Nov. 12, 1946. D. H. RING 2,410,838

COUPLING SYSTEM

Filed March 26, 1942

FIG. 1

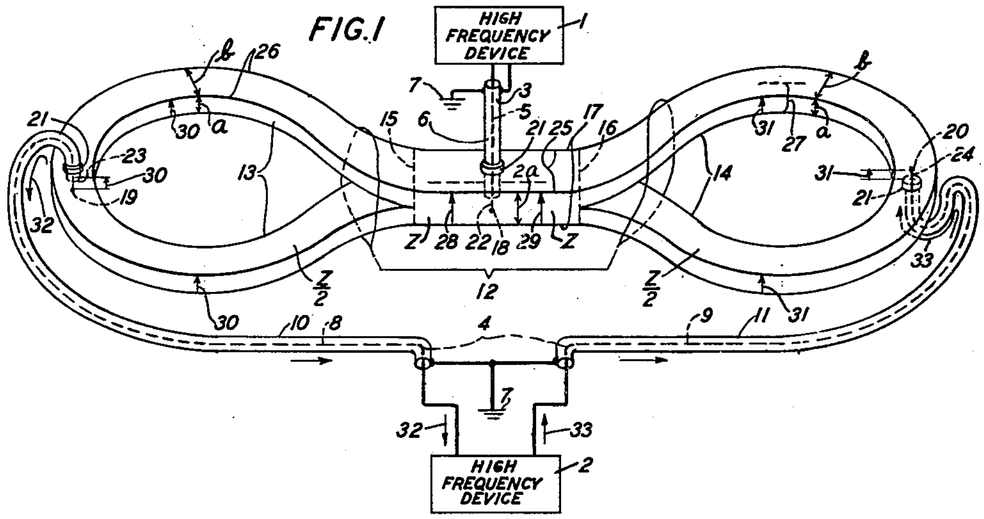


FIG. 3

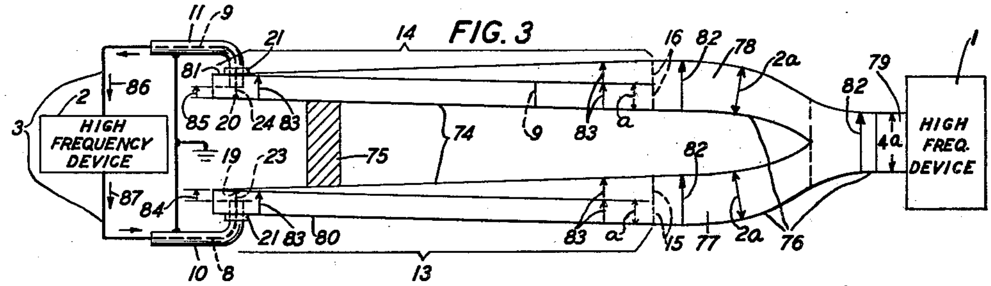
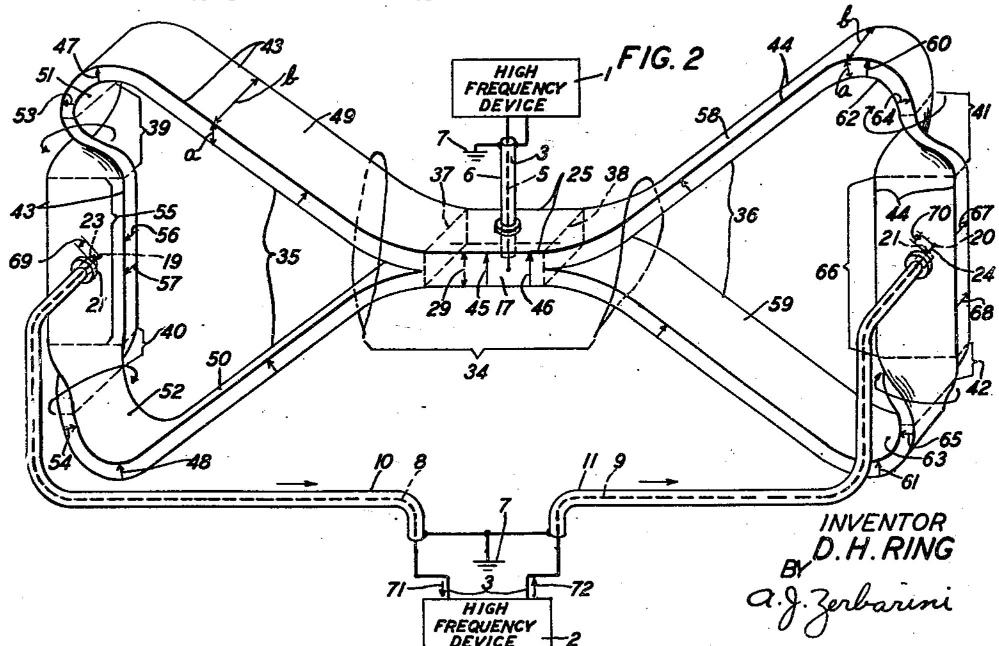


FIG. 2



INVENTOR
D. H. RING
BY A. J. Zerbarini
ATTORNEY

Patented Nov. 12, 1946 2,410,838

UNITED STATES PATENT OFFICE

2,410,838

COUPLING SYSTEM

Douglas H. Ring, Red Bank, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application March 26, 1942, Serial No. 436,275

18 Claims. (Cl. 178—44)

1

This invention relates to microwave transmission systems and particularly to means for coupling balanced lines to unbalanced lines and to wave guides.

As is known, in the long wave (above 500 meters), broadcast wave (200 to 500 meters), short wave (10 to 200 meters) and ultra short wave (1 to 10 meters) fields, circuit arrangements comprising quarter wave coaxial line high impedances, or half wave-length phase reversers, are used for coupling between, and matching the impedances of, a line comprising conductors having equal or balanced impedances to ground and a line comprising conductors having substantially different impedances to ground. Patents 2,110,278, R. C. Shaw, March 8, 1938; 2,127,088, W. S. Percival et al., August 16, 1938; 2,231,152, W. Buschbeck, February 11, 1941; and 2,231,839, N. E. Lindenblad, February 11, 1941, illustrate these types of prior art coupling devices. While these and other arrangements heretofore utilized have been employed with success in the above-mentioned frequency or wave-length bands for single frequency and multiple frequency operation over a medium size frequency band, it now appears desirable to employ, especially in the microwave field (1 meter and less), coupling apparatus which is, as compared to the prior art devices, simple in design and construction. Moreover, it is now desirable to achieve satisfactory coupling between balanced and unbalanced lines at all frequencies included in a band which is exceedingly wide and considerably greater than the medium size band mentioned above.

It is one object of this invention to transfer microwave energy between different types of line channels efficiently and without reflection loss.

It is another object of this invention to couple a microwave balanced line channel to a microwave unbalanced line channel.

It is still another object of this invention to match the impedances of an unbalanced grounded line channel and a balanced ungrounded line channel over a band of microwave carrier frequencies.

It is a further object of this invention to couple a dielectric channel to a balanced line channel for operation over a single microwave frequency or a band of microwave frequencies without reflection loss.

As used herein, the term "quadrilateral" generically includes rectangular and square and the term "rectangular" excludes square.

According to the preferred embodiment of the

2

invention an unbalanced line comprising an ungrounded conductor enclosed in a grounded coaxial conductor is connected to two coaxially shielded conductors of a balanced line through separate folded wave guide impedance transformers of the type disclosed in the application of H. T. Friis, Serial No. 435,017, filed March 17, 1942, or of the type disclosed in the application of A. C. Beck, Serial No. 435,016, filed concurrently therewith, the balanced line conductors being inserted into a particular one of the wide walls of the rectangular folded transformer at the longitudinal section mid-point, so that the currents conveyed by the balanced line conductors have opposite polarities. More specifically, assuming the use of a flat or pancake type of folded rectangular wave guide transformer section, such as disclosed in the Beck application, the orifice of one folded section is joined through a rectangular connecting wave guide member to the orifice of the other folded section. The inner conductor of the coaxial unbalanced line extends into the connecting member in a direction aligned with the short transverse dimension of said member and the two conductors of the balanced line are connected to different folded wave guide sections, each through an aperture at the section mid-point. The mid-point apertures are located in oppositely related wide walls of the sections. With this arrangement, assuming a transmitter is connected to the unbalanced line and a load or antenna is connected to the balanced line, the wavelets delivered to the folded section from the unbalanced line are similarly polarized at the section orifices and at the mid-point apertures. Since the antenna or pickup portions of the balanced line conductors, which portions are included in the folded guide sections, extend in opposite point directions, the polarization components induced in the aforementioned antenna portions are oppositely polarized and energy flows in series through the balanced line conductors and the load circuit. The coaxial unbalanced line and each coaxially shielded conductor of the balanced line are coupled to their associated wave guide channels through a multifrequency impedance matching connection of the type disclosed in the application of A. C. Beck, Serial No. 429,358, filed February 3, 1942. The short transverse dimensions for the connecting guide member and the folded sections are selected so that the impedance of the unbalanced line is matched to the connecting member, and the impedance to ground of each of the balanced line conductors matches the folded section impedance attached thereto, whereby the unbalanced line and balanced line are efficiently coupled and their impedances are matched, the energy being transferred between these lines without reflection loss.

The invention will be more fully understood from a perusal of the following specification taken in conjunction with the drawing on which like reference characters denote elements of similar function and on which:

Fig. 1 is a perspective view of one embodiment of the invention for coupling different types of line channels;

Fig. 2 is a perspective view of another embodiment for coupling different types of line channels; and

Fig. 3 is an elevational view of an embodiment of the invention for coupling a wave guide to a balanced line channel.

Referring to Fig. 1 reference numerals 1 and 2 designate high frequency devices, device 1 being a transmitter or other source of single frequency or multifrequency energy when device 2 is a receiver, antenna or other load circuit, and vice versa. Numerals 3 and 4 denote respectively an unbalanced coaxial line channel and a balanced line channel, the unbalanced coaxial line 3 comprising an ungrounded inner conductor 5 and an outer coaxial conductor 6 directly connected to ground 7 and balanced line 4 comprising the inner conductors 8 and 9 enclosed respectively in the grounded coaxial shields 10 and 11. Numeral 12 denotes a double impedance transformer comprising two folded rectangular or square wave guide sections 13 and 14 each constructed in accordance with the teaching of the application of A. C. Beck, Serial No. 429,358, mentioned above and having their end apertures superimposed to form the large orifices 15 and 16, respectively. As shown on the drawing, the sections 13 and 14 are each folded in the plane of the long transverse guide dimension *b*, that is, in a plane perpendicular to the plane of polarization of the wave component utilized. The orifices 15 and 16 are joined together through the straight quadrilateral wave guide member 17. If desired, the member 17 may be omitted and the orifices 15 and 16 of the two folded sections 13 and 14 may be directly connected together.

The line 3 is coupled to the mid-point 18 of the straight connecting member 17 and the shielded conductors 8 and 9 are attached respectively to the mid-points 19 and 20 of folded sections 13 and 14, each through a multifrequency impedance matching device comprising a sleeve 21 and constructed in accordance with the A. C. Beck application, Serial No. 429,358, mentioned above. In this type of multifrequency matching connection both the inner conductor 5 and the outer conductor 6, in the case of line 3, for example, are inserted through one wide wall of connecting member 17 and into the dielectric channel. The outer conductor 6 encloses a portion, dependent upon the adjustment of sleeve 21, of the section of the inner conductor 5 included in the guide member 17. The exposed inner conductor portion 22 constitutes an antenna element for collecting or emitting energy. Similarly, the portions of conductors 8 and 9 extending into folded sections 13 and 14 are partly shielded, respectively, by the coaxial shield members 10 and 11, the exposed portions 23 and 24 constituting pick-up or antenna elements. For reasons explained below, line 3 and one of the balanced line conductors, for example, conductor 8, are inserted respectively through the corresponding wide walls

25 and 26 of the guide member 17 and folded section 13, and the other balanced line conductor 9 is inserted through the oppositely related wide wall 27 of folded guide section 14.

Considering the various impedance relations of the combined parts of the embodiment illustrated by Fig. 1, the impedance Z/2 between the ungrounded conductor 5 of line 3 and the grounded conductor 6 is matched over a band of frequencies to the input impedance Z/2 of the two-way guide member 17 by adjustment of the impedance matching device comprising sleeve 21, as disclosed in the A. C. Beck application, Serial No. 429,358. The input impedance Z/2 of member 17 comprises the two characteristic impedances, each Z, of the two portions of guide 17, the two portions of guide 17 being connected in parallel with respect to the exciter element 22. The characteristic impedance of each folded guide section 13 and 14 is Z/2, that is, one half of the characteristic impedance Z of guide member 17, as explained in the A. C. Beck application, Serial No. 435,016, and the impedance of each folded loop 13 and 14 at its orifice is Z and matches the characteristic impedance Z of the guide member 17.

The impedance at each of mid-points 19 and 20 of loop sections 13 and 14, as seen looking into sections 13 and 14 comprises two impedances, each Z/2, in parallel and equals Z/4. The impedances Z/4 of the ungrounded conductors 8 and 9, constituting the balanced line 4, matched respectively to sections 13 and 14 by means of the multifrequency impedance devices each comprising a sleeve 21. The impedance of the balanced line 4 is equal to the sum of the impedances, each Z/4, of line conductors 8 and 9, and is therefore equal to the impedance Z/2 of the unbalanced line 3. Thus, as explained in the A. C. Beck application, Serial No. 429,358, each of the folded guide sections 13 and 14 constitutes in effect an impedance transformer for changing the characteristic impedance Z of guide 17 to the characteristic impedance Z/4 of the line conductor 8 or 9; and, in accordance with the invention, the impedances of lines 3 and 4 are matched.

In operation, assuming device 1 is a source of single frequency or multifrequency energy and device 2 is a load circuit, microwave energy is supplied over line 2 from the antenna or exciter element 22 and similarly polarized components or wavelets 28 and 29 are propagated bilaterally in guide member 17. In the folded sections 13 and 14 the wavelets have the same polarity, as shown by arrows 30 and 31, respectively. Since the lines 8 and 9 are inserted through the oppositely related wall members 26 and 27 of folded sections 13 and 14, the antenna elements 23 and 24 are energized with oppositely polarized waves so that, as shown by arrows 32 and 33, the currents flowing in conductors 8 and 9 are of opposite polarity relative to the load 2 and ground 7, and flow in series through the load circuit 2. Hence, in accordance with the invention, coupling at microwave frequencies between a grounded unbalanced line and an ungrounded line, balanced with respect to ground, is accomplished.

The embodiment illustrated by Fig. 2 is the same as that illustrated by Fig. 1 except that impedance transformers of the type disclosed in the application of H. T. Friis, Serial No. 435,017, mentioned above are used in place of transformers 13 and 14, Fig. 1; and lines 8 and 9 project through corresponding, rather than oppositely related, wide walls of the folded guide sections. In this figure, numeral 34 designates a double impedance transformer comprising two folded rectangular wave guide sections 35 and 36, each constructed in accordance with the teaching of the Friis application mentioned above and each having its two end apertures superimposed to form the orifices 37 and 38, respectively. The sections 35 and 36 are each folded in the plane of the short transverse guide dimension *a*, that is, in the plane of polarization of the wave component utilized. The folded section 35 includes a pair of oppositely twisted or rotated quadrature polarity changers 39 and 40 and the folded section 36 also includes a pair of oppositely twisted quadrature polarity changers 41 and 42. As viewed from the midpoint 19 of folded section 35, the changers 39 and 40 have respectively a 90-degree clockwise and a 90-degree counter-clockwise twist; and, as viewed from the mid-point 20 of folded section 36, the changers 41 and 42 have respectively a 90-degree clockwise and a 90-degree counter-clockwise twist. The unbalanced line 3 and both balanced conductors 8 and 9 are inserted respectively through the corresponding wide walls 25, 43, and 44 of the wave guide member 17 and sections 35 and 36. As in the structure of Fig. 1, the coaxial line 3 and the coaxially shielded conductors 8 and 9 are connected to the longitudinal mid-points of the associated wave guide structures each through a multifrequency impedance matching coupling device comprising sleeve 21. The impedance relations among the various parts of the embodiment illustrated by Fig. 2 are the same as those of the embodiment illustrated by Fig. 1.

In operation, Fig. 2, assuming device 1 is a transmitter and device 2 is a load circuit, similarly polarized wavelets, as represented by arrows 45 and 46, are propagated bilaterally in straight guide member 17 to the orifices 37 and 38 of the folded sections 35 and 36. As shown by arrows 47 and 48, the wavelets in the two angularly related legs 49 and 50 of the folded sections 35 are similarly polarized. By reason of the opposite curvatures 51 and 52 in the legs 49 and 50, the polarities are shifted 90 degrees in opposite directions and have opposite polarities at the bends as shown by arrows 53 and 54. The opposite polarity relation resulting from the curved quadrants 51 and 52 is in a sense compensated by the polarity changers 39 and 40 which function to shift the wavelet polarities in opposite directions and to produce in the linear portion 55 of the folded section 35 the similarly polarized wavelets 56 and 57. In this connection it should be noted that while the polarity relation of the two components changes during the propagation along legs 49 and 50, their phase angles are the same at corresponding points in the legs and at mid-point 19, since the two dielectric propagation paths traversed by the wavelets are of equal lengths. In a similar manner components of corresponding polarity are established in legs 58 and 59 of folded section 36, as shown by arrows 60 and 61. These components are rendered in polarity opposition by the oppositely curved quadrants 62 and 63, as indicated by arrows 64 and 65. The polarity changers 41 and 42 function to produce in the linear portion 66 of folded section 36 wavelets having the same polarities as represented by wavelets 67 and 68. As explained in connection with the folded section 35, the wavelets 67 and 68 have equal phase angles at the midpoint 20.

It will be noted that the polarity of wavelets 67, 68 in the portion 66 of folded section 36, is oppositely related to that of wavelets 56, 57 in portion 55 of guide section 35. Since the line conductors 8 and 9 extend through corresponding walls 43 and 44 of the sections 35 and 36, the energies induced in the pick-up antenna elements 23 and 24 of line conductors 8 and 9 are oppositely polarized, as indicated by arrows 69 and 70, and current flows in series through line conductors 8 and 9 to the load circuit 2, as illustrated by arrows 71 and 72. Thus, in accordance with this embodiment of the invention, coupling between a grounded line 3 and an ungrounded line 4 is successfully accomplished and impedance matching between an unbalanced line and a balanced line is achieved. While in the embodiment of Fig. 2, the lines 8 and 9 extend away from the same side of the composite structure 34, the two polarity changers and included linear guide portion of one transformer, for example, changers 41 and 42 and linear guide portion 66 of transformer 36, may together with the portion of line 9 attached thereto, be in effect rotated 180 degrees as a unit and line 8 and 9 will then extend away from opposite sides of the doubled transformer 34.

Referring to Fig. 3 which is a cross-sectional view taken in the plane of polarization of the wave component utilized, reference numeral 74 denotes a double transformer comprising two folded sections 13 and 14, the double transformer 74 being formed, generally speaking, by bending the double transformer 12, Fig. 1, near its center point so that transformer 14 is positioned parallel to and above transformer 13. Numeral 75 denotes a strut for rigidly maintaining folded sections 13 and 14 at a given spacing. Numeral 76 designates a Y-type wave guide connector similar to that disclosed in the application of G. C. Southworth, Serial No. 346,175, filed July 18, 1940, the Y-connector having its legs 77 and 78 connected respectively to the orifices 15 and 16 of sections 13 and 14, and its stem portion 79 connected to the high frequency device 1. The coaxially shielded conductors 8 and 9 of the balanced line 4 extending from device 2 are inserted respectively in the outside wide walls 80 and 81 of sections 13 and 14.

As explained in the above-mentioned Southworth application, the impedance of stem portion 79 matches the impedance of the two leg portions 77 and 78, since the short transverse dimension $4a$ of stem portion 79 is equal to the sum of the short transverse dimension $2a$ of leg 77 and dimension $2a$ of leg 78. Similarly, leg 76 is matched to section 13, and leg 78 is matched to section 14, since the short transverse leg dimension $2a$ of each leg equals the over-all dimension $2a$ of the superimposed apertures forming the orifice of the section. As in the structure of the preceding figures, the coaxially shielded conductors 8 and 9 are connected to the longitudinal mid-points of sections 13 and 14, each through a multifrequency impedance matching device.

In operation, Fig. 3, assuming as before that device 1 is a single frequency or multifrequency source of energy and high frequency device 2 is a load circuit, and assuming also that the wavelets in stem member 79 are polarized as shown by arrow 82, the wavelets in leg members 77, 78, in folded sections 13 and 14 are polarized in the same direction, as shown by arrows 82 and 83. Since line conductors 8 and 9 extend in opposite directions through the wide walls 80 and 81, respectively, of sections 13 and 14, the components absorbed by pick-up antenna elements

23 and 24 of lines 8 and 9 are oppositely polarized, as illustrated by arrows 84 and 85, and the current flows in series through balanced line conductors 8 and 9 and the load circuit 2, as shown by arrows 86 and 87. Consequently, and in accordance with the invention coupling, and impedance matching between a wave guide or dielectric channel and a balanced line are attained.

Although the invention has been explained in connection with certain specific embodiments thereof, it is to be understood that it is not to be limited to these embodiments since other apparatus may be satisfactorily employed in practicing the invention.

What is claimed is:

1. In combination, a first line and a second line each comprising two conductors, the impedances between one conductor of the first line and the two conductors of the second line being equal, means for coupling said lines comprising two pairs of electrically parallel wave guide channels, one pair being included between said first line and one of the two conductors of the second line and the other pair being included between said first line and the other conductor of the second line.

2. In combination, a first line comprising two metallic conductors having equal impedances to ground, a second line comprising a grounded conductor and an ungrounded conductor, and means for coupling said lines comprising a separate looped wave guide section connected between the second line and each of said metallic conductors.

3. A combination in accordance with claim 2, said looped wave guides each having a rectangular cross section and being folded in the plane of the long transverse guide dimension.

4. A combination in accordance with claim 2, said looped wave guides each having a rectangular cross section and being folded in the plane of the short transverse guide dimension.

5. In combination, a first line comprising an inner conductor and a grounded outer conductor, and a second line comprising a pair of ungrounded conductors each enclosed in a grounded coaxial shield, and means for coupling said lines comprising a pair of independent wave guide looped sections each connected at one end to said first line and at its mid-point to a different one of the conductors of said second line.

6. In combination, an unbalanced line, a balanced line comprising a pair of conductors, and means for coupling said lines comprising a pair of folded wave guide coupling sections each having their two end apertures superimposed, a connecting wave guide section extending between the apertures of said coupling sections, the unbalanced line being connected to said connecting section, and said conductors each being attached to the mid-points of different coupling sections.

7. In combination, an unbalanced line, a balanced line comprising a pair of conductors, and means for coupling said lines comprising a pair of folded wave guide coupling sections each having their two end apertures superimposed, the superimposed apertures of one section being joined to the superimposed apertures of the other section, said unbalanced line being connected to said folded sections at the junction, and said conductors each being connected to the mid-point of a different coupling section.

8. In combination, an unbalanced line, a balanced line comprising a pair of conductors, a pair of folded wave guide coupling sections each having superimposed end apertures and a pair of oppositely twisted quadrature polarity changers, a connecting wave guide section extending between the apertures of said coupling sections, said line being connected to an intermediate point of said connecting section, said conductors being connected to different coupling sections at the longitudinal section mid-point and between the polarity changers of the section, whereby the energies transferred between said lines are of opposite polarity in said line conductors.

9. In combination, a balanced line comprising a pair of coaxially shielded conductors, a double impedance transformer comprising a pair of rectangular wave guide sections each folded in the plane of its long transverse dimensions, a rectangular wave guide member connecting the open ends of said folded sections, said unbalanced line extending through one wide wall of said member, and said balanced line conductors extending through opposite walls of said folded sections.

10. A balanced line-unbalanced line coupling device comprising a pair of folded rectangular wave guide sections having long and short transverse dimensions and correspondent and uncorrespondent wide walls, said sections having their end orifices connected together and an aperture at their junction for connection to said unbalanced line, each section having an aperture at its longitudinal mid-point for junction with one conductor of said balanced line.

11. A device in accordance with claim 10, said sections each being folded in the plane of its long transverse dimension, the mid-point apertures being located in uncorrespondent wide walls of said sections.

12. A device in accordance with claim 10, said sections each being folded in the plane of its short transverse dimension and including a pair of oppositely rotated quadrature polarity changers symmetrically located relative to the section mid-point.

13. A device in accordance with claim 10, said sections each being folded in the plane of its short transverse dimension and including a pair of oppositely rotated quadrature polarity changers, the mid-point apertures being located in uncorrespondent wide walls of said sections.

14. In combination, a balanced line comprising a pair of conductors, a main wave guide section, a pair of folded wave guide sections, the end orifices of said folded sections being connected to said main guide, and said conductors being each connected to different folded sections at the longitudinal mid-point of the section.

15. A combination in accordance with claim 14, the end orifices of said folded section being connected to the main wave guide section through a Y-type wave guide section having its two leg portions joined to the orifices of said folded sections and its stem portion connected to the main guide.

16. A combination in accordance with claim 14, said folded wave guide sections being positioned parallel to each other, the end orifices of the said folded sections being connected to the main guide through a Y-type wave guide section having its two legs joined to the orifices of said folded sections and its stem connected to the main guide.

17. In combination, an unbalanced line comprising two conductors connected in series with a first high frequency device and having unequal impedances to ground, a balanced line comprising two conductors connected in series with a second high frequency device and having equal imped-

ances to ground, and a double impedance transformer for coupling said lines and matching their impedances comprising a pair of folded wave guide impedance transformer sections having their open ends joined together, at least one conductor of said unbalanced line connected to said double transformer at the junction of said sections, and the conductors of said balanced line being connected to different sections at the section longitudinal mid-point.

18. In combination, a first line comprising a first ungrounded conductor enclosed in a first outer coaxial grounded conductor, a second line comprising a second ungrounded conductor and a third ungrounded conductor each enclosed, respectively, in a second outer coaxial grounded conductor and a third outer coaxial grounded conductor, means for coupling said lines comprising two rectangular wave guide sections each folded in the plane of its long transverse dimension and having their two apertures super imposed, a connecting rectangular wave guide joining the apertures of one section to the apertures of the other section, said first ungrounded conductor projecting within and along a short transverse dimension of said connecting guide section and said first outer conductor enclosing a portion of said first inner conductor positioned within the connecting guide, said second underground conductor and the associated second outer conductor projecting through one side wall of one folded coupling section, and the third ungrounded conductor and associated third outer conducter projecting through the oppositely related side wall of the other folded wave guide coupling section, and a high frequency device between the ungrounded conductors of the second line.

DOUGLAS H. RING.