

W. W. HANSEN

HIGH-FREQUENCY BRIDGE CIRCUIT

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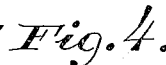
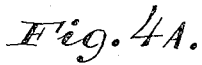
Fig. 2A.

INVENTOR
WILLIAM W. HANSEN
BY *Paul B. Hunter.*
ATTORNEY

W. W. HANSEN

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INVENTOR
WILLIAM W. HANSEN
BY *Paul B. Hunter.*
ATTORNEY

UNITED STATES PATENT OFFICE

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HIGH-FREQUENCY BRIDGE CIRCUIT

William W. Hansen, Garden City, N. Y., assignor
to The Sperry Corporation, a corporation of
Delaware

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The present invention relates to apparatus for the conduction and/or transmission of ultra high frequency energy. More particularly, the present invention is concerned with apparatus for efficient energy coupling between a balanced source and an unbalanced load, or between an unbalanced source and a balanced load.

In dealing with ultra high frequency circuits, it is often desirable to provide an ultra high frequency voltage which is substantially balanced or symmetrical with respect to ground. This often presents a problem, since many types of ultra high frequency generators are arranged for providing an unbalanced output circuit as, for example, an output circuit supplied through a coaxial transmission line wherein a tubular shield at substantially ground potential forms one conductor and the inner wire at relatively high voltage is the other conductor. In such systems, of course, the asymmetrical nature of the coaxial line often proves disadvantageous. For example, it has been found that in cases where the inner conductor of a coaxial line is connected to one of the one-fourth wavelength elements of a dipole antenna and the outer conductor or shield of the coaxial line is connected to the other of the one-fourth wavelength elements of the antenna, unsatisfactory performance of the dipole antenna results from unequal excitation of the two quarter-wave elements.

Accordingly, it is an object of the present invention to provide an ultra high frequency transformer for coupling an unbalanced transmission line or device to a balanced transmission line or device.

It is another object of the present invention to provide ultra high frequency transformer apparatus for receiving energy from an unbalanced input circuit and providing a balanced output circuit.

It is another object of the present invention to provide ultra high frequency transformer apparatus for receiving energy from a balanced input circuit and providing an unbalanced output circuit.

A further object is to provide a device for coupling a dipole antenna to an unbalanced transmission line in such a manner as to provide balanced excitation of quarter-wave elements of the dipole antenna.

In accordance with a feature of the present invention, a reactance bridge circuit is provided in which alternate elements around the ring circuit of the bridge are inductive and capacitive reactance elements. Such elements may be provided

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in compact, easily constructed form by the use of transmission-line sections of suitable length, each transmission-line section being short-circuited at one end and connected at its opposite or input end in the ring circuit of the bridge. The lengths of the transmission-line sections between their short-circuited ends and their input ends are adjusted to provide the desired reactances at the operating wavelength of the transformer.

The foregoing objects and general description of the present invention will become clear and other objects will become apparent from the following description of the present invention, taken in conjunction with the drawings, wherein:

Fig. 1 is a sectional plan view, Fig. 2 is a front elevation and Fig. 2A is a further sectional detail view of a transformer constructed in accordance with the present invention, and employed to couple a coaxial transmission line to a dipole antenna;

Fig. 3 is a schematic diagram illustrating the application of parallel-conductor transmission-line sections to the transformer bridge arrangement of the present invention;

Fig. 4 is a reactance bridge diagram for illustrating the principles of the structures illustrated in Figs. 1 to 3, and Fig. 4A is a vector diagram showing the voltage relations therein; and

Fig. 5 is a front elevation, partly in section, of a transformer generally similar to that of Figs. 1 and 2, employed for coupling a coaxial transmission line to a balanced transmission line having two parallel conductors.

Referring now to Figs. 1, 2 and 2A, a source of energy 11 is shown connected between the inner conductor 12 and the tubular outer conductor 13 of a coaxial transmission line 14, for supplying ultra high frequency energy to the quarter-wave portions 15 and 16 of a dipole antenna. The tubular outer conductor 13 usually is grounded, as shown at 10. According to common practice, one element 15 of the dipole antenna 15, 16 might be connected to the outer conductor 13 of the transmission line 14, while the other quarter-wave portion 16 of the dipole antenna might be connected to the inner conductor 12 of the transmission line 14. As noted above, however, such a connection of quarter-wave portions of a dipole antenna directly to the inner and outer conductors of a coaxial transmission line often results in inequality of excitation of the quarter-wave antenna elements, and thus in impaired performance of the antenna.

In accordance with the present invention, a compact transformer 17 is provided for receiving

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the asymmetrical excitation from source 11 through the coaxial line 14 and providing accurately balanced excitation to the elements 15 and 16 of the half-wave dipole antenna. The transformer 17 comprises a tubular outer conductor 18 having two diametrically opposite openings 19 and 21 midway between the ends thereof, for clearance of the dipole antenna 15, 16. Between the openings 19 and 21 there is provided a further opening 22 for receiving the outer tubular conductor 13 of the coaxial transmission line 14. A rigid, electrically conductive junction of the tubular outer conductor 18 and the tubular outer conductor 13 is provided, as by soldering these elements together at the opening 22.

A conductive member 24 having a disc end 25 and an axially extending portion 26 having a length of substantially three-eighths the wavelength of source 11 is provided within one end of the tubular outer conductor 18 of transformer 17. A cylindrical recess 27 is formed in the end of extension 26 of the member 24 to a depth substantially equal to one-eighth the wavelength of source 11. Another conductive member 31 is provided in the opposite end of the tubular outer conductor 18. The conductive member 31 has bored therein a cylindrical recess 32 of a depth substantially equal to three-eighths of the wavelength source 11, and the member 31, along a substantially one-eighth wavelength portion 33 thereof, is turned down to a reduced diameter which may be equal to the outer diameter of the axial extension 26 of member 24.

A further conductor such as a stiff wire element 35 is seated in a suitable socket 36 in the member 24 and a suitable opening 37 in the member 31, and serves as an electrical conductive connection between these points. Conductor 35 is connected to the inner conductor 12 of coaxial line 14 at a junction 41.

The transformer described above forms two coaxial transmission-line sections three-eighths wavelength long and two further coaxial transmission-line sections one-eighth wavelength long, each having an input end at the middle of transformer 17 and being short-circuited at its opposite end. The first three-eighths wavelength transmission-line section, designated I, comprises the outer cylindrical surface of the axial extension 26 of member 24 cooperating, as an inner conductor, with the portion of the tubular outer conductor 18 extending to the left of the coaxial line 14. The short-circuiting connection between inner conductor 26 and outer conductor 18 of this three-eighths wavelength transmission-line section is provided by the disc end 25 of the member 24. The second three-eighths wavelength transmission-line section, designated II, comprises the portion of conductor 35 extending to the right of inner conductor 12, cooperating with the cylindrical bore 32 in the member 31 which forms the outer conductor therefor.

The third coaxial transmission-line section III, characterized by a length equal to one-eighth of the wavelength of source 11, comprises the portion of the inner conductor 35 extending to the left of the junction 41, in cooperation with the cylindrical bore 27 in the extension 26 of the member 24. The fourth coaxial transmission-line section IV has as its inner conductor the reduced-diameter portion 33 of the member 31, in cooperation with a coextensive portion of the outer conductor 18.

It will be noted that the input end of coaxial transmission-line section III is connected be-

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tween the inner conductor of the transmission-line section II and the inner conductor of transmission-line section I. It will be seen also that the input end of transmission-line section IV is connected between the outer conductor of transmission-line section II and the outer conductor of the transmission-line section I.

From the foregoing description, it will be seen that the outer conductor 13 of coaxial transmission line 14 is connected to the junction between the outer conductor of transmission-line section I and the outer conductor of the one-eighth wavelength transmission-line section IV. Also, the inner conductor 12 of the coaxial line 14 is connected to the junction 41 of the inner conductors of transmission-line section II and the one-eighth wavelength transmission-line section III. A first output terminal of the transformer 17 is provided by the junction between the inner conductor of section I and the outer conductor of section III, this junction being the end of the axially extending portion 26 of member 24. As shown, one of the quarter-wavelength elements 16 of the dipole antenna 15, 16 may be connected, as by a soldered joint, to this annular junction between sections I and III. A second output terminal of transformer 17 is the similar annular junction between the outer conductor of transmission-line section II and the inner conductor of transmission-line section IV, to which is connected the other quarter-wavelength element 15 of antenna 15, 16.

The operation of the apparatus shown in Figs. 1 and 2 is better understood by reference to the equivalent circuits in Figs. 3 and 4. In Fig. 3 is shown a transformer substantially equivalent to that illustrated in the sectional view of Fig. 1, but comprising three-eighths wavelength two-wire or parallel-conductor transmission-line sections I' and II' and one-eighth wavelength parallel-conductor transmission-line sections III' and IV'.

The transmission-line sections I', II', III' and IV' are arranged with their input ends closely adjacent in a compact configuration, and are short-circuited at their remote ends by connector bars 5. The one-eighth wavelength transmission-line section III' is connected between a first input terminal of the transmission-line section I' and a first input terminal of the transmission-line section II'. The transmission-line section IV' is similarly connected between the second input terminal of the transmission-line section I' and the second input terminal of the section II'.

With the above connections, the transmission-line sections I', III', II' and IV' are connected consecutively in clockwise order in a ring circuit or bridge having a first pair of opposite junction points 45 and 46 between transmission-line sections I' and III' and sections II' and IV', respectively, and a second pair of opposite junction points 47 and 48 between transmission-line sections I' and IV' and sections II' and III', respectively.

The unbalanced source 11', which may have one terminal 49 connected to ground, is connected to one pair of opposite junctions 47 and 48 to deliver energy to the transmission-line bridge transformer 17', while the other pair of opposite junctions 45 and 46 is connected to a balanced load 51, here represented as a resistor of which a center-tap or midpoint could be coupled through a leakage path to ground.

By comparison of Fig. 1 with Fig. 3, wherein corresponding transmission-line sections bear

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similar Roman numeral designations, except that those of Fig. 3 are given a prime mark, the circuit interconnection of the four transmission-line sections embodied within the transformer 17 is made readily apparent.

The operation of the transformers of Figs. 1 and 2 and Fig. 3 is best understood by reference to Fig. 4, wherein is shown a bridge circuit embodying capacitor I'', inductor III'', capacitor II'' and inductor IV'' connected consecutively in clockwise order around a ring circuit and forming two pairs of opposite junctions 45', 46' and 47', 48' of a bridge.

An unbalanced or asymmetrical source 11' is shown connected to one pair of opposite junctions 47' and 48', while a balanced load 51' is shown connected to opposite junctions 45' and 46'. As is well known, a short-circuited transmission-line section one eighth wavelength long presents an inductive reactance equal in magnitude to the characteristic impedance of the transmission line. Similarly, a short-circuited transmission-line section three-eighths wavelength long presents an input impedance which is capacitive and which is equal in magnitude to the characteristic impedance of the transmission line. Thus, the equivalence of the bridge circuit arrangement shown in Fig. 4 with the transformers shown in Figs. 1 and 2 and Fig. 3 will be readily appreciated.

Preferably, the ratio of diameters of the inner and outer conductors of coaxial transmission-line sections I and IV in Fig. 1 is made equal to the diametral ratio of the inner and outer conductors of coaxial transmission-line sections II and III. The impedances presented at the input terminals of these short-circuited transmission-line sections are then all reactances of equal magnitude, those of sections I and II being capacitive, and thus of opposite sign to the inductive reactances of sections III and IV. Accordingly, adjoining transmission-line sections I and III form a first series-resonant circuit connected across transmission line 14, and sections II and IV form a second series-resonant circuit similarly connected.

From a study of the equivalent diagram of Fig. 4, it is readily seen that if reactances I'', II'', III'' and IV'' are all of equal magnitude, then the currents flowing through all of the reactance elements will be of equal magnitude. The voltages e_I , e_{II} , e_{III} and e_{IV} across the reactance elements are of equal magnitude also. As seen in Fig. 4A, the vector sum of voltages e_{IV} and e_{III} is equal to the vector voltage e_s applied by the source 11'. Similarly, the vector sum of voltages e_{IV} and e_{II} is equal to the source voltage e_s . The voltage e_L across load 51' is given by the difference of the vector voltages across two reactance elements adjacent one of the source terminals, e. g., the difference of the voltages e_{IV} and e_{II} across inductance IV'' and capacitance I''. This is seen in Fig. 4A, where

$$e_L = e_{IV} - e_{II}$$

Thus, by the equivalence of the diagram in Fig. 4 to the transformers of Figs. 1, 2, and 2A and Fig. 3, it is seen that the transmission line transformers provide balanced output from an unbalanced source, or, more generally, serve to couple an unbalanced device to a balanced device.

It should be noted that while Figs. 1 and 2 illustrate the use of the transformer 17 as a coupling device between an unbalanced source and

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a balanced load, this coupling device is equally useful for coupling a balanced source to an unbalanced load. For example, if the dipole antenna 15, 16 is employed for receiving signals from a distant transmitting station, and the coaxial transmission line 14 is connected to the unbalanced input terminals of a receiver, the transformer 17 then functions for supplying energy from a balanced source (antenna 15, 16) to an unbalanced load. Similarly, the source 11' in Fig. 3 and 11'' in Fig. 4 may be replaced by a suitable energy utilization device, which may be grounded at one terminal thereof, and the balanced load 51 or 51' may be replaced by a balanced source, the transformer 17 or 17' remaining effective as a coupling device without tending to impair the balanced condition of the source.

In Fig. 5 is shown an arrangement generally similar to that shown in Figs. 1 and 2, with the exception that a two-wire shielded cable 61, having two inner conductors 62 and 63 enclosed within an outer shielding tubular conductor 64, is shown joined to the transformer 17 and coupled thereby to the coaxial transmission line 14.

It will be noted that one conductor 62 of the two-wire transmission line 61 is connected to the junction between coaxial transmission-line sections I and III, while the other conductor 63 is connected to the junction between coaxial transmission-line sections II and IV. Thus, the conductors 62 and 63 are connected in place of quarter-wave elements 15 and 16 of the dipole antenna illustrated in Figs. 1 and 2.

The shielding conductor 64 may be joined to the tubular outer conductor 18 of transformer 17 at an opening opposite the junction of the conductor 18 with conductor 13. Either transmission line 61 or transmission line 14 may be coupled to an energy utilization device, the other transmission line being coupled to a suitable source of energy. Thus, the transformer 17 is suitable for coupling an unbalanced source connected to transmission line 14 to a balanced load connected to transmission line 61, or for coupling a balanced source connected to line 61 to an unbalanced or asymmetrical load connected to transmission line 14.

As one illustration of the operation of the structure shown in Fig. 5, for example, a receiver 71 may be connected to the inner and outer conductors 12 and 13 of the coaxial transmission line 14, and a dipole receiving antenna 72 may be connected to the conductors 62 and 63 of the transmission line 61.

It will be readily apparent that the transmission line sections I, II, III and IV could be made in other lengths than those illustrated without departure from the principles of the present invention. For example, sections I and II could be made five-eighths wavelength long and sections III and IV could be made three-eighths wavelength long; or sections I and II could be made seven-eighths wavelength long and sections III and IV could be made five-eighths wavelength long. Thus the lengths of the transmission-line sections may be chosen from a wide variety which are known to provide reactive input impedance and accordingly to satisfy the requirements of an inductance-capacitance bridge as illustrated in Fig. 4.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be

made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus for coupling a device for supplying radio energy of a predetermined wavelength to a utilization device therefor, comprising a bridge circuit having four elements connected in a ring circuit to form two pairs of opposite junctions, each element consisting of a transmission-line section adapted to present a reactive input impedance with successive ones of said transmission-line sections around said ring circuit being alternately constructed for capacitive input reactance and inductive input reactance, one of said transmission-line sections comprising a first coaxial transmission-line section having an inner conductor and a coaxial outer conductor, and an adjoining one of said transmission-line sections around said ring circuit comprising a further coaxial transmission line serially connected to and arranged coaxially with said first coaxial line section, means for connecting said energy-supplying device to one of said pairs of opposite junctions, and means for connecting said utilization device to the other of said pairs of opposite junctions.

2. A bridge circuit for operation at a predetermined wavelength, comprising four impedance elements connected in a ring circuit to form two pairs of opposite junctions, each element consisting of the input terminals of a transmission-line section short-circuited at its opposite end, the successive transmission-line sections around said ring circuit being respectively one-eighth wavelength long and three-eighths wavelength long, means for applying a voltage of said predetermined wavelength between one pair of said opposite junctions, and utilization means coupled to the other pair of said opposite junctions.

3. Ultra high frequency apparatus comprising first and second transmission-line sections of a first length, each short-circuited at one end and having first and second input terminals at the opposite end, third and fourth transmission-line sections of a second length, each short-circuited at one end and having a pair of input terminals at the opposite end, the input terminals of said third transmission-line section being connected to the first input terminals of said first and second transmission-line sections, respectively, and the input terminals of said fourth transmission-line section being connected to the second input terminals of said first and second transmission-line sections, respectively, means for applying ultra high frequency voltage between the second input terminal of said first transmission-line section and the first input terminal of said second transmission-line section, and means for utilizing a voltage produced between said first input terminal of said first transmission-line section and said second input terminal of said second transmission-line section.

4. A bridge circuit for operation at a predetermined wavelength, comprising a first inductive impedance element and a first capacitive impedance element connected in series, said first inductive impedance element and said first capacitive impedance element comprising two coaxial transmission-line sections formed by an axial conductor, a first tubular conductor coaxial therewith and a second tubular conductor coaxial with said axial conductor and said first tubular

conductor; a second inductive impedance element and a second capacitive impedance element connected in series, said second inductive impedance element and said second capacitive impedance element comprising two further coaxial transmission-line sections formed by a further axial conductor, a further tubular conductor coaxial therewith, and a still further tubular conductor coaxial with said further conductors; means connected at one junction to said first capacitive impedance element and to said second inductive impedance element, and at an opposite junction to said first inductive impedance element and to said second capacitive impedance element, and a utilization device coupled to a junction intermediate said first impedance elements and to a junction intermediate said second impedance elements.

5. Ultra high frequency apparatus comprising a coaxial transmission line, a balanced two-wire transmission line, and a shielded transformer device for transferring ultra high frequency energy between said coaxial line and said balanced line while maintaining the outer conductor of said coaxial line at equal voltage difference from the voltages of the two wires of said balanced line, said transformer comprising a wire extending transversely of said coaxial line and connected at an intermediate point thereon to the inner conductor of said coaxial line, two tubular conductors connected to said wire at opposite ends thereof and extending toward the inner conductor of said coaxial line and having ends spaced from said inner conductor, said ends being connected to said two wires of said balanced line, and a tubular outer conductor coaxial with said two tubular conductors and said wire and forming an outer shield therefor, said tubular outer conductor being bonded to the outer conductor of said coaxial line.

6. Ultra-high-frequency apparatus comprising an electrically asymmetrically coaxial transmission-line having a tubular shielding outer conductor, an electrically symmetrical load, and an ultra-high-frequency transformer device having a tubular shielding outer conductor secured to the outer conductor of said coaxial line the axis of said coaxial transmission line being perpendicular to the axis of said tubular shielding outer conductor, said transformer device further comprising a closed ring network of serially-connected transmission-line impedance elements of substantially parallel energy-propagation axes formed within said transformer outer conductor, said device being rigidly supported by said coaxial line and connected to said load for providing symmetrical coupling of said load to said transmission line and for transferring energy between said load and said coaxial transmission line.

7. An ultra-high frequency network comprising an inductive reactance element and a capacitive reactance element in series, one of said reactance elements comprising an inner conductor and a first tubular conductor coaxial therewith and forming with said inner conductor a first coaxial transmission line, means providing a low-impedance current conduction path between said inner conductor and said first tubular conductor, the other of said reactance elements comprising a second tubular conductor of inner diameter exceeding the outer diameter of said first tubular conductor and forming with said first tubular conductor, a second coaxial transmission line section, said second transmission line section in-

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cluding means therein providing a low-impedance current conduction path between said first tubular conductor and said second tubular conductor, said first tubular conductor having an open end an appreciable distance from the said current conduction path means in said first and second transmission line sections, and means for supplying radio frequency potential between said inner conductor and said second tubular conductor at points thereon adjacent said open end of said first tubular conductor, the length of the transmission path between said open end of said first tubular conductor and one of said current conduction path means being shorter than an odd number of quarter wave-lengths by an amount appreciably less than one-quarter wavelength, and the length of the transmission path between said open end of said first tubular conductor and the other of said current conduction path means being greater than an odd number of quarter-wavelengths by an amount appreciably less than one-quarter wavelength.

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8. An ultra high frequency network as defined in claim 7, wherein said inductive reactance element and said capacitive reactance element have equal reactance magnitudes, whereby said first and second transmission line sections serve as a series-resonant circuit.

WILLIAM W. HANSEN.

REFERENCES CITED

10 The following references are of record in the file of this patent:

UNITED STATES PATENTS

	Number	Name	Date
15	2,107,025	Buschbeck, et al.	Feb. 1, 1938
	2,222,169	Buschbeck et al.	Nov. 19, 1940
	2,286,179	Lindenblad	June 9, 1942
	2,318,237	Lindenblad	May 4, 1943
	2,327,418	Goldman	Aug. 24, 1943
20	2,416,790	Barrow	Mar. 4, 1947
	2,416,981	Crosby	Mar. 4, 1947