be apparent from the following description when read in connection with the accompanying drawing wherein:

Figs. 1, 2, 3 and 4 are diagrammatic sketches of circuits and apparatus of wave filter traps embodying my invention.

In Fig. 1, an inductance 1 and a capacitance 2 are connected in the incoming leads of a filter trap device. An inductance 3 in series with a capacitance 4 is connected between the leads of the filter trap system. The elements 1, 2, 3 and 4, taken together, form a filter trap unit which is repeated as a second unit in the inductance 5, the capacitance 6, the inductance 7 and the capacitance 8. To illustrate the possibility of varying the form of the filter trap, I have shown the inductance 7 and

capacitance 8 in parallel. Obviously, the invention is applicable to filters in which the second shunt 7—8 is arranged like the first one 3—4. Inductively related to coil 3 is a coil 9 having taps connected to a triode 11, the cathode of which is heated by a battery 12, and plate energy for which is furnished by a battery 14.

In Fig. 2, the inductance 1 and the capacitance 2, in series, and the inductance 3 and the capacitance 4, in parallel, are positioned as in Fig. 1. Inductively connected with the inductance 3 is an inductance 9. A triode 11 having a filament-heating current source 12 and a plate current source 14 has the grid and the cathode thereof connected to the terminals of inductance 3 and the anode thereof connected through an inductance 9 to a battery 14, the other terminal of which is connected to the cathode of the triode 11. A second non-regenerated unit, of the construction according to the prior art, may be combined therewith in which are provided the inductance 5, the capacitance 6, the inductance 7 and the capacitance 8, as before.

In Fig. 3, a pair of units similar to the first unit of Fig. 2 are provided in which similar reference numerals indicate similar parts.

In Fig. 4, a slightly different unit is made up of an inductance 1, a capacitance 2, an inductance 3 shunted by a capacitance 4 and connected across the terminals of the supply circuit. An inductance 15 is provided in inductive relation with the inductance 1. A triode 16, having a filament current supply 17 and a plate current supply 18, is provided, the grid and cathode of which are connected to the terminals of the inductance 1. The anode of the triode 16 is connected through an inductance 15 to the battery 18, the other terminal of which is connected to the cathode. The Figure further shows an additional unit similar to the first unit of Fig. 2 in which similar numerals represent similar structures.

In the operation of my device, the magnetic coupling between the coil connected in the anode circuit of each triode is adjusted to such a value that a regenerative action is obtained, but without the development of sustained oscillations. Under these conditions, the occurrence of current in the filter circuit causes alternating current energy of the same frequency to be impressed upon the inductance, thereby reducing the effective resistance thereof.

The reduction in effective resistance thereby obtained is equally as satisfactory as an actual reduction in ohmic resistance in improving the attenuation of the filter trap to a predetermined frequency, and in increasing the conductance of the desired frequencies.

I find that, in the case of a multi-section filter system, regeneration applied to one of the elements thereof is effective in reducing the apparent resistance of several adjacent sections, with the corresponding gain in conductance and attenuation.

It is to be noted that, while the actual ohmic rsitance of the impedance elements of the filter is largely neutralized and compensated for by the regeneration, with respect to the resonance currents and potentials developed in the unit, it, the resistance, remains of consequence in that it determines the width of the frequency band to which the unit is responsive.

By this means, I am enabled to obtain a greater attenuation per unit section of filter system than is possible in the prior art. I am also enabled to obtain greater conductance of the desired frequencies and sharper separation between conduction and attenuation of frequencies than is possible in the prior art.

While I have shown only three embodiments of my invention in the accompanying drawing, it is capable of various changes and modifications without departing from the spirit thereof, and it is desired, therefore, that only such limitations shall be placed thereon as are imposed by the prior art or indicated in the appended claims.

I claim as my invention:

1. A filter chain comprising a plurality of sections, each section having inductive and capacitive reactors as constituent elements thereof, and means for regenerating each section at the frequency it is desired that the chain shall least attenuate.

2. A wave filter system comprising a plurality of filter sections and regenerative means applied to a plurality of said filter sections, said plurality being less than all of said filter sections, and influencing sections not directly regenerated.

3. A wave-filter system comprising, in combination, a plurality of filter sections, each section being constituted by one or more reactors, and a regeneratively connected thermionic device coupled to said filter system, the coupling being accomplished through the medium of one of the reactors comprised in an intermediate section of said filter system.

4. A wave-filter system comprising, in combination, a plurality of recurrent filter sections, each section including one or more reactors, and a regeneratively connected thermionic device coupled to said filter system, the coupling being accomplished through the medium of one of said reactors, the said reactor functioning also in the regenerative connection of said thermionic device.

5. A wave-filter system comprising, in combination, a plurality of filter sections, each section being constituted by one or more reactors, and regeneratively connected thermionic devices coupled to at least two of said sections, the coupling being accomplished through the media of the reactors comprised in the said sections.

6. A wave-filter system comprising, in

combination, a plurality of filter sections designed to attenuate certain frequencies and to conduct certain frequencies, each section comprising one or more reactors, and a thermionic device having input and output circuits regeneratively coupled together, at least one of said reactors being included in one of said circuits, whereby the efficiency of said filter section is materially increased.

In testimony whereof, I have hereunto subscribed my name this 2nd day of August, 1924.

LESTER O. MARSTELLER.