June 22, 1954

S. BOBIS ET AL

2,682,037

EQUALIZER

Filed Sept. 8, 1950

FIG. 1

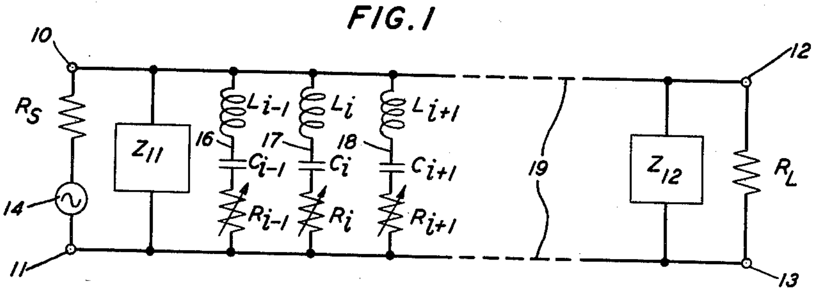


FIG. 3

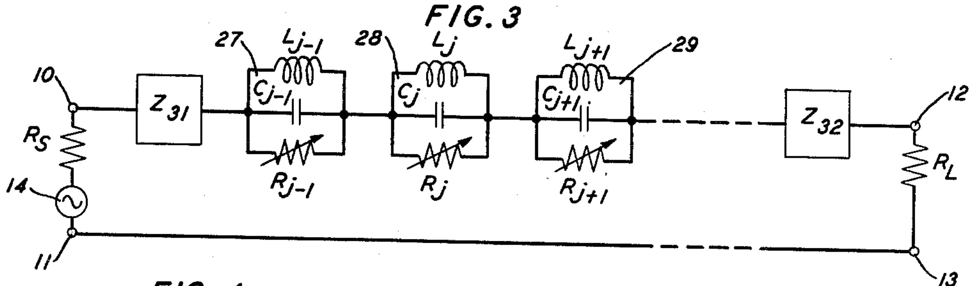


FIG. 4

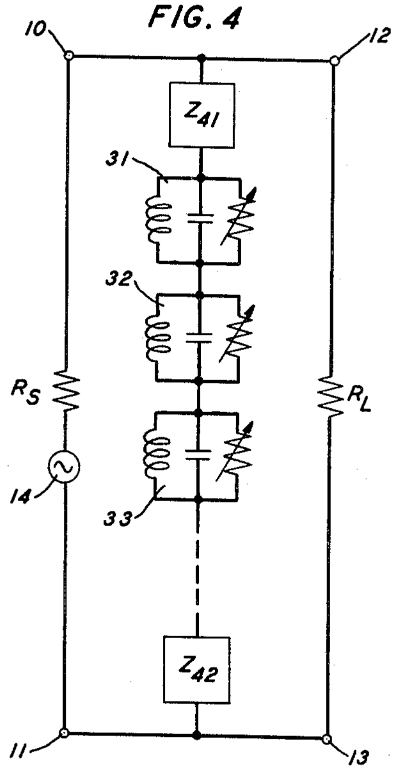
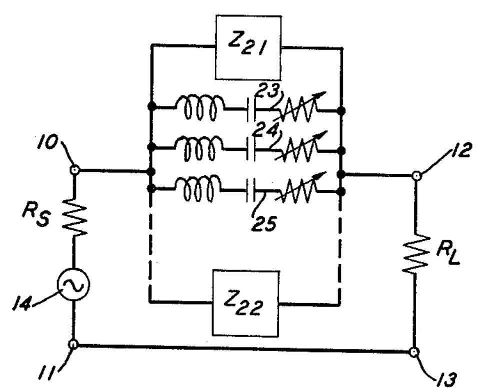
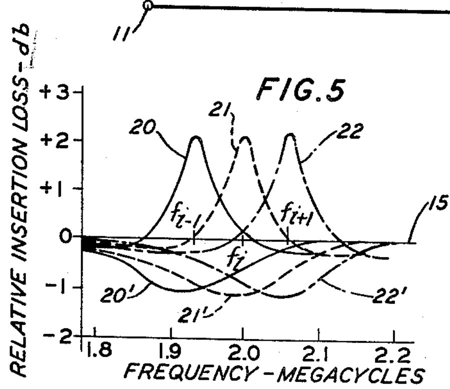


FIG. 2





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Patented June 22, 1954

2,682,037

UNITED STATES PATENT OFFICE

2,682,037

EQUALIZER

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Application September 8, 1950, Serial No. 183,872

1 Claim. (Cl. 333—28)

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This invention relates to wave transmission networks and more particularly to adjustable multirange loss equalizers.

The principal object of the invention is to adjust the loss in a wave transmission system independently over a number of adjoining or overlapping frequency ranges.

Further objects are to reduce the flat loss, the number of component elements and the cost, and to simplify the construction, of an adjustable multirange loss equalizer.

In the embodiments disclosed herein the adjustable multirange loss equalizer in accordance with the present invention is adapted for operation between a source of alternating signals and a load to introduce an adjustable amount of loss in each of at least three overlapping frequency ranges. The loss may be either positive or negative relative to a constant, or flat, loss. The equalizer comprises at least three like impedance arms connected in like manner to form a coupling branch between the source and the load. Each arm is resonant at a different frequency, corresponding approximately to the maximum adjustable positive loss in one of the ranges, and comprises an inductance, a capacitance and an adjustable resistance. The inductance and capacitance in one of the arms have values determined by the impedance of the source, the impedance of the load, the resonant frequencies of the three arms, a factor chosen to make the loss of the equalizer substantially constant over all of the ranges for predetermined equal normal settings of the resistances, and the current ratio corresponding to this constant loss.

Four different circuit arrangements of the component impedance elements of the equalizer are shown. In two the inductance, capacitance and resistance in each arm are connected in series, the arms connected in parallel to form the coupling branch, and the coupling branch connected either in parallel or series with the source and the load. In the other two, the elements in each arm are connected in parallel and the arms are connected in series to form a coupling branch which is connected either in series or in parallel with the source and the load. Additional impedance elements may be included in order to improve the performance of the equalizer, especially over the highest and the lowest frequency ranges.

Compared with known types of adjustable multirange loss equalizers, the ones disclosed herein require fewer elements, cost less to manufacture, and have less flat loss. They are particularly useful where a large number of small loss adjustments are required, as in mop-up equalizers for television systems, but may also be used for larger but perhaps less precise adjustments.

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

Figs. 1 and 2 are schematic circuits of adjustable equalizers in accordance with the invention in which the elements in each impedance arm are connected in series and the arms are connected in parallel to form a coupling branch which is connected in parallel or in series with the source and the load;

Figs. 3 and 4 show two other embodiments of the invention in which the elements in each arm are connected in parallel, the arms are connected in series to constitute the coupling branch, and the coupling branch is connected in series or in parallel with the source and the load; and

Fig. 5 shows typical insertion loss-frequency characteristics obtainable with the equalizer of Fig. 1.

Taking up the figures in greater detail, the circuit of Fig. 1 shows one embodiment of an adjustable multirange loss equalizer in accordance with the invention comprising a pair of input terminals **10**, **11** and a pair of output terminals **12**, **13**. A signal source of alternating electromotive force **14** of impedance R_S is connected to the input terminals **10**, **11** and a suitable load of impedance R_L is connected to the output terminals **12**, **13**.

The equalizer comprises at least three like impedance arms **16**, **17** and **18** connected in like manner to form a coupling branch between the source impedance R_S and the load R_L. The equalizer will introduce an adjustable amount of loss, either positive or negative relative to the flat loss, in each of three frequency ranges, with maximum adjustable positive loss at the frequencies f_{i-1}, f_i and f_{i+1}, respectively. More frequency ranges may be provided by adding more impedance arms similar to **16**, **17** or **18**, as indicated by the broken lines **19**. An equalizer with more than fifty such arms, operable over a like number of frequency ranges, has been made and successfully tested.

In Fig. 1 each of the arms **16**, **17** and **18** comprises an inductance, a capacitance and a variable resistance connected in series. In arm **17** these elements are, respectively, L_i, C_i, and R_i, in arm **16** they are L_{i-1}, C_{i-1} and R_{i-1}, and in arm 18 they are L_{i+1}, C_{i+1} and R_{i+1}. The arms 16, 17 and 18 are connected in parallel to form a coupling branch which is connected in parallel with the source impedance R_S and the load R_L. Each of the arms 16, 17 and 18 is resonant at a different frequency corresponding approximately to the maximum adjustable positive loss in one of the frequency ranges.

The values of the inductance L_i and the capacitance C_i in arm 17 are determined by the source impedance R_S, the impedance of the load R_L, the three frequencies f_i, f_{i+1} and f_{i-1}, a factor K chosen to make the loss of the equalizer substantially constant over all of the ranges for predetermined equal normal settings of the variable resistances R_i, R_{i+1} and R_{i-1}, and the current ratio A corresponding to this constant loss. Explicitly, the elements L_i and C_i in arm 17 have approximately the following values:

$$L_i=\frac{R_{01}}{2\pi(f_{i+1}-f_{i-1})} \qquad (1)$$

and

$$C_i=\frac{f_{i+1}-f_{i-1}}{2\pi f_i^2 R_{01}} \qquad (2)$$

where

$$R_{01}=\frac{KR_SR_L}{(R_S+R_L)(A-1)} \qquad (3)$$

and the optimum value of K falls between two and three. Similar expressions may be set up for the values of the inductance and capacitance in each of the other arms 16 and 18. The minimum average value of the nominally constant flat loss is determined by the adjustment range required. The flat loss will ordinarily have small deviations from its average value. These deviations are, in general, reduced to tolerable amplitudes by sufficiently increasing the flat loss. For the range of K given, the normal value of each of the variable resistances will fall between 0.5 R_{01} and 1.5 R_{01}.

It should be pointed out that the effect of the inclusion in Equations 1 and 2 of the frequencies f_{i+1} and f_{i-1} of the neighboring arms of the equalizer and the term R_{01} is to take advantage of the contributions of those neighboring arms to the total conductance and thus the total loss of the equalizer arm for the frequency f_i and the intermediate frequencies. It is an aspect of this invention that the interactions between neighboring arms of the equalizer are utilized to attain substantially flat normal conductance and loss characteristics for equal normal settings of the variable resistances R_i, R_{i+1}, and R_{i-1} due to the elements L_i and C_i having the particular values determined by the Formulas 1, 2 and 3.

The two shunt impedance arms Z_{11} and Z_{12} are added, when required, to improve the loss characteristic, especially over the highest and the lowest frequency ranges, or to provide some special type of correction. They may include one or more inductances, capacitances or resistances and are designed to meet the partcular loss requirements of the equalizer.

Fig. 5 gives typical insertion loss-frequency characteristics obtainable with an equalizer of the type shown in Fig. 1. The loss in decibels relative to the average flat loss, shown by the horizontal line 15, is plotted against the frequency in megacycles. That is, the departure, either positive or negative, from the flat loss is shown. The solid-line curves 20 and 20′ define the adjustment limits obtainable by varying the resistance R_{i-1} while keeping the resistances R_i and R_{i+1} at their normal values. The broken-line curves 21, 21′ and the dot-and-dash curves 22, 22′ give the same limits for adjustments, respectively, of the resistances R_i and R_{i+1} with the other variable resistances set at their normal value. As already mentioned, the normal values for all of the resistances R_i, R_{i+1} and R_{i-1} required to give a flat loss are approximately equal. It will be noted that the frequency at which the maximum positive loss occurs in each range substantially coincides with the frequency of the maximum negative loss. The spacing of these maxima is dictated by the type of loss correction required. The pattern may, for example, be arithmetic, geometric, a combination of these, or of some other type. In the characteristics shown, each of the three positive loss curves 20, 21 and 22 overlaps the adjacent curve by at least half, and each of the negative curves 20′, 21′ and 22′ overlaps the adjacent one by more than half.

Fig. 2 shows a second embodiment of the invention. The coupling branch is made up of the parallel combination of three arms 23, 24 and 25 and the impedances Z_{21} and Z_{22} which correspond, respectively, to the arms 17, 18, 19 and the impedances Z_{11} and Z_{12} in Fig. 1. In Fig. 2, however, the coupling branch is connected in series with the source impedance R_S and the load R_L.

A third embodiment of the invention is shown in Fig. 3. The coupling branch comprises the three arms 27, 28 and 29 and the two impedances Z_{31} and Z_{32} all connected in series with the source impedance R_S and the load R_L. Each of the arms 27, 28 and 29 consists of the parallel combination of an inductance, a capacitance and a variable resistance. In arm 28 these elements are, respectively, L_j, C_j and R_j, in arm 27 they are L_{j-1}, C_{j-1} and R_{j-1}, and in arm 29 they are L_{j+1}, C_{j+1} and R_{j+1}. The impedances Z_{31} and Z_{32} are included for the same purpose as the impedances Z_{11} and Z_{12} in Fig. 1. The arms 27, 28 and 29 are antiresonant, respectively, at the frequencies f_{i-1}, f_i and f_{i+1}. The elements in the arm 28 have approximately the following values:

$$L_j=\frac{R_{02}(f_{i+1}-f_{i-1})}{2\pi f_i^2} \qquad (4)$$

and

$$C_j=\frac{1}{2\pi(f_{i+1}-f_{i-1})R_{02}} \qquad (5)$$

where

$$R_{02}=\frac{(R_S+R_L)(A-1)}{K} \qquad (6)$$

A has the same significance as in Equation 3, and K again has an optimum value falling between two and there to obtain a substantially flat loss over all of the ranges. For this range of K the normal value of each of the variable resistances required to give a flat loss falls between $R_{02}/0.5$, or $2R_{02}$, and $R_{02}/1.5$, or 0.67 R_{02}. Similar expressions may be written for the inductance and capacitance in each of the other arms 27 and 29.

Fig. 4 shows a fourth embodiment of the invention. The coupling branch comprises the series combination of the arms 31, 32 and 33 and the impedances Z_{41} and Z_{42} which correspond, respectively, to the arms 27, 28, 29 and the impedances Z_{31} and Z_{32} in Fig. 3. However, in this case, the coupling branch is connected in parallel with the source impedance R_S and the load R_L.

By proper design, loss characteristics similar to those given in Fig. 5 may be obtained with any one of the circuits shown in Figs. 2, 3 and 4. The choice of circuit depends, among other things, upon the magnitudes of the source impedance R_S and the load impedance R_L and upon the required values of the component elements. It will be understood, of course, that additional impedance arms may be employed in any of these circuits to provide additional adjustment ranges, if desired.

What is claimed is:

An equalizer for operation between a signal source of impedance R_S and a load of impedance R_L to introduce an adjustable amount of loss in each of at least three adjoining frequency ranges comprising at least three impedance arms connected directly in parallel with both said source and said load, each of said arms comprising the series combination of an inductance, a capacitance and an adjustable resistance, and the inductance L_i and capacitance C_i in one of said arms having approximately the values

$$L_i=\frac{R_{01}}{2\pi(f_{i+1}-f_{i-1})}$$

and

$$C_i=\frac{f_{i+1}-f_{i-1}}{2\pi f_i^2 R_{01}}$$

where

$$R_{01}=\frac{KR_SR_L}{(R_S+R_L)(A-1)}$$

f_i is the frequency of maximum adjustable loss in one of said ranges, f_{i+1} and f_{i-1} are, respectively, the frequencies of maximum adjustable loss in the ranges adjacent to said one range, K is a constant having a value between two and three chosen to make the loss of the equalizer substantially constant for predetermined equal settings of said resistances, and A is the current ratio corresponding to said substantially constant loss.

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