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TRANSMISSION NETWORK

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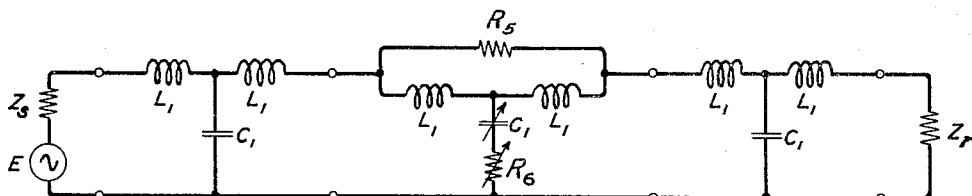
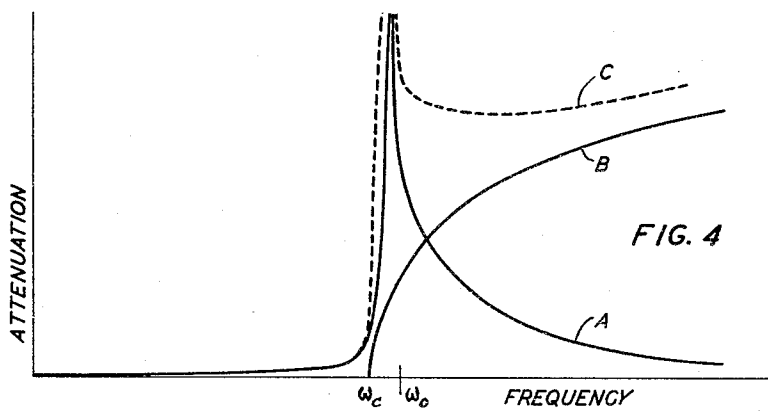
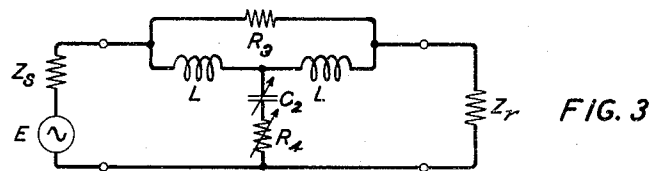
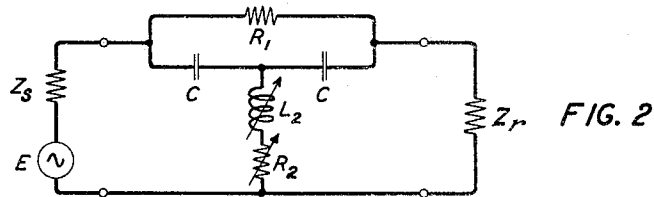
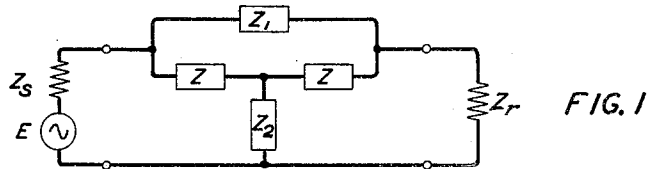


FIG. 5

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TRANSMISSION NETWORK

Application filed February 11, 1932. Serial No. 592,241.

This invention relates to a frequency selective transmission network and more particularly to a network in which transmission is substantially prevented at a predetermined frequency.

In a frequency selective transmission network it is advantageous to have the resistances of the various meshes contribute directly to the proper operation of the circuit. An appreciable amount of resistance is generally unavoidable and if the action of the network is dependent upon the absence of resistance, the theoretical transmission properties of the network will not be realized in practice. If on the other hand the action of the network is made dependent upon the resistances of the various meshes, the theoretical properties of the network can be practically realized.

In accordance with the present invention a network of three circuit meshes is provided, each mesh containing reactive elements and resistive elements. Each circuit mesh is coupled to the other two meshes. The wave source impedance is included in one of the meshes, and the load impedance is included in another mesh. The elements of the network are so proportioned that, at a predetermined frequency, two equal electromotive forces are induced in the output mesh by any electromotive force which may be impressed upon the input mesh. One of these induced electromotive forces is transferred directly from the input mesh to the output mesh. The second electromotive force is transmitted from the input mesh to the output mesh through the intermediary of the third mesh. With the proper adjustment of the circuit elements, as disclosed below, the two electromotive forces induced in the output mesh may be adjusted so that at one or more frequencies they are opposite in phase as well as equal in amplitude. When this balance is obtained, the transmission from the input to the output of the network is substantially prevented at a predetermined frequency.

Referring to the attached drawing:

Fig. 1 represents the general schematic form of the network of the invention;

Figs. 2 and 3 show specific forms of the network of Fig. 1;

Fig. 4 gives typical attenuation characteristics of the networks of Figs. 3 and 5; and

Fig. 5 shows the network of Fig. 3 in combination with a low-pass filter.

As shown in Fig. 1 the general schematic form of the network of the invention is of the bridged-T type, comprising a pair of equal impedances Z connected in series between two of the network terminals, a bridging branch Z_1 connected between the outer terminals of impedances Z , and a central branch Z_2 connected between the common terminal of impedances Z and the remaining pair of network terminals. The impedances Z_s and Z_r represent the terminal loads between which the network may be connected, and a wave source of electromotive force is represented by E , which is shown connected in series with one of the terminal impedances.

The propagation constant P and the characteristic impedance K of the network of Fig. 1 are given by the equations

$$P = 2 \tanh \sqrt{\frac{ZZ_1}{(Z_1 + 2Z)(Z + 2Z_2)}} \quad (1)$$

$$\text{and } K = \sqrt{\frac{ZZ_1(Z + 2Z_2)}{Z_1 + 2Z}} \quad (2)$$

For infinite attenuation it is necessary that the fraction under the radical in Equation (1) equal unity, for which condition

$$ZZ_1 = (Z_1 + 2Z)(Z + 2Z_2) \quad (3)$$

A specific form of the invention is illustrated in Fig. 2, in which the two capacitances C form the pair of equal series impedances, the resistance R_1 is the bridging branch and the variable inductances L_2 connected in series with the variable resistance R_2 constitutes the central branch. Resistance R_2 may be made up, in part, of the effective resistance associated with inductance L_2 . Applying to the network of Fig. 2 the condition for infinite attenuation established by Equation (3) gives

$$\frac{R_1}{j\omega C} = \left(R_1 + \frac{2}{j\omega C}\right) \left(2R_2 + j2\omega L_2 + \frac{1}{j\omega C}\right) \quad (4)$$

where j is the quadrantal operator having its usual significance and ω is the frequency, in radians per second, impressed upon the terminals of the network.

Equating the resistances on the two sides of Equation (4) and letting ω_0 equal the frequency of infinite attenuation gives

$$2R_2 = \omega_0^2 CL_2 R_1. \quad (5)$$

Equating the reactances on the two sides of Equation (4) gives

$$\omega_0^2 C^2 R_1 R_2 + 2\omega_0^2 CL_2 = 1. \quad (6)$$

From Equations (5) and (6) expressions may be found for R and C in terms of ω_0 , R_2 and L_2 , as follows:

$$R_1 = 4R_2 \left[1 + \left(\frac{R_2}{\omega_0 L_2} \right)^2 \right] \quad (7)$$

$$C = \frac{1}{2\omega_0^2 L_2} \left[\frac{1}{1 + \left(\frac{R_2}{\omega_0 L_2} \right)^2} \right]. \quad (8)$$

These equations enable the design to be computed by assigning values to R_1 , C and the suppression frequency ω_0 .

Another specific form of the invention is shown in Fig. 3 in which the two inductances L form the pair of equal series impedances, the resistance R_3 is the bridging branch and the variable capacitance C_2 in series with the variable resistance R_4 constitutes the central branch. Using the same procedure as above the condition for infinite attenuation established by Equation (3) may be applied to the network of Fig. 3 and expressions may be found for R_3 and L in terms of ω_0 , R_4 and C_2 . These equations are

$$R_3 = 4R_4 [1 + (\omega_0 C_2 R_4)^2] \quad (9)$$

$$L = \frac{2}{\omega_0^2 C_2} [1 + (\omega_0 C_2 R_4)^2]. \quad (10)$$

A typical attenuation characteristic of the network of Fig. 3 is shown by curve A of Fig. 4. The curve starts from zero at zero frequency, rises to a maximum at the frequency of suppression ω_0 and then falls away to a finite value at infinite frequency. The attenuation at high frequencies is largely dependent upon the value of the bridging resistance R_3 . If R_3 is very large the attenuation will be large at infinite frequency and if R_3 is small then the attenuation at the high frequencies will be correspondingly small. If R_3 is infinite in value, that is, if the branch containing R_3 is open-circuited, the bridged-T circuit degenerates into the ordinary ladder-type, constant $-k$, low-pass filter section. For such a filter section the cut-off frequency ω_c is given by the equation

$$\omega_c = \sqrt{LC_2}. \quad (11)$$

It is apparent, therefore, that the shape of

the attenuation characteristic in the region below the suppression frequency ω_0 is dependent upon this hypothetical cut-off frequency, which may be so chosen as to give a desired characteristic in the low frequency region. From Equation (2) it may be found that at zero frequency the characteristic impedance K_0 of the network of Fig. 3 is given by the equation

$$K_0 = \sqrt{\frac{2L}{C_2}}. \quad (12)$$

The characteristic impedance may, therefore, be given some desired value at zero frequency by choosing the ratio of L to C_2 . There are then four variables, L , C_2 , R_3 and R_4 , and four conditions which may be imposed, two, corresponding to Equations (9) and (10), to provide infinite attenuation at the suppression frequency ω_0 , one, presented by Equation (11), to determine the shape of the attenuation characteristic, and one, represented by Equation (12), to fix the impedance at zero frequency. When these conditions are imposed the values of the elements may be computed in terms of the general parameters ω_0 , ω_c , and K_0 .

The attenuation characteristic of the network of Fig. 2 is somewhat similar to the one for the network of Fig. 3, discussed above, in that the curve has its maximum value at the frequency of suppression ω_0 . Below this frequency it falls away to a finite value at zero frequency and above the suppression frequency it falls away to zero at infinite frequency. The design in this case also may be determined in terms of the more general parameters representing the characteristic impedance of very high or infinite frequency and the cut-off frequency of the prototype high-pass filter obtained by making R_1 infinite and R_2 zero. The high-pass filter cut-off frequency ω_c and the characteristic impedance at infinite frequency, denoted by K_∞ , are given by the equations

$$\omega_c = \frac{2}{\sqrt{L_2 C}} \quad (12)$$

and

$$K_\infty = \sqrt{\frac{2L_2}{C}}. \quad (13)$$

In the network of Fig. 2, if the values of C and R_1 are fixed the suppression frequency ω_0 may, of course, be adjusted to any value by adjusting the values of L_2 and R_2 and the latter two elements may be made variable, as indicated in the drawing, for this purpose. Or, if desired, L_2 and R_2 may be made the fixed elements and R_1 and the pair of condensers C may be made the variable elements. Likewise, in the network of Fig. 3 the elements C_2 and R_4 are shown as variable, so that the frequency ω_0 may be readily selected.

In Fig. 5 the suppression network of Fig.

3 is shown connected in series with a two-section low-pass filter. The inductances L_1 and the capacitance C_1 of the suppression section may have the same values as the corresponding elements used in the filter sections. Such a combination may be used, for example, as a filter for use in conjunction with a rectifier for smoothing out the residual fluctuations of the rectified current. The attenuation peak of the suppression network may be placed at the frequency of the most prominent component of the current fluctuations thereby suppressing that component completely. Alternatively, the arrangement may be used for sharpening the cut-off of the filter. A typical attenuation characteristic of the low-pass filter portion of the network of Fig. 5 is shown by curve B of Fig. 4, in which ω_0 is the cut-off frequency. By placing the suppression frequency ω_0 of the bridged-T section close to this cut-off, the attenuation characteristic of the suppression section is made to take the form shown by curve A. The attenuation of the entire network is shown by curve C, the sharp cut-off, and steeply-rising attenuation being attained as the result of the small separation of the frequencies ω_0 and ω_0 .

What is claimed is:

1. A wave transmission network having a pair of input terminals and a pair of output terminals, said network comprising an electrical path between each input terminal and a corresponding output terminal, a pair of equal reactances connected in series in one of said paths, a resistance connected in parallel with said pair of reactances between the outer terminals thereof and an impedance connected between the junction point of said pair of reactances and a point in the other of said paths, said impedance comprising a second resistance and a third reactance, connected in series relation, the sign of said third reactance being opposite to the sign of said pair of equal reactances.

2. A bridged-T network comprising a pair of reactive elements in series, a resistance connected between the outer terminals of said reactive elements and a central branch connected to the common terminal of said reactive elements, said central branch comprising a second resistance in series with a third reactive element, the reactance of said third reactive element being of opposite sign to the reactance of said pair of reactive elements, and said two resistances cooperating substantially to prevent transmission through said network at a finite frequency.

3. A wave transmission network comprising a pair of input terminals and a pair of output terminals, a resistance connected directly between an input terminal and an output terminal, a pair of reactances having a common terminal and having their other terminals connected respectively to the terminals of said resistance, and an impedance path having one terminal connected to the common terminal of said pair of reactances and having connections from its other terminal to the remaining input terminal and output terminals, said impedance path comprising a second resistance and a third reactance in series, the sign of said third reactance being opposite to the sign of said pair of reactances, said network having a band of low attenuation and said resistances cooperating to produce complete suppression at one frequency.

4. A wave transmission network comprising four impedance paths arranged in the form of a bridged-T, two of said paths consisting of one kind of reactance, the third of said paths comprising reactance of the opposite sign in series with a resistance, and the fourth of said paths consisting of a second resistance, whereby said network effectively suppresses waves of a certain frequency.

5. A wave transmission network comprising two capacitances and an inductance arranged in the form of a T, a resistance in series with said inductance, and a second resistance bridged across said two capacitances.

6. A wave transmission network comprising two inductances and a capacitance arranged in the form of a T, a resistance in series with said capacitance, and a second resistance bridged across said two inductances.

7. An electric wave filter having a pair of input terminals and a pair of output terminals, said filter comprising a pair of inductances connected in series between an input terminal and a corresponding output terminal, a resistance connected in parallel with said pair of inductances between the outer terminals thereof, and an impedance having one terminal connected to the common terminal of said pair of inductances and having connections from its other terminal to the remaining input and output terminals, said impedance comprising a capacitance and a second resistance, said two resistances cooperating to produce a peak in the attenuation characteristic of said filter.

8. An electric wave filter having a pair of input terminals and a pair of output terminals, said filter comprising a pair of capacitances connected in series between an input terminal and a corresponding output terminal, an inductance having one terminal connected to the common terminal of said pair of capacitances and having connections from its other terminal to the remaining input and output terminal, and a resistance connected in parallel with said pair of capacitances between the outer terminals thereof, said resistance cooperating with the effective resistance of said inductance to produce a peak in the attenuation characteristic of said filter.

9. A wave transmission network having a pair of input terminals and a pair of output terminals, said network comprising an electrical path between each input terminal and a corresponding output terminal, a plurality of reactances of like character connected in series in one of said paths, a separate reactance of opposite sign to said plurality of reactances connected between each junction point of said plurality of reactances and a point in the other of said paths, a resistance bridged from a point in one of said plurality of reactances to a point in an adjacent reactance of the same sign, and a second resistance connected in series with the reactance of opposite sign connected from the junction point bridged by said first resistance to a point in the other of said paths, said two resistances cooperating substantially to prevent transmission through said network at one frequency.

10. A plurality of serially connected, ladder-type, low-pass filter sections, each of said sections comprising an inductance in series with the line and a capacitance in shunt with the line, at least one of said filter sections being modified by bridging a resistance from a point in one of said inductances to a point in an adjacent inductance and by adding a second resistance in series with the capacitance of the section thus bridged by said first resistance whereby complete suppression of one frequency is effected by the modified filter section.

11. A plurality of low-pass, ladder-type filter sections connected in tandem, each of said sections comprising a pair of input terminals and a pair of output terminals, two inductances connected in series between an input terminal and a corresponding output terminal, a capacitance having one terminal connected to the common terminal of said two inductances and having connections from its other terminal to the remaining input and output terminals, at least one of said filter sections being modified by adding a resistance in series with said capacitance and by bridging a second resistance across said two inductances between the outer terminals thereof, said two resistances cooperating to produce a peak in the attenuation characteristic of said modified filter section.

In witness whereof, I hereunto subscribe my name, this 10th day of February 1932.

JOHN G. KREER, JR.