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ELECTRICAL CIRCUIT COUPLING APPARATUS

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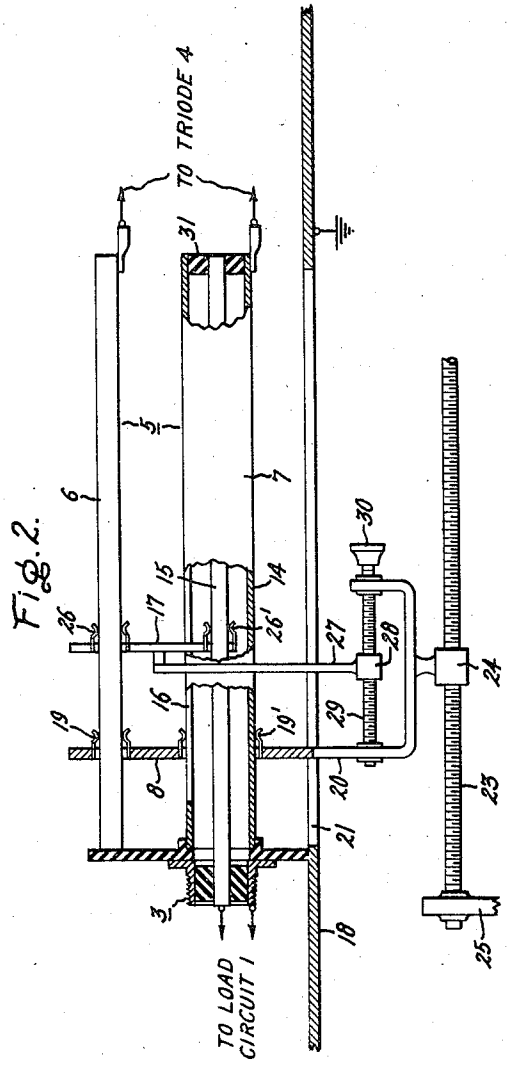

Fig. 2.

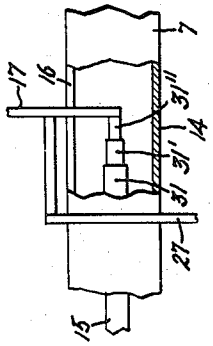

Fig. 3.

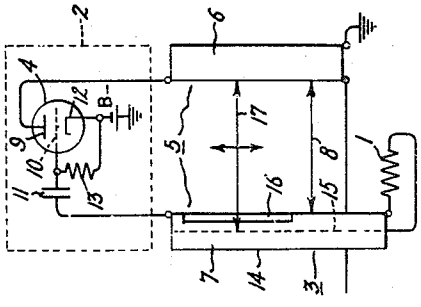

Fig. 1.

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ELECTRICAL CIRCUIT COUPLING APPARATUS

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The present invention relates generally to a coupling arrangement for electrical circuits and particularly to an arrangement for coupling together electrical circuits with a desired impedance transformation.

It is common practice at high frequencies to employ a non-radiating, closed transmission line, such as a coaxial cable, for transmitting radio frequency power over any appreciable distance. It is also common practice at these high frequencies to employ tuned, open transmission lines for establishing the operating frequency of associated electrical circuits, such as amplifiers or oscillators. Since each of these practices have merit in their respective fields of application, the need often arises for combining them, while insuring at the same time, that a high efficiency of power transfer is achieved through the combined system over a wide range of operating frequencies.

It is, therefore, an object of my invention to provide an impedance matching arrangement capable of a large, adjustable range of impedance transformation over a wide frequency band.

Another object of my invention is to provide an improved arrangement for coupling together electrical circuits by means of transmission lines.

Another object of my invention is to provide a novel arrangement for coupling a coaxial conductor transmission line to a parallel conductor transmission line.

Another object of my invention is to couple a single ended electrical system to a double ended system with a minimum of effect on the balance or degree of unbalance of the double ended system.

In accordance with one embodiment of my invention, an arrangement is provided for coupling a load circuit by means of a coaxial conductor transmission line to a parallel conductor transmission line, wherein the parallel line forms the tunable tank circuit of a source of radio frequency energy, such as an amplifier or oscillator. To provide for coupling and proper matching of the load circuit to the radio frequency source, one of the conductors of the parallel line comprises a hollow outer conductor slotted for a portion of its length, and an inner conductor forming a coaxial transmission line with the hollow conductor. The coaxial line is terminated by the load circuit. Means are provided for electrically connecting a short circuit between the parallel conductors, at an adjustable distance from the radio frequency source, in order to establish the desired resonant operating condition. Means are also provided for electrically connecting the inner conductor through the slotted portion of the hollow outer conductor with the other conductor of the parallel line so as to provide the desired transformation of load impedance into the radio frequency source.

In another embodiment of my invention, the inner conductor is made telescopically adjustable in length so that its length may be automatically and properly adjusted to obtain the desired impedance transformation of the load to the source.

The features of this invention which are believed to be novel are set forth with particularity in the appended claims. The present invention itself, both as to its organization and advantages thereof, may best be understood by references to the following description when read in connection with the accompanying drawings wherein:

Fig. 1 is an abbreviated circuit diagram of my invention.

Fig. 2 is a sectional view of a preferred embodiment of the arrangement of Fig. 1.

Fig. 3 is a sectional view of a further embodiment of the invention incorporating a telescoping conductor.

Reference is made to Fig. 1 wherein a load or output circuit 1, represented by a resistance, is coupled to a source of high frequency waves 2 by means of a coaxial conductor transmission line 3. The source 2 might be any device capable of supplying waves, such as an oscillator or amplifier. For purposes of this discussion source 2 is considered to comprise an oscillator employing an ultra high frequency triode 4 associated with a frequency determining tank circuit in the form of the resonant parallel conductor transmission line 5. The transmission line 5 comprises spaced conductors 6 and 7 and is tunable by means of a conventional sliding contactor 8 to any desired operating frequency.

The oscillator arrangement is conventional in that the anode 9 of triode 4 is connected to one end of conductor, 6 of the resonant line 5, and its grid 10 connected through the direct current isolating capacitor 11 to one end of the other conductor 7 of line 5. The cathode 12 is conneceted through a direct voltage source, B—, to ground. A resistor 13 connected between grid 10 and cathode 12 establishes the operating bias for the triode oscillator. Depending upon the position of contractor 8 along the lengths of conductors 6 and 7, and the parameters of the triode circuit, an operating frequency is established for oscillator 2, and radio frequency power is generated and made available in the resonant line 5. The transfer of this high frequency power from source 2 to the load circuit 1, is accomplished in an efficient manner and over a wide range of frequencies, in the following manner.

The conductor 7 is made to comprise a hollow outer conductor 14, which actually forms with conductor 6 the resonant tank circuit of source 2, and an inner conductor 15 forming a coaxial conductor transmission line with outer conductor 14. The resultant coaxial line is then extended to form the coaxial line 3 feeding the load circuit 1.

In order to obtain the desired impedance match between the input and output circuits, outer conductor 14 is slotted along a portion of its length, as shown at 16, to expose the inner conductor 15. A sliding contactor 17, movable in the direction of the associated vertical arrows, is provided for connecting any selected point along the length of the exposed conductor 15 through slot 16 with a corresponding point along the length of conductor 6.

Thus, by selecting a proper impedance match with contactor 17, the impedance of the load circuit 1, the coaxial line 3, the resonant line 5 and the source 2 are properly matched to insure an efficient transfer of radio frequency power, available in the line 5, to the load circuit 1. It should be noted that this coupling and impedance matching is accomplished without effecting the impedance of either conductor of the resonant line 5 to ground. The latter is an important consideration. In an initially unbalanced case, the impedance from conductor 6 to ground may be designed to be different from the impedance of conductor 7 to ground. This might be done where source 2 is of an unbalanced nature, to establish the proper operating voltages on this source. Then, if coupling and impedance matching change these original impedances to

ground differently, the proper condition will not be maintained for the source 2, and the desired operation will be attained. In an initially balanced case, the impedance from 6 to ground is designed to be equal to the impedance from 7 to ground. This might be done where source 2 is of a balanced nature, to establish the proper operating conditions for this source. Again, if the coupling and impedance matching change the original impedances to ground differently, the proper conditions will not be maintained for the source 2, and again the desired operation will not be attained.

This can perhaps be explained better by referring now to Fig. 2 of the drawings, showing a preferred physical embodiment of my invention.

To simplify the discussion of Fig. 2, the reference numerals of Fig. 1 are repeated in Fig. 2 whenever similar components are involved. In any practical arrangement using a parallel resonant transmission line, such as 5, the conductors 6 and 7 must be prevented from radiating radio frequency power by confining the conductors within a metallic shielding box. This box, or shield is represented by the section 18. No analysis of any method of coupling to a shielded parallel resonant line is correct unless the shield is considered in the analysis. If the distributed impedance, principally capacity, between the shield 18 and the conductor 7 is the same as that between shield 18 and conductor 6, the system is said to be balanced. If the distributed impedance between shield 18 and conductor 7 is not the same as the distributed impedance between shield 18 and conductor 6, the system is said to be unbalanced.

In the particular arrangement disclosed, the system has been made unbalanced initially in a specific manner to develop the proper ratio of anode radio frequency voltage to grid radio frequency voltage on the triode driving the system. This has been done by properly dimensioning the outside diameters of conductors 6 and 7 to take into account the fact that conductor 7 is closer to the shield 18 than is conductor 6 and also that different capacities to ground exist in the grid and anode of triode 4 when connected to conductors 6 and 7. Now, if the radio frequency voltages from anode to ground and grid to ground of the triode 4 are inversely proportional to the capacities of the anode circuit to ground, and the grid circuit to ground, equal currents will flow through these capacities, no current is developed in the shield 18, parasitic couplings are minimized, and the designed operation is obtained. For example, if the radio frequency voltage from anode to ground is 6 times larger than the radio frequency voltage from grid to ground, but the grid to ground capacity is 6 times larger than the anode to ground capacity, equal currents will flow in each capacitor, and no current will return to the cathode 12 through the shield 18.

Now when a load circuit, such as 1, is added to the line 5, this equal current flow through both capacity 6 to 18 and capacity 7 to 18 can still be maintained if the coupling system does not alter the conductor to shield impedance differently for one conductor than it does the other. Applicant's invention accomplishes just this result.

Some of the further novel features of applicant's invention are evident in Fig. 2. To accomplish tuning of the resonant line 5, contactor 8 comprises spring fingers 19 and 19' for slidably engaging the resonant line conductors 6 and 7. Contactor 8 has an arm 20 passing through a slot 21, provided in shield 18 along the length of the conductors 6, and 7. A U-shaped extension 22, of arm 20 is arranged to be driven along the length of slot 20 and conductors 6 and 7 by means of the threaded shaft 23 cooperating with the driven member 24. By axially rotating shaft 23 relative to the stationary support 25, which may form part of, or be attached to the shield 18, member 24 and hence also contactor 8 are driven along slot 21 such that fingers 19 and 19' progressively, slidably engage different points along the length of conductor 6 and 7. Actually this amounts to adjusting the length of a tuning stub comprising the resonant line 5.

In order to accomplish matching of impedances in the system, contactor 17 comprises spring fingers 26 and 26' for slidably engaging the resonant line conductor 6 and the inner conductor 15 through slot 16. Contactor 17 has an arm 27 passing through slot 21 in the shield 18 which is arranged to be driven along slot 21 in the manner of arm 20. This is accomplished by having a driven member 28 attached to or forming part of arm 27 cooperate with a threaded shaft 29 mounted within the U-shaped extension 22. By axially rotating shaft 29, by means of knob 30, relative to the shaft bearing portions of extension 22, driven member 28 and hence contactor 17 are driven along slot 21 relative to the position of the contactor 8 such that fingers 26 and 26' progressively, slidably engage different points along the length of conductors 6 and 7. This amounts to selecting an optimum impedance matching point for coupling the load circuit 1 to the triode 4.

It should be noted that applicants' novel arrangement permits the controlling of both frequency and impedance match externally of the shield through a common slot.

Referring to Fig. 2, the portion of the inner conductor 15 between the contactors 17 and the dielectric spacer 31 at its end has a shunting action which can usually be tolerated at the operating frequencies. For example, if the length of this portion is less than 90 degrees, at the system operating frequency, it represents a capacitance in shunt with the coaxial conductor transmission line 3 which might be neglected in view of the overall simplicity of applicants' arrangement. However, if it is objectionable, the inner conductor 15 may be made collapsible along its length such that no extension exists beyond the contactor 17.

Referring to Fig. 3, such a collapsible conductor 15 is shown to comprise portions 31, 31', 31'' telescopic within one another. The contactor 17 is rigidly fastened to the end telescopic portion 31'' and arranged to drive the telescopic portions relative to one another such that as spring finger 26 moves along conductor 6 the length of inner conductor 15 is automatically adjusted in length.

Although the present invention has been described in terms of an oscillator feeding a load circuit, it is to be understood that the invention may be suitably applied to any circuit employing a pair of spaced conductors as a resonant transmission line and coupled to a load circuit or a source by means of a coaxial conductor transmission line.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects and therefore the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. An impedance transformer for coupling together a first and second circuit, comprising an electrically conductive slotted shield, a pair of conductors spaced with respect to said shield, one of said conductors comprising a hollow outer conductor forming an electrical transmission line with the other conductor of said pair, and an inner conductor forming a coaxial conductor transmission line with said hollow conductor, said outer conductor being slotted for a portion of its length, means for connecting said outer and other conductor to said first circuit, means for connecting said inner and outer conductor to said second circuit, means for providing a predetermined matching of impedances of said first and second circuits comprising means mounted on one side of said shield and passing through the slot in said

shield for selectively electrically connecting any one of a plurality of points on said inner conductor, and spaced along its length, through the slot in said outer conductor with the other conductor of said pair.

2. An arrangement for electrically coupling a first and second circuit comprising a pair of conductors, one of said conductors comprising a hollow outer conductor forming a tuned electrical transmission line with the other conductor of said pair, said line forming a frequency determining circuit for said first circuit, said one conductor comprising an inner conductor forming a coaxial conductor transmission line with said hollow conductor, means for coupling said second circuit to said coaxial line, said outer conductor being slotted for a portion of its length, said inner conductor being collapsibly adjustable in length at one end, means for matching the impedances of said first and second circuits comprising means for selectively, electrically connecting the collapsible end of said inner conductor through the slot in said hollow conductor with any one of a plurality of points on and spaced along the length of the other conductor of said electrical transmission line, said last named means being mechanically connected to the collapsible end of said inner conductor for adjusting the length of said inner conductor simultaneously with the selection of connecting points on said other conductor of said electrical transmission line.

3. In combination, a radio frequency source, a load circuit, a pair of parallel spaced conductors, means for electrically connecting said radio frequency source to one end of said parallel conductor transmission line, means for tuning said parallel conductor transmission line to establish a desired resonant operating condition, one of said conductors comprising a hollow, outer conductor slotted along a portion of its length and an inner conductor forming a coaxial conductor transmission line with said outer conductor, means for electrically coupling said load circuit to said coaxial transmission line at the end remote from its connection to said source, means for matching the impedance of said source and said load circuit through said coaxial and parallel conductor transmission lines comprising means for electrically connecting said inner conductor through the slot in said outer conductor to the other conductor of said parallel conductor transmission line.

4. An electrical impedance matching arrangement comprising a first circuit, a second circuit, a pair of spaced apart conductors, one of said conductors comprising a hollow outer conductor forming an electric transmission line with the other conductor of said pair, and an inner conductor forming a coaxial conductor transmission line with said outer conductor, means for electrically coupling said first circuit between said outer conductor and said other conductor, means for electrically coupling said second circuit between said inner conductor and said outer conductor, said outer conductor being slotted for a portion of its length, means for matching the impedances of said second circuit, said transmission lines and said first circuit comprising means for electrically connecting said inner conductor through the slotted portion of the hollow outer conductor to said other conductor at a point intermediate the points of electrical coupling of said first and second circuits to said electrical and coaxial transmission lines.

5. An electrical arrangement for coupling a three-terminal network to a two-terminal network, comprising an electrically conductive shield, a pair of parallel spaced conductors, spaced from and electrically balanced with respect to said shield, said shield being slotted along a portion of its length, one of said conductors comprising a hollow outer conductor forming a resonant transmission line with the other conductor of said pair, and an inner conductor forming a coaxial conductor transmission line with said hollow conductor, means for coupling said outer conductor to a first terminal of said three-terminal network, means for coupling said other conductor of said pair to a second terminal of said three-terminal network, means for coupling said outer conductor to a first terminal of said two-terminal network, means for coupling said inner conductor to a second terminal of said two-terminal network, means for coupling said other conductor of said pair of said outer conductor and to a third terminal of said three-terminal network, said hollow conductor being slotted along a portion of its length, means mounted on one side of said shield and passing through its slotted portion for electrically connecting said parallel conductors together to establish the resonant operating condition of said parallel line, and means to establish an impedance transformation between said transmission lines comprising means for electrically connecting said inner conductor through the slotted portion of said hollow outer conductor with the other conductor of said parallel line.

6. An electrical arrangement comprising a source of waves comprising a control electrode circuit and an output electrode circuit, a load circuit, a pair of spaced apart conductors, one of said conductors comprising a hollow outer conductor forming a resonant transmission line with the other conductor of said pair, and an inner conductor forming a coaxial conductor transmission line with said hollow conductor, said hollow outer conductor being slotted along its length, said inner conductor being telescopically adjustable in length at one end, means for connecting said control electrode circuit between said outer conductor and one end of said other conductor, means for connecting said output electrode circuit between said one end of said other conductor and the other end of said other conductor, means for connecting the load circuit between said inner and outer conductors, means for providing a predetermined matching of the impedance of said source and said load circuit comprising means for selectively, electrically connecting said inner conductor, through the slot in said hollow outer conductor, with any one of a plurality of points on and along said other conductor, said last named means being mechanically connected to the telescopic end of said inner conductor to simultaneously adjust the length of said inner conductor with the selection of connecting points on said other conductor.

7. In combination, a first electrical circuit, a second electrical circuit, a pair of parallel spaced conductors, one of said conductors comprising a hollow, outer conductor forming a parallel transmission line with the other conductor of said pair, and an inner conductor forming a coaxial conductor transmission line with said outer conductor, said hollow conductor being slotted along a portion of its length, means for electrically coupling said first circuit across said parallel line, means for tuning said parallel line to establish a desired resonant operating condition for said first circuit, comprising means for adjusting the electrical length of said line, means for electrically coupling said second circuit to said coaxial transmission line at the end remote from said first circuit, and means for electrically coupling said inner conductor through the slotted portion of said hollow outer conductor to the other conductor of said resonant transmission line at points intermediate the coupling of said first and second circuits to said transmission lines.

8. An electrical coupling arrangement comprising a first circuit, a second circuit, a pair of electrical conductors, one of said conductors comprising a hollow outer conductor forming an electrical transmission line with the other conductor of said pair, and an inner conductor forming a coaxial conductor transmission line with said outer conductor, means for electrically coupling said first circuit between said pair of conductors, means for electrically coupling said second circuit between said inner and outer conductors, and means for matching the impedances of said circuits and transmission lines comprising means for electrically coupling said other

conductor of said pair to an intermediate point of said inner conductor.

9. An electrical coupling arrangement comprising a pair of conductors, one of said conductors comprising a hollow outer conductor and an inner conductor, said inner conductor forming a coaxial conductor transmission line with said hollow conductor, said hollow conductor and the other conductor of said pair forming an electrical transmission line electrically balanced with respect to a reference plane, an electrical circuit unbalanced with respect to said reference plane, and means for coupling said electrical circuit to said balanced line in a balanced manner comprising means for coupling said electrical circuit between said inner and outer conductors and means for electrically connecting said inner conductor with said other conductor.

10. In combination an electrical signal amplifying device comprising an input electrode circuit and an output electrode circuit, a load circuit, means for electrically coupling said device to said load circuit comprising a pair of conductors, one of said conductors comprising a hollow outer conductor and an inner conductor, said inner conductor forming a coaxial conductor transmission line with said hollow conductor, said hollow conductor and the other conductor of said pair forming an electrical transmission line, means for electrically coupling said load circuit between said inner and outer conductors, means for electrically coupling said output electrode circuit between spaced points on said other conductor of said pair and means for electrically coupling said input electrode circuit between said outer conductor and said other conductor of said pair of conductors, and means for electrically connecting an intermediate point of the other conductor of said pair to an intermediate point of said inner conductor.

11. An impedance transformer for coupling a three-terminal network to a two-terminal network comprising a pair of conductors, one of said conductors comprising a hollow outer conductor and an inner conductor forming a coaxial conductor transmission line with said hollow conductor, said hollow conductor and the other conductor of said pair forming an electrical transmission line, means for coupling a first terminal of said three-terminal network to a first point on said outer conductor, means for coupling a second terminal of said three-terminal network to a first point on said other conductor of said pair of conductors, means for coupling a first terminal of said two-terminal network to a second point on said outer conductor, means for coupling the second terminal of said two-terminal network to a first point on said inner conductor, means for coupling a third terminal of said three-terminal network with said first terminal of said two-terminal network and said other conductor of said pair of conductors, and means for adjusting the impedance of said transformer comprising means for electrically coupling an intermediate point of said inner conductor with said other conductor.

12. An arrangement for coupling a three-terminal network to a two-terminal network comprising a transmission line comprising only one pair of conductors, means for adjusting the electrical length of said line to establish a resonant condition in a portion thereof, one of said conductors comprising an outer and an inner conductor forming a coaxial conductor transmission line, means for coupling a first point on said outer conductor to a first terminal of said three-terminal network, means for coupling a first point on said other conductor of said pair to a second terminal of said three-terminal network, means for coupling a second point on said outer conductor to a first terminal of said two-terminal network, means for coupling said inner conductor to a second terminal of said two-terminal network, a third point on said outer conductor, intermediate said first and second points on said outer conductor, means for interconnecting said other conductor of said pair, said third point on said outer conductor, and a third terminal of said three terminal network, and means modifying the impedance of said combination comprising means for electrically connecting an intermediate point of the other conductor of said pair within said resonant portion to an intermediate point of said inner conductor.

13. An arrangement for coupling a balanced electrical transmission system to an unbalanced electrical transmission system, said balanced system comprising a three-terminal electrical network, means for energizing one terminal of said three-terminal network with a reference potential and the other two terminals with equal amplitude voltages of opposite phase, said unbalanced system comprising a two-terminal electrical network, means for energizing one terminal of said two-terminal network with said reference potential, said balanced system comprising a pair of electrical conductors, one of said conductors comprising a hollow outer conductor and an inner conductor, said inner conductor forming a coaxial conductor transmission line with said hollow conductor, said hollow outer conductor and the other conductor of said pair forming an electrical transmission line, means for electrically coupling the remaining two terminals of said three-terminal electrical network to said hollow outer conductor and the other conductor of said pair respectively, means for electrically coupling the other terminal of said two-terminal network to said inner conductor, means for effectively adjusting the electrical length of said electrical transmission line, and means for interconnecting a desired point on said inner conductor to a desired point on said other conductor of said pair.

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