

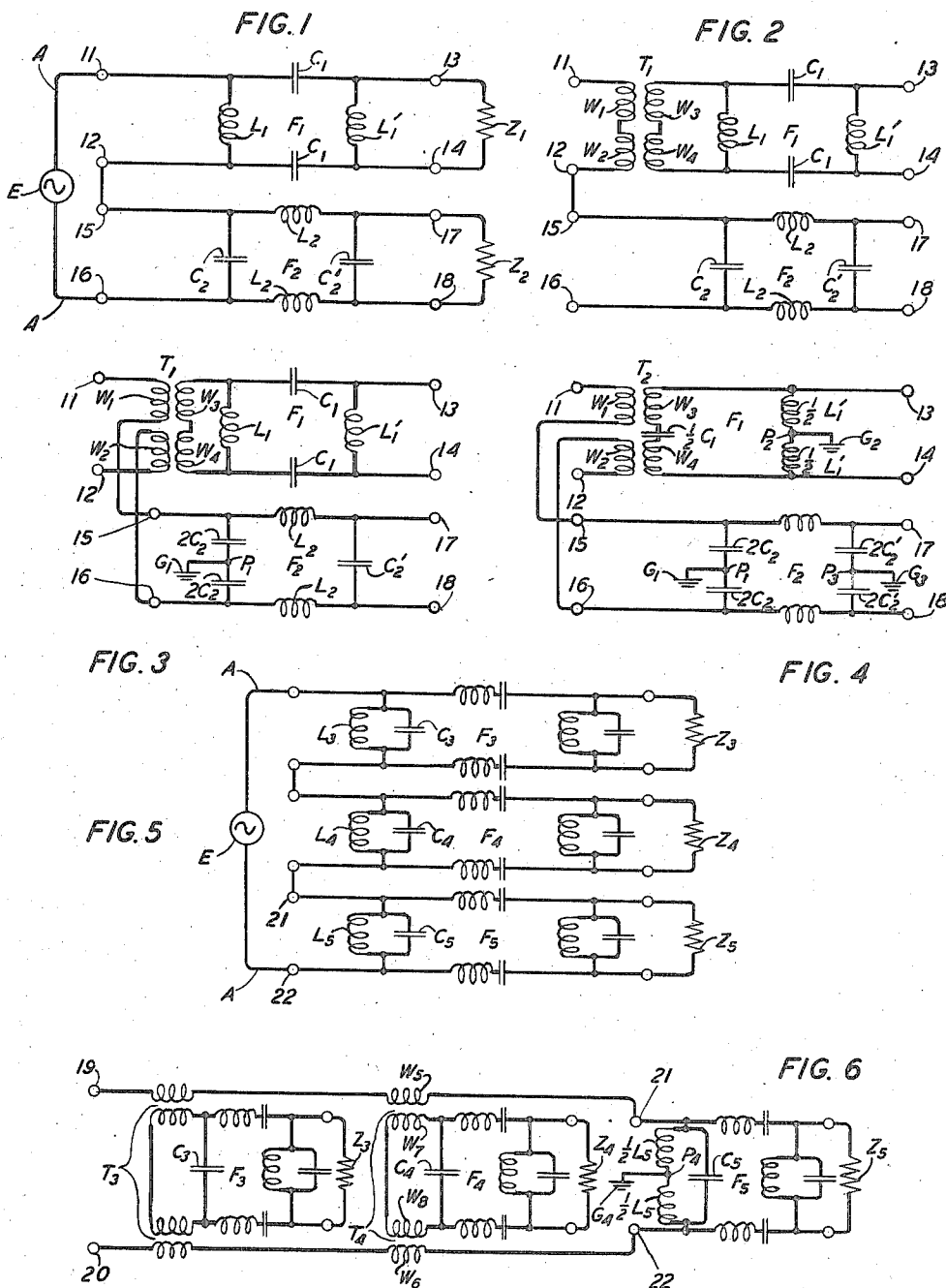
May 19, 1936.

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2,041,098

WAVE TRANSMISSION NETWORK

Filed May 19, 1934



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2,041,098

WAVE TRANSMISSION NETWORK

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Application May 19, 1934, Serial No. 726,454

21 Claims. (Cl. 178—44)

This invention relates to wave transmission networks and more particularly to a balanced arrangement of a plurality of wave filters connected in series at their input ends.

An object of the invention is to connect in series the input terminals of a plurality of balanced wave filters in such a way as to preserve the balance to ground condition throughout the entire structure.

Another object is to connect a plurality of branch circuits to a transmission line through respective filters in such a manner as to preserve the balance of the line throughout the entire range of operating frequencies.

A feature of the invention is a line filter set comprising a balanced low-pass filter and a balanced high-pass filter connected in series at the ends next to the line and so arranged that the condition of balance to ground is maintained throughout the entire structure.

Another feature is a plurality of balanced band filters connected effectively in series at their line ends in such a way that the combination may be bridged across a transmission line without disturbing the balance to ground.

In wave transmission systems there is often encountered the problem of separating currents of different frequencies transmitted over a line into two or more channels, each of which will pass a certain band of frequencies while excluding all others. It is customary to employ for this purpose wave filters of the general type disclosed in U. S. Patents Nos. 1,227,113 and 1,227,114 to George A. Campbell, issued May 22, 1917. When such a set of filters is connected to a transmission line it is desirable that the balance of the line with respect to ground be not disturbed thereby. In accordance with the present invention, this requirement is met by maintaining a condition of balance to ground throughout the entire combination of filters. For example, in a line filter set comprising a low-pass filter and a high-pass filter connected in series relation, the high-pass filter employs at its input end a transformer the primary of which consists of two equal windings, and the low-pass filter is connected in series between the two halves of this primary winding. In a modified form of the invention this transformer takes the place of a shunt inductance in the high-pass filter. As a further modification the transformer secondary is made of two equal windings and the series capacitances of the high-pass filter are lumped together and connected between the two halves of the secondary. Since such an arrangement of filters is a

completely balanced structure, electrical mid-points at the input and output ends may be provided for grounding purposes, if desired.

The invention may be applied to any number of filters, as, for example, a set of band filters. An additional four-winding transformer is required for each added filter, and the two halves of the primary winding are symmetrically located with respect to the electrical midpoint so that the balance of the structure is maintained throughout.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying drawing, of which:

Fig. 1 shows a combination of low-pass filter and high-pass filter with their input terminals connected in series, to which the invention is applicable;

Fig. 2 represents an intermediate step in working out the invention, in which a four-winding transformer is introduced into the high-pass filter;

Fig. 3 illustrates schematically one form of the invention in which the low-pass filter is connected between the two halves of the transformer primary winding;

Fig. 4 is a schematic representation of a modified form of the invention in which the transformer acts as a shunt inductance in the high-pass filter and the series capacitances of the high-pass filter are connected in series between the two halves of the transformer secondary;

Fig. 5 shows a set of band filters to which the invention is applicable; and

Fig. 6 illustrates schematically the application of the invention to the band filter set of Fig. 5.

Fig. 1 shows a line filter set comprising a balanced high-pass filter F_1 and a balanced low-pass filter F_2 having their respective input terminals 11, 12 and 15, 16 connected in series across the transmission line A in which there is a wave source of electromotive force E. The respective output terminals 13, 14 and 17, 18 of the filters are connected to separate channels or terminal apparatus the impedances of which are represented, respectively, by Z_1 and Z_2 . The function of such a filter set is to separate the alternating currents of various frequencies received over the line A into two bands, one comprising the high frequencies and the other the low frequencies. The high frequency range is transmitted through filter F_1 to the load Z_1 and the low frequency range is distributed through filter F_2 to the load Z_2 .

In order to make the input impedance between terminals 11, 16 of the combination of filters as nearly as possible a constant resistance over the entire operating frequency range and thereby match the impedance of the transmission line A, it is desirable to design the filters F_1 and F_2 as complementary filters, in accordance with the method set forth in U. S. Patent No. 1,557,230 to Otto J. Zobel, issued October 13, 1925. As shown in Fig. 1, the filter F_1 is terminated at the line end in a shunt inductance L_1 and at the drop end in a shunt inductance L_1' , and the capacitances C_1 , C_1' are connected in series therebetween. The filter F_2 is terminated at the line end in a shunt capacitance C_2 and at the drop end in a shunt capacitance C_2' , with the inductances L_2 , L_2' interposed as series impedances. Only a single full section is shown for each filter but more sections may be added if the attenuation requirements so dictate.

Fig. 2 represents an intermediate step in working out the invention, in which there is introduced at the input end of the high-pass filter F_1 a transformer T_1 the primary of which consists of the two equal windings W_1 and W_2 and the secondary of which is made up of two more equal windings W_3 and W_4 . The transformer T_1 is a so-called ideal transformer, that is, its windings have large self-inductances and the coupling factor is substantially unity.

An embodiment of the invention is shown in Fig. 3, where the input end of filter F_2 is connected in series between the two halves W_1 , W_2 of the transformer primary, and the terminals 11, 12 serve as input terminals for the combination. The shunt capacitance C_2 is replaced by an equivalent impedance branch consisting of two capacitances in series, each equal in value to $2C_2$. Both filters function in exactly the same manner as before but there is now provided at the input end of the combination an electrical midpoint P_1 which may be grounded or otherwise fixed in potential as shown at G_1 . Terminals 11, 12 of the filter set may now be connected to the transmission line A without disturbing the condition of balance to ground.

The preferred form of the invention is shown in Fig. 4, in which the transformer T_1 is replaced by a transformer T_2 , designed to take the place of the shunt inductance L_1 of the high-pass filter F_1 , thus permitting the inductance L_1 to be left out of the circuit. The two capacitances C_1 , C_1' which are now directly in series with the transformer secondary, are replaced by an equivalent capacitance, equal in value to $\frac{1}{2}C_1$, which is connected in series between the two halves W_3 , W_4 of the secondary winding.

In order to provide an electrical midpoint P_2 at the output end of the filter F_1 the shunt inductance L_1' is tapped at its center. Similarly, the electrical midpoint P_3 at the drop end of the filter F_2 is provided by replacing the shunt capacitance C_2' by an equivalent impedance branch consisting of two capacitances in series, each equal in magnitude to $2C_2'$. The points P_2 and P_3 may be grounded or otherwise fixed in potential, as shown at G_2 and G_3 , thus providing a system of filters which is completely balanced with respect to ground both at the input and the output ends.

The invention is applicable to any number of filters connected in series, as, for example, the set of balanced band filters F_3 , F_4 and F_5 shown in Fig. 5. At their line ends the filters are connected in series to the transmission line A, and

at their drop ends they are terminated, respectively, in the load impedances Z_3 , Z_4 and Z_5 . The filters have mutually exclusive transmission bands, each filter selecting its own range of frequencies and transmitting it to the proper load impedance. At its line end each filter has a shunt termination comprising an inductance and a capacitance connected in parallel, these elements being designated L_3 and C_3 for the filter F_3 , with corresponding notation for the other filters.

Fig. 6 illustrates the application of the invention to the set of filters shown in Fig. 5. The filter F_5 remains unchanged except that the shunt inductance L_5 is replaced by two inductances each equal in magnitude to $\frac{1}{2}L_5$ so that the electrical midpoint P_4 may be provided for grounding, as shown at G_4 . The filter F_4 is connected effectively in series with the filter F_5 by means of the transformer T_4 which comprises two equal primary windings W_5 , W_6 and two secondary windings W_7 , W_8 . The winding W_5 is connected in series with the lead between input terminal 19 of the combination and terminal 21 of the filter F_5 , while the winding W_6 is placed in the lead between input terminal 20 and terminal 22. The secondary windings W_7 and W_8 of the transformer T_4 are connected in series with each other and are shunted across the condenser C_4 . The transformer is so designed that it takes the place of the shunt inductance L_4 , which latter is omitted in Fig. 6. Similarly, the transformer T_3 takes the place of the shunt inductance L_3 and at the same time serves to couple the filter T_3 to the combination in such a way that the line ends of all of the filters are connected effectively in series while the balance of the structure with respect to the point P_4 is maintained. If it is desired to ground the drop ends of the filters, the shunt branches at these ends may be divided into two equal parts and grounding taps provided, as shown in Fig. 4.

What is claimed is:

1. A line filter set comprising a balanced low-pass filter and a balanced high-pass filter having their inputs connected in series at the end next to the line, said filter set being so arranged that the condition of balance to ground is maintained throughout the entire structure, and having an electrical midpoint at the line end available for grounding purposes.

2. In combination, a transformer the primary of which comprises two equal windings, a wave filter having its input terminals connected in series between said two windings, and a second wave filter connected to the secondary of said transformer.

3. In combination, two balanced wave filters and a transformer comprising four windings, one of said filters being connected between two of said windings, and the other of said filters being connected across the outer ends of the other two of said windings, said transformer serving as a shunt inductance in said last mentioned filter, and a series impedance in said last mentioned filter being connected between the inner ends of said other two windings.

4. In combination, a transformer the primary of which consists of two equal windings and the secondary of which consists of two other equal windings, a balanced wave filter having its input connected in series between said primary windings, a capacitance connected in series between said secondary windings, and an inductance con-

nected across the outer terminals of said transformer secondary.

5. In combination, a transformer having four windings, two of said windings comprising the primary and the other two of said windings comprising the secondary, a balanced low-pass filter connected between said primary windings, a balanced high-pass filter connected to said secondary, a series impedance of said high-pass filter being connected in series between said secondary windings, and said transformer serving as a shunt inductance in said high-pass filter.

6. In a wave transmission system, a transformer the primary of which consists of two equal windings, a balanced wave filter having its input connected in series between said equal windings, and a second balanced filter having its input connected to the secondary of said transformer, whereby the condition of balance to ground is maintained throughout said system.

7. In combination, a transformer the primary of which comprises two equal windings, and two wave filters having mutually exclusive transmission bands, the input of one of said filters being connected in series between said equal windings, and the input of the other of said filters being connected to the secondary of said transformer.

8. In combination, a balanced wave filter, a transformer having a primary divided into two equal windings, each of said windings being connected, respectively, in series with an input terminal of said balanced filter, and a second filter having its input connected to the secondary of said transformer.

9. In combination, two wave filters connected in series at their input ends, one of said filters comprising a transformer the primary of which consists of two equal windings, and the other of said filters being connected between said two windings.

10. In combination, a transformer the primary of which consists of two equal windings, a balanced wave filter connected between said two windings, and a second filter connected to the secondary of said transformer, the electrical midpoint at the input end of said first mentioned filter being available for grounding purposes.

11. In combination, a transformer the primary of which comprises two equal windings, a balanced wave filter connected between said two windings, and a second filter connected to the secondary of said transformer, the electrical midpoint at the input end of said first mentioned filter and also the electrical midpoints at the output end of each of said filters being available for grounding.

12. In combination, a transformer the primary of which comprises two equal windings, a balanced low-pass filter connected between said two windings, and a high-pass filter connected to the secondary of said transformer, said transformer serving to take the place of a shunt inductance in said high-pass filter.

13. In combination, a transformer the primary of which consists of two equal windings, a wave filter connected between said two windings, and a second filter connected to the secondary of said transformer, said transformer serving to take the place of a shunt inductance in said second filter.

14. A balanced arrangement of transmission

networks comprising a pair of terminals, a balanced wave filter, electrical connections from each of said terminals to said filter, a plurality of transformers, and a plurality of other filters, one of said other filters being connected to the secondary of each of said transformers, and the primary of each of said transformers consisting of two equal windings, one of said windings being connected in series with each of said electrical connections.

15. A balanced system of networks comprising a balanced wave filter, a plurality of other filters, and a plurality of transformers, one of said transformers being associated with each of said other filters, the primary of each of said transformers consisting of two equal windings, and said windings being symmetrically disposed with respect to said balanced filter.

16. In combination, a transformer the primary of which comprises two equal windings, a wave filter connected between said two windings, a second transformer the primary of which comprises two equal windings connected in series with said filter and symmetrically disposed with respect thereto, a second filter connected to the secondary of said first mentioned transformer, and a third filter connected to the secondary of said second transformer.

17. In combination, a balanced wave filter having a pair of input terminals, a plurality of transformers having divided primary windings, said windings being connected in series with said terminals and being symmetrically disposed with respect to said filter, and a plurality of other filters, one of said other filters being connected to the secondary of each of said transformers.

18. In combination, a balanced wave filter, a plurality of transformers having primaries divided into equal windings, said windings being connected in series with the input of said balanced filter and being symmetrically disposed with respect thereto, and a plurality of other filters, one of said other filters being connected to the secondary of each of said transformers.

19. A balanced arrangement of transmission networks comprising a plurality of transformers having divided primary windings symmetrically arranged with respect to ground, and a plurality of wave filters, one of said filters being connected to the secondary of each of said transformers.

20. In combination, a plurality of transformers having divided primary windings, and a plurality of wave filters, one of said filters being connected to the secondary of each of said transformers, each of said transformers serving to take the place of a shunt inductance in the filter with which it is associated, and said primary windings being symmetrically disposed with respect to ground.

21. A balanced arrangement of transmission networks comprising a pair of input terminals, a ground terminal, an electrical path between each of said input terminals and said ground terminal, a plurality of wave filters and a plurality of transformers, the primary of each of said transformers consisting of two equal windings, one of said windings being connected in series with each of said paths, and one of said filters being connected to the secondary of each of said transformers.

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