Feb. 6, 1945. C. B. WATTS, JR 2,368,694

COUPLING DEVICE

Filed Aug. 15, 1942

Fig:1.

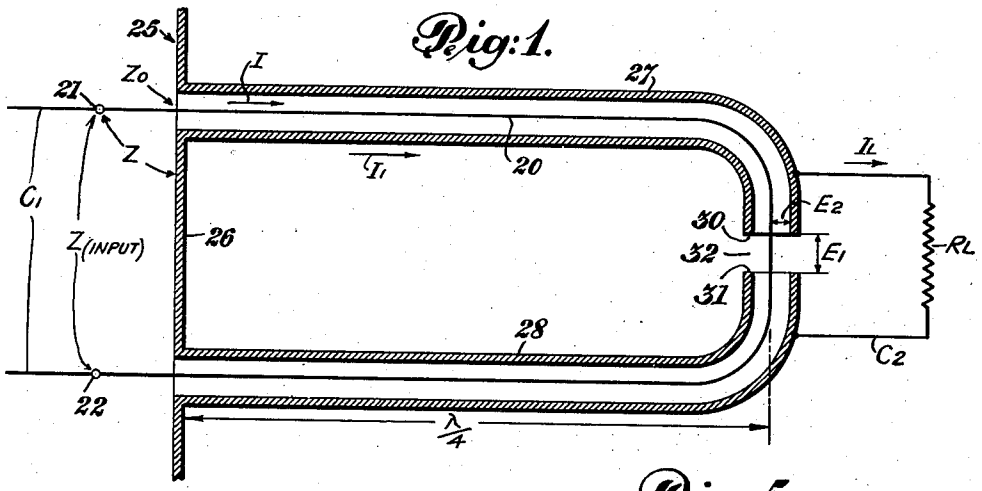


Fig:5.

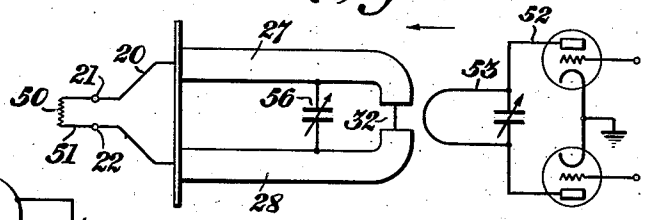


Fig:2.

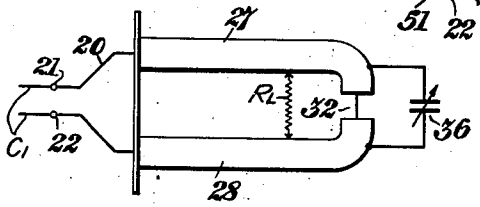


Fig:3.

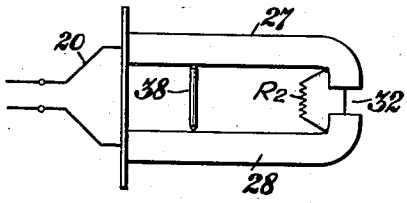


Fig:6.

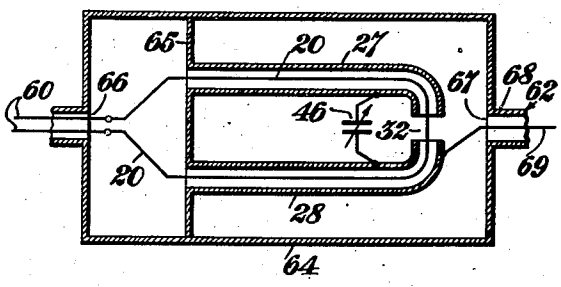
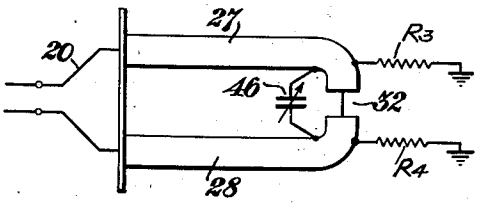


Fig:4.



INVENTOR
CHESTER B. WATTS, JR.
BY Percy P. Lantzy
ATTORNEY

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COUPLING DEVICE

Chester B. Watts, Jr., East Orange, N. J., assignor to Federal Telephone and Radio Corporation, a corporation of Delaware

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10 Claims. (Cl. 178—44)

This invention relates to coupling devices and one of the objects of the invention is to provide improved means for coupling two circuits together so that unbalanced currents and/or voltages occurring in one of the two circuits are prevented from spreading to the other thereof.

It is generally regarded that in a two-wire radio frequency transmission line only balanced currents and voltages are present and apparatus associated with the circuit is accordingly designed with this in mind. However, it is not unusual for various reasons to have unbalanced components of current and voltage crop up in the circuit. Unless particular pains are taken to cope with unbalanced current and voltage components, they are likely to spread throughout the circuit without any special relation to the balanced components thereby causing unexpected and undesirable effects.

The term "balanced" as used herein is given its usual meaning that for two-wire transmission line circuits the respective voltages of the two wires with respect to ground are equal in magnitude and opposite in phase, and that the currents thereof are likewise. The term "unbalanced" also is used in its usual sense, that the respective voltages and currents of the two wires are equal in magnitude and have the same phase. Any arbitrary distribution of voltages and currents that may exist in a two-wire circuit may be considered as composed of a set of balanced components of voltages and currents plus a set of unbalanced components of voltages and currents.

In order to discriminate between balanced and unbalanced components, it has been a practice heretofore to couple inductively two circuits together by a device comprising a loop conductor having two legs co-axially shielding the major portion of the loop. Employed with this prior device is a separate tunable circuit inductively coupled with the shield. This coupling arrangement effects a coupling between a circuit connected on the one hand to the conductor loop and another circuit connected on the other hand to the tunable circuit, whereby unbalanced currents and voltages present in one of the circuits are prevented from being transmitted from one to the other of the coupled circuits.

In accordance with my invention, I have discovered that for most such coupling arrangements, the separate tunable circuit can be eliminated and that the circuit formerly associated with the separate tunable circuit can be, if desired, directly connected to the shield. I have also found that the leg portions of the shield may be tuned to resonance at the frequency of the input current of one of the circuits by either a condenser connected between the legs thereof or by a short circuiting bar movable along the lengths of the legs. I have also discovered that not only a real impedance at the terminals of the conductor loop may be obtained by adjustment of the condenser or the short circuiting bar, as the case may be, but also by changing the position of the points at which a circuit, such as a resistor load, is connected to the shield, the magnitude of this real impedance may be varied. In general, the value of the real impedance at the input decreases as the load resistor is moved away from the exposed portion of the loop conductor. I have found that a very well balanced load effect can be produced by the coupling feature of my invention independent of whether or not the resistor or resistors used are balanced to ground. Thus, even where two very unequal resistors are connected, one to one leg and the other to the other leg of the shield, the impedance at the input of the conductor will be balanced.

It is another object of this invention, therefore, to provide simplified coupling means for coupling two circuits together wherein the shield portion of the coupling means is tunable to obtain resonance at the frequency of the input voltage.

Another object of this invention is to provide means for coupling together a dual wire transmission line and a co-axial line.

The above objects and others ancillary thereto will become more apparent upon consideration of the following detailed description to be read in connection with the accompanying drawing, in which,

Fig. 1 is a cross-sectional view of a coupling device in accordance with this invention;

Figs. 2, 3, 4 and 5 are views in side elevation of other forms of coupling devices and applications thereof in accordance with this invention; and

Fig. 6 is a cross-sectional view of one of the forms of this invention shown coupling a dual wire transmission line to a co-axial transmission line.

Referring to Fig. 1 of the drawing, a coupling device in accordance with this invention is shown to comprise a loop conductor 20 having terminals 21 and 22 adapted to be connected to one of the circuits C1 to be coupled. A shield 25 is provided for the loop conductor 20. This shield comprises a shielding plate 26 having mounted thereon a pair of substantially L-shaped tubular members 27 and 28. These tubular members are disposed at right angles to the plate 26 and form to-

gether a split loop, that is, the ends 30 and 31 of the tubular members are disposed toward each other with a gap 32 therebetween. The main portion of the loop conductor 20 is disposed in co-axial shielded relation within the tubular members with a small part thereof exposed at the gap 32. The lengths of the tubular members 27 and 28 are equal and the gap 32 is small compared to the length of the tubular members.

This shielding arrangement of the loop conductor 20 provides a co-axial transmission line, the two parts of which are electrically uniform and identical. The effective electrical lengths of the tubular members 27 and 28 are preferably selected as a quarter wavelength of the energy to be transmitted from the line C1 to the load circuit C2. The load circuit C2, which may comprise a resistor R_L or some other load, is directly connected to the legs 27 and 28 of the shield.

Since the conductor 20 and the tubular legs 27 and 28 are shown identical in all of the figures of the drawing I have used the same reference characters for these parts throughout the drawing.

In the case of a load R_L (Fig. 1), the input impedance $Z_{(input)}$ may be easily calculated, assuming that the legs 27 and 28 are a quarter wavelength long. The loop conductor 20 is treated as a single wire co-axial line having surge impedance Z_0, carrying current I at the input end whose component parts are I^+, which comprises the forward wave progressing to the right and I^-, which is the reflected wave progressing to the left. Thus, $I=I^++I^-$. At the right-hand end of the device, one quarter wavelength away from the left-hand end, the current may be expressed as

$$I=I^+\angle \underline{-90°}+I^-\angle \underline{+90°}$$

or

$$I=-jI^++jI^-$$

The shield itself may be similarly treated as a dual transmission line having surge impedance Z_1 with current

$$I_1=I_1^++I_1^-$$

at the left-hand end thereof.

The voltage across the shield at the left-hand end is equal to zero and may be expressed by the following equation:

$$Z_1(I_1^+-I_1^-)=0 \quad (1)$$

The voltage E_1 across the gap 32 is equal and opposite to the voltage E_2 at the right-hand end of each leg between the inside of the shield and the conductor 20. This relationship may be expressed by the following equation:

$$Z_1(-jI_1^+-jI_1^-)=-Z_0(-jI^+-jI^-) \quad (2)$$

Since the voltage E_1 across the gap 32 is equal to the voltage across the load resistor R_L an equation may be written as follows:

$$Z_1(-jI_1^+-jI_1^-)=I_LR_L \quad (3)$$

The current flowing on the shield at the right-hand end thereof is equal to the current flowing into the load resistance plus the current flowing in the conductor 20 at the gap 32 and this relation may be expressed as follows:

$$-jI_1^++jI_1^-=I_L-jI^++jI^- \quad (4)$$

The foregoing equations may be simplified as indicated in the following five equations:

$$I_1^+-I_1^-=0 \quad (5)$$

$$Z_1(I_1^++I_1^-)=-Z_0(I^++I^-) \quad (6)$$

$$Z_1(I_1^++I_1^-)=jI_LR_L \quad (7)$$

$$I_1^+-I_1^-=jI_L+I^+-I^-=0 \quad (8)$$

and therefore

$$jI_L=-I^++I^- \quad (9)$$

Solving Equation 6 by using the Equation 5 which in effects states that $I_1^+=I_1^-$ it follows that:

$$2I_1^+Z_1=-Z_0(I^++I^-) \quad (10)$$

$$2I_1^+Z_1=jI_LR_L \quad (11)$$

$$-Z_0(I^++I^-)=jI_LR_L \quad (12)$$

Substituting for jI_L in Equation 12 the value given in Equation 9, it follows that:

$$-Z_0(I^++I^-)=R_L(-I^++I^-) \quad (13)$$

$$\frac{Z_0}{R_L}=\frac{I^+-I^-}{I^++I^-} \quad (14)$$

Since the impedance at one of the terminals to shield is

$$Z=\frac{Z_0(I^+-I^-)}{I^++I^-} \quad (15)$$

$$Z=\frac{Z_0^2}{R_L} \quad (16)$$

and since the input impedance

$$Z_{(input)}=2Z=\frac{2Z_0^2}{R} \quad (17)$$

or

$$Z_{(input)}=\frac{Z_0^2}{R_{L/2}} \quad (18)$$

it will be clear that the input impedance is independent of the surge impedance Z_1 of the shield itself at least as long as the shield is tuned to one quarter wavelength, but that it varies with the square of the surge impedance Z_0 of the conductor 20 and inversely with the load resistance R_L. Thus, the impedance at the terminals 21, 22 of the loop conductor 20 will be real and balanced.

Should a shield not exactly one quarter wavelength long be used, it may be effectively made resonant by a condenser 36 (Fig. 2) or by a movable shorting bar 38 (Fig. 3). Thus tuned, the impedance effect is substantially the same as calculated above. If the shield is not resonant, then the input impedance contains reactance in addition to the resistance.

Referring to Fig. 2 of the drawing, a form of coupling device in accordance with this invention is shown provided with a variable condenser 36 connected across the legs 27 and 28 of the shield whereby the shield may be tuned to resonance at the frequency of the input current. The condenser 36 may be connected between the legs 27 and 28 at any points therealong as desired. It will be observed, however, that the same condenser will have a sharper tuning effect when connected close to the gap 32, and that the tuning effect is decreased as the connections to the condenser are moved along the length of the legs 27 and 28 toward the left-hand end thereof.

The circuit having the load R_L may be connected between the legs 27 and 28 as shown in Fig. 1 or the connections thereof may be arranged with movable contact means for adjustment along the length of the legs as indicated in Fig. 2. As the load resistor R_L is moved away

from the gap 32, the value of the real impedance at the input terminals of the conductor 20 decreases. Thus, the value of the real impedance at the input terminals 21, 22 may be varied by moving the connecting points of the load circuit.

In Fig. 3 of the drawing, another form of the invention is shown wherein the shield is tuned by a shorting bar 38 movable along the length of the legs 27 and 28. The load R_2 in this form may be connected to the legs 27 and 28 as shown in Fig. 3 or it may be connected thereto in the manner of the resistors shown in Figs. 1, 2 and 4. The movement of the shorting bar 38 varies the tuning of the shield, in the same manner as condenser 36 in Fig. 2 does.

In Fig. 4, I have shown the shield having a tunable condenser 46 similar to the condenser in the form shown in Fig. 2. In this form, two loads R_3 and R_4 are shown, the load R_3 being connected between the leg 27 and ground while the load R_4 is connected to the leg 28 and ground. These loads need not be equal but in fact may be very unequal to the extent of one being zero, and still the impedance at the input terminals will be balanced.

The tuned coupling device of this invention may be used to couple a source of energy to the loop conductor 20 for transmission by a line 51 to a load 50 such as an antenna. This application of the coupling means of this invention is shown in Fig. 5. An amplifier plate circuit 52 is shown provided with a tuned circuit 53 disposed in the vicinity of the coupling device. The shield of the coupling device may be provided with a suitable condenser 56 similar to the form shown in Fig. 4 by which the shield can be tuned to the frequency of the current carried by the tuned circuit 53. The effective coupling of the amplifier plate circuit 52 to the line 51 may be varied by controlling the tuning of the condenser 56. Thus, energy may be transmitted to the antenna 50 as desired, and at the same time the transmission of unbalanced currents and voltages between the two circuits may be blocked. Instead of the coupling arrangement shown, the circuit 53 may be broken and the two sides thereof directly connected to the shield; that is, one side of the circuit 53 may then be connected to the leg 27 and the other side to the leg 28.

Another application of the coupling device of this invention is shown in Fig. 6 wherein the device is used to provide a coupling between a two-wire transmission line 60 and a co-axial transmission line 62. The shield comprises a box structure 64 having a partition 65 upon which is mounted a shield in accordance with the form shown in Fig. 4, for example, having legs 27 and 28 and a tunable condenser 46. One end of the box structure 64 is provided with an opening 66 through which the transmission line 60 is adapted to be connected to the terminals of the loop conductor 20. The opposite end of the box structure 64 is provided with an opening 67 to receive for connection to the end wall of the structure, the outer conductor 68 of the co-axial transmission line 62. The inner conductor 69 is extended into the box structure and connected to one of the legs of the shield.

While I have shown and described several embodiments of the invention, I recognize that many additional embodiments and variations are possible without departing from the invention. It is to be understood, therefore, that the forms herein shown and described are to be regarded as illustrative of the invention only and not as restricting the appended claims.

What I claim is:

1. A device for coupling two circuits together to prevent unbalanced voltages and currents occurring in one from spreading to the other of two circuits comprising a continuance loop conductor connected to one of said circuits, a shield for said conductor, said shield having two hollow legs the free ends of which extend toward one another to provide a gap therebetween, said loop conductor being co-axially mounted within said legs whereby it is shielded along the lengths of the legs and exposed at said gap, at least one of said legs being connected to the other of the two circuits, and said legs being of an electrical length in the order of substantially one quarter wavelength of the current to be transmitted from one to the other of said circuits.

2. A device for coupling two circuits together to prevent unbalanced voltages and currents occurring in one from spreading to the other of two circuits comprising a continuous loop conductor connectable to one of said circuits, a shield for said conductor adapted to be coupled to the other of said circuits, said shield having two hollow legs the free ends of which extend toward one another to provide a gap therebetween, said loop conductor being co-axially mounted within said legs whereby it is shielded along the lengths of the legs and exposed at said gap, said legs being of an electrical length in the order of substantially one quarter wavelength of the current to be transmitted from one to the other of said circuits, and means to tune said shield to resonance at the frequency of said transmitted current.

3. The coupling device as defined in claim 2 wherein the tuning means comprises a condenser connected between the legs of the shield.

4. The coupling device as defined in claim 2 wherein the tuning means comprises a shorting bar disposed between the legs of the shield and adjustable along the lengths thereof.

5. The coupling device as defined in claim 2 wherein the circuit coupled to the shield is connected to both of the legs thereof.

6. The coupling device as defined in claim 2 wherein the circuit coupled to the shield comprises means conductively connecting the circuit to the legs thereof, and said connecting means being adjustable lengthwise of said legs to vary the connecting points thereof.

7. The coupling device as defined in claim 2 wherein one of the circuits comprises a dual transmission line connected to the loop conductor and the other circuit comprises a co-axial transmission line wherein the inner conductor thereof is connected to one leg of the shield and the outer conductor thereof is connected to another portion of the shield.

8. Apparatus for coupling to a balanced dual transmission line comprising a co-axial line, a housing having a partition therein, a pair of L-shaped tubular legs substantially completely enclosed within said housing and mounted on said partition with the long portions thereof disposed in parallel relation and the short portions thereof disposed in opposed relation with the ends thereof spaced apart, a loop conductor disposed co-axially with respect to the tubular legs and spanning the space between the ends thereof, said loop conductor being connectable to the dual line, the outer conductor of the co-axial line being connectable to said housing and the inner con-

ductor of the co-axial line being connectable to one of said legs, whereby unbalanced voltages and currents occurring in one of the said lines will be prevented from spreading to the other line.

9. The coupling device as defined in claim 8 wherein means are provided for tuning the pair of legs to resonance at the frequency of the current transmitted from one to the other of said lines.

10. The coupling device as defined in claim 8 wherein a condenser is connected between the legs to tune them to resonance at the frequency of the current to be transmitted from one to the other of said lines.

CHESTER B. WATTS, JR.