June 11, 1946. H. T. FRIIS 2,401,751

COUPLING SYSTEM

Filed March 17, 1942

FIG. 1

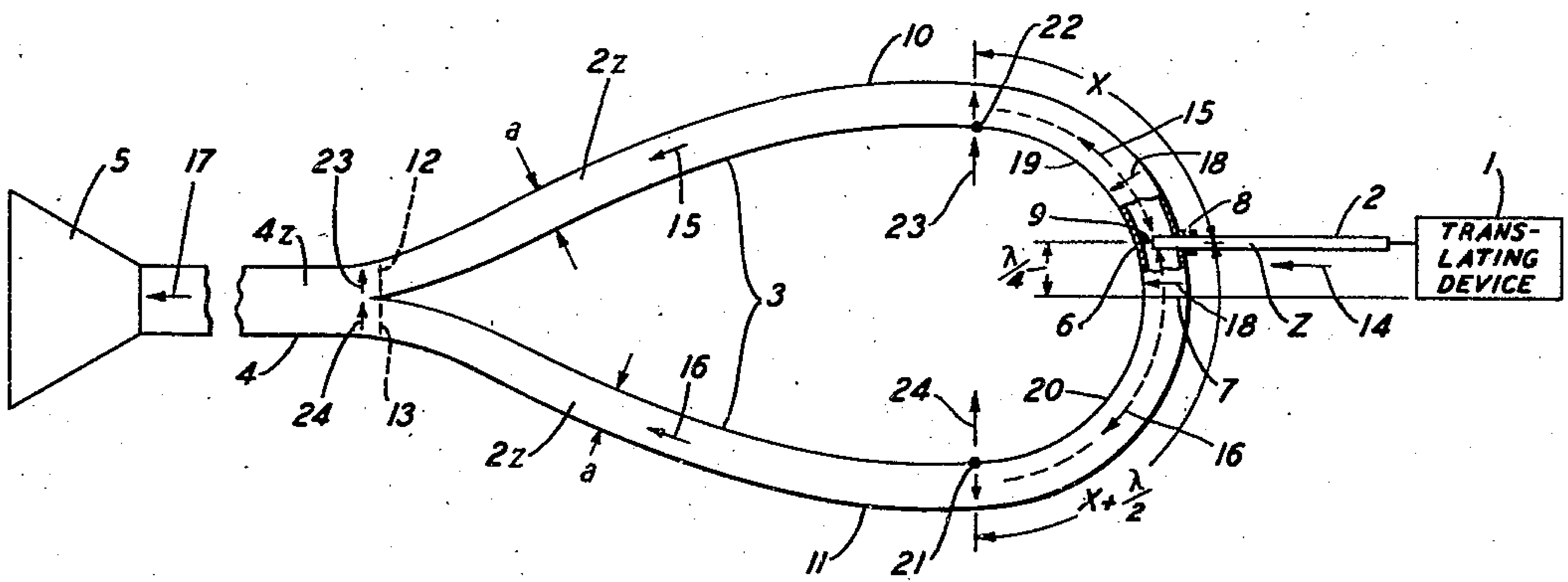
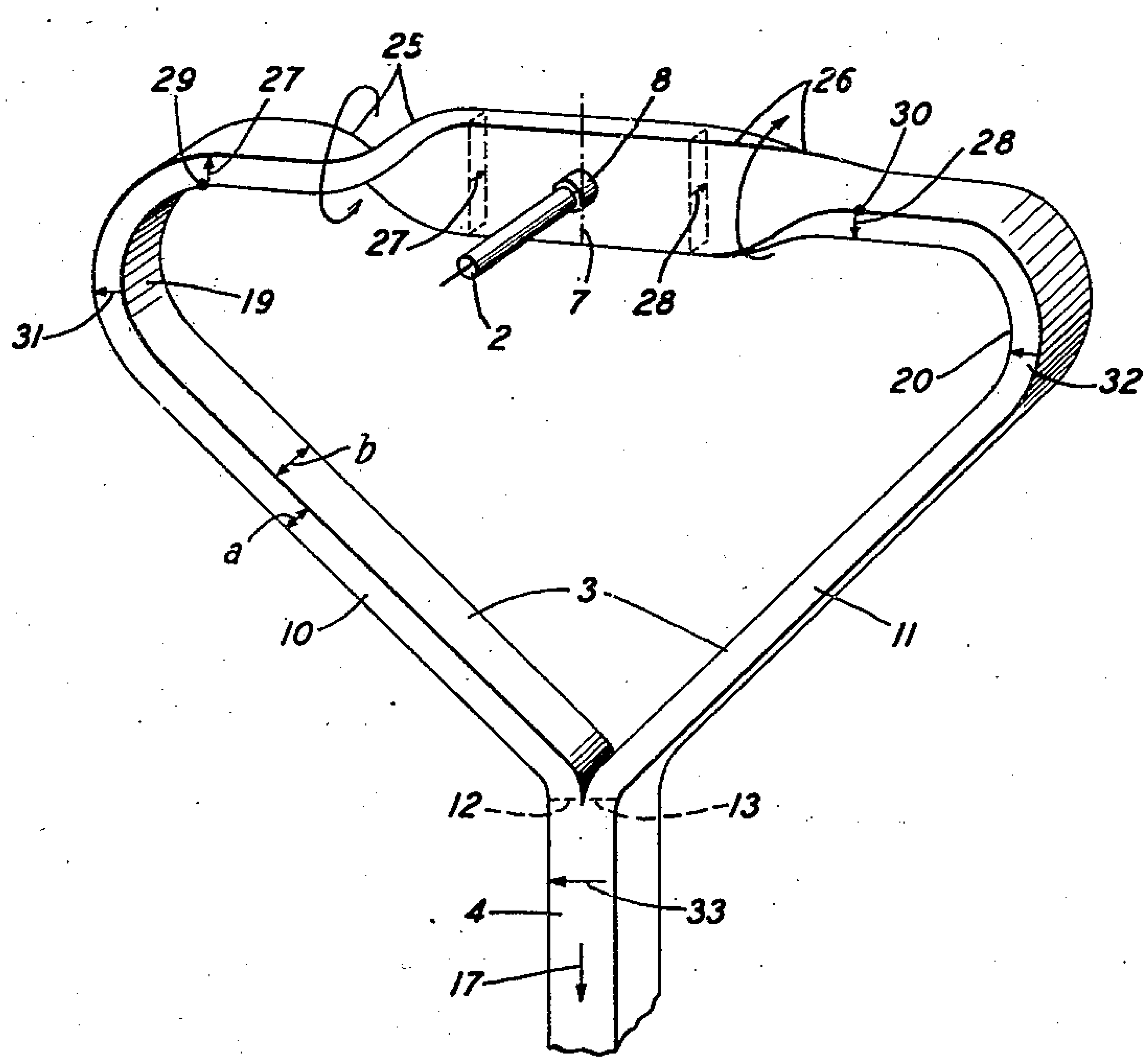


FIG. 2



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Patented June 11, 1946

2,401,751

UNITED STATES PATENT OFFICE

2,401,751

COUPLING SYSTEM

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Application March 17, 1942, Serial No. 435,017

8 Claims. (Cl. 178—44)

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This invention relates to microwave coupling devices and, more particularly, to wave guide transmission line coupling arrangements.

Heretofore, as disclosed in Patent 2,232,179 granted to A. P. King on February 18, 1941, and the copending applications of G. C. Southworth Serial No. 346,175, filed July 18, 1940, and A. C. Beck Serial No. 429,358, filed February 3, 1942, coupling between a wave guide and a line is ordinarily effected by inserting the line in the dielectric channel through a special aperture located at a point between the extremities or end orifices of the guide. In the systems disclosed in the King patent and Southworth application the portion of the inner coaxial line conductor included within the guide, and usually designated the "exciter," is tuned by means of a pair of piston tuners for matching at a particular frequency the impedance of the line to the total wave guide impedance which comprises the parallel impedances of the two branch dielectric channels extending in opposite directions relative to the exciter. In the system of the Beck application, matching over a band of frequencies between the line and the total wave guide impedance is accomplished by omitting the critical frequency tuners and by shielding a portion of the exciter. Also, while in the single frequency systems of the King patent and the Southworth application an adjustable piston reflector positioned within the guide and spaced one-quarter wave-length from the exciter may be, and often is, utilized for the purpose of blocking one branch channel or, more accurately, for the purpose of converting without energy loss the bilateral wave propagation within the guide to a unilateral propagation, this arrangement cannot be employed for this purpose in the multi-frequency system of the Beck application because of the frequency limitation imposed by the one-quarter wave-length spacing mentioned above. Moreover, even in the single frequency system, a completely satisfactory impedance match and a conversion from bilateral to unilateral wave propagation in the guide, have not always been obtained because of the difficulty of critically adjusting the tuning pistons and the reflector piston, and of maintaining the proper adjustments.

It is one object of this invention to secure, in single frequency transmission systems comprising a wave guide coupled to a line, unilateral wave propagation within the guide without utilizing a reflecting piston.

It is another object of this invention to secure, in a multifrequency transmission system comprising a wave guide coupled to a line, unilateral propagation in the wave guide.

It is still another object of this invention to match the impedances of a dielectric channel

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and a conductive channel having substantially different impedances.

It is a further object of this invention to transfer energy between a coaxial line and a wave guide, and over a wide carrier frequency microwave band, with minimum reflection loss.

It is also an object of the invention to couple different types of transmission channels for multifrequency operation without introducing reflection losses and without utilizing auxiliary adjustable apparatus.

As used herein, the term "transmission channel" is employed in a generic sense and includes a line or conductive channel and a dielectric or wave guide channel. Also, the comprehensive term "quadrilateral" includes rectangular and square; and the term "rectangular" is used in a narrow sense and excludes "square."

In accordance with one preferred embodiment of the invention a coaxial line or line channel having an impedance Z is connected to a quadrilateral wave guide or dielectric channel having a considerably larger impedance as, for example, 4Z, through a rectangular folded or looped wave guide coupling section having an impedance 2Z. The curvature of the folded wave guide section is in the plane of the short transverse dimension of the guide and the end apertures of the folded section are superimposed in a manner such that the short transverse dimensions of the end apertures are aligned. Stated differently, the looped wave guide section is bent or folded in the plane of polarization of the utilized wave component. The coaxial line is coupled through a matching device of the type disclosed in the copending application of A. C. Beck mentioned above to an intermediate point of the rectangular folded wave guide section; and the superimposed end apertures of the looped section are joined to an end orifice of the quadrilateral wave guide.

For multifrequency operation the coaxial line is connected to the longitudinal center point of the rectangular loop section and the resulting two parts or branches of the loop section extending between the center point and the superimposed apertures include quadrature polarity changers, whereby the polarities of the utilized components or wavelets are rendered colinear in the superimposed apertures. For single frequency operation the twisted wave guide portions or polarity changers are omitted and the line is connected to the loop at a point one-quarter wave-length removed from the longitudinal mid-point of the folded guide so that the lengths of the propagation paths in the two branches differ a half wave-length. By reason of the half wave-length difference the components propagated in the two loop branches and having at the exciter or coupling point a zero phase angle difference and identical polarities, are 180 degrees out of phase, and therefore colinearly polarized, at the superimposed apertures. More specifically, the 180 degree phase angle difference resulting from the 90 degree displacement of the coupling point relative to the above-mentioned longitudinal center point, is in a sense a compensation for the two oppositely directed quadrature changes produced in the polarities of the branch wave components by the two bends or quadrants of opposite curvatures in the two branches. The combined characteristic impedances of the superimposed loop apertures are serially associated and equal to the characteristic impedance, 4Z, of the quadrilateral guide. In addition, the coaxial line impedance Z is matched to that of the loop section connected thereto.

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 an elevational view of an embodiment of the invention arranged for single frequency operation; and

Fig. 2 is a perspective view of a different embodiment used for multifrequency operation.

Referring to Fig. 1, reference numeral 1 designates a translation device for transmitting or receiving waves of a given frequency and numeral 2 denotes a conductive channel or coaxial line connected thereto. The line channel 2 is connected through a rectangular wave guide section 3 folded or looped in the plane of its short transverse dimension a to a quadrilateral main wave guide or dielectric channel 4 and a radiating or collecting device such as horn 5. The line channel 2 is attached to the folded wave guide at a point 6 one-quarter wave-length removed from the longitudinal center point 7 of the folded wave guide 3 and is coupled thereto through a unifrequency-multifrequency coupling device of the type disclosed in the copending application of A. C. Beck mentioned above and comprising the adjustable sleeve member 8.

Considering the impedance relations of the system of Fig. 1, the sleeve 8 is adjusted and a particular value for the short transverse dimension a of the loop 3 is selected so that the exposed portion 9 of the inner conductor of line 2 has a length and impedance, as explained in the Beck application, such that the characteristic impedance Z of line 2 is matched at the single operating frequency to the total folded wave guide impedance comprising the two parallel impedances of the branches 10 and 11. Thus, assuming the line 2 has a characteristic impedance Z equal to 100 ohms, each of loop sections 10 and 11 has a characteristic impedance 2Z equal to 200 ohms so that the two impedances connected in parallel equal the line impedance. The dielectric channel has a characteristic impedance 4Z which may be taken as the value of its input or send end impedance since the length of the guide 4 in wave-lengths is relatively great and may be considered infinite. Inasmuch as the apertures 12 and 13 are superimposed with their transverse dimensions aligned, the aperture impedances are additive, the characteristic impedance of a rectangular wave guide channel being directly proportional to the short transverse dimension and substantially independent of the long transverse dimension, as disclosed in the copending application of G. C. Southworth mentioned above. Thus the total impedance 2Z+2Z of the apertures is 4Z, that is, equal to the input impedance or characteristic impedance of the main guide 4. Hence, the folded guide 3 consitutes an impedance transformer for matching the main guide 4 to the line 2.

In operation, while the energies conveyed between the device 1 and the horn 5, and propagated in the branches 10 and 11 of the folded section 3, flow relative to point 6 in opposite or bilateral directions the combination including loop 3 functions to produce only unilateral propagation in the dielectric channel 4. Assuming that device 1 is a transmitter, the arrows 14, 15, 16 and 17 denote the directions of propagation respectively in line 2, branch 10, branch 11 and guide 4. The wavelets propagated in direction 15 and 16 have, at point 6, the same phase angle and are similarly polarized in the direction 18 aligned with both the short transverse dimension a and the exposed exciter 9, that is, in a horizontal direction included in the plane of the drawing. By reason of the oppositely curved portions or quadrants 19 and 20 in branches 10 and 11, respectively, the instantaneous polarities of these wavelets are rotated 90 degrees in opposite directions. At the two corresponding points 21 and 22 equally distant from the superimposed apertures 12 and 13, the wavelets have opposite phase angles, since the lengths of the two paths extending between point 6 and points 21 and 22 differ by one-half wave-length; and in a sense, this opposite phase angle relation compensates for the opposite polarity relation produced by the oppositely curved quadrants 19 and 20 so that the wavelets are similarly polarized at points 21 and 22 and similarly polarized at the superimposed apertures 12 and 13, as shown by arrows 23 and 24.

Referring to the multifrequency embodiment illustrated by Fig. 2, the coaxial line 2 is connected to the longitudinal center point 7 of the folded guide 3. As in the system of Fig. 1, the section 3 is folded in the plane of its short transverse dimension a and the line and the folded guide are coupled through a unifrequency-multifrequency coupling device of the type disclosed in the above-mentioned Beck application and comprising a sleeve 8. The sides or branches 10 and 11 of the folded section 3 include, respectively, 90 degree polarity changers 25 and 26, the twist or rotation of these polarity changers, relative to center point 7, being of opposite sense. As in the system of Fig. 1, the main guide 4 is connected to an antenna such as a horn and the coaxial line 2 is connected to a translation device.

In operation, assuming the system is used for transmitting and that the translation device is a multifrequency wave source, the sleeve 8 is adjusted to secure a substantially flat frequency-impedance match characteristic, as explained in the Beck application, whereby the impedance Z of the coaxial line is matched over a carrier frequency band to the input impedance comprising the two impedances, 2Z and 2Z, of branches 10 and 11 connected in parallel. As in Fig. 1, the serially connected impedances of apertures 12 and 13, taken together, equal the input impedance 4Z of the main wave guide 4.

The translation device connected to line 2 functions to establish in the folded wave guide section 3 oppositely propagated wavelets 27 and 28 which, at point 7, have the same phase angle and are similarly polarized in a direction coincident with the short transverse dimension a. As seen from point 7, the polarity of wavelet 27 is rotated 90 degrees in a counter-clockwise direction and that of wavelet 28, 90 degrees in a clockwise direction by the polarity changers 25 and 26, respectively, so that at the corresponding points 29 and 30 equally distant from the superimposed apertures 12 and 13, these wavelets are oppositely polarized but have the same time phase angle. The wavelets are then oppositely rotated 90 degrees by the bent or curved portions 19 and 20 of branches 10 and 11 and, at a second pair of corresponding points 31 and 32 equally distant from the superimposed apertures 12 and 13, the wavelets 27 and 28 are in polarity agreement and therefore combine to produce a maximum vector resultant 33 in the guide 4.

Thus, in accordance with the invention, the system or combination illustrated by Fig. 2 and comprising the multi-frequency coaxial line-wave guide coupling device, and a folded wave guide section including the oppositely twisted or rotated polarity changers and having its two apertures superimposed and joined to the end orifice of a main dielectric channel, functions to match over a band of carrier frequencies including several hundred megacycles, the impedances of a conductive channel and a dielectric channel which impedances may be greatly different. At the same time the system produces unilateral or one-way propagation in the main dielectric channel.

Although the invention has been explained in connection with certain embodiments thereof it should be understood that it is not to be limited to these arrangements inasmuch as other apparatus may be employed in successfully practicing the invention. More particularly, the folded wave guide coupling section and the main wave guide may each have a square instead of a rectangular cross section. Also, any other type of line channel, such as a two-wire balanced line and even a dielectric wave guide channel, may be substituted for the coaxial line 2, and the invention may be utilized for coupling two dielectric channels or for coupling a balanced line channel to a main wave guide channel.

What is claimed is:

1. In combination, a coaxial line having a given impedance and an inner conductor and an outer conductor, a wave guide having a different impedance, and means for coupling said line and guide and producing unilateral propagation in said guide comprising a rectangular wave guide looped section having an impedance intermediate said impedances, the end openings of said loop section being superimposed and connected to the first-mentioned guide, said coaxial line being connected to said section at an intermediate point thereof, the inner line conductor extending into and perpendicularly across said section and the outer conductor enclosing at least one-half of the inner conductor portion included in said section.

2. In a transmission system, a first wave guide having an input impedance Z, a line conductor having a characteristic impedance

$$\frac{Z}{4}$$

a coupling wave guide looped section having a characteristic impedance

$$\frac{Z}{2}$$

said conductor being connected to an intermediate point in said coupling section and the end openings of said section being superimposed and joined to one end opening of said first guide, whereby reflection losses along said system are eliminated and the wave propagation in said first wave guide is unilateral.

3. In combination, a main rectangular dielectric channel having a short transverse dimension, a conductor channel, said channels having different impedances, and a transformer for matching said impedances comprising a plurality of rectangular dielectric branch channels, each of the last-mentioned channels having a short transverse dimension equal to one-half of said first-mentioned short dimension and being connected between the conductor channel and said main dielectric channel.

4. In combination, a quadrilateral wave guide having an end orifice, a coaxial line, and means for connecting said guide and line and matching their impedances over a band of frequencies comprising a rectangular wave guide folded in the plane of its short transverse dimension and having superimposed end apertures joined to the end orifice of said quadrilateral guide, a multifrequency impedance matching coupler connecting said line to the mid-point of said rectangular guide and comprising a conductor extending within said guide along said short transverse dimension, the rectangular guide branches included between said mid-point and the quadrilateral guide orifice being oppositely rotated 90 degrees, each in the plane of its cross-sectional area, whereby wave components transferred between said line and said quadrilateral guide have the same polarity at the junction of said orifice and said superimposed apertures.

5. In combination, a first rectangular wave guide having an end orifice, a coaxial line comprising two conductors, said line and guide having different impedances, an impedance matching transformer included between said guide and line and comprising a second rectangular wave guide having side walls of different widths and openings at both ends, said coaxial line connected to said second guide at an intermediate point thereof and extending within the guide in a direction coincident with the shorter transverse guide dimension, said second guide being folded in the plane of the shorter dimension and having its openings superimposed and connected to said orifice.

6. A combination in accordance with claim 5, the lengths of the branches extending between said intermediate point and said openings being equal.

7. A combination in accordance with claim 5, the length of the branch included between said intermediate point and one of said openings being a half wave-length or a multiple thereof greater than the length of the branch extending between said point and the other of said openings.

8. A quadrilateral dielectric wave channel-transmission line coupling device comprising a folded rectangular wave guide having a short transverse dimension equal substantially to one-half of the short transverse dimension of said channel, means for energizing said guide with transverse electric H_{11} waves, said guide being folded in the plane of polarization of said waves, said folded guide having its end apertures superimposed for junction with said channel and an aperture at an intermediate point for junction with said line, and the two guide branches included between said intermediate aperture and said superimposed end apertures being oppositely twisted 90 degrees.

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