March 21, 1933. W. H. T. HOLDEN 1,902,031

FILTERING APPARATUS

Filed Jan. 6, 1931

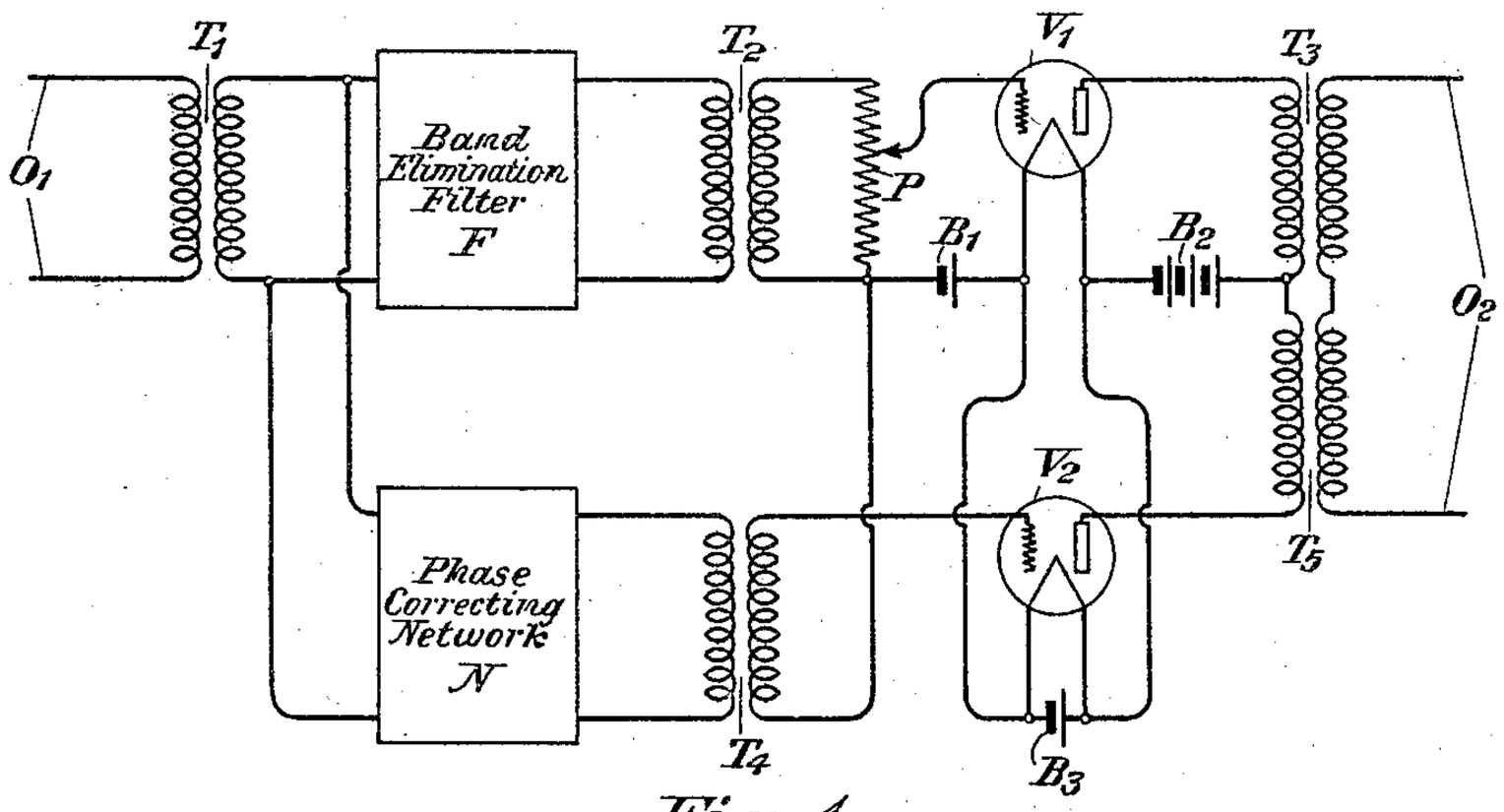

Fig. 1

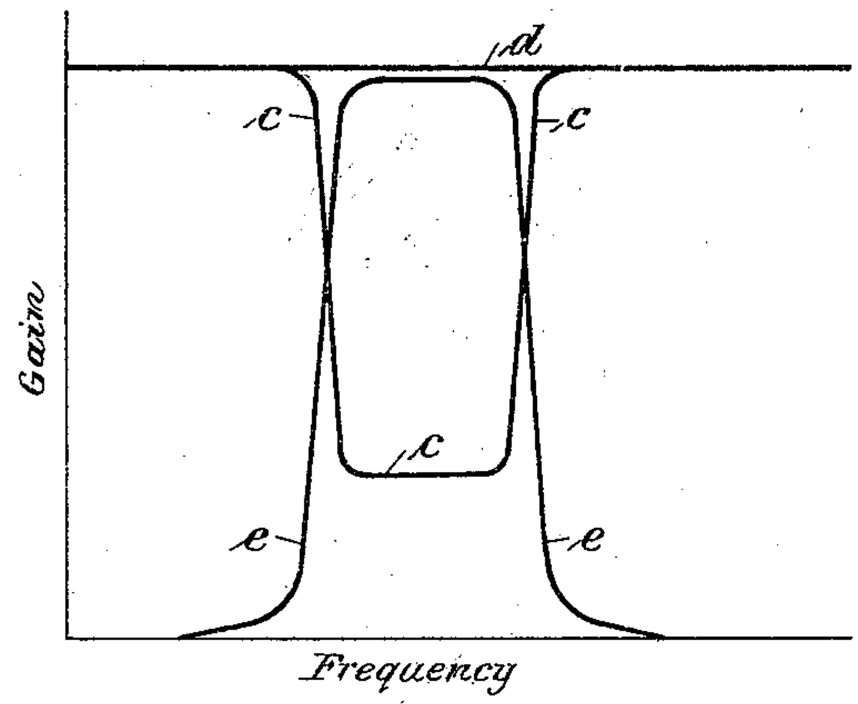

Fig. 2

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UNITED STATES PATENT OFFICE

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FILTERING APPARATUS

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This invention relates to signaling systems and to filters and current-suppressing systems. More particularly, this invention relates to systems arranged so as to greatly increase the effectiveness of filters or current-suppressing apparatus.

This invention will find application in radio or carrier systems generally where it is desired to very efficiently eliminate the effect of currents having frequencies within certain prescribed limits or, if desired, of currents having frequencies outside such limits. This invention will find special application in connection with filtering apparatus designed to provide means whereby a cheap and somewhat inefficient filter will be converted into a highly desirable and very effective filter. From another aspect of this invention, it will be considered to provide apparatus for converting a cheap filter of one type such, for example, as the band elimination type, into a very effective filter of a different type, such, for example, as the band pass type, and vice versa.

This invention may be broadly considered as comprising two electron tubes which may form an amplifier having two parallel paths to which currents of the same frequencies are transmitted, some of which have smaller amplitudes than others, and these currents are independently obtained from these tubes and impressed upon balancing transformers. If these amplifying paths have equal gains, the transmitted currents which have equal amplitudes will exhibit equal and opposite effects in the transformers, and these effects will be nullified in a common circuit connected or otherwise coupled to these transformers. However, currents which do not have equal amplitudes after transmission through the two parallel paths, will not be completely nullified, and their effects will be properly registered in the common circuit.

This invention will be better understood from the detailed description hereinafter following, when read in connection with the accompanying drawing, in which Fig. 1 represents an embodiment of the invention given merely for the purpose of illustration, and Fig. 2 represents a number of curves to explain the features of the invention.

Referring to Fig. 1 of the drawing, the reference character O_1 designates an input circuit which supplies a plurality of currents of a wide variety of frequencies which may be those forming a very broad band and may include other bands and individual currents. All of these currents are transmitted through a transformer T_1 to a filter designated F which may, for example, be of the band elimination type. Such a filter will substantially suppress currents having frequencies between certain well defined limits, while freely transmitting currents of all frequencies without these limits. Between the limits of the filter F all currents will be attenuated by a somewhat definite amount, and the magnitude of the attenuation will depend on the quality or the design of the filter, and this in turn usually depends on the number of sections included in the filter. It is a well known fact that the effectiveness of the filter, i. e., the amount of attenuation it presents to certain undesired frequencies as compared to other desired frequencies, is raised by increasing the number of its sections, and conversely, a filter having a smaller number of sections will be one of lower effectiveness. The filter F may be composed of a single section or may include merely a few sections, i. e., two or three sections, and the single section of the few sections may each be of a type which includes a piezo-electric crystal.

The currents freely transmitted by the filter F substantially without attenuation and those having frequencies within the limits of this filter transmitted with quite large and substantially uniform attenuation, are impressed on the grid and filament electrodes of an amplifying tube V_1 through a transformer T_2 and a potentiometer P. A battery B_1 fixes the bias of the grid electrode of the tube V_1 with respect to its filament. The potentiometer P may be manipulated to change the gain of the currents transmitted through transformer T_2. The currents amplified by the tube V_1 appear in its output circuit, which includes a battery B_2, the primary winding

of a transformer T_3 and the plate and filament electrodes of the tube V_1.

The currents transmitted from the input circuit O_1 through transformer T_1 also reach a phase correcting network designated N which may be of any well known type and which is employed to equalize the phases of the currents transmitted therethrough with those transmitted through the filter F. This neutralizing network is designed to be especially efficient for currents having frequencies within the limits of the filter F, wherein precise phase correction will occur. Thereafter, these currents become impressed on the grid and filament electrodes of another amplifying tube V_2 through a transformer T_4.

The tube V_2 is an amplifier of the same general type as V_1 and is preferably one equal in all of the tube characteristics. Especially should these tubes be equal in their amplifying factors, for both should equally amplify all currents reaching their input circuits.

The currents amplified by the tube V_2 flow through its output circuit, which includes the battery B_2, the primary winding of a transformer T_5, and the plate and filament electrodes of the tube V_2. It is to be noted that the battery B_1 equally biases the grid electrodes of the tubes V_1 and V_2, that battery B_2 provides the same positive potentials for the plate electrodes of these tubes and that their filament electrodes are connected in parallel relationship with respect to a common battery B_3.

The primary windings of the transformers T_3 and T_5 are so connected that their effects may be continually in opposition. Equal currents of a common frequency impressed upon these windings will have practically no effect in an output circuit O_2, which is connected in series with the secondary windings of the transformers T_3 and T_5. While transformers do not have the theoretically perfect balance, their balance should, in the practice of this invention, be equal to the gain of either of the tubes V_1 or V_2. The transformers T_3 and T_5 have identical characteristics and, therefore, voltages transmitted therethrough which are 180 degrees out of phase with each other in the output circuits of tubes V_1 and V_2 will annul each other, while voltages which are in phase with each other or are out of phase with each other by some angle different from 180 degrees will not annul each other.

Current flowing through the primary windings of the transformers T_3 and T_5 which have equal amplitudes, will oppose each other and their effects will not appear in the output circuit O_2. This will be the case with currents of all frequencies outside the limits of the filter F.

Currents of all frequencies within the limits of this filter will, however, have different effects upon the primary windings of the transformers T_3 and T_5. These currents will affect the primary winding of the transformer T_5 more greatly than the primary winding of the transformer T_3 and currents of all of these frequencies will be found in the output circuit O_2.

Curve *c* of Fig. 2 represents the relation between the frequency of various currents and their gain after amplification by the tube V_1. This curve shows that currents of all frequencies outside the limits of the filter F will be transmitted quite uniformly and at a high gain and that those currents of frequencies within these limits will be substantially uniformly attenuated. If the tube V_1 amplifies currents having frequencies outside the limits of the filter F to a level of, for example, about 24 decibels, it may be assumed that the level of the currents of frequencies within the limits of the filter F will, for example, be about 7 decibels. This filter may be considered as one which causes an attenuation of about 17 decibels at undesired frequencies.

Curve *d* of Fig. 2 represents the level of the energy passing through the phase correcting network N and amplified by the tube V_2. Here all frequencies are equally amplified, especially because the network N has practically no frequency discrimination. Currents of all frequencies will have substantially the same level and this may be assumed for illustrative purposes to be, for example, about 24 decibels.

Curve *e* of Fig. 2 shows the nature of the currents flowing through the output circuit O_2. Practically all currents having frequencies within the limits of the filter F freely flow through the circuit O_2 and have a level almost equal to the level of those currents flowing in the output circuit of the tube V_2. Currents of frequencies within the limits of the filter F will be greatly attenuated and their level, in the illustrated case, may be about 24 decibels less than the level of those currents having frequencies within the limits of the filter.

It will be apparent that a device having the characteristic *e* exhibits an attenuation for frequencies outside certain limits considerably greater than a device having a characteristic such as *c* which exhibits an attenuation for frequencies within these limits. In the illustrated case this difference in attenuation may, for example, be about 7 decibels. Thus, the effectiveness of a device having the characteristic *e* greatly exceeds the one with the characteristic *c*.

The figures given in the illustration are not to be considered as in any way limiting the invention, for these may be greatly varied in different cases without departing

from the spirit of the invention and the scope of the appended claims.

It will be seen that the arrangement described herein involves apparatus for addition to an inefficient filter of poor quality which may be of the band elimination type in order to render the arrangement a high quality filtering apparatus of, for example, the band pass type. The arrangements of this invention in effect convert a filter of one type, i. e., the band elimination type, into one of a very different type, i. e., the band pass type. If the filter F were of the band pass type, the over-all circuit would have a characteristic of the band elimination filter. This inversion of properties may be avoided, however, if such is desired, but in that event the band elimination filter F shown in Fig. 1 would have to be one having a very flat characteristic for currents of frequencies within the limits of the filter. Such a device is not ordinarily found and must generally be specially designed.

While this invention has been disclosed in certain particular arrangements merely for the purpose of illustration, it will be understood 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. Band pass filtering apparatus comprising a band elimination filter, two amplifying circuits coupled, respectively, to the input and output circuits of the filter, both amplifying circuits having equal gains, and a pair of transformers connected to said circuits and coupled so as to be in opposition.

2. The combination of a source of currents having different frequencies, a band elimination filter, a phase correcting network in parallel with said filter with respect to said course of currents, two equal amplifying circuits coupled, respectively, to said filter and said network, and a pair of transformers connected to said amplifying circuits and coupled so as to be mutually opposing.

3. The combination of a filter greatly suppressing currents of frequencies within certain limits and freely transmitting currents of frequencies without said limits, and means coupled to said filter for converting the combination into one freely transmitting currents of all frequencies within said limits while greatly suppressing currents of all frequencies without those limits, said means including a phase correcting network.

4. The combination of a band elimination filter, apparatus connected in parallel with with said filter for equalizing the phases of currents transmitted therethrough with those freely passed by the filter, two amplifiers coupled respectively to the filter and the equalizing apparatus, and means for bringing the currents transmitted by said amplifiers into opposition.

5. The combination of two parallel amplifiers having the same gains and two transformers coupled to said amplifiers and arranged in opposition, said transformers having a loss equal to the gains of said amplifiers.

In testimony whereof, I have signed my name to this specification this 5th day of January 1931.

WILLIAM H. T. HOLDEN.