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H. W. ELSASSER

WAVE FILTER

Filed March 24, 1921

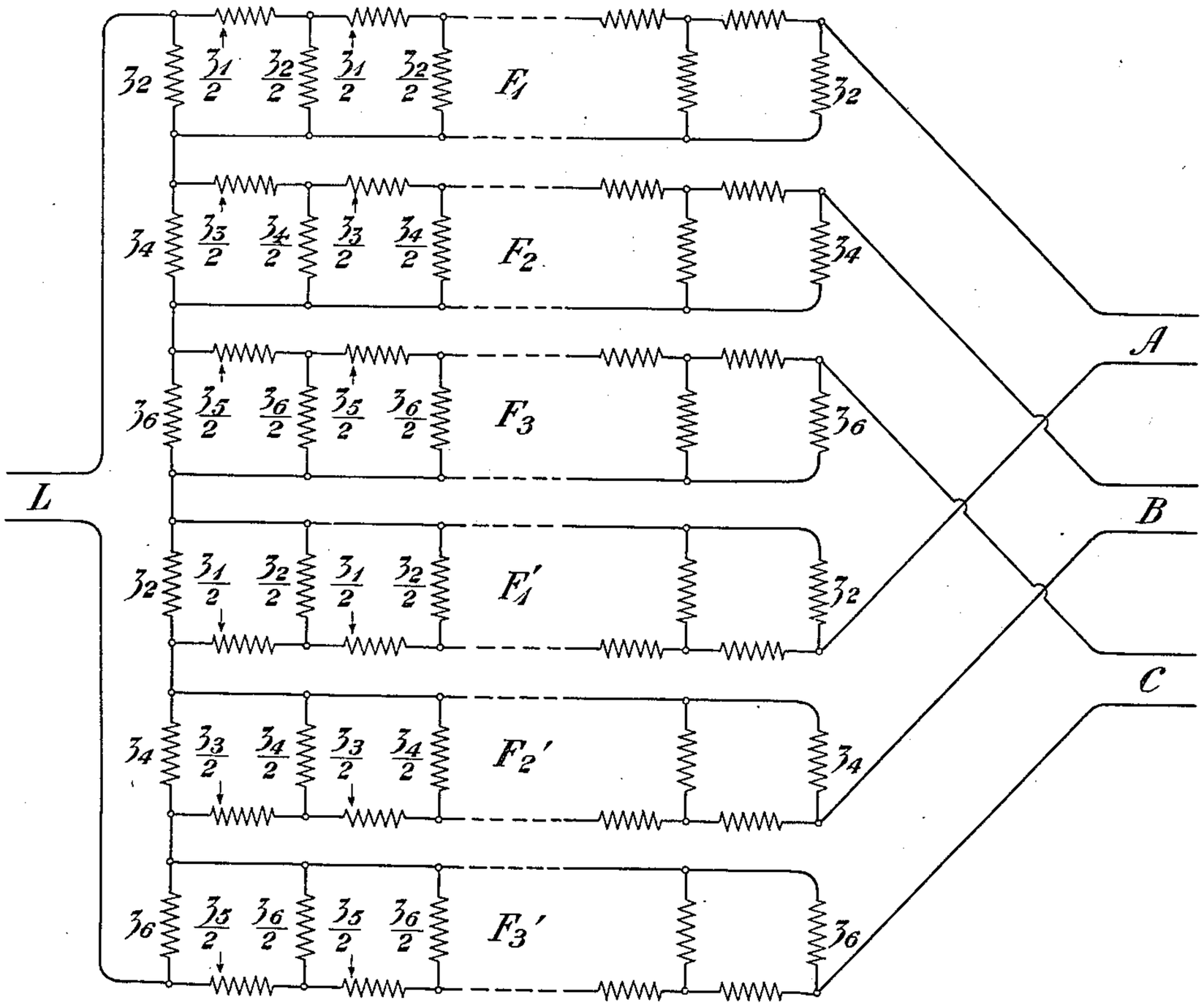

Fig. 1

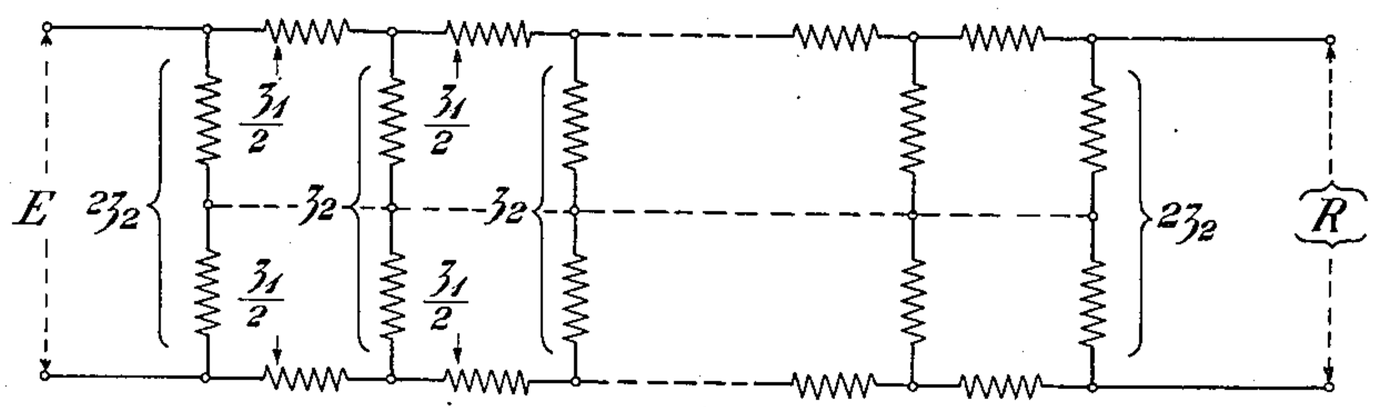

Fig. 2

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UNITED STATES PATENT OFFICE.

HENRY W. ELSASSER, OF NEW YORK, N. Y., ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

WAVE FILTER.

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To all whom it may concern:

Be it known that I, HENRY W. ELSASSER, residing at New York, in the county of New York and State of New York, have invented certain Improvements in Wave Filters, of which the following is a specification.

It is an object of my invention to provide a new and improved combination of circuits with wave filters so as to attain efficient operation. Another object of my invention is to dispose a plurality of wave filters in series combination with a transmission line and at the same time preserve the balance of the line. Another object is to arrange a plurality of filters of different frequency ranges in series, without requiring the use of transformers and without unbalancing the line. Still another object of my invention is to connect a plurality of branch circuits to a transmission line through respective filters in such a manner as to preserve the balance on the line at all operating frequencies. All these objects and others will become apparent on consideration of one specific embodiment of the invention which I have chosen to disclose in this specification, with the understanding that the invention is defined in the appended claims. I will now proceed to describe the particular embodiment of the invention shown in the drawings, for which Figure 1 is a general diagram, and Fig. 2 is a modified detail for purposes of explaining the theory involved.

Having a transmitting line L over which alternating currents of various frequencies are received, it is desired to distribute frequencies within a certain range to the branch circuit A, other frequencies to the branch circuit B and still others to the branch circuit C, excluding from the other branch circuits those frequencies which it is desired to receive in one of them.

This purpose is to be accomplished by the interposition of wave filters, each of the type having recurrent sections of series and shunt elements. Such a filter is shown in Fig. 2 where each section has a series impedance Z_1 and a shunt impedance Z_2. As shown in Fig. 2, the series impedances Z_1 are each halved, the two equal parts being placed on the two sides of the filter circuit. Each shunt impedance Z_2 is shown consisting of two equal sections in series with one another; the purpose of this disposition will become apparent presently.

Wave filters of this type may have various terminations. In the illustrative example shown in the drawings, I have disclosed "mid-shunt" terminations; this term means that the filters end with a shunt element whose admittance is half that of the normal intermediate shunt elements, in other words, its impedance is twice that of the normal intermediate shunt elements. Hence, as shown in Fig. 2, the end shunt elements each have the value $2Z_2$. This termination is used so that the impedance of any filter for the range of frequencies which it does not transmit is substantially zero.

If an alternating electromotive force E is applied across the input terminals of the filter of Fig. 2, there will be a certain frequency range for which the current will be transmitted without attenuation to the receiving circuit R across the output terminals. For every frequency lying outside this range the current in R will be attenuated, that is, most of the current will be shunted through the elements Z_2. The frequency range for free transmission is determined by the choice of the impedances Z_1 and Z_2.

To accomplish the distribution of frequencies from the line L to the circuits A, B and C in the manner which I have stated to be desired, I first determine the proper values of Z_1 and Z_2 for the desired impedance and transmitting frequency range for circuit A. Next I determine in the same way the values of Z_3 for the series impedances and Z_4 for the shunt impedances for the proper filter to give the desired impedance and free transmitting range for the circuit B. In the same way I determine the proper values of Z_5 and Z_6 for a filter for branch circuit C. Then I construct the filters and connect them up in the manner

shown in Fig. 1 which with its legends is self-explanatory for the present purpose so that it will not be necessary to trace the various circuits in detail.

Let us consider what happens when an alternating current is received over the line L of a frequency within the range which is desired to be transmitted to circuit A but excluded from circuits B and C. For this purpose it will be convenient to give further consideration to Fig. 2. The alternating current of the frequency referred to will be transmitted without attenuation from the input end E to the receiving end R. Now suppose the middle points of all the shunt elements Z_2 are connected together by a conductor of negligible impedance as indicated by the dotted line in Fig. 2—this virtually converts the filter of Fig. 2 into two filters in series, the dotted line conductor affording the series connection between them. Since the filter was perfectly balanced across the entire circuit before this change was made, the dotted line conductor merely connects the neutral points of the network and the operation will be the same as before. The frequency range depends on the ratio of the series and shunt impedances which are unchanged in each of the two half filters of Fig. 2 as compared with the original whole filter. The impedance of each of the two half filters is easily shown to be one-half that of the whole filter so that the impedance of the two filters in series is the same as of the original whole filter.

Returning to Fig. 1, alternating currents lying within the frequency range desired for branch circuit A are transmitted without attenuation by the filters F_1 and F_1'. The impedances of filters F_2, F_2', F_3 and F_3' are however substantially zero for this frequency range, due to the method of terminating these filters. Filters F_1 and F_1' are therefore in series and balanced with respect to the line as indicated in Fig. 2. Accordingly, the frequency range considered will be transmitted without attenuation to the branch circuit A, but shunted off from the branch circuits B and C.

It will be seen that the impedance of the free transmitting filters is inserted equally on both sides of the line so that the balance of the line is preserved. The balance of the line with a non-symmetrical disposition of filter or filters has been secured heretofore by the interposition of a transformer or transformers. I have made it possible to avoid the use of transformers for this purpose thus avoiding the objection due to their leakage reactance and the undesirable impedance which was inserted in the line thereby for the non-transmitting ranges of the filters. The arrangement shown in Fig. 1 keeps the number of non-transmitting filters always the same between the two transmitting filters, that is, this number is always two. Thus the branch circuits A, B and C are similarly disposed in reference to the line and the respective transmitting and non-transmitting filters of the system.

I claim:

1. A transmission line, a plurality of branch circuits and respective wave filters between said line and said branch circuits, each said filter being divided and its parts connected in series between the two conductors of the line with parts of other filters between them so as to preserve the balance of the line.

2. A transmission line, a plurality of branch circuits and two equal filters for each branch circuit, all said filters being connected in series and the two filters for each branch circuit being non-adjacent in the series.

3. A transmission line, a plurality of branch circuits, and two equal filters for each branch circuit connected respectively to the conductors thereof, all the filters being connected in series across the line, and arranged so that the two equal filters for one branch are separated by one or more of the other filters.

4. A transmission line, a plurality of branch circuits, and wave filters interposed between said line and said branch circuits, each filter being separated into two parts and each pair of parts of one filter being separated by parts of other filters so as to preserve the balance of the line.

5. A transmission line, a plurality of branch circuits, a pair of equal wave filters connected respectively on each conductor of each branch circuit, the input terminals of all said wave filters being connected in series across said line, and arranged so that the two equal filters for one branch are separated by one or more of the other filters.

6. A transmission line, a plurality of branch circuits, a pair of equal wave filters connected respectively on each conductor of each branch circuit, the input terminals of all said wave filters being connected in series across said line, the number of interposed filters being the same between any two equal filters for a respective branch circuit.

7. A transmission line, a plurality of branch circuits and respective pairs of wave filters for said branch circuits, the members of each pair being equal and all having mid-shunt termination and having their input terminals connected in series across the line, and arranged so that the two equal filters for one branch are separated by one or more of the other filters.

8. A transmission line, a plurality of branch circuits, a pair of equal wave filters connected respectively on each conductor of each branch circuit, the input terminals of

all said wave filters being connected in series across said line, each pair of equal filters having a frequency range lying outside the frequency ranges of the other such pairs, and each filter having substantially zero impedance for frequencies outside its range, and arranged so that the two equal filters for one branch are separated by one or more of the other filters.

In testimony whereof, I have signed my name to this specification this 18th day of March, 1921.

HENRY W. ELSASSER.