Dec. 1, 1942. D. W. PETERSON ET AL 2,304,015

RADIO FREQUENCY TRANSMISSION LINE

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FIG. 1.

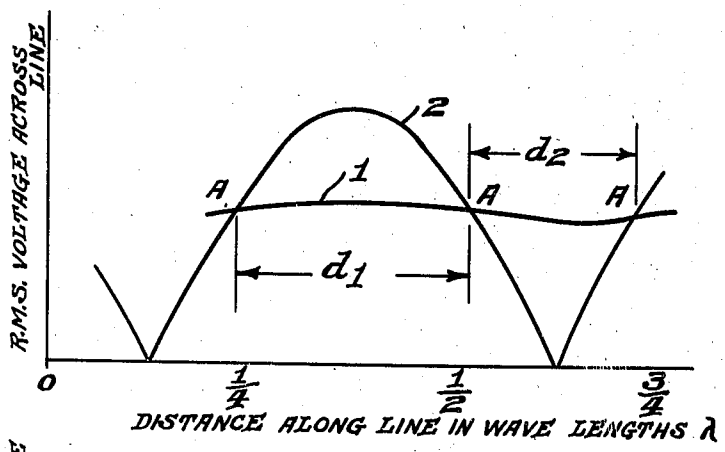

FIG. 2.

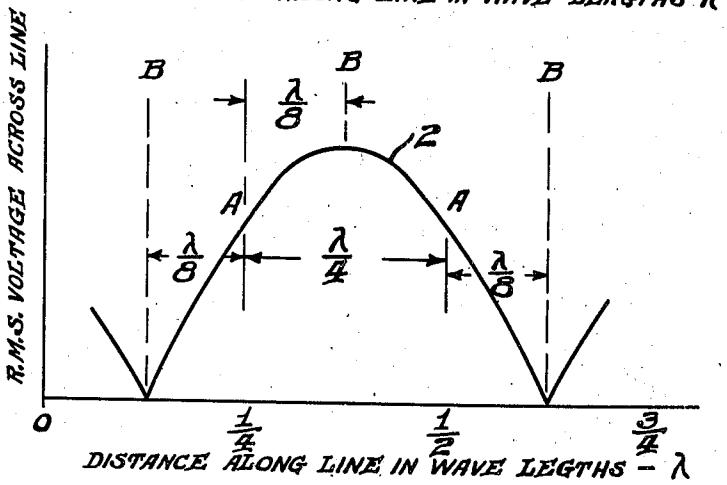

FIG. 3.

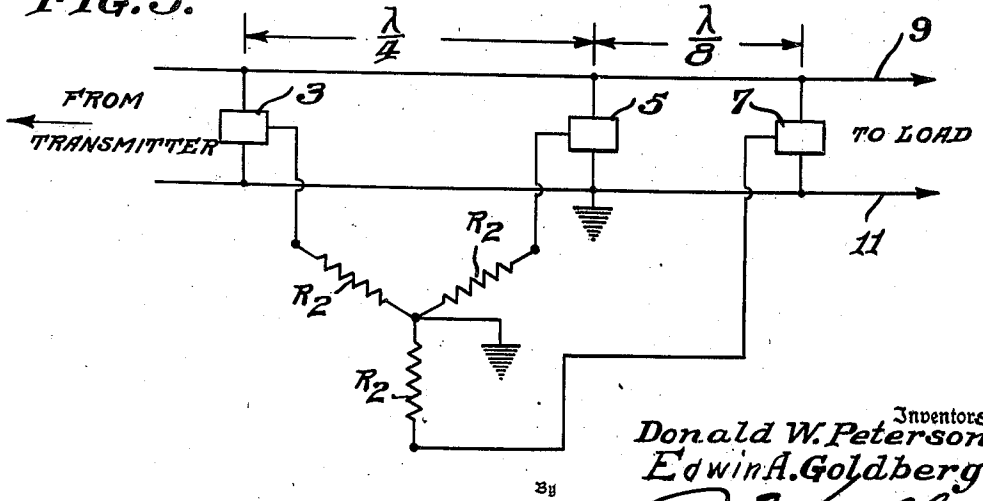

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FIG. 4.

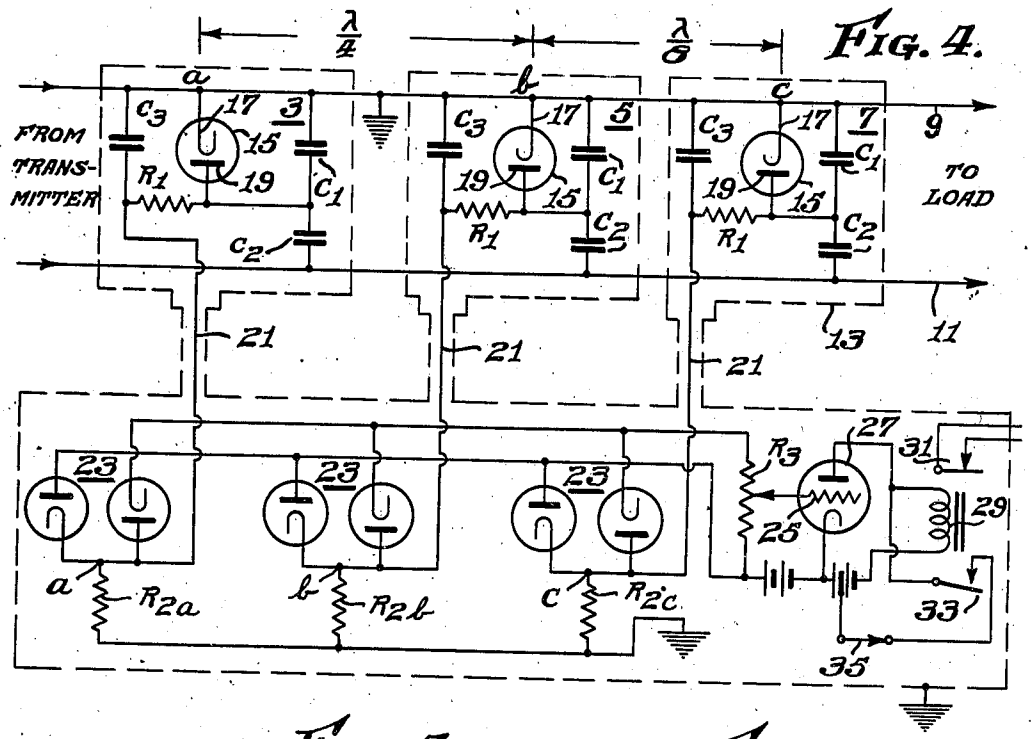


FIG. 5.

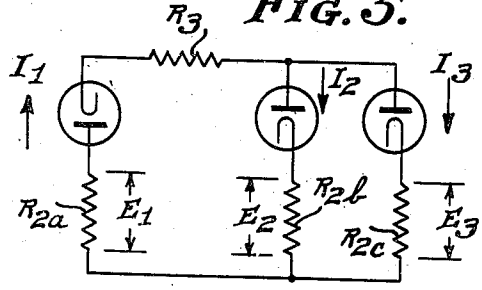


FIG. 6.

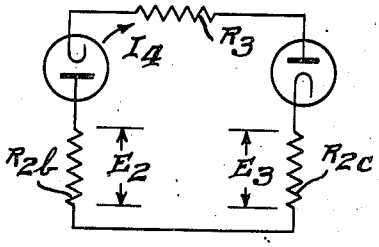
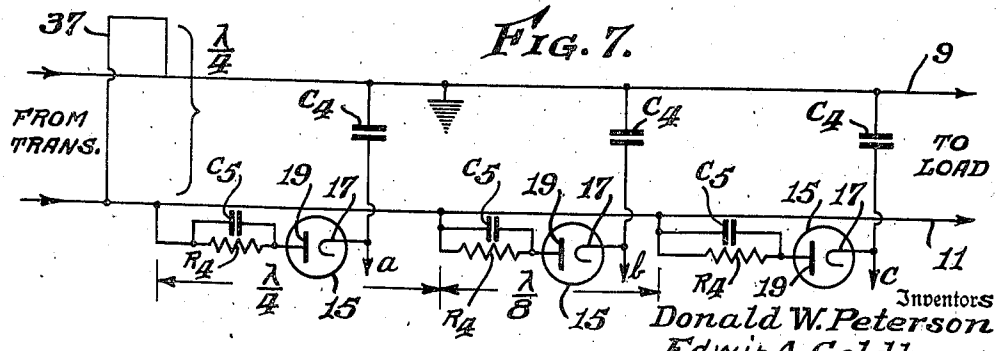


FIG. 7.



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UNITED STATES PATENT OFFICE

2,304,015

RADIO FREQUENCY TRANSMISSION LINE

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Application June 30, 1941, Serial No. 400,530

16 Claims. (Cl. 250—17)

This invention relates to radio frequency transmission lines, and more particularly to a protective device therefor.

Concentric transmission lines, such as are used with radio frequency transmitters, are known to be very costly, and for this reason a transmission line of as small size as possible is used. The size of such line which is selected for a given transmitter output will ordinarily be governed by the maximum standing wave voltage which occurs during short-circuit or open-circuit of the line. Under certain circumstances, as when the line becomes temporarily improperly terminated from some unforeseen or uncontrollable cause, a standing wave may occur which is greater than that existing during normal operation of the line. In such cases, a standing wave voltage may result which exceeds the tolerable maximum and causes breakdown of or other damage to the line. To guard against this possibility, it has been necessary to use transmission lines of greater size than that dictated by the aforementioned factors which govern selection of a suitable line, with the resultant increase in cost.

The primary object of our invention is to provide an improved radio frequency transmission line which will not be subject to the aforementioned disadvantages.

More particularly, it is an object of our invention to provide an improved protective device for radio frequency transmission lines which will protect such lines from damage upon the occurrence of undesirable standing waves therein.

Another object of our invention is to provide an improved protective device as aforesaid which will enable the use of transmission lines of least expense.

Still another object of our invention is to provide an improved protective device for radio frequency transmission lines which will promptly shut off a transmitter connected thereto when the ratio of maximum to minimum standing wave voltage exceeds a predetermined value.

A further object of our invention is to provide an improved radio frequency transmission line which can be operated at higher voltages than has been customary heretofore.

It is also an object of our invention to provide an improved transmission line and protective device therefor as above set forth which is highly efficient and reliable in use, simple in construction, and inexpensive in cost.

In accordance with our invention, we connect a plurality of rectifiers across the transmission line at different distances from each other (for example, three rectifiers may be used spaced from each other at distances equal to one-fourth and one-eighth the wavelength of the standing wave) and connect their outputs to a normally balanced Y network. These rectifiers respond to changes in line voltage at the points where they are respectively located, and a plurality of them should be used since, in certain cases, a single rectifier, or even two rectifiers alone, will not always see a change in line voltage. The output voltages of the rectifiers will become increasingly unequal as the ratio of maximum to minimum standing wave voltage increases, and this inequality is employed to unbalance the Y network and change the bias on a triode coupled thereto, thereby causing its plate current to change. The latter change is used to operate a suitable relay the contacts of which are in the control circuit of the transmitter. The arrangement is such that, upon creation of an undesirable standing wave, the relay operates to shut off the transmitter, thereby eliminating possibility of damage to the transmission line by that standing wave.

The novel features that we consider characteristic of our invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description, when read in connection with the accompanying drawings in which

Figures 1 and 2 are curves showing standing waves with reference to which the principles embodied in our invention are explained,

Figure 3 is a block diagram illustrating one arrangement according to our invention,

Figure 4 is a wiring diagram showing the details thereof,

Figures 5 and 6 are equivalent electrical diagrams showing certain features of our invention, particularly with reference to the modification shown in Fig. 4, and

Figure 7 is a wiring diagram of a portion of a modified circuit in accordance with our invention.

Referring more particularly to the drawings, wherein similar reference characters designate corresponding parts throughout, there is shown a curve 1, which represents a standing wave to which a suitable transmission line, such as a coaxial line, may be subject during normal operation, that is, when the line is suitably terminated. Should the line become short-circuited or open-circuited, or should the load vary appreciably as a result of some unforeseen cause or condition,

a standing wave 2 of the same wavelength as the wave 1 but of a much greater amplitude may result. As a consequence, the ratio of maximum to minimum voltage in the case of the wave 2 is much greater than in the case of the wave 1. If this ratio exceeds a predetermined tolerable ratio, a condition such as arcing may result which would damage the line. If, however, a suitable protective device is provided to cut off the supply of energy from the transmitter coupled to the line, the danger of damaging the line will be obviated.

Rectifiers judiciously placed along the transmission line can be made to produce a change in potential across a resistor upon the occurrence of a predetermined standing wave. Such rectifiers respond to the line voltage at the points where they are located, and the rectified voltage delivered thereby is a function of the line voltage at such points. In certain cases, however, a single rectifier, or even two rectifiers spaced from each other along the line, might not always see a change in line voltage. For example, if the points A of Fig. 1 are considered, at which both the wave 1 and the wave 2 have the same voltage, it will be obvious that a change will not affect a single rectifier placed at either of these points. Similarly, for some magnitude and location of standing wave, two rectifiers placed any distance d_1 or d_2 apart (Fig. 1) will not be affected by a change in voltage. However, if two rectifiers are placed at the points A—A spaced from each other one-fourth the wave length of the standing wave, and a third rectifier is placed on either side of the other two rectifiers a distance one-eighth the wavelength of the standing wave, as at any of the points B in Fig. 2, there will always be a change in voltage across at least one of the rectifiers. Such an arrangement is shown in Fig. 3 wherein the rectifiers 3, 5 and 7 are connected to a transmission line comprised of a pair of coaxial conductors 9 and 11, the rectifiers 3 and 5 being spaced from each other a distance $\lambda/4$, where λ is the wave length of the standing wave, and the rectifier 7 being spaced from the rectifier 5 a distance $\lambda/8$. The rectifiers 3, 5 and 7 are connected to a balanced Y network in each of the branches of which is included a resistor R_2. Unbalance of this network in response to a change in the standing wave detected by one or more of the rectifiers may be availed of to operate a relay which turns off the transmitter.

Referring to Fig. 4, we have shown one arrangement or circuit employing the above principles. Connected to the transmission line 9—11 are the rectifiers 3, 5 and 7 spaced from each other as above described and enclosed within a grounded shield 13. Each of the rectifier units comprises a pair of serially connected capacitors C_1 and C_2 connected across the conductors 9 and 11, and a diode 15 the cathode 17 of which is connected to one side of the line, for example, the grounded conductor 9. The anode 19 of the diode 15 is, in each case, connected to the common end of the capacitors C_1 and C_2. A third capacitor C_3 is, in each case, also connected to the conductor 9, and a resistor R_1 is connected between the capacitor C_3 and the anode 19. The capacitor C_1 can be varied in value to make the rectifier suitable for operation at lower or higher power. The capacitor C_2 is preferably connected to the inner conductor 11 of the coaxial transmission line, and therefore its reactance is made high compared with the characteristic impedance of the line.

Each of the resistors R_1 is connected by a shielded lead 21 to the high potential end of a separate one of the grounded resistors R_2. Also connected to the point of highest potential of each of the resistors R_2 is a full wave rectifier 23 in series with which is a resistor R_3 connected to the grid 25 of a triode 27 in the output circuit of which is connected the winding 29 of a suitable relay.

The direct current produced by any of the rectifiers 3, 5 and 7 is approximately proportional to the impressed radio frequency voltage. If R_1 is much smaller than R_2 (for example, 1,000 ohms and 100,000 ohms, respectively), a maximum usable voltage will be produced across each of the resistors R_2 which is approximately proportional to the radio frequency voltage of the line. Let E_a, E_b, and E_c be the line voltages at the respective rectifier points *a*, *b* and *c*. If it is assumed that E_a is greater than E_b and that E_b is greater than E_c, the current through the resistor R_3 results from the superposition of the currents I_1 and I_4 in the equivalent circuits of Figs. 5 and 6.

Let E_1, E_2 and E_3 be the potentials across the respective resistors R_{2a}, R_{2b}, and R_{2c} produced by the rectified currents. Let R_d be the resistance of each diode 23 where it is assumed that the resistance of each is the same. The Kirchoff's equations for Fig. 5 will then be as follows, bearing in mind that $I_3=I_1-I_2$:

$$E_1-(R_d+R_3)I_1-R_dI_2-E_2=0 \quad (1)$$

$$E_1-(R_d+R_3)I_1-R_d(I_1-I_2)-E_3=0 \quad (2)$$

Simultaneous solution yields:

$$I_1=\frac{2E_1-E_2-E_3}{3Rd+2R_3} \quad (3)$$

Kirchoff's equation for Fig. 6 results in:

$$I_4=\frac{E_2-E_3}{2R_d+R_3} \quad (4)$$

Let the potential drop across $R_3=E_g$.

Then, $E_g=R_3(I_1+I_4)=R_3$

$$\left(\frac{2E_1-E_2-E_3}{3R_d+2R_3}+\frac{E_2-E_3}{2R_d+R_3}\right) \quad (5)$$

Assuming that $R_3>>R_d$,

$$E_g\doteq\frac{2E_1-E_2-E_3}{2}+E_2-E_3\doteq E_1+\frac{E_2}{2}-\frac{3}{2}E_3 \quad (6)$$

Examination of Equation 6 shows that if $E_1=E_2=E_3$, then $E_g=0$. If $E_1=E_2$, and $E_3<E_1$, then, $E_g\neq 0$. If $E_1>E_2>E_3$, then, again $E_g\neq 0$.

Current through the resistor R_3 always must be in the same direction. The rectifiers 23, which will rectify both positive and negative half cycles of the currents derived from the transmission line, are arranged in opposite relation, in pairs, to insure this result. This direction is preferably chose to make the grid 25 of the triode 27 become less negative for an increase in standing wave, so that the relay 29 can be operated when the standing wave increases. This relay may then be made to open a switch 31 in circuit with the transmitter to shut off the transmitter, or disconnect it from the transmission line. Preferably, the relay 29 also closes a switch 33 of a holding circuit which keeps the relay closed, a switch 35 being provided for manual operation to reset the relay.

With the above described arrangement, care must be taken to keep radio frequency current out of the D.-C. circuits. For this purpose, the capacitor C_3 is provided which, in combination with the resistor R_1, in each case, provides a path for and filters out the radio frequency current. It is

also for this reason that the shield 13 is provided. In operation of the device, the triode 27 is preferably biased to a plate current lower than that required to operate the relay 29. After the transmitter is turned on, the resistor R_3 is adjusted to a point where the relay will operate upon a slight increase of E_g, which opposes the bias supplied by the battery in the grid circuit. Thus, an increase of the potential drop E_g reduces the bias on the grid 25.

In Fig. 7, we have shown a modified form of our invention. In this modification a conductor 37 is provided across the line 9—11, the conductor 37 being of a length equal substantially to one-fourth the wavelength of the standing wave or to an odd multiple thereof. One side of a capacitor C_4 is connected to the grounded conductor 9, and the other side thereof is connected to the cathode 17 of the rectifier 15 in each case. The anode 19 of each rectifier is connected through a resistor R_4 to the other transmission line conductor 11, the resistor R_4 being shunted by a capacitor C_5. Connection is made from each of the cathodes 17 of this modification to each of the points *a*, *b*, *c* of the resistors R_{2a}, R_{2b}, and R_{2c} of Figure 4, respectively, the circuits being otherwise the same as above described in connection with the modification shown in Fig. 4. The conductor 37 in this modification of the invention, which shorts the transmission line conductors, provides a D.-C. path for the rectified currents but appears as a very high shunt impedance at the operating frequency and therefore does not materially affect the characteristics of the line.

From the foregoing description, it will be apparent to those skilled in the art that we have provided a simple and effective way of protecting radio frequency transmission lines from becoming damaged as a result of excessive voltages resulting from undesirable standing waves. Although there are shown and described but two forms of our invention, it will be apparent to those skilled in the art that many other modifications thereof are possible. We, therefore, desire it to be understood that we do not wish to limit ourselves except in so far as is made necessary by the prior art and by the spirit of the appended claims.

We claim as our invention:

1. In a system including a transmitter having a control switch in circuit therewith and coupled to a transmission line subject to normal and abnormal standing waves, said system also including a normally balanced network coupled to said transmission line and subject to balance and unbalance depending upon whether said transmission line is subject to said normal or to said abnormal wave, respectively, and also including a grid controlled electron discharge device, the method of controlling said transmitter which comprises deriving electrical energy from said waves at a plurality of points spaced along said waves, rectifying said energy, applying said rectified energy to said network, deriving a potential from said network when it becomes unbalanced in response to said abnormal wave, applying said potential to the control electrode of said grid controlled electron discharge device whereby to alter the output of said device, and utilizing said altered output to actuate said switch to shut off said transmitter when said abnormal wave occurs.

2. In a system including a transmitter having a control switch in circuit therewith and coupled to a transmission line subject to normal and abnormal standing waves, said system also including a normally balanced Y-network coupled to said transmission line and subject to balance and unbalance depending upon whether said transmission line is subject to said normal or to said abnormal wave, respectively, and also including a grid controlled electron discharge device, the method of controlling said transmitter which comprises deriving from said waves currents at a plurality of points spaced along said waves, rectifying said currents, applying said rectified currents to said network, deriving a potential from said network when it becomes unbalanced in response to said abnormal wave, applying said potential to the control electrode of triode said electron discharge device whereby to alter the output thereof, and utilizing said altered output to actuate said switch to shut off said transmitter when said abnormal wave occurs.

3. In a combined transmitter having a control switch in circuit therewith and a transmission line coupled thereto, said transmission line being subject to a normal standing wave during normal operation and an undesired standing wave during abnormal operation, the method of controlling said transmitter which comprises deriving current from said waves at each of a plurality of spaced points therealong, rectifying each of said currents, feeding each of said rectified currents along separate paths including a common resistor, deriving a biasing potential from said resistor, applying said biasing potential to the control electrode of a grid controlled electron discharge device whereby to alter the output of said device, and utilizing said altered output to actuate said switch to shut off said transmitter when said undesired standing wave has reached a magnitude such that the ratio of maximum to minimum voltage resulting therefrom has exceeded a predetermined value.

4. The method set forth in claim 3 characterized in that two of said currents are derived at points spaced along said standing waves substantially one-fourth the wavelength thereof, and characterized further in that a third of said currents is derived at a point spaced along said waves from at least one of said first named points substantially one-eighth the wavelength thereof.

5. In a radio frequency transmitting system, the combination of a transmission line adapted to be connected to a radio frequency transmitter and subject to a predetermined standing wave under normal operating conditions, a control circuit for said transmitter including a relay, an electron discharge device including a control electrode, said relay being connected in the output circuit of said device, a plurality of rectifiers connected to said line at spaced points therealong for rectifying voltages derived from said line, the spacing of said rectifiers along said line being such that at least one of said rectifiers will respond to a change in voltage resulting from a change in magnitude of said standing wave produced by abnormal operating conditions, and means for applying the output of said one rectifying device to said control electrode whereby to alter the bias thereon and thereby alter said output circuit for operating said relay.

6. The invention set forth in claim 5 characterized in that at least three rectifiers are employed two of which are spaced from each other a distance along said transmission line equal to substantially one-fourth the wavelength of said standing waves, and the third of which is spaced from at least one of said two rectifiers a distance along said line equal to substantially one-eighth the wavelength of said standing waves.

7. In a radio frequency transmitting system, the combination of a transmitter including a control switch therefor, a transmission line coupled to said transmitter, said line being subject to a normal standing wave under normal operating conditions and to an undesired standing wave under abnormal operating conditions, means for deriving from either of said standing waves at a plurality of spaced points therealong a current, means for rectifying each of said currents, means providing a separate path for each of said rectified currents and including a resistor common to all of said paths, an electron discharge device having a control electrode, means for deriving a biasing potential from said resistor and applying it to said control electrode, and a relay associated with said switch, said relay being connected in the output circuit of said electron discharge device and being operable to actuate said switch upon application of a predetermined potential to said control electrode derived from said resistor in response to said undesired standing wave.

8. The invention set forth in claim 7 characterized in that said normal standing wave is of a magnitude such as to have a predetermined maximum to minimum voltage ratio, and characterized further in that said relay is operated when the undesired standing wave is of a magnitude such that said ratio is substantially exceeded.

9. The invention set forth in claim 7 characterized in that said paths are connected in Y relation, characterized further in that each of the branches of said Y includes a resistor, and characterized still further in that each of said resistors is connected to a separate one of said rectifying means, whereby rectified current is supplied to each of said resistors, said Y constituting a network which is normally balanced when said transmission line is subject to said normal standing wave, and said network becoming unbalanced when said transmission line becomes subject to an undesired standing wave to produce a current through said first named common resistor effective to provide the biasing potential necessary to alter the output of said electron discharge device.

10. The invention set forth in claim 7 characterized in that each of said paths includes means for rectifying both positive and negative half cycles of the currents derived from said transmission line, said last named means all being connected in series with said resistor.

11. In a radio frequency transmission line, the combination of a pair of conductors, a pair of serially connected capacitors connected across said conductors, a rectifier having a pair of cooperating electrodes, one of said electrodes being connected to one of said conductors and the other of said electrodes being connected to the common end of said capacitors, a third capacitor having one end connected to said first named conductor, and a resistor connecting said second named electrode with the other end of said third capacitor.

12. The invention set forth in claim 11 characterized in that one of said conductors is connected to ground, characterized further in that one of said electrodes is a cathode, and characterized still further in that said cathode is connected to said grounded conductor.

13. In a radio frequency transmission line, the combination of a pair of conductors, a third conductor connected across said pair of conductors, and a rectifying circuit also connected across said pair of conductors in parallel relation to said third conductor, said circuit comprising a capacitor connected to one of said pair of conductors, a rectifier having a pair of electrodes one of which is connected to said capacitor, and a resistor connecting the other of said electrodes to the second one of said pair of conductors.

14. The invention set forth in claim 13 characterized in that said transmission line is subject to a standing wave, and characterized further in that said third conductor is of a length equal substantially to one-fourth the wave length of said standing wave.

15. The invention set forth in claim 14 characterized by the addition of a second capacitor connected in shunt relation to said resistor.

16. The invention set forth in claim 14 characterized in that one of said first named pair of conductors is connected to ground, characterized further in that said capacitor is connected to said grounded conductor, characterized further in that one of said rectifier electrodes is a cathode, and characterized still further in that said cathode is connected to said capacitor.

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CERTIFICATE OF CORRECTION.

Patent No. 2,304,015. December 1, 1942.

DONALD W. PETERSON,ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, second column, line 13, claim 2, strike out "triode"; page 4, second column, line 37, claim 15, and line 40, claim 16, for the claim reference numeral "14" read --13--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 11th day of December, A. D. 1945.

(Seal)

Leslie Frazer
First Assistant Commissioner of Patents.