

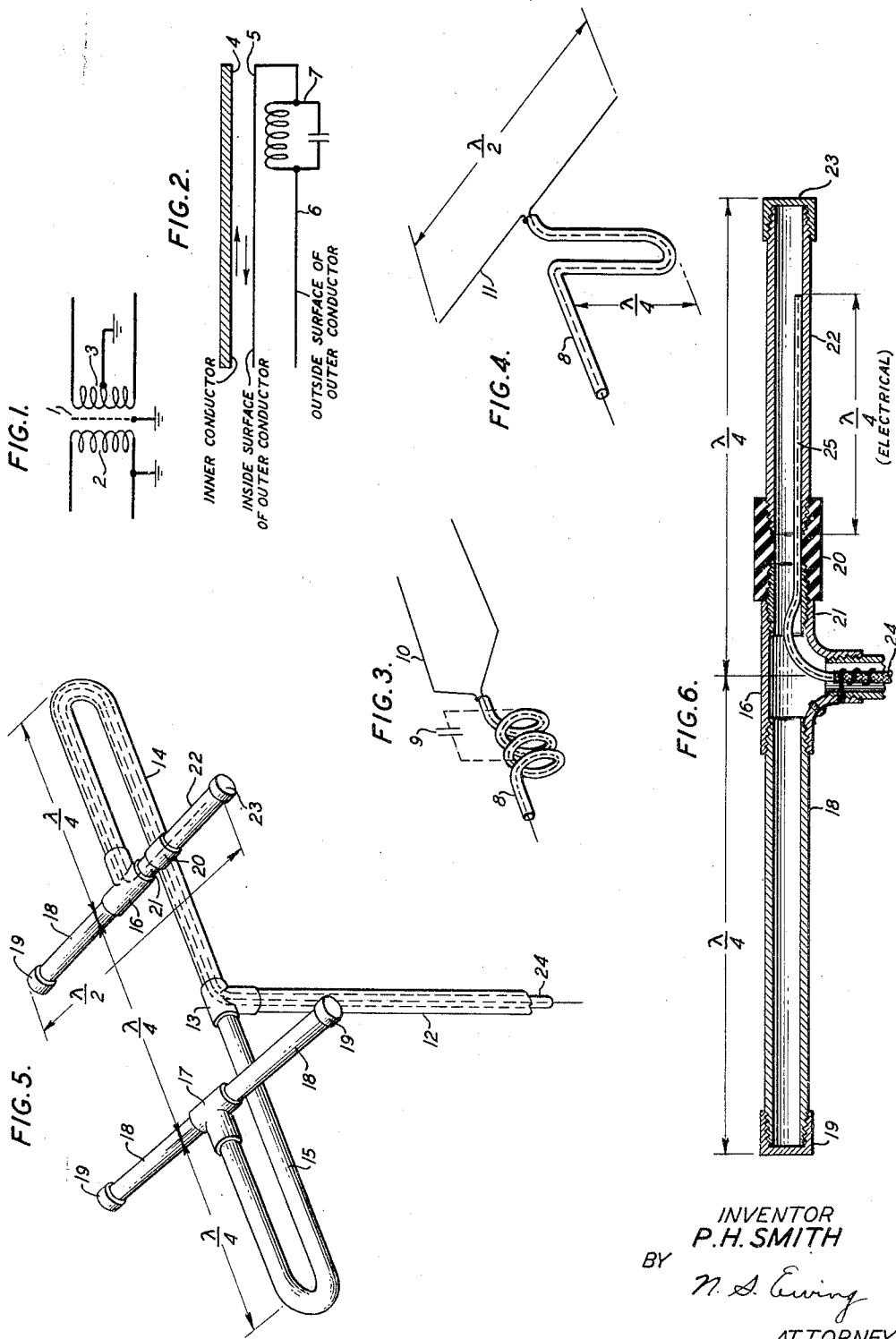
March 27, 1951

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2,546,322

BALANCED TO UNBALANCED COUPLING

Filed April 14, 1948



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2,546,322

BALANCED TO UNBALANCED COUPLING

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Application April 14, 1948, Serial No. 21,013

13 Claims. (Cl. 250—33)

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This invention relates primarily to the coupling together of balanced and unbalanced electrical circuits, the term "balanced" denoting circuits in which the voltages between the respective conductors and a neutral, such as ground, are substantially equal and the term "unbalanced" denoting circuits in which such voltages are substantially different. More particularly, the invention relates to coupling methods and devices involving coaxial cables.

One object of the invention is to couple a circuit which is balanced with respect to ground with a circuit which is unbalanced with respect to ground over a relatively broad band of frequencies and in a simple manner.

Another and more particular object is to enable a flexible coaxial cable to be used as a coupling device without the necessity of removing the protective insulation from a portion of the outer conductor of the cable.

Connecting a circuit which is balanced with respect to ground with a circuit which is unbalanced with respect to ground presents certain problems, particularly at high frequencies. For example, it is undesirable to feed energy through a coaxial transmission line, which is unbalanced with respect to ground, directly into a balanced system, such as a pair of parallel conductors, a shielded pair, or a center-fed dipole antenna. To do so would permit energy to leak off to ground along the outer surface of the coaxial line and, furthermore, cause undesired radiation from the unbalanced line. It is desirable that the junction be effected by a device permitting an efficient transfer of energy with as little leakage to ground as possible.

The outside surface of the inner conductor of a coaxial cable is normally well above ground potential, and the outside surface of the outer conductor is normally at or near ground potential. Both conductors of a balanced transmission line are usually well above ground potential. The inner conductor of the coaxial line can be connected to one wire of the balanced line, and the outer conductor can be connected to the other wire, but, at the point of connection, it is highly desirable, as will be shown hereinafter, that a high impedance be introduced between a point near the end of the outer conductor of the coaxial line and the remaining outside surface of the outer coaxial conductor to prevent power leakage to ground and to establish the required balanced-to-ground driving potential across the input terminals of the balanced line.

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high impedance is introduced in series with the outside surface of the outer conductor of a coaxial cable by shaping the cable in an appropriate manner and an unbalanced circuit and a balanced circuit are coupled together by the shaped section of coaxial line.

The nature of the invention will be more thoroughly understood after a study of the following detailed description and the attached drawings. In the drawings:

Fig. 1 illustrates the circuit action of the invention;

Fig. 2 represents the conditions existing in a coupling device embodying the invention;

Fig. 3 shows one specific embodiment of the invention;

Fig. 4 shows another specific embodiment of the invention;

Fig. 5 shows an antenna system containing an embodiment of the invention; and

Fig. 6 illustrates a method of terminating the coaxial transmission line in the antenna system of Fig. 5.

The circuit action of the present invention is illustrated in Fig. 1. A coaxial coupling device in accordance with the present invention may be compared with a one-to-one, electrostatically shielded, transformer 1, in which the primary 2 is grounded at one side and the secondary 3 is grounded at a mid-point of the winding. A transmission line connected to the primary 2 may be unbalanced with respect to ground, while one connected to the secondary 3 may be balanced with respect to ground.

Fig. 2 demonstrates the conditions which exist in a coaxial coupling device constructed in accordance with the present invention. At high frequencies, due largely to skin effect, a coaxial line is, in effect, composed of three conducting surfaces. Current normally flows on the outside surface 4 of the inner conductor and on the inside surface 5 of the outer conductor. Current flows on the outside surface 6 of the outer conductor only in the event of abnormal conditions. For all practical purposes, the inside surface 5 can be considered to be, in effect, insulated from the outside surface 6 of the outer conductor at all but the end points of the cable. The outside surface 6 of the coaxial line is normally at or near ground potential. In accordance with the present invention, an anti-resonant circuit 7 is formed, introducing a high impedance in series with the outside surface 6 very close to the end of the cable. The outside surface 6 is thus effectively insulated from the inside surface 5 at

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the end of the cable and the inside surface 5 is free to rise above ground potential. A balanced two-wire line may be connected at this point with little or no leakage of energy to ground at the junction. Currents flowing on the outside surface 6 of the outer conductor of the coaxial cable are effectively blocked by the insertion of this high impedance.

One specific embodiment of the invention is shown in Fig. 3. A section of coaxial cable 8 is coiled over a portion of its length at the end which is to be connected to a balanced circuit. The distributed capacity 9 between turns tunes the coil approximately to anti-resonance, the net effect being to create a high impedance in series with the outside surface of the outer conductor of the cable in the vicinity of the coil. The balanced circuit coupled to the coaxial cable may be a balanced transmission line 10, as shown, or practically any other type of balanced circuit. An unbalanced circuit may be connected to the other end of the section of coaxial cable 8 or the cable may itself constitute the unbalanced circuit.

A further specific embodiment of the invention is shown in Fig. 4. The operation is the same as that of the embodiment described in Fig. 3, the only difference in the embodiments being that the section of coaxial cable 8 is shaped in a different manner to introduce the required high impedance. In the present embodiment, the cable is bent back upon itself at a point near its end for a distance of approximately a quarter of a wavelength. A half-wave antenna 11 is shown connected to the end of the coaxial cable as a balanced load. When such an antenna is used, it is usually desirable that the axis of the antenna be substantially normal to the plane of the quarter-wave loop.

In each of the foregoing embodiments, sections of coaxial cable so shaped may be used as coupling devices for coupling a circuit which is unbalanced with respect to ground to a circuit which is balanced with respect to ground or vice versa. For example, an unbalanced antenna might be fed from a balanced transmission line in this manner. In some instances, the coaxial line may itself constitute the unbalanced circuit or the balanced line may constitute the balanced circuit. In all embodiments, a high impedance is introduced which effectively insulates the end of the outer conductor of the coaxial cable from the rest of the outer surface of that conductor. While such an impedance is greatest at precisely the frequency to which the de-coupler is tuned, it remains high as compared to the impedance of the balanced circuit and the device is operative over a considerable band width.

In most instances it will be desirable that the shaped portion of the coaxial cable be located very close to the end which is to be connected to the balanced circuit. The shaped portion may be located a short distance from the end, but, in such an event, the different capacitances to ground of the respective coaxial conductors will tend to reintroduce unbalance. This reintroduced unbalance becomes greater as the distance between the shaped portion of the cable and the end which is connected to the balanced circuit increases.

If the circuits which are to be coupled together possess different characteristic impedances, it will usually be desirable to utilize a suitable impedance matching device as, for example, the stub transformer disclosed in the present inven-

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tor's previous United States Patent 2,041,378, since the shaped section of coaxial cable does not, alone, serve to transform impedances. The balancing operation, however, need not be impaired by the addition of such a device to the circuit.

Fig. 5 shows a simple antenna system adapted to include an embodiment of the present invention. The antenna shown is of a type suitable for use in the reception of high frequency, horizontally polarized, waves such as those employed in television and frequency modulation broadcasting. The example shown is constructed of galvanized iron pipe, with a coaxial line inserted and suitably terminated therein, and is, therefore, of simple, rugged, and relatively inexpensive construction. As shown in Fig. 5, the array is supported by a vertical section of pipe 12. A T-section 13 is attached to the top of the vertical section 12. A substantially horizontal pipe 14 having a 180-degree bend is attached to one side of the T-section 13, the distance from the T-section 13 to the bend being approximately three-eighths of a wavelength and the distance from the bend to the other end of the pipe 14 being substantially a quarter of a wavelength. The plane of the 180-degree bend is substantially vertical. A second pipe 15 similar to the first pipe 14 is attached to the other side of the T-section 13.

Two additional T-sections 16 and 17 are attached to the respective ends of the pipes 14 and 15, the plane of the T-sections 16 and 17 being substantially horizontal. Two sections of pipe 18, each approximately a quarter of a wavelength long, are attached to the respective sides of the T-section 17, and caps 19 are attached to the other ends of each of the pipes 18. Another quarter-wavelength of pipe 18 is attached to one side of the other T-section 17 and a cap 19 is added to its free end. An insulating coupling 20 is attached to the other side of the T-section 16 by means of a short section of pipe 21. A length of pipe 22 is then attached to the other side of the coupling 20 and a cap 23 added to its free end. The total length of the pipe 22, the insulating coupling 20, and the short section of pipe 21 is substantially a quarter of a wavelength. A flexible coaxial transmission line 24 is inserted through the vertical pipe 12, the bent pipe 14, and terminated in the T-section 16 and the attached quarter-wave pipe 22 in a manner which will be described later.

The 180-degree bends in the described antenna structure operate to couple the unbalanced coaxial transmission line to the balanced half-wave driven antenna and reflector in much the same manner as that described in previous embodiments of the invention. The outside surface of the outer conductor of the coaxial cable 24 is connected electrically to the pipe structure in the T-section 16 and, therefore, the pipe may, for all practical purposes, be considered to be the equivalent of the outer conductor of the cable since there is no potential difference or electric or magnetic field between the inner surface of the pipe and the outer surface of the coaxial cable.

The method of terminating the coaxial line in the antenna system of Fig. 5 is illustrated in Fig. 6. A section view of the T-section 16 and the attached members is shown. In the described embodiment, a coaxial line 24 of the flexible type is used. In order to establish the equivalent of an electrical connection between the center con-

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ductor of the coaxial line and the insulated end 22 of the dipole antenna at the operating frequency only, without making an actual conductive connection, a well known property of open circuited quarter wave transmission lines is made use of in the following manner: A portion of the outer conductor is stripped off and the inner conductor 25 is inserted through the insulating coupling 20 for a distance of a quarter of a wavelength along the length of pipe 22. The insulation is left on the inner conductor 25 and, since it has a dielectric constant greater than that of air, the impressed wave is retarded, the insulation reducing all electrical lengths by reducing the speed of propagation. The length of the insulated inner conductor along the length of pipe 22 is thus less than that of the pipe itself. The pipe 22 remains completely insulated from the rest of the system due to the insulating effect of the coupling 20. The outer conductor of the cable 24 is connected electrically to the T-section 16, completing the termination.

Although the invention has been described largely with reference to certain specific embodiments, various other embodiments and modifications, within the spirit and scope of the appended claims, will occur to those skilled in the art.

What is claimed is:

1. In a transmission system operative over a predetermined range of frequencies, in combination, a circuit which is balanced with respect to ground, a circuit which is unbalanced with respect to ground, and means for coupling said circuits together which comprises a uniform section of coaxial cable bent to form an antiresonator tuned to a frequency within said operating range of frequencies in series with the outside surface of the outer conductor of said coaxial cable, said antiresonator being disposed adjacent one end of said coaxial cable to prevent the introduction of any substantial capacity to ground from the portion of the outer conductor of said coaxial cable beyond said antiresonator, said balanced circuit terminating upon the inner and outer conductors, respectively, of said coaxial cable at the said end thereof, said unbalanced circuit being connected to said coaxial cable at the other end thereof, and said portion of the outer conductor beyond said antiresonator being of such length and so arranged that its capacity to ground is negligible.

2. In a transmission system operative over a predetermined range of frequencies, a combination, in accordance with claim 1, in which said coupling means consists of a section of coaxial cable coiled over at least part of its length, whereby the distributed capacity between turns tunes said coil approximately to antiresonance.

3. In combination, a circuit which is unbalanced with respect to ground, a circuit which is balanced with respect to ground, means for coupling said circuits together which comprises a uniform section of coaxial cable shaped to introduce, over a predetermined range of frequencies, a high impedance in series with the outside surface of the outer conductor of said coaxial cable, connections from said unbalanced circuit to the inner and outer conductors, respectively, at one end of said coaxial cable, and connections from said balanced circuit to the inner and outer conductors, respectively, at the other end of said coaxial cable, said coupling means comprising a section of coaxial cable bent back upon itself for a distance of substantially a quarter of a wavelength.

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4. An antenna structure which comprises a balanced antenna element, a number of sections of metal pipe, at least one of said sections containing a loop, wherein the pipe is bent back upon itself for a distance of substantially a quarter of a wavelength, and being connected to said balanced antenna element, and a coaxial feed line, said coaxial line being inserted inside of said section which is connected to said antenna element and being terminated in said antenna element.

5. An antenna which comprises a section of metal pipe having substantially a 180-degree bend substantially a quarter of a wavelength from one end, a metal T-section attached to said end, the cross arm of said T-section being substantially normal to the plane of said bend, a first section of pipe substantially a quarter of a wavelength long attached to one side of said T-section, a metal cap attached to the end of said first quarter-wave section, a second section of pipe substantially a quarter of a wavelength long attached physically to but insulated electrically from the other side of said T-section, a metal cap attached to the end of said second quarter-wave section, and a coaxial cable extending through said bent section of pipe and terminated in said second quarter-wave section.

6. An antenna, in accordance with claim 5, in which said coaxial cable is of the flexible type and is terminated by the outer conductor being removed for a distance of substantially a quarter of an electrical wavelength, the electrical wavelength being somewhat reduced from the free space wavelength because of the presence of the insulating material between the conductor of said coaxial cable which is left on after removing a portion of the outer conductor, the insulated inner conductor being inserted into said second quarter-wave section of pipe, and the outer conductor of said cable being connected electrically to said T-section.

7. In combination, a balanced half-wave antenna, a coaxial transmission line folded back upon itself at one end for a distance of substantially a quarter of a wavelength, the axis of said antenna being substantially normal to the plane of the fold, and connections from the inner and outer conductors, respectively, at the folded end of said coaxial line to said balanced antenna.

8. An antenna system designed to operate over a predetermined range of frequencies which comprises an individual balanced antenna element, a tubular conductor connected to said antenna element and folded back upon itself for a distance of substantially a quarter of a wavelength at an intermediate operating frequency at a distance of substantially a quarter of a wavelength from said antenna element measured along said tubular conductor, and an internal conductor within said tubular conductor coupled to said antenna element.

9. An antenna system designed to operate over a predetermined range of frequencies which comprises a pair of individual balanced antenna elements, a tubular conductor having at least two branches, each connected to a respective antenna element and each folded back upon itself for a distance of substantially a quarter of a wavelength at an intermediate operating frequency at a point close to its respective antenna element, and an internal conductor within said tubular conductor and one of its branches coupled to one of said antenna elements.

10. In a system operative over a predetermined range of frequencies, in combination, a balanced

antenna, a coaxial transmission line of substantially uniform cross-section, and an antiresonator tuned to a frequency within said operating frequency range comprising the outside surface of the outer conductor of an end section of said uniform coaxial line, whereby the electrical balance of said balanced antenna is substantially undisturbed by the capacity to ground of the outer conductor of said uniform coaxial line beyond said antiresonator, the end section being looped to bring different portions of the outside surface of the outer conductor of said uniform coaxial line into juxtaposition, and said balanced antenna terminating upon the inner and outer conductors, respectively, of said uniform coaxial line at its looped end.

11. In combination, a circuit which is balanced with respect to ground, a circuit which is unbalanced with respect to ground, and means for coupling said circuits together which comprises a length of coaxial cable of substantially uniform cross-section and an antiresonator, tuned to the operating frequency of the system, at one end of said coaxial cable, said antiresonator consisting of the outside surface of the outer conductor of an end section of said uniform coaxial cable, the length of said coaxial cable beyond the antiresonator being substantially zero to prevent the introduction of any substantial capacity to ground from the outer conductor beyond said antiresonator, said balanced circuit terminating upon the inner and outer conductors, respectively, of said coaxial cable at the said end thereof, and said unbalanced circuit being connected to the other end of said coaxial cable.

12. In a radio frequency transmission system, in combination, a balanced transmission line and a uniform coaxial transmission line, an end section of said uniform coaxial line being bent to form an antiresonator tuned to the operating frequency of the system whereby a high im-

pedance is introduced in series with the outside surface of the outer conductor of said coaxial line, the coaxial line beyond the antiresonator being negligibly short to prevent the introduction of any substantial capacity to ground from the outer conductor of said coaxial line beyond said antiresonator, and said balanced line terminating upon the inner and outer conductors of said coaxial line at its bent end.

13. In a radio frequency transmission system, in combination, a circuit that is balanced with respect to ground and a uniform coaxial transmission line, said uniform coaxial line being turned back upon itself at least once at one end to form an antiresonator, tuned to the operating frequency of the system, of the outside surface of its outer conductor, the length of said coaxial line beyond the antiresonator being substantially zero to prevent the introduction of any substantial capacity to ground from the outer conductor beyond said antiresonator, and said balanced circuit terminating upon the inner and outer conductors of said coaxial line at its turned end.

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