Dec. 2, 1941.

W. R. LUNDRY

2,265,042

ATTENUATION EQUALIZER

Filed Oct. 24, 1940

FIG. 1

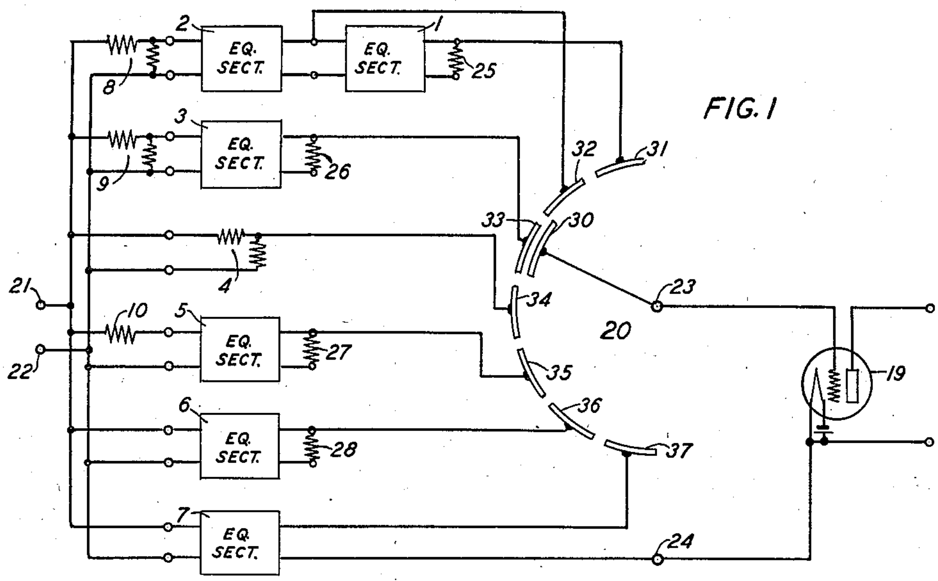


FIG. 2

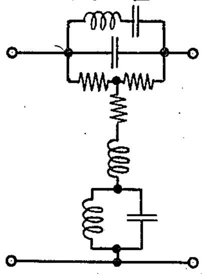


FIG. 3

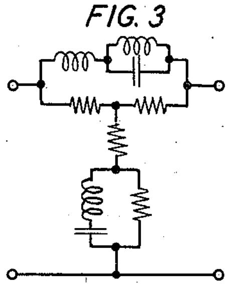


FIG. 4

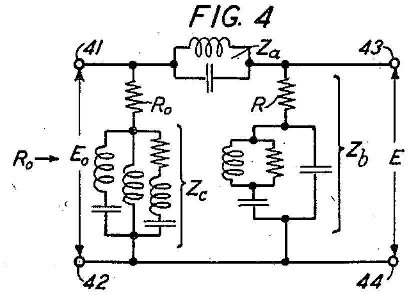
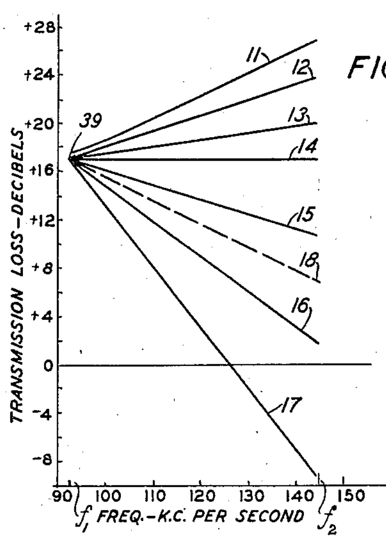


FIG. 5



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ATTENUATION EQUALIZER

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5 Claims. (Cl. 178—44)

This invention relates to wave transmission networks and more particularly to networks used as attenuation equalizers.

An object of the invention is to vary continuously the transmission loss of an attenuation equalizer to provide a family of similar characteristic curves.

Another object is to provide such a family of curves all of which have the same loss at some fixed reference frequency.

Another object is to extend the curves to the region below the axis of zero loss.

Another object is to provide a variable attenuation equalizer having a linear loss characteristic which may be continuously varied from a positive slope to a negative slope and which will have the same loss, at some reference frequency, for all settings.

A further object of the invention is to provide an attenuation equalizer which will give a voltage gain when operating between a constant nonreactive input load and a high impedance output load.

Transmission circuits often require the use of variable attenuation equalizers which may be regulated to compensate for attenuation changes caused by changes in the temperature or other weather conditions. Under some circumstances it is desirable that the equalizer be continuously adjustable to provide a family of similar loss characteristics all of which pass through a common point. To make the equalizer more useful it is also sometimes required that the family of curves be extended into the region of transmission gain.

The attenuation equalizer of the present invention meets all of these requirements in a simple and efficient manner. The network comprises a number of sections connected in parallel at their input ends and coupled at their output ends by means of a potentiometer to a high impedance load. The potentiometer may, for example, be of the condenser type, and the output load may be the input circuit of a thermionic tube. The equalizer sections are preferably of the constant resistance type and one or more of the sections may be designed to provide a voltage gain. The individual sections may, for example, be so designed that their loss characteristics over the useful frequency range are substantially straight lines having different slopes, some positive and some negative, but all having the same loss at some reference frequency. Under these circumstances by an adjustment of the potentiometer there may be selected any one of an infinite family of loss characteristics all of which are linear and in effect pivot about a fixed point.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying drawing, in which like reference characters represent like or similar parts and in which:

Fig. 1 is a diagrammatic representation of a variable attenuation equalizer in accordance with the invention;

Fig. 2 shows the circuit of an equalizer section the loss characteristic of which will have a positive slope;

Fig. 3 shows an equalizer section the loss characteristic of which will have a negative slope;

Fig. 4 shows the circuit of an equalizer section which will provide a voltage gain; and

Fig. 5 gives typical transmission loss characteristics obtainable with the variable equalizer of Fig. 1.

A typical circuit of a variable attenuation equalizer in acordance with the present invention is shown schematically in Fig. 1, wherein **21** and **22** are the input terminals and **23** and **24** are the output terminals. The circuit is shown in the unbalanced form and the path between terminals **22** and **24** may be grounded or otherwise fixed in potential. It is preferable that the equalizer work into a high impedance load, as, for example, the input circuit of a thermionic tube **19**, which may be the first tube of an amplifier.

The component equalizer sections **2**, **3**, **5**, **6** and **7** and the resistance pad **4** are all connected in parallel at their input ends. Section **2** is connected in tandem with section **1**, and the latter is terminated at its output end in a resistance **25** equal in value to the image impedance of the section. Sections **1** and **2** should have matching image impedances at their junction. Sections **3**, **5** and **6** are likewise terminated in their image impedances **26**, **27** and **28**, while section **7**, as explained hereinafter, is designed to work into a high impedance load.

The output voltages of the component equalizer sections are selectively combined by means of the condenser potentiometer **20**. The high potential sides of the output ends of the sections **1** to **7** are connected, respectively, to the fixed condenser plates **31** to **37**. The movable plate **30** is connected to the output terminal **23** of the equalizer as a whole.

The equalizer sections are preferably of the constant resistance type and may, for example, be bridged-T structures such as are shown in

Figs. 2 and 3 and more fully described in U. S. Patent 1,606,817 to G. H. Stevenson issued November 16, 1926. Section **2** may, for example, be of the type shown in Fig. 2 and may have its component impedance elements so proportioned that its loss characteristic over the useful frequency range extending from f_1 to f_2 is substantially a straight line with a positive slope, such as curve **12** of Fig. 5. The resistance pad **8** may be connected in tandem with the section **2** to increase the minimum loss at the lower end of the frequency range to some desired value. This pad may be designed to provide an impedance transformation, if desired. Equalizer section **1** may also be of the type shown in Fig. 2 and may be designed so that, when connected in tandem with section **2** and pad **8**, the entire combination will have the transmission loss characteristic shown by curve **11** of Fig. 5. Likewise, section **3** may have the configuration of Fig. 2 and may be proportioned so that it, together with its associated pad **9**, will have the loss characteristic shown by curve **13** of Fig. 5.

The equalizer sections **5** and **6** may have the configuration shown in Fig. 3 and may be designed to have linear loss characteristics with negative slopes. Section **5** and the associated series resistance **10** may, for example, provide the loss of curve **15** of Fig. 5 and section **6** alone may have the loss shown by curve **16**.

Section **7** may take the form shown in Fig. 4, described in more detail hereinafter. This section may be so designed that its loss characteristic, as shown by curve **17** of Fig. 5, has a negative slope and, at its lower end, crosses the zero axis and extends into the region of negative loss, that is, transmission gain.

In the preferred form of the equalizer the pad **4** has the constant loss given by curve **14** of Fig. 5 and each of the sections **2**, **3**, **5**, **6** and **7** in conjunction with its associated pad, if any, has this same loss at some frequency f_1 at the lower end of the frequency range covered. Section **1** is designed to have a minimum loss at f_1 and at any other frequency has a loss equal to the difference between curves **11** and **12**.

Now if the movable condenser plate **30** is placed directly opposite the fixed plate **32**, for example, the loss of the equalizer as a whole will be that shown by curve **12**. Also, if the plate **30** is moved to a position opposite to any of the other fixed plates **33**, **34**, **35**, **36** or **37** the loss characteristic will be that given, respectively, by curves **13**, **14**, **15**, **16** or **17**. Furthermore, if the plate **30** is stopped at some intermediate position, so that part of it is opposite one fixed plate and another part is opposite an adjacent plate, the loss characteristic will be a curve falling between the curves associated with the two plates. For example, if the plate **30** overlaps both fixed plates **35** and **36** the loss will be that given by the dotted curve **18**. For any of these settings the loss curve will be substantially linear and at the frequency f_1 will pass through the point **39**. There is thus provided an infinite family of linear curves which may have a positive, a zero or a negative slope and which, in effect, pivot about the point **39**. The particular characteristic obtained depends upon the setting of the movable condenser plate **30**.

If the plate **30** is placed opposite the fixed plate **31** the loss of the equalizer will be the sum of the losses of the sections **1** and **2** and the pad **8**, given by curve **11**. This curve does not pass through the point **39**, because of the inherent minimum loss of section **1**, but it is substantially linear and passes close to the pivot point. By making the plate **30** overlap portions of both of the plates **31** and **32** there may be provided a series of curves which fall between curves **11** and **12**.

The movable plate **30** may be adjusted manually or, if desired, it may be placed under the automatic control of a pilot wire or a pilot channel to provide attenuation equalization for an associated transmission circuit.

As already mentioned, equalizer section **7** has the property that, over at least a portion of the frequency range it provides a transmission gain, as shown by curve **17** of Fig. 5. The design of this section will now be considered in greater detail.

As shown in Fig. 4 the circuit consists of a series impedance branch Z_a, a shunt impedance branch Z_b at the output end and a second shunt impedance branch at the input end. The ratio of the input voltage E_0 across terminals **41**, **42** to the output voltage E across terminals **43**, **44** is given by the expression

$$\frac{E_0}{E}=1+\frac{Z_a}{Z_b} \qquad (1)$$

Provided the resistive components of the impedances Z_a and Z_b are small it is only necessary to have their reactive components of opposite sign and the ratio of Z_a to Z_b less than two in order to make this voltage ratio less than unity and thus obtain a voltage gain from the section over the frequency range in which these conditions prevail. The maximum gain is provided when Z_a and Z_b are equal in magnitude.

The input impedance R_0 of the section may be made a constant pure resistance by adding a shunt branch at the input end provided either Z_a or Z_b includes a series resistance, such as R in Fig. 4, which is equal to or greater than R_0. This shunt branch consists of a resistance R_0 in series with a general impedance Z_c which is the inverse, with respect to R_0, of the sum of the impedances Z_a and Z_b reduced by the value of the resistance R_0. In equation form,

$$Z_c=\frac{R_0^2}{Z_a+Z_b-R_0} \qquad (2)$$

So long as Z_a and Z_b are physical and R is greater than R_0 than Z_c will be physical.

In the above discussion it has been assumed that the equalizer section of Fig. 4 is to work into a load impedance which is high compared to the shunt impedance Z_b. This condition is satisfied in the equalizer system of Fig. 1 where the load is the input circuit of the thermionic tube **19**.

What is claimed is:

1. An equalizer having an input impedance R_0 which is a constant pure resistance for providing a voltage gain when operating between an input load of impedance R_0 and an output load of high impedance comprising a series branch of impedance Z_a, an output shunt branch of impedance Z_b and an input shunt branch including a resistance of value R_0 and an impedance Z_c connected in series, the impedances Z_a and Z_b having over some portion of the useful frequency range a ratio not exceeding two, reactive components of opposite sign and resistive components the sum of which is at least equal to R_0, and the impedance Z_c being the inverse, with respect to R_0, of the sum of the impedances Z_a and Z_b reduced by the value of the resistance R_0.

2. An equalizer in accordance with claim 1 in which the impedance Z_a is of the same order of magnitude as the impedance Z_b.

3. An equalizer in accordance with claim 1 in which the impedance Z_a has substantially no resistive component.

4. An equalizer in accordance with claim 1 in which said output shunt branch includes a series-connected resistor.

5. An equalizer in accordance with claim 1 having a transmission loss characteristic which is substantially a straight line over said useful frequency range.

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