

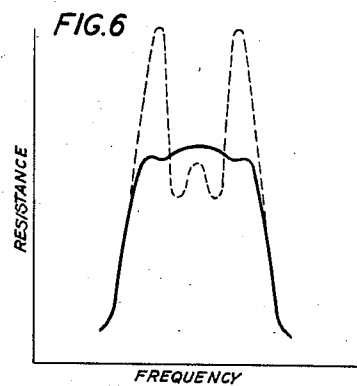
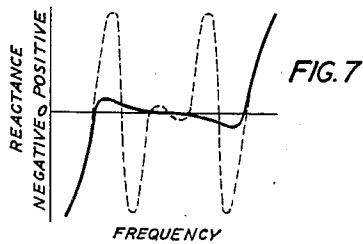
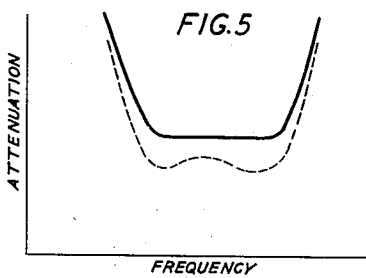
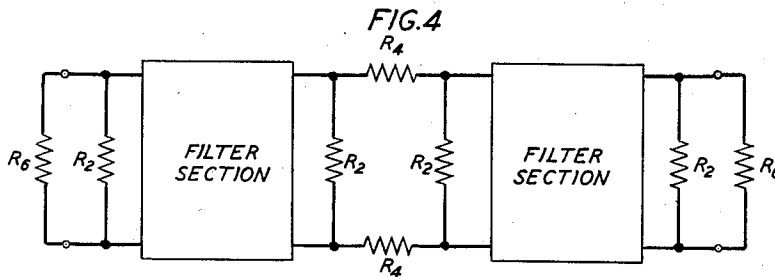
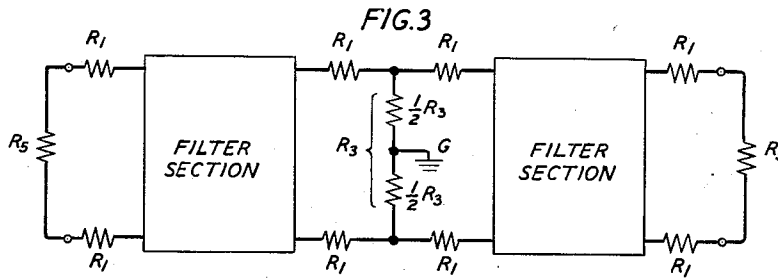
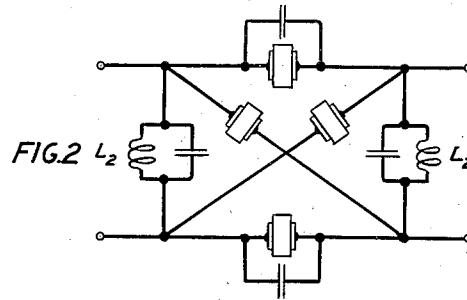
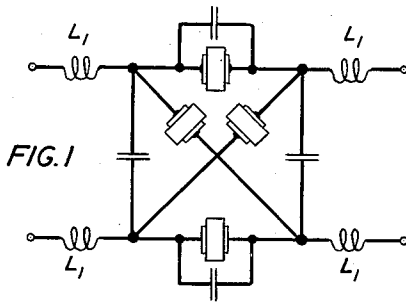
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1,969,571

TRANSMISSION NETWORK

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1,969,571

TRANSMISSION NETWORK

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Application March 17, 1933, Serial No. 661,268

16 Claims. (Cl. 178-44)

This invention relates to wave transmission networks and more particularly to wave filters employing in combination piezoelectric crystals and inductance coils as impedance elements.

5 An object of the invention is to improve the transmission and impedance characteristics of wave filters.

Another object is to reduce the attenuation distortion in the transmission band of wave filters due to the inherent resistance associated with the component inductance coils.

Another object is to decrease the impedance irregularities at the input terminals of a multi-section wave filter caused by reflection effects at the junction points of the filter sections.

15 A further object is the elimination of longitudinal currents from the output of a balanced wave filter.

A feature of the invention is a multi-section wave filter in which an ohmic resistance has been inserted between adjacent sections, and the load impedances between which the filter is connected have been modified in order to reduce the reflection effects otherwise caused by the effective resistance inherent in the reactance elements comprising the filter.

20 The well-known property of resonance in piezoelectric crystals and their extremely small energy dissipation make them highly suitable for use as impedance elements in wave transmission networks. When they are thus used in wave filters it has been found necessary to associate inductance coils with the crystals in order to broaden the transmission band obtainable. The introduction of the more highly dissipative inductances tends to increase the transmission loss in the transmission range and also to distort the attenuation characteristic in this range. The attenuation distortion is the more objectionable of these two effects, since the increased transmission loss may easily be made up by the use of a properly designed thermionic tube amplifier. Therefore, if the dissipation in the coils, needed to widen the band of the filter, has only the effect of increasing the loss equally over the entire frequency range of the filter a satisfactory result is obtained.

In the types of filter sections usually employed the resistance of the inductance coils may be considered as effective at the ends of the section, either in series or in parallel with the filter. In accordance with the present invention these resistances are incorporated with the load impedances by making these impedances either smaller or larger, depending upon whether the

coil resistances are effectively in series or in shunt with the filter. Also, between filter sections these effective resistances are incorporated with added ohmic resistances in such a way as to form a constant resistance attenuator of essentially the same impedance as the filter. If the resistances are effectively in series with the filter then a shunt resistance is added between the sections; if the effective resistances are in shunt with the filter, the added resistance is placed in series between the sections. In this way the filter is terminated in its characteristic impedance both at the ends and at the junctions of the sections. As a result a constant loss independent of frequency is added to the attenuation characteristic of the filter which would be obtainable if the elements were dissipationless. Also, the terminal impedance of the filter in the transmission band is made much more uniform, since the reflection effects are eliminated at the ends of the filter and at the points where the sections are joined.

In the case where the added resistance is connected in shunt, this resistance may be tapped and grounded at its center point, thus providing a low impedance path to ground for undesired longitudinal currents which may be flowing in the same direction along the two sides of a balanced filter.

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

Figs. 1 and 2 are schematics of typical wave filter sections to which the invention is applicable;

Figs. 3 and 4 show diagrammatically two embodiments of the invention; and

Figs. 5, 6 and 7 are diagrams to which reference is made in explaining the advantages of the invention.

A typical wave filter section to which the invention is applicable is shown in Fig. 1. The section consists of a lattice of piezoelectric crystals, shunted at each end by condensers and with four equal inductance coils L_1 in series with the combination. Condensers are also shunted across the two crystals in series with the line. For a more detailed description of this type of filter section reference is made to my copending application, Serial No. 489,268, filed October 17, 1930. The energy dissipation in the crystals and the condensers will ordinarily be very small in amount and therefore may safely be neglected. The resistance associated with each inductance

L_1 is effectively in series with each coil, as represented by the resistances R_1 of Fig. 3. The value of the resistance R_1 may be found by direct measurement or by well known methods of computation. In accordance with the invention each load impedance R_s is reduced in value to allow for the two series coil resistances R_1 . In equation form,

$$R_s = R_0 - 2R_1 \quad (1)$$

where R_0 is the characteristic impedance of the filter in the transmission band. In this way, the filter is terminated at each end in its characteristic impedance, and therefore, reflection effects at these points are eliminated.

Between filter sections there will be two coil resistances in series in each side of the line. If left uncorrected, there will thus be an impedance mismatch between the sections. In accordance with the invention, however, an ohmic resistance R_3 is shunted across the line between the two junction points of the series coil resistances R_1 . The value of R_3 is so chosen that, in combination with the four resistances R_1 , it forms a constant resistance attenuator of impedance R_0 . In equation form

$$R_3 = \frac{R_0^2}{4R_1} - R_1 \quad (2)$$

When the resistance R_3 , evaluated in accordance with Equation (2), is added each filter section faces its characteristic impedance at the junction of the sections, and reflection effects at this point are thereby eliminated. The multi-section filter shown in Fig. 3 will, therefore, have the attenuation characteristic which would be obtained if elements having no dissipation were used, with the addition of a constant loss over the entire extent of the frequency range. This additional loss may readily be compensated, when necessary, by the use of a distortionless amplifier, as mentioned above.

As shown in Fig. 3 the added shunt resistance R_3 may be tapped at its electrical mid-point and connected to the ground G in order to eliminate undesired longitudinal currents which may be flowing in phase along the two sides of a balanced filter. Grounding the center point of this resistance has no effect upon the loop current flowing in the filter, since the voltage producing this current is balanced with respect to ground. However, a low impedance path to ground is thereby provided for the longitudinal currents which flow along both sides of the filter in the same direction and utilize ground as the return path. These undesired longitudinal currents are in this way effectively eliminated and do not appear in the output of the filter.

Another type of filter section to which the invention is applicable is the one shown in Fig. 2, which differs from the section shown in Fig. 1 only in that the inductance coils L_2 are shunted across the ends of the filter instead of being in series therewith. At any one frequency the resistance associated with the inductances may be represented as effectively in shunt across the input and output filter terminals, as shown by the resistances R_2 of Fig. 4. In order to match the impedance of the load to that of the filter, the load impedance R_0 is increased in value to compensate for the shunt resistance R_2 . The required value for R_0 is given by the equation

$$R_0 = \frac{R_2 R_0}{R_2 - R_0} \quad (3)$$

where R_0 is the characteristic impedance of the filter section.

Where two of the sections join, a pair of equal resistances R_4 are inserted in series between the sections. The value of the resistance R_4 is given by the equation

$$R_4 = \frac{R_0^2 R_2}{R_2^2 - R_0^2} \quad (4)$$

When these modifications have been made the filter sections shown in Fig. 4 are terminated at each end in their characteristic impedance and, as a result, reflection effects at the ends of the filter and between sections are eliminated. The filter will then have the attenuation characteristic of a filter composed of dissipationless elements, with a small added loss which is constant with frequency. At the same time, the terminal impedance of the filter will be more uniform in the transmission band.

Some of the advantages of the application of the invention to a band pass filter composed of two sections of the type shown in Fig. 1 are illustrated by the diagrams of Figs. 5, 6 and 7. Fig. 5 shows the attenuation-frequency characteristic of the filter in the transmission band. The dotted line curve gives the attenuation of the filter, when the load impedances R_s of Fig. 3 are equal to the characteristic impedance R_0 of the section and the shunt impedance R_3 is infinite in magnitude. The solid line curve shows the attenuation obtained when the load impedances are evaluated in accordance with Equation (1) and the shunt resistance R_3 , determined according to Equation (2), is added. It is apparent from a comparison of the two curves that the attenuation distortion in the transmission band of the filter has been eliminated. The small amount of added loss may easily be made up in an associated amplifier. The dotted line curve and the solid line curve of Fig. 6 give a comparison of the terminal resistance of the two-section filter of Fig. 3, respectively, before and after the application of the invention. The two curves of Fig. 7 show the improvement in the terminal reactance of the filter under similar conditions. It will be noted that the impedance of the filter in the transmission band is made considerably more uniform by the application of the invention. As a result, the reflection effects which occur between the filter and the load are greatly reduced.

The inductance coils L_1 and L_2 of Figs. 1 and 2 are shown as located external to the lattice portion of the filter sections but these coils may, of course, be incorporated within the lattices and the principles of the invention may be applied equally well, provided the coils are so located that the effective resistance associated therewith may be represented as being in series or in shunt with the input and output filter terminals. The invention is also applicable to other types of filter sections, as, for example, ladder and bridged-T sections. Also, in applying the invention it is sometimes found that more satisfactory results are obtained by assigning a value to R_0 which is slightly larger or smaller than the characteristic impedance of the filter, when determining the values of the various resistances in accordance with Equations (1), (2), (3) and (4).

What is claimed is:

1. In combination, a multi-section wave filter and an attenuator located between two sections of said filter, the characteristic impedance of said attenuator being substantially equal to the characteristic impedance of said filter, and at least one of the component resistances of said at-

tenuator being formed by the effective resistance inherent in the elements comprising said filter.

2. In combination, a wave filter having a plurality of sections and a constant resistance attenuator located between two adjacent sections of said filter, the characteristic impedance of said attenuator being substantially equal to the characteristic impedance of the sections of said filter, and at least one of the component resistances which comprise said attenuator being formed by the effective resistance inherent in the elements which comprise the sections of said filter.

3. In combination with a multi-section wave filter, a resistance inserted between two adjacent sections of said filter, the magnitude of said resistance depending upon the characteristic impedance of said filter and also upon the effective resistance inherent in the reactance elements which comprise the sections of said filter, whereby each of said two adjacent sections at their junction point faces an impedance which is substantially equal to the characteristic impedance of the section.

4. In combination, two wave filter sections connected in tandem and a resistance shunted across the line at the junction of said two sections, the magnitude of said resistance depending upon the characteristic impedance of said filter sections and also upon the effective resistance inherent in the reactance elements which form said sections, whereby reflection effects at the junction of said two sections are reduced.

5. In combination, two wave filter sections connected in cascade and a resistance connected in series between said two sections, the magnitude of said resistance depending upon the characteristic impedance of said filter sections and also upon the inherent resistance of the reactance elements comprising said sections, whereby the attenuation distortion in the transmission band of said filter is reduced.

6. In combination, a wave filter and a load impedance connected to the terminals of said filter, the magnitude of said load impedance differing from the characteristic impedance of said filter by an amount which depends upon the inherent effective resistance of the reactance elements comprising said filter, whereby said filter is terminated in its characteristic impedance, thereby reducing the attenuation distortion and impedance irregularities in the transmission band of said filter.

7. In combination, a wave filter and a load impedance associated with said filter, the magnitude of said load impedance being smaller than the characteristic impedance of said filter by an amount equal to the inherent resistance of the reactance elements comprising said filter and effectively in series with said filter, whereby said filter is terminated in its characteristic impedance.

8. In combination, a wave filter and a load impedance connected to the terminals of said filter, the magnitude of said load impedance being larger than the characteristic impedance of said filter by an amount which depends upon the inherent resistance of the reactance elements comprising said filter and effectively in shunt with the terminals of said filter, whereby said filter is terminated in its characteristic impedance.

9. In combination, a multi-section wave filter comprising piezoelectric crystals and inductance coils as reactance elements, and an attenuator located between two sections of said filter,

at least one of the component resistances of said attenuator being formed by the effective resistance inherent in the inductance coils comprising said filter.

10. In combination, a multi-section wave filter comprising piezoelectric crystals and inductance coils as reactance elements, and a resistance inserted between two adjacent sections of said filter, the magnitude of said resistance depending upon the characteristic impedance of said filter and the effective resistance inherent in said inductance coils, whereby each of said two adjacent sections at their junction point faces an impedance which is substantially equal to the characteristic impedance of said filter.

11. In combination, two wave filter sections connected in series relation, and a resistance connected in shunt with the line at the junction of said two sections, said filter sections comprising piezoelectric crystals and inductance coils as reactance elements, and the magnitude of said resistance depending upon the characteristic impedance of said filter sections and also upon the magnitude of the effective resistance inherent in said inductance coils, whereby the attenuation distortion otherwise present in the transmission band of said filter is reduced.

12. In combination, two wave filter sections connected in tandem, and a resistance connected in series between said two sections, said filter sections comprising piezoelectric crystals and inductance coils as reactance elements, and the magnitude of said resistance depending upon the characteristic impedance of said filter sections and also upon the magnitude of the effective resistance inherent in said inductance coils, whereby reflection loss is eliminated in the transmission band of said filter.

13. A frequency selective wave transmission system comprising a wave filter having two pairs of terminals, and transmission devices representing terminal impedances connected to said pairs of terminals, said filter comprising piezoelectric crystals and inductance coils as reactance elements, and the magnitude of at least one of said terminal impedances differing from the characteristic impedance of said filter by an amount which depends upon the inherent effective resistance of said inductance coils, whereby said filter is effectively terminated in its characteristic impedance.

14. In a frequency selective transmission system, a multi-section broad band wave filter having piezoelectric crystals and inductance coils as reactance elements, a resistance inserted between two adjacent sections of said filter, and transmission devices representing terminal impedances connected to the ends of said filter, the magnitude of at least one of said terminal impedances differing from the characteristic impedance of said filter by an amount which depends upon the inherent effective resistance of said inductance coils, and the magnitude of said inserted resistance depending upon the characteristic impedance of said filter and also upon the effective resistance inherent in said inductance coils, whereby said filter is terminated in its characteristic impedance, and each of said two adjacent sections at their junction faces an impedance which is substantially equal to the characteristic impedance of said filter, thereby reducing the attenuation distortion and impedance irregularities otherwise present in the transmission band of said filter due to the inherent effective resistance of said inductance coils.

15.	In combination, two lattice type wave filter sections connected in cascade, and a resistance inserted between said two sections, said filter sections comprising piezoelectric crystals and inductance coils as reactance elements, and the magnitude of said inserted resistance depending upon the characteristic impedance of said filter sections and also upon the magnitude of the effective resistance inherent in said inductance coils, whereby each of said two sections at their junction faces an impedance which is substantially equal to the characteristic impedance of said filter, thereby reducing the attenuation distortion and impedance irregularities otherwise present in the transmission band of said filter due to the inherent effective resistance of said inductance coils.	
16.	In combination, two balanced wave filter sections connected in tandem and a resistance shunted across the line at the junction of said two sections, said resistance being grounded at its electrical mid-point, and the magnitude of said resistance being determined with respect to the characteristic impedance of said filter sections and also with respect to the effective resistance inherent in the reactance elements which comprise said sections, whereby the attenuation and impedance characteristics of the filter are improved and longitudinal currents are effectively drained off and thereby eliminated from the output of the filter.	
	WARREN P. MASON.	
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