

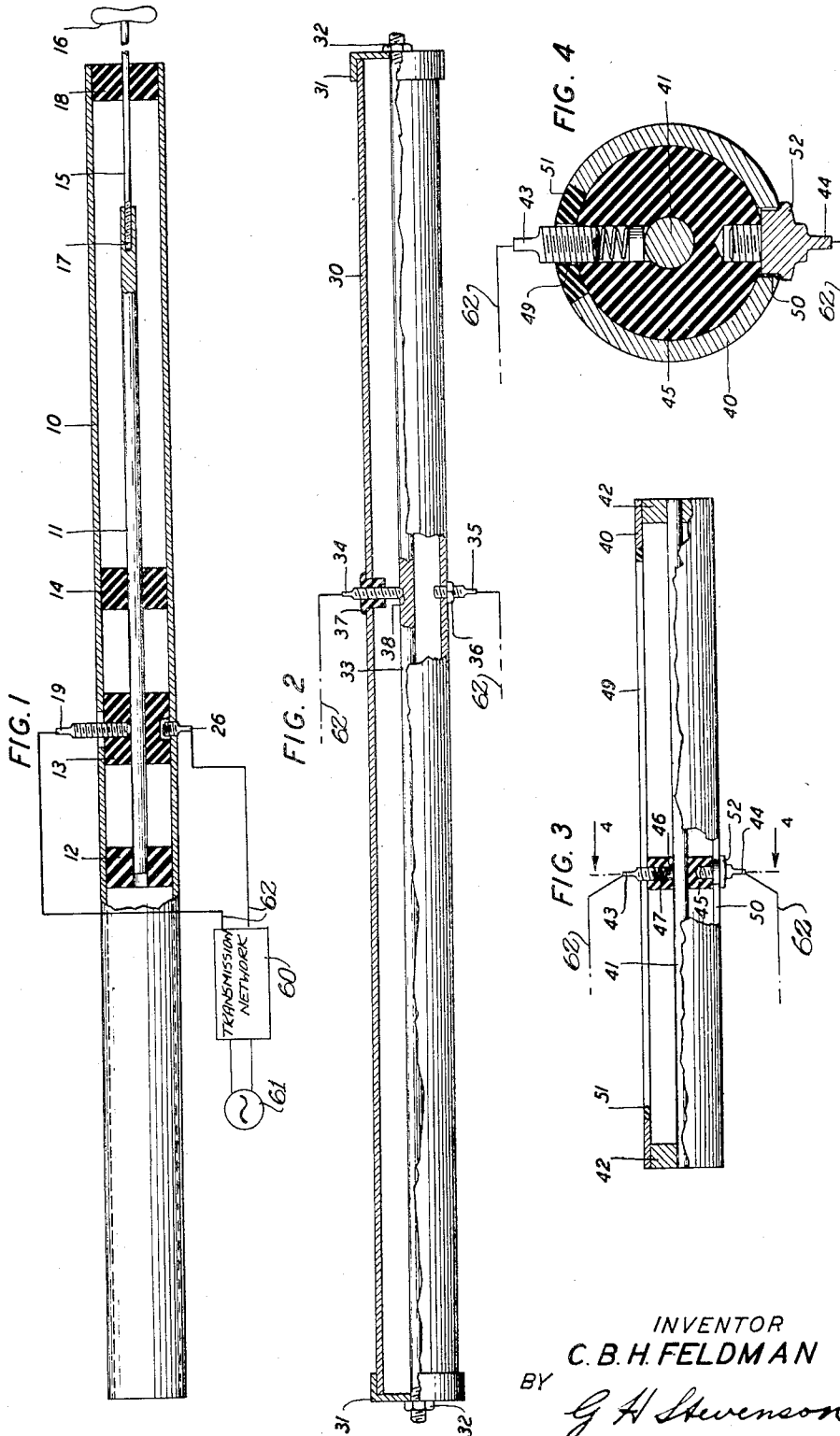
Nov. 14, 1933.

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1,935,313

HIGH FREQUENCY RESISTANCE ELEMENT

Filed June 13, 1930



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1,935,313

HIGH FREQUENCY RESISTANCE ELEMENT

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Application June 13, 1930. Serial No. 460,857

10 Claims. (Cl. 178—44)

This invention relates to electrical wave transmission networks and more particularly to networks adapted to dissipate wave energy at very high frequency.

5 The principal object of the invention is to stabilize and otherwise improve resistance elements operating in high frequency systems.

Another object is to properly terminate high frequency transmission lines such as are used in short wave radio systems, so that resonances, or standing waves are substantially suppressed.

In making tests on a line employed in transmitting very high frequency signals, it is often desirable to terminate the line by a resistance equal to the characteristic impedance of the line. Under this condition resonances or wave reflections within the line are substantially damped and the maximum amount of power is transmitted. It is also desirable sometimes to employ resistances in connection with antennae used in short wave radio stations for the purpose of improving the directivity. These resistances should be characterized by stability of resistance value, virtual freedom from reactance at the operating frequency, ability to dissipate considerable amounts of power, a high degree of mechanical strength and ability to withstand the weather.

Difficulty has heretofore been experienced in the use of resistance elements at high frequency, due to the presence of appreciable amounts of inductance, and to the uncertainty of the "skin effect". Graphite rods have been employed as resistance elements in high frequency systems and by virtue of the high resistivity, are fairly free from skin effect and excessive reactance; but the resistance value of the graphite is not always stable, the contact resistance is uncertain and the mechanical strength is not great.

In accordance with this invention, there is provided a resistance element suitable for use at a single high frequency, for example, in the order of twenty megacycles, which is primarily dependent upon the geometric dimensions of the device and only to a smaller extent upon the electrical resistivity of the conducting material. The resistance value can be regulated by suitably fixing the size and shape; so there can be selected a conducting material which has a low, stable, resistivity.

50 The device comprises a pair of parallel connected, uniform lines, the remote ends of which are terminated for the condition of full wave reflection, that is, in an open circuit or a short circuit. The parallel lines are in general of unequal length, one being shorter than the length required

for the condition of resonance, the other being longer than the resonance length. It is well understood that a line shorter than the resonance length has a reactance opposite in sign to that of a line longer than the resonance length. Accordingly, it is contemplated to maintain the lengths of the two lines in such relation to each other that these opposite reactances are substantially equal, and thereby annul each other; the input impedance is then substantially resistive.

A substantially non-reactive input impedance can be obtained by employing a pair of open circuited lines the combined length of which is a half wave length, or by using a pair of closed circuited lines having an overall length equal to a full wave length. By varying the lengths of the individual lines while maintaining the overall length constant, the input resistance may be varied at will and will remain substantially free from reactance.

The resistance value is dependent upon the characteristic, or surge, impedance of the lines; and since this is determined by the distributed capacity and inductance, the input resistance is dependent primarily upon the physical dimensions of the line.

In the preferred form, the two parallel lines are composed of concentric conductors which are integral members for the two lines. The member which serves as an outer conductor for both lines is a hollow cylindrical conductor, and the inner conductor for both lines is a concentric rod. The remote ends of the line are preferably open circuited.

A feature of the invention is the means for mounting and making connection to the inner conductor.

Another feature is the mounting of the inner conductor in a contact bushing which permits adjustment of the effective lengths of the two parallel lines, thereby permitting the adjustment of the resistance value.

The resistance elements of this invention are enclosed within an outer shell, and are well adapted to withstand the weather; which makes them suitable for out-door use, such as for terminating wave antennae and other out-door lines.

The invention will be more clearly understood from the following detailed description and reference to the drawing, of which

Fig. 1 illustrates a transmission system including an adjustable concentric line resistance element in accordance with the invention, in which the lines are open circuited and the central conductor movable;

Fig. 2 shows a non-adjustable resistance element embodying the invention in which the concentric lines are closed circuited;

Fig. 3 shows a side elevation, partly in section, of a resistance element embodying the invention, in which the position of the terminals is adjustable; and

Fig. 4 is an end view of a section of the element in Fig. 3, taken at line 4—4.

The resistance device illustrated in Fig. 1 comprises a hollow, cylindrical tube 10, of a non-magnetic, conducting material and a non-magnetic, conducting rod 11 held concentrically within the tube by means of insulating guide bushings 12, 13 and 14, the bushing 13 being centrally located with respect to the ends of the pipe. The rod is free to be moved lengthwise within the tube. To enable the rod to be thus moved there is provided a long shaft 15 of small cross-section having a handle 16 at one end and threaded at the other end to permit engagement with corresponding threads tapped into a hole 17 drilled in one end of the rod. The shaft 15 need not be in place except when adjustments are being made, but if it be made of a non-conducting material there is no objection to leaving it in the position shown. Plugs 18 are inserted in each end of the tube to prevent rain and other foreign material from entering. The plug at the end at which the adjusting shaft is located is provided with a concentric hole of sufficient diameter to permit the free passage of the shaft. This hole may be closed by a plug or other suitable means, upon withdrawing the shaft.

Connection to the inner conductor is made by means of a terminal screw 19 threaded into bushing 13 and making contact with conductor 11, a clearance hole being provided in the outer tube around the terminal screw.

A terminal lug 26 is threaded into the tube at a point opposite the lug 19. The end of lug 26 projects slightly within the pipe shell and into a recess 27 cut in the insulating guide bushing 13, thereby acting as a set pin for the bushing.

The resistance device is illustrated as terminating a transmission network 60 of any sort requiring a resistance termination. The output leads 62 from the network 60 are connected to the screw 19 and lug 26, respectively, as shown, and a source 61 of high frequency waves is connected to the input side of the network.

The resistance device in Fig. 1 consists effectively of a pair of uniform transmission lines connected in parallel at terminals 19 and 26, one side of the lines being constituted by the tube and the other side by the inner rod. The lengths of the lines are the distances of the ends of the inner rod, from the central contact points. Since the ends do not make electrical contact with the outer tube, the lines are open circuited at their ends. The overall length of the two lines, that is the length of the concentric rod, is made preferably equal to half the length of the electrical wave with which the device is to be used. The impedance at the input terminals of the shorter of the open circuited lines is expressed by:

$$Z' = Z_0 \coth pl \quad (1)$$

where Z' is the input impedance of the shorter of the lines;

Z_0 is the characteristic impedance of the line, that is, the impedance of an infinite length of the line;

p is the propagation constant per unit of length; and

l is the length in centimeters of the line.

The impedance at the input terminals of the longer of the open circuited lines is expressed by:

$$Z'' = Z_0 \coth p(L-l) \quad (2) \quad 80$$

where Z'' is the input impedance of the longer of the lines; and

L is the total length in centimeters of the two parallel connected lines, that is, the length of the inner rod. 85

It can be shown from Equations (1) and (2) that the impedance measured at the terminal lugs of the device in Fig. 1, is expressed by the equation:

$$Z = \frac{Z_0^2}{4R_0} \cos^2 \frac{2\pi l}{\lambda} + 4R_0 \frac{l}{L} \left(1 - \frac{l}{L}\right) \sin^2 \frac{2\pi l}{\lambda} - \frac{Z_0}{2} \left(1 - \frac{2l}{L}\right) \sin \frac{4\pi l}{\lambda} \quad (3) \quad 90 \quad 95$$

where Z is the impedance of the device,

λ is the wave length, and

R_0 is the impedance which the device would have if the two parallel lines were of equal length, that is, if $l = L - l$. For the concentric type of line such as that of Fig. 1 the values of Z_0 and R_0 are expressed by the following equations:

$$Z_0 = 138 \log_{10} \frac{b}{a} \text{ ohms,} \quad (4) \quad 105$$

where b is the inside diameter of the pipe shell in cm.; and

a is the outside diameter of the concentric rod in cm.

$$R_0 = \frac{1}{8} \sqrt{\mu \rho f} \left(\frac{1}{a} + \frac{1}{b} \right) L \cdot 10^{-9} \text{ ohms,} \quad (5) \quad 110$$

approximately, where

ρ is the resistivity of the pipe and rod material in electro-magnetic units; 115

μ is the magnetic permeability of the metal, equal to unity in the case of the non-magnetic material;

f is the frequency of the electrical waves in cycles per second. 120

So long as the dissipation is small, the impedance of each of the parallel-connected lines is very largely reactive. The impedance of the shorter line, since it is less than one quarter wave length, is capacitative and that of the longer line, which is greater than quarter wave length, is inductive. Since the two lines differ from a quarter wave length by equal amounts, the reactances of the two lines are very nearly equal in magnitude, and therefore neutralize each other. Actually the neutralizing is not complete, as may be seen from Equation 3, but in practice it is found that the residual reactance is only about one per cent of the resistance. By making the total length of the two lines very slightly greater than one half wave length complete neutralization can be obtained. 125 130 135

Fig. 2 illustrates a resistance element in accordance with the invention in which the parallel-connected lines are closed circuited and their lengths fixed. The device comprises a hollow electrical conducting tube, 30, closed at its ends by tight fitting metallic caps 31 firmly held in place by nuts 32 tightened down on the threaded ends of a concentrically located metallic rod 33. The input terminals of the device are terminal lugs 34 and 35 to which are attached leads 62 so that the device may be connected to the output of a transmission network as in Fig. 1. The latter of these lugs screws into the tube and is held 140 145 150

in place by a lock nut 36; and the former screws through an insulating bushing 37 and into a recess 38 in the rod 33. The bushing 37 is forced through a hole in the tube opposite terminal lug 35. The terminal lugs are located at a point on the tube unequally distant from the two ends, the exact location being determined by the desired value of resistance.

The device of Fig. 2 differs from that of Fig. 1 in that the lines effectively connected in parallel at the input terminals, instead of being open circuited, are short circuited at their ends by the metallic caps 31. A further difference is that the device of Fig. 2 is non-adjustable, and is designed to have but a single value of resistance.

The impedance of the shorter of the two closed circuited lines of Fig. 2 is expressed by the equation:

$$Z_1' = Z_0 \tanh \rho l_1 \quad (7)$$

and the impedance of the longer of the lines is expressed by:

$$Z_1'' = Z_0 \tanh \rho (L_1 - l_1) \quad (8)$$

where Z_1' is the input impedance of the shorter line;

Z_1'' is the input impedance of the longer line; L_1 is the overall length of the two lines, that is, of rod 33; and

l_1 is the length of the shorter of the lines.

The length of the line in Fig. 2 should be twice the length of rod 11 in Fig. 1, for signal waves of the same frequency.

The resistance device of Fig. 3 is an adjustable type, but differs from that in Fig. 1 in having a movable pair of contacts instead of a movable concentric rod. The advantage of the movable contact type is that the total length of the device is only about half the length of the movable rod type. The device comprises a tube 40 and a concentric rod 41 held firmly in place by end bushings 42 of insulating material. Terminal lugs 43 and 44 for connection to an external circuit are screwed into radial holes in a bushing 45 of insulating material and are supplied with leads 62. Lug 43 makes electrical connection with rod 41 by a disc 46 held against the rod by a compressed spring 47. Bushing 46 is fitted within the pipe and over the rod so that it is free to slide longitudinally. To allow the bushing and the terminal lugs to be thus moved, slots 49 and 50 are provided, extending on opposite sides of the tube for the length over which it is desired to move the bushing. This construction is more clearly seen with the aid of Fig. 4, which is a cross-sectional view at line 4-4. To prevent terminal 43 of the inner rod from touching the outer pipe shell and thus short circuiting the resistance element, the sides of the slot 49 are covered with an insulating material 51, which may be a rubber strip cemented to the pipe. Terminal lug 44 is provided with a projecting metallic flange 52 for the purpose of making contact with the shell of the pipe.

The adjustable resistance device of Figs. 3 and 4 is electrically equivalent to the element in Fig. 1 when the length of the pipe 40 and rod 41 is equal to the length of rod 11 in Fig. 1 and when the diameters of the pipes and rods are the same for the two lines.

The devices of Figs. 1 to 4 ordinarily occupy considerable space; for example, for use with a 16 meter wave, the length of the inner rod of the device in Fig. 1 is 8 meters, and the length of the outer pipe is about 16 meters. For the

same 16 meter wave, the device of Fig. 2 is 16 meters long and the device of Fig. 3 is 8 meters long. The outside diameters of the pipes will usually be in the order of 1 inch. It is evident, then that the figures are drawn much out of proportion, but this is necessary for a proper showing of the details.

In designing one of the open-circuited types of elements, the length of the device is determined by the wave length, the total line length being made equal to a quarter wave length. In fixing on the diameters of the pipe and of the concentric rod, values can be assigned which will give any convenient value of characteristic impedance, Z_0 . For example, if the pipe has an inside diameter of .75 inch and the concentric rod an outside diameter of .23 inch it is found from Equation (1) that Z_0 is equal to 70.7 ohms. Where the conducting material of the element is bronze, it is found from Equation (6) that the mid-point resistance R_0 is .25 ohm. It is to be noticed that the thickness of the material is not important, only the surfaces being used at the high frequencies of radio communication. By substituting the numerical values for Z_0 , R_0 and λ in the first two terms of Equation (4), the length l for any desired resistance value can be determined. In the case of the adjustable types of resistance elements, the length l can be adjusted until the desired resistance value is obtained; the desired value can be observed by measurement.

In the case of resistance elements composed of short-circuited lines, the design procedure is the same as in the case of the open-circuited type, except that the short-circuited lines are twice the length of the open-circuited lines. The greater length of the closed-circuited type generally makes the open-circuited type more desirable.

It is to be understood that the resistance device of the invention may be employed as a two-terminal circuit element in a variety of arrangements and is not limited to use as a termination for a transmission network as shown in Fig. 1.

What is claimed is:

1. An electrical resistance element for use at a single frequency comprising two lines having equal characteristic impedances, the input ends of said lines being connected in parallel and the output ends terminated for the condition of full wave reflection, lengths of said lines being proportioned with respect to each other to have substantially equal and opposite reactances.

2. A high frequency electrical resistance element for use at a pre-assigned frequency comprising a conducting cylindrical shell and a conductor located concentrically within said shell, the length of said inner conductor being one-half the wave length at said frequency and the ends of the conductors being terminated for the condition of full wave reflection, the input terminals of said element being a point on said shell and an adjacent point on said inner conductor, said points being intermediate the ends of the conductors.

3. An electrical resistance device comprising two lines, the input ends of which are connected in parallel, the lengths of said lines differing from the resonance length at a pre-assigned frequency by substantially equal amounts, one being less than, the other greater than the resonance length whereby the reactances of said lines substantially annul each other and the input impedance is substantially resistive.

4. An electrical resistance device for use at a preassigned frequency comprising a conducting tube, a metallic rod the length of said rod being one-half the wave length at said frequency, means for holding said rod in concentric position within said tube, the ends of the system so formed being open for full wave reflection therefrom, a pair of terminals, one of said terminals making contact with said tube, the other of said terminals making contact with said rod, said terminals being located adjacent each other at points intermediate the ends of said pipe and rod, and means for insulating the terminal connected to the rod, from the pipe.

5. An adjustable electrical resistance device for use at a preassigned frequency comprising a conducting tube, a metallic rod the length of said rod being one-half the wave length at said frequency, means for maintaining said rod in concentric position within said tube, the ends of the system so formed being open for full wave reflection therefrom, means for moving said rod longitudinally with respect to said tube, a terminal connected to said tube at a point intermediate its ends, a second terminal fastened in an insulating bushing, said bushing extending through said tube shell at a point opposite said first terminal, and means for causing said second terminal to make contact with said rod.

6. An adjustable high frequency resistance device for use at a preassigned frequency comprising a cylindrical conducting shell, an inner conductor concentrically located within said shell, the length of said inner conductor being one-half the wave length at said frequency and the ends of the system so formed being open for full wave reflection therefrom, a pair of terminals mounted in a bushing, said bushing being movable lengthwise within said shell, and means for making contact between said shell and the first of said terminals, means associated with said bushing for effecting contact between the second of said terminals and said inner conductor, and means associated with said shell for insulating said second terminal from said shell.

7. An adjustable high frequency resistance device according to claim 6 in which the means for making contact between the shell and the first of said terminals comprises a longitudinal slot in the shell, through which said first terminal extends, and a protrusion on the terminal for engaging with the edges of said slot.

8. A high frequency electrical resistance element for use at a preassigned frequency comprising a conducting cylindrical shell and a conductor located concentrically within said shell, the length of said inner conductor being the wave length at said frequency and the ends of the system so formed being short-circuited for full wave reflection therefrom, the terminals of said element being a point on said shell and an adjacent point on said inner conductor, said points being intermediate the ends of the conductors.

9. A high frequency electrical resistance element for use at a preassigned frequency comprising a conducting cylindrical shell, an inner concentric conductor free to move lengthwise with respect to said shell, the length of said inner conductor being one-half the wave length at said frequency and the ends of the system so formed being open for full wave reflection therefrom, the terminals of said elements being a point on said shell and an adjacent point on said inner conductor, said points being intermediate the ends of the conductors, and means for maintaining said inner conductor in its concentric position.

10. A variable electrical resistance element for use at a preassigned frequency comprising a conducting cylindrical shell, an inner concentric conductor, the length of said inner conductor being one-half the wave length at said frequency and the ends of the system so formed being open for full wave reflection therefrom, a bushing fitted within said shell, said inner conductor being free to move lengthwise through said bushing, and means for electrically connecting to the inner conductor through said bushing and to the outer shell at a point adjacent said bushing.

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