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TRANSLATING CIRCUIT

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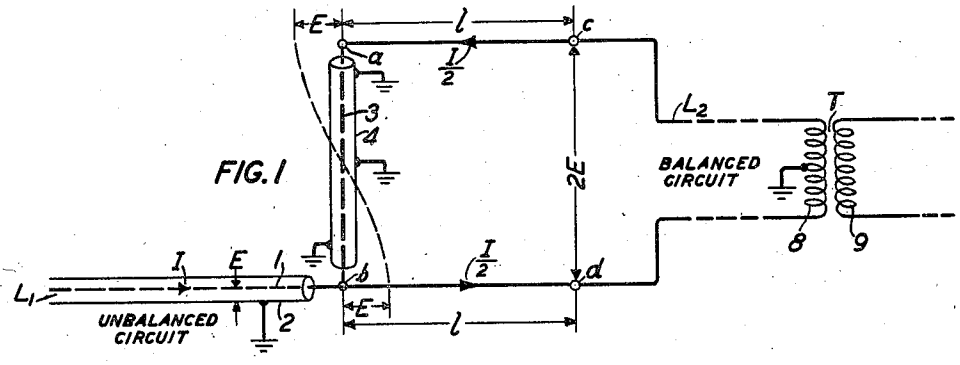

FIG. 1

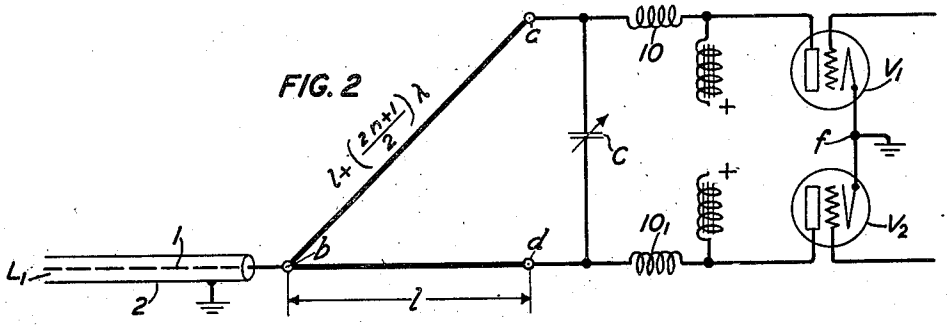

FIG. 2

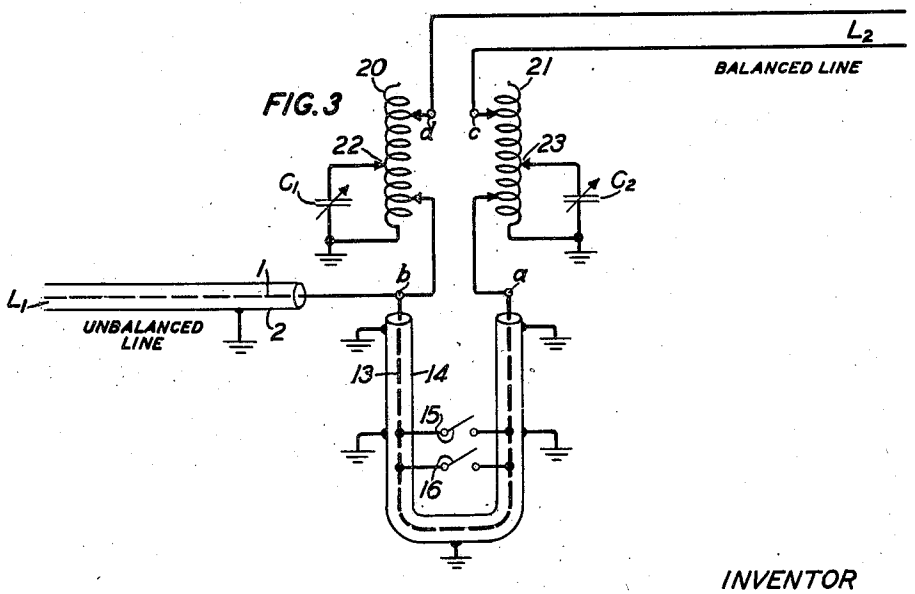

FIG. 3

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TRANSLATING CIRCUIT

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20 Claims. (Cl. 178—44)

This invention relates to systems for the translation of electrical energy and more particularly to signaling systems operating at radio frequencies.

To maintain the two sides of an electrical circuit in balanced relation with respect to ground is a problem frequently encountered in the design of high frequency signaling systems. It is a particularly difficult problem to meet where the frequencies are of the order of those employed in short wave radio transmission. The slightest unbalance in the output circuit of a push-pull amplifier, for example, may be sufficient to create a "singing" condition that will render the amplifier useless. Where, also, an antenna of balanced type is to be connected to a remote transmitter or receiver through a transmission line, one side of which is grounded, it is desirable, though for a different reason, that the balanced condition remain undisturbed. One of the chief sources of unbalance in such systems is in the device used to couple the balanced circuit to a circuit that is not electrically balanced with respect to ground.

An object of the present invention is to couple an unbalanced or grounded circuit to a balanced circuit without disturbing the balance of the latter.

In accordance with the invention, the transformation from a balanced circuit to an unbalanced circuit is effected by taking advantage of the changes in phase that a wave transmitted along a conductor undergoes. The nature of the present invention will more fully appear in the following description of several specific embodiments which are illustrated in the three figures of the accompanying drawing.

In the accompanying drawing, Figure 1 shows a device for coupling an unbalanced circuit to a balanced circuit.

Figure 2 shows a different embodiment of the invention.

Figure 3 shows still another embodiment of the invention.

Referring to Fig. 1, there is shown a device providing for the bilateral translation of electrical waves between an unbalanced circuit L_1 and a balanced circuit L_2. The unbalanced circuit is represented as a coaxial conductor pair comprising a central conductor 1 and a grounded, tubular return conductor 2 surrounding the central conductor and effectively shielding it. The balanced circuit shown comprises a pair of ordinary conductors connected to winding 8 of transformer T, winding 8 being grounded at its center point. The balanced circuit L_2 may be coupled to another balanced circuit associated with winding 9 of transformer T, such as the input of a push-pull amplifier; or circuit L_2 may, for example, comprise an open wire transmission line connected to the members of a horizontal double-V, or diamond-shaped, antenna or of a similar balanced radiating structure. The unbalanced circuit L_1, likewise, may comprise a transmission line of open wire, or other type, or merely a connection to adjacent apparatus.

Between the terminals *c*, *d*, of the balanced circuit is connected a linear conductor 3, the terminals of which are represented as *a* and *b*. Shielding the conductor 3 is a tubular conductor 4, which is grounded preferably at a plurality of points. The connections between the terminals of conductor 3 and the terminals of circuit L_2 are made of the same length *l* and preferably are balanced physically with respect to ground, so that the electrical balance at terminals *c*, *d* is not affected.

The length of conductor 3 is critically related to the frequency of the waves which are to be transmitted, or more accurately, to the length of the waves as they are transmitted through the conductor. As an approximation, the length of conductor 3 may be one-half wave length or any odd multiple thereof, or symbolically,

$$\left(\frac{2n+1}{2}\right)\lambda$$

where n is an integral number and λ is the wave length.

Where conductor 3 is thus proportioned it is apparent that the phase of a wave transmitted from terminal *c* of the balanced circuit and through conductor 3 to terminal *b* of the latter, will be altered exactly one-half cycle with respect to a similar wave transmitted directly from terminal *d* of the balanced circuit to terminal *b*. Since, then, the phases of the voltage waves appearing at the respective terminals *c*, *d*, of the balanced circuit are exactly opposite, it follows that the waves transmitted through the two sides of the circuit to point *b* will be in phase with respect to any external load connected between point *b* and ground. Because of the phase reversal in conductor 3, point *b* is effectively at the same potential with reference to both terminals of the balanced circuit. Any circuit connected to point *b*, therefore, will have the same effect on the two sides of the balanced circuit and the balance of the latter will not be affected. Circuit L_1, being connected between point *b* and

ground accordingly has no unbalancing effect on circuit L_2 with which it is coupled.

The bilateral character of the coupling circuit is believed to require but little discussion. Voltage variations created between point *b* and ground by waves in line L_1, are transferred to points *c* and *d* and the terminals of winding **8**. The reversal in phase occurring in conductor **3** results in the phase opposition of the waves at the respective terminals of winding **8** which is necessary for the translation of waves through the transformer.

Fig. 2 illustrates an embodiment of the invention as utilized for coupling the output circuit of a balanced or push-pull amplifier to an unbalanced circuit such as a coaxial conductor transmission line L_1. In this case the separate conductor **3** of critical length shown in Fig. 1 is omitted and the terminals *c* and *d* of the balanced circuit are connected directly to the point *b* and the unbalanced circuit connected thereto. The required phase change is obtained by making the conductor *bc* electrically longer than conductor *bd* by an amount equivalent to one-half a wave length or an odd multiple thereof. Thus, if the length *bd* be represented by *l*, the length *bc* must be

$$l+\left(\frac{2n+1}{2}\right)\lambda$$

The embodiment of the invention shown in Fig. 3 has certain advantages over the systems hereinbefore described, particularly with regard to compactness, flexibility and accurate matching of the impedances of the connected circuits. It is similar to the system shown in Fig. 1 with the substitution of a U-shaped conductor **13** for the linear conductor **3** of the latter figure and with the insertion of tuned circuits in the connections *ac* and *bd*. Arranging conductor **13** in the form of a U or long, narrow loop does not materially alter its effectiveness as a phase shifting device and it has the advantage that the terminals need not be widely separated from each other. Moreover the over-all dimensions are reduced. With a straight conductor as in Fig. 1, a length of the order of thirty feet would be required in a system operating at fifteen megacycles per second, whereas the length of the space required may be reduced to approximately half the amount by using the U construction. In any of these cases an unshielded conductor may alternatively be employed.

Operation at different frequencies is made possible by providing short-circuiting connections across the loop at different points, these connections being selectively completed by means of remotely controlled switches **15**, **16**. The exact location of the short-circuiting connections may be adjusted from time to time to accommodate changing load conditions.

Terminals *a* and *b* of conductor **13** are connected to intermediate points of inductance coils **21** and **20**, respectively, the adjacent terminals of which are grounded. Condensers C_1 and C_2 are connected between ground and taps **22** and **23**, respectively, of the respective coils **20** and **21**. The terminals *c*, *d* of the balanced line L_2 are symmetrically connected to taps on the two coils. The tuned circuits comprising condensers C_1 and C_2 and coils **20** and **21** permit an adjustment of the impedance ratio of the transforming system. Without such adjustment an impedance ratio of 1:4 is obtained, looking from the unbalanced circuit to the balanced circuit. This may be seen from Fig. 1, where E represents the voltage across the unbalanced circuit and I, the current therein. Going into the balanced circuit the current I divides and produces in that circuit a circulating current of I/2. The voltages E produced across both halves of the balanced circuit are added in phase, resulting in a total of 2E. The impedance of the balanced circuit therefore appears as

$$\left(\frac{2E}{I/2}\right)$$

or four times the impedance (E/I) of the unbalanced circuit. The tuned circuits are also useful in correcting small phase differences that may exist at the terminals of the balanced circuit. By slight variations in the length of the conductor **13**, likewise, impedance and phase dissymmetries of the system may be compensated for.

The combination of coaxial conductor line and balanced open wire line illustrated in Fig. 3 may be used, for example, where a balanced or symmetrical antenna array is to be connected to a remote radio station. The open wire line provides an impedance match for the antenna, while the coaxial conductor line provides an efficiently shielded transmission path to the station.

Although the invention has been described with reference to specific embodiments and applications of it, it is to be understood that the invention is limited only by the scope and spirit of the appended claims.

What is claimed is:

1. In a high frequency transmission system, a circuit balanced to ground, a circuit one side of which is grounded, and leads from the terminals of said balanced circuit to the ungrounded side of said second mentioned circuit, the electrical lengths of said leads differing from each other by an odd number of half-wave lengths of the waves transmitted therethrough.

2. In a high frequency transmission system, a circuit balanced to ground, a circuit one side of which is grounded, and connections from the terminals of said balanced circuit to the ungrounded side of said second mentioned circuit, and means in said connections for reversing the relative phases of waves transmitted therethrough.

3. In a high frequency transmission system, a circuit balanced to ground, a conductor having an electrical length equivalent to an odd number of half-wave lengths of the waves transmitted, symmetrical connections from the terminals of said balanced circuit to the terminals of said conductor, and a circuit connected between one terminal of said conductor and ground.

4. In a high frequency transmission system, a balanced circuit, an unbalanced circuit, means for coupling said circuits in energy transfer relation comprising connections from the terminals of said balanced circuit to one side of said unbalanced circuit, the relative electrical lengths of said connections being such that the balance of said first mentioned circuit is maintained.

5. In a high frequency transmission system, a balanced circuit, an unbalanced circuit, and means for coupling said circuits in energy transfer relation comprising connections from the terminals of said balanced circuit to one side of said unbalanced circuit, one of said connections including a phase reversing device comprising a conductor greater in length than the shortest distance between its terminals.

6. A combination in accordance with claim 4, comprising means for adjusting the relative effective geometrical lengths of said connections to adapt said coupling means for operation at different frequencies.

7. In a high frequency transmission system, a balanced circuit, an unbalanced circuit, and means for coupling said circuits comprising connections from said balanced circuit to said unbalanced circuit, the electrical lengths of said connections being substantial and different by an amount such that the balance of said first mentioned circuit is preserved.

8. A combination in accordance with claim 7, in which said connections consist of conductors.

9. In a high frequency transmission system, a circuit substantially balanced with respect to ground, a circuit unbalanced with respect to ground, and means coupling said circuits in energy transfer relation, said coupling means comprising a first connection from a point on one side of said balanced circuit to a point in said unbalanced circuit, a second connection from a point on the other side of said balanced circuit to a point in said unbalanced circuit, said connections differing in electrical lengths by an amount corresponding to the difference in phase between said respective points on said balanced circuit and ground.

10. In a high frequency transmission system, a balanced circuit and an unbalanced circuit and means for coupling said circuits together comprising connections from said balanced circuit to a common point on said unbalanced circuit, the electrical lengths of said connections differing by an amount sufficient to introduce the phase change required to maintain the electrical balance of said balanced circuit.

11. A combination in accordance with claim 10 in which said coupling includes means effective to match the impedances of said balanced and unbalanced circuits.

12. A combination in accordance with claim 10 comprising means for suppressing radiation from said coupling connections.

13. A combination in accordance with claim 10 in which each of said connections comprises the inner conductor of a coaxial pair, the outer conductor of each pair being grounded at a plurality of points.

14. In combination, a circuit balanced with respect to ground, a circuit unbalanced with respect to ground and means for coupling said circuits in energy transfer relation comprising a conductor connected across said balanced circuit, said conductor being electrically and physically symmetrical with respect to ground and said balanced circuit, and a connection from said unbalanced circuit to a point on said conductor that is an odd number of half wave-lengths farther from one end of said conductor than from the other end.

15. In a high frequency coupling arrangement comprising a circuit which is normally unsymmetrical with respect to ground potential, a second circuit which is normally symmetrical with respect to ground potential, means for providing a circuit coupling arrangement between said unsymmetrical and symmetrical circuits, said means comprising conductor leads from the terminals of said symmetrical circuit to the ungrounded side of said unsymmetrical circuit, the electrical lengths of said conductor leads differing from each other by an odd number of half wave lengths of the waves transmitted therethrough.

16. In a high frequency coupling arrangement comprising a circuit which is normally unsymmetrical with respect to ground potential, a second circuit which is normally symmetrical with respect to ground potential, means for providing a symmetrical circuit coupling arrangement between said unsymmetrical and symmetrical circuits, said means comprising concentric conductors, at least one of said conductors being grounded and branched, the difference in the geometric length of said branch lines being differently chosen so as to compensate for the unsymmetrical circuit arrangement.

17. In a high frequency coupling arrangement comprising a circuit which is normally unsymmetrical with respect to ground potential, a second circuit which is normally symmetrical with respect to ground potential, means for providing a symmetrical circuit coupling arrangement between said unsymmetrical and symmetrical circuits, said means comprising concentric conductors, at least one of said conductors being grounded and branched, the difference in length of said branches being such as to compensate for the unsymmetrical circuit arrangement.

18. In a high frequency coupling arrangement comprising a circuit which is normally unsymmetrical with respect to ground potential, a second circuit which is normally symmetrical with respect to ground potential, means for providing a symmetrical circuit coupling arrangement between said unsymmetrical and symmetrical circuits, said means comprising concentric conductors, at least one of said conductors being grounded and branched, the difference in length of said branches being an uneven number of half waves so as to compensate for the unsymmetrical circuit arrangement.

19. In a high frequency transmission system, a circuit substantially balanced with respect to ground, a circuit unbalanced with respect to ground, and means coupling said circuits in energy transfer relation comprising a connection from a point in said balanced circuit to a point in said unbalanced circuit and a connection from a point of different phase in said balanced circuit to a point in said unbalanced circuit, the electrical lengths of said connections differing by an amount sufficient to introduce the phase change required to maintain the electrical balance of said balanced circuit at the frequency of transmission.

20. A combination, in accordance with claim 19, in which at least the electrically longer of said connections comprises the inner conductor of a coaxial pair.

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