United States Patent [19]

Watson

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[54] **WAVEGUIDE COUPLERS**

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Nov. 4, 1972 Great Britain 50949/72

[52] **U.S. Cl.** .... **333/10,** 333/98 R

[51] **Int. Cl.** **H01p 5/14**

[58] **Field of Search** 333/10

[56] **References Cited**

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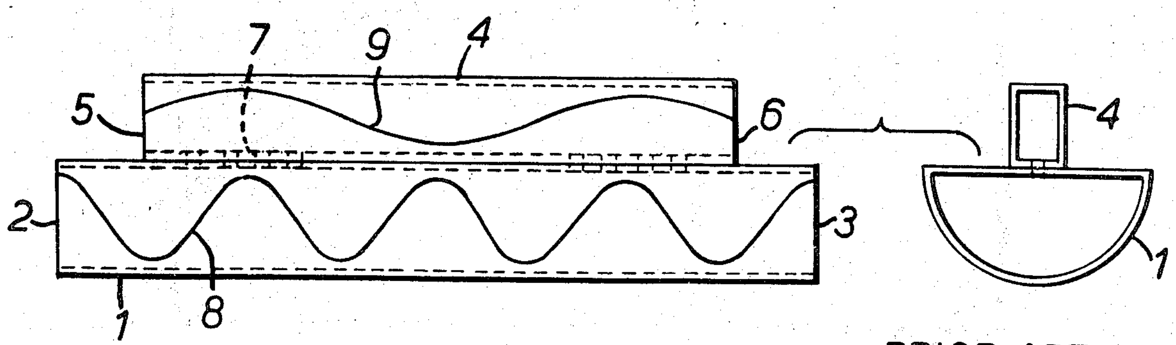
Attorney, Agent, or Firm—Baldwin, Wight & Brown

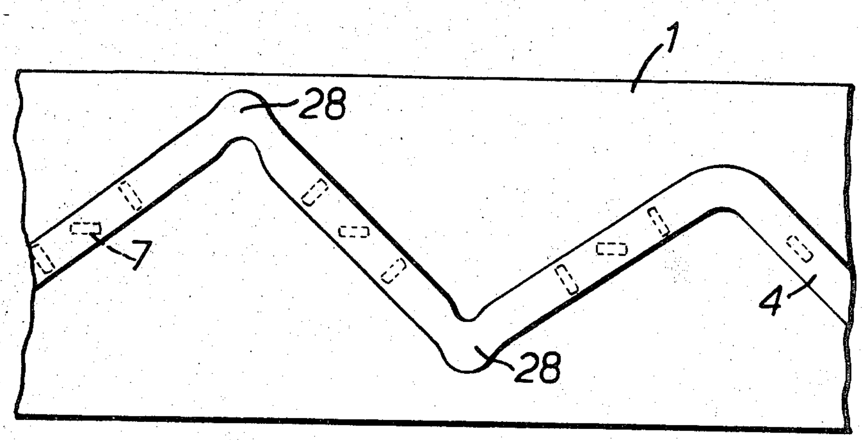
[57] **ABSTRACT**

A waveguide coupler for coupling energy between a first length of waveguide capable of supporting waves of one phase velocity and a second length of waveguide capable of supporting waves having a further phase velocity has a common wall with coupling apertures between the two waveguide lengths. The waveguide length capable of supporting waves of higher phase velocity is non-rectilinear in the longitudinal direction so that an incident wave in one of the lengths is capable of coupling into the other length. The non-rectilinear length is approximately sinusoidally shaped.

20 Claims, 7 Drawing Figures



PRIOR ART



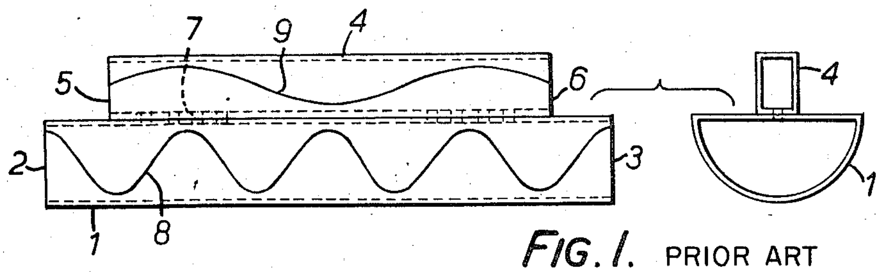


FIG. 1. PRIOR ART

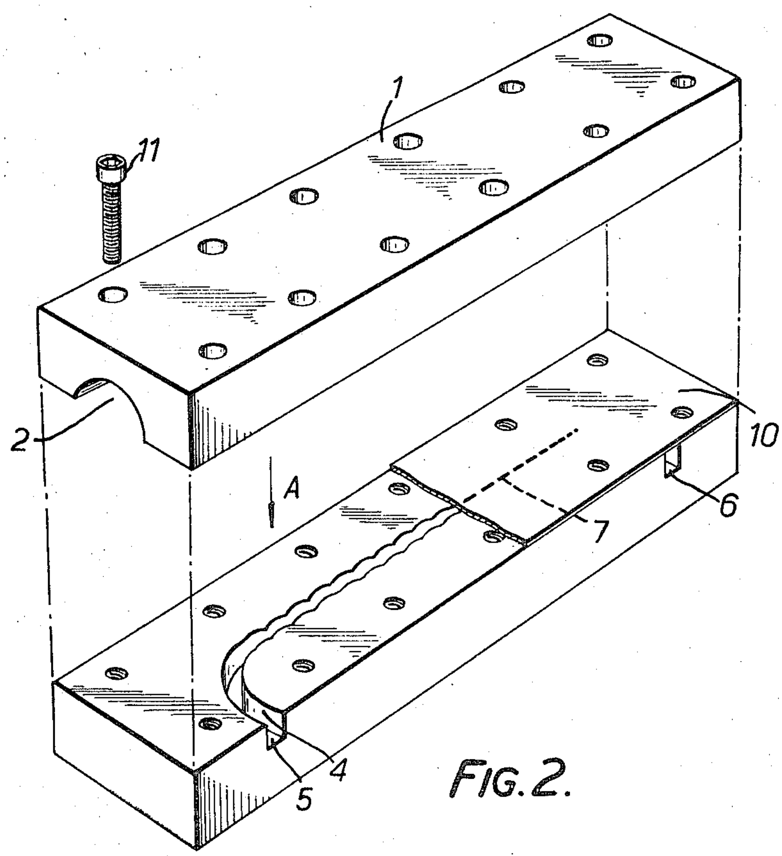


FIG. 2.

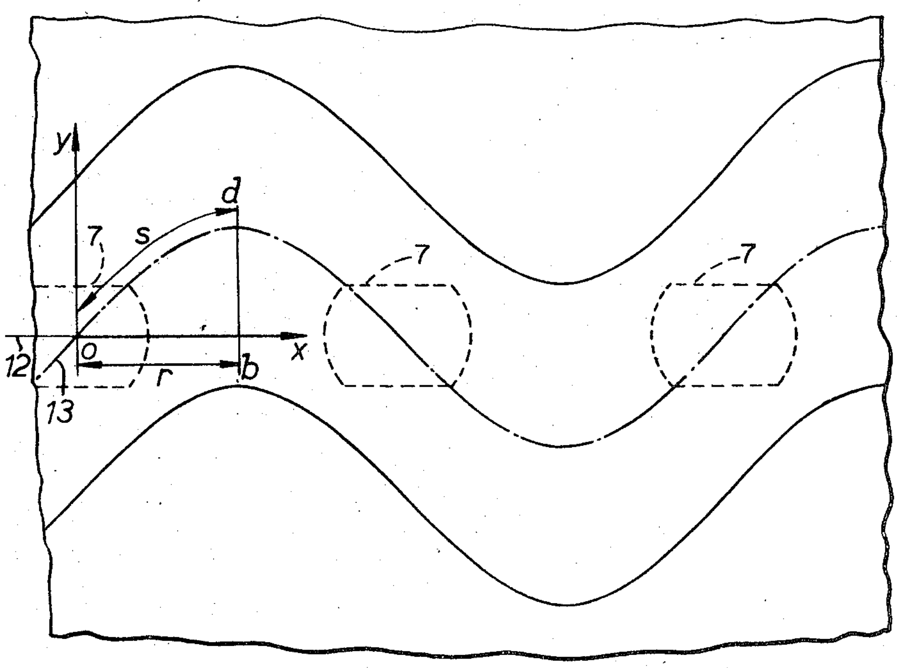


FIG. 3.

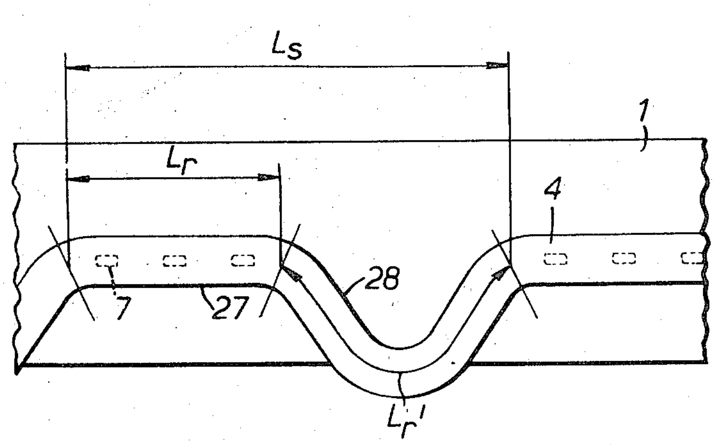


FIG. 4.

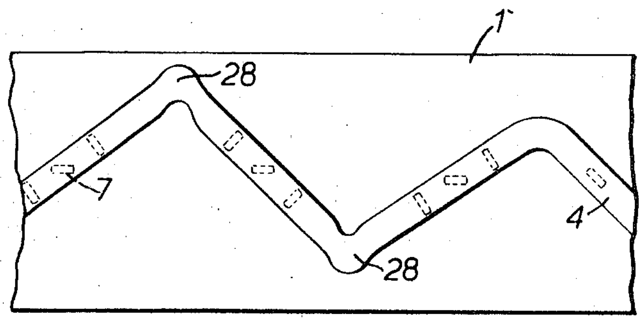


FIG. 5.

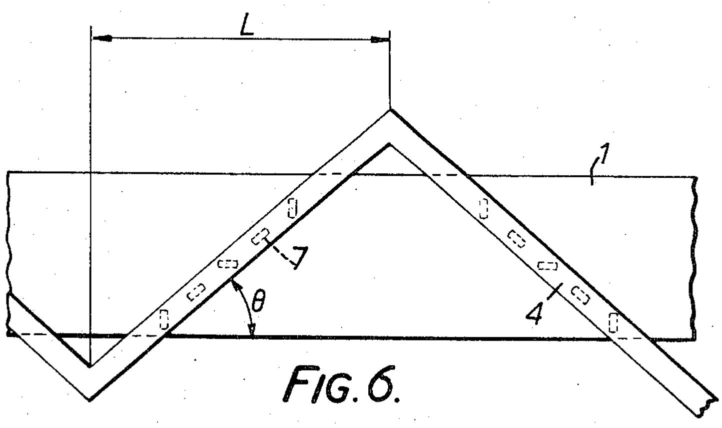


FIG. 6.

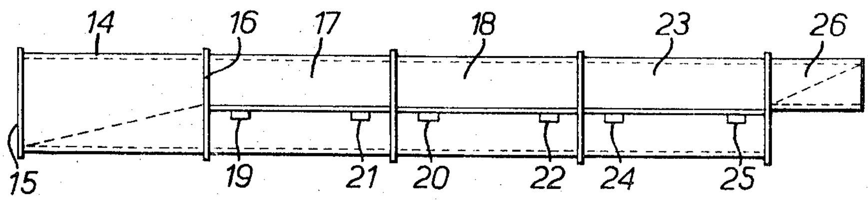


FIG. 7.

WAVEGUIDE COUPLERS

This invention relates to waveguide couplers and more particularly to an improved waveguide coupler for coupling energy between two lengths of waveguide each capable of supporting electromagnetic waves having phase velocities different from those of the waves supportable by the other.

A known waveguide coupler comprising a semi-circular sectioned waveguide and a rectangularly sectioned waveguide, the latter being capable of supporting electromagnetic waves having a faster phase velocity than that of those supported by the semi-circularly sectioned waveguide, will now be described with reference to FIG. **1** of the accompanying drawings. The waveguide coupler of FIG. **1**, comprises a semi-circularly sectioned waveguide **1**, having an input port **2** and an output port **3**, which has its flat outer wall attached to a narrow wall of a rectangularly sectioned waveguide **4** which also has a port **5** and an output port **6**. Two groups of four coupling holes **7** are provided through the contacting portions of the semi-circular and rectangular waveguides, the distance between the holes **7** in each group being approximately a quarter of the wavelength of the electromagentic wave in the semi-circular waveguide **1** from which energy is to be coupled into the rectangular waveguide **4**. Both the output port **3** and the port **5** of the rectangular waveguide are terminated in matched loads (not shown).

Represented diagrammatically within semi-circular waveguide **1** and the rectangular waveguide **4** are two waves **8** and **9** respectively which are shown for the purpose of explanation only. The wave **8** is an incident input wave containing the $TE_{01}^{\frown}$ mode of wave propagation and the wave **9** is a coupled wave produced in waveguide **4** and which is of the $TE_{10}^{\square}$ mode, the dominant mode for a rectangular waveguide. Since phase velocity is directly proportional to wavelength it will be seen that the wave **9** has two times the phase velocity of the wave **8**. It will also be noted that the periodicity of the groups of holes **7** coincides with the beat wave length of the waves **8** and **9**.

The coupling holes **7** are shaped and dimensioned in accordance with known principles to produce the desired bandwidth of coupling. However, because the coupling holes **7** are only in selected parts of the available coupling region between the abutting faces a long length of coupler is required to enable satisfactory coupling between the two waveguides and because long lengths of coupler are required (of the order of 5 feet is common) such couplers tend to be lossy.

The present invention seeks to provide a coupler of reduced length and attenuation compared with the above described known coupler for similar frequencies of operation.

According to this invention in its broadest aspect a waveguide coupler for coupling energy between two lengths of waveguide each capable of supporting electromagnetic waves having phase velocities different from those supportable by the other, and having a common interconnecting wall therebetween is such that one of the waveguides has a non-rectilinear form in the longitudinal diection such that the ratio of the non-rectilinear length of said one waveguide to the length of the other waveguide is substantially equal to the ratio of their respective phase velocities and wherein coupling apertures are provided in the common interconnecting wall so that energy from an incident electromagnetic wave in said non-rectilinear length of waveguide is capable of being coupled to the other waveguide, or vice versa, to produce a coupled output electromagnetic wave therein.

According to one aspect of this invention a waveguide coupler, for coupling energy between two lengths of waveguide each capable of supporting electromagnetic waves having phase velocities different from those supportable by the other, and having a common interconnecting wall therebetween is such that the length of waveguide capable of supporting waves having the higher phase velocities is approximately sinusoidally shaped in the longitudinal direction and is provided with coupling apertures in the common interconnecting wall so that energy from an incident electromagnetic wave in one of said lengths of waveguide is capable of being coupled to the other length of waveguide to produce a coupled output electromagnetic wave therein.

The expression "approximately sinusoidally" and similar expression are herein employed to include not only true sinusoidal shapes but also shapes consisting of a succession of inclined straight line portions which together approximate to a sinusoidal shape or combinations of straight and curved line portions. In the case where the sinusoidal shape consists of a succession of inclined straight line portions the "corners" where the straight line portions meet may be smoothed or rounded off.

The expression "common wall" is intended to cover the case where a single wall serves as a wall of the two separate lengths of waveguide and also the case where the two lengths each have separate walls which are coupled together.

In one embodiment of the invention the waveguide capable of supporting waves having the higher phase velocities is a true sinusoid or a succession of inclined straight line portions. In such an embodiment the coupling apertures are in the form of longitudinally disposed slots positioned such that the centre of each slot lies substantially on the zero axis of the sinusoid midway between adjacent oppositely phased peaks of the sinusoid.

In a further embodiment of the invention the waveguide capable of supporting waves having the higher phase velocities is a succession of straight line portions having a common longitudinal axis with the waveguide capable of supporting waves having the lower phase velocities, and connected between the straight line portions are curved portions providing a compensating loop so as to substantially match the differing phase velocities between the two lengths of waveguide. In said further embodiment the coupling apertures are provided along the common longitudinal axis and are either slots or circular holes.

In another embodiment of the invention the waveguide capable of supporting waves having the higher phase velocities is a true sinusoid or a succession of inclined straight line portions with a compensating loop provided in the region of maximum amplitude of the sinusoid so as to substantially match the differing phase velocities of the two lengths of waveguide. In such an embodiment the coupling apertures are preferably slots.

In yet a further embodiment the waveguide capable of supporting waves having the higher phase velocities is a true sinusoid or a succession of inclined straight line portions which extend beyond the common interconnecting wall, the extended portion providing a compensating loop to substantially match the differing phase velocities of the two lengths of waveguide. In such an embodiment the coupling apertures are preferably slots.

Preferably the overall dimensions of the aperture is just less than the spacing between the apertures, and the apertures and sinusoidal guide are dimensioned such that the apertures do not extend over the side walls of the sinusoidal guide, said overall dimensions of the apertures being made equal to a quarter of the wavelength of the geometric frequency of the extreme frequencies to be present in the waveguide intended to support the electromagnetic wave from which energy is to be coupled into the other guide.

In a preferred embodiment of the invention the sinusoidally shaped length of waveguide is of a rectangularly sectioned waveguide, and the other length of waveguide is a semi-circularly sectioned length of waveguide, the common longitudinal wall between the two lengths of waveguide forming the flat wall of the semi-circularly sectional length of waveguide.

A number of couplers may be connected together to form a band branching system. Preferably such a band branching system comprises first and second serially connected couplers in accordance with this invention for converting energy from a semi-circular sectioned waveguide to a rectangular sectioned waveguide, both first and second serially connected couplers being capable of operating at predetermined different ranges of frequencies and each capable of coupling from semi-circular sectioned waveguide to rectangular sectioned waveguide; a transitional section waveguide that is capable of transferring energy at one end thereof from a circular section waveguide to a semi-circular sectioned waveguide at the other end thereof; a slot coupler known per se capable of operating at a lower range of frequencies than the serially connected couplers and also capable of coupling from a semi-circular sectioned waveguide to rectangular sectioned waveguide; and a load; wherein the semi-circular end of the transitional section waveguide is connected to the first serially connected coupler which possesses the higher frequency coupling apertures whilst the second serially connected coupler is connected to the known slot coupler, the known slot coupler in turn being connected to the load, the combination being capable of operating such that an incident wave possessing the $TE_{10}^{\square}$ mode in circular waveguide is transferred to semi-circular waveguide by the transitional section waveguide, high frequency energy is coupled into rectangular section waveguide operating in the $TE_{10}^{\square}$ mode by the first serially connected coupler, mid-band frequency energy is coupled into rectangular section waveguide operating in the $TE_{10}^{\square}$ mode by the second serially connected waveguide, and the remaining low frequency energy is coupled into the rectangular section waveguide operating in the $TE_{10}^{\square}$ mode by the coupler known per se.

The invention will now be described, by way of example, with reference to the accompanying drawings in which:

FIG. **1** is a coupler according to the prior art.

FIG. **2** shows an exploded, partially sectioned view of a semicircular to rectangular coupler in accordance with one embodiment of this invention,

FIG. **3** shows an enlarged part plan view in the direction of arrow 'A' in FIG. **2** with axes and distance inscribed thereon, and with the positions of coupling slots shown in dotted outline, and

FIG. **4** shows a part plan view of a semi-circular to a rectangular coupler in accordance with a further embodiment of the invention,

FIG. **5** shows a part plan view of a semi-circular to rectangular coupler in accordance with another embodiment of the invention,

FIG. **6** shows a part plan view of s semi-circular to rectangular coupler in accordance with yet a further embodiment of the invention, and

FIG. **7** shows a band branching network utilising couplers in accordance with this invention.

In the Figures like numbers denote like parts.

Referring to FIG. **2** a semi-circularly sectioned waveguide **1** has an input port **2** and an output port (not shown). A rectangularly sectioned waveguide **4**, which is sinusoidally shaped in the longitudinal direction, has an input port **5** and an output port **6**. A coupling plate **10**, in which coupling slots **7** are formed, is provided between the waveguides **1** and **4**. The slots **7** are spaced on the zero axis of the sinusoid midway between adjacent oppositely phased peaks of the sinusoid. The coupling plate **10** forms a common interconnecting wall between the flat face of the semi-circular guide **1** and one of the narrow walls of the rectangular guide **4**. Twelve fixing screws **11** (only one of which is shown for clarity) are provided for securing the assembly of waveguides **1** and **4** and coupling plate **10** together. The output port of the guide **1** and the input port **5** of the guide **4** are terminated in matched loads (not shown) so as to absorb undirected power.

The ends of the rectangular waveguide **4** adjacent the input port **5** and output port **6** are provided with a radius which is typically three times the broad wall dimension of the guide **4**. Between the two radiused ends the guide **4** is sinusoidally shaped, the amplitude of the sinusoid increasing gradually from the ends so as to minimise undesirable reflections in the guide **4**.

Referring now to FIG. **3**, the longitudinal axis of the coupler is referenced **12** and the centre line of the sinusoidally shaped narrow wall of waveguide **4** is referenced **13**. For the purposes of explanation as to how the sinusoid is dimensioned, x and y coordinates are shown. The x co-ordinate lies on the longitudinal axis of the coupler and the y co-ordinate is perpendicular thereto at a point where the centre line **13** intersects the longitudinal axis **12**. The longitudinal axial distance between a trough of the sinusoid at point o and a peak of the sinusoid at point b is referenced r. The length of the plane curve described by the centre line of the sinusoidal shaped guide between a trough at point o and a peak at point d is given by s.

Now, in a practical embodiment the period of the sinusoid is substantially equal to one half the guided wavelength of the geometric mean of the highest and lowest frequencies required to be coupled. Ideally, zero dB coupling loss is required between the waveguides **1** and **4**, although in practice this ideal is not attainable because some reflection and losses always occur when performing coupling. However, for substantially zero dB coupling between the guides **1** and **4** the phase change in the semi-circular guide **1** must equal the phase change in the rectangular guide **4**, i.e.,

$$\beta TE_{01}^{\frown} \cdot r = \beta TE_{10}^{\square} \cdot s$$

where

$\beta TE_{01}^{\frown}$ = phase change coefficient for the $TE_{01}^{\frown}$ mode in semi-circular waveguide.

$\beta TE_{10}^{\square}$ = phase change coefficient for the $TE_{10}^{\square}$ mode in rectangular waveguide.

$$s=\int_0^b \sqrt{1+\left(\frac{dy}{dx}\right)^2}dx$$

$$\therefore T\beta E_{01}^{\frown}\cdot r=\beta TE_{10}^{\square}\int_0^b \sqrt{1+\left(\frac{dy}{dx}\right)^2}dx$$

From this general expression the amplitude of the sinusoid may be calculated.

In operation energy of the $TE_{01}^{\frown}$ mode and frequency range enters input port **2** and although the waveguide **4** has a higher phase velocity than the waveguide **1**, because the ratio of the lengths of the waveguides **1** and **4** substantially equal to the ratio of the phase velocities between the waveguides **1** and **4**, the energy is coupled into the waveguide **4** by the coupling slots **7**. Output energy in the $TE_{10}^{\square}$ mode is then taken from port **6**.

Referring to FIG. **4**, the embodiment shown therein has the rectangular waveguide **4** with its narrow wall adjacent the flat face of the semi-circular waveguide **1**. The waveguide **4** has a straight portion **27**, in which the coupling slots **7** are situated, provided along a common axis with the longitudinal axis of the waveguide **1**. As an alternative to coupling slots, circular holes may be used which are dimensioned such that they do not excite unwanted coupled modes in the waveguides from which output energy is to be taken. Phase compensating loops **28** are provided at predetermined distances along the waveguide **4** consistent with the physical limitations, i.e., bending radii, and with maintaining the compensating loops as short as possible. The compensating loops **28** are provided so as to substantially match the phase velocities of the two waveguides **1** and **4**. It will be realised by those skilled in the art that the length of the compensating loop becomes shorter as the frequency to be coupled in increased. In a practical embodiment of this nature the length of the compensating loop is calculated from the following equation:

$$\beta TE_{01}^{\frown}\cdot L_s-\beta TE_{10}^{\square}(L_r+L_r^1)=0$$

where

L_s = the length of the period of the sinusoidal waveguide **4**.

L_r = the mean length of the straight portion of waveguide **4**.

L_r^1 = the mean length of the compensating loop portion **28** of the waveguide **4**.

Referring to FIG. **5** a further embodiment of the invention is shown in which the waveguide supporting the waves having the higher phase velocities — waveguide **4** — is provided with phase compensating loops **28**. The waveguide **4** with its narrow wall abutting the flat face of waveguide **1** has a succession of inclined straight line portions with the compensating loops provided in the regions of maximum amplitude, where it is not possible to provide effective coupling apertures. The arrangement of FIG. **5** will produce a coupler having a shorter overall length than that of FIGS. **2** and **4**. The coupling apertures are preferably slots which are angled in the interconnecting wall such that they do not excite unwanted modes in the waveguide to which energy is coupled.

A further embodiment shown with reference to FIG. **6** has the approximately sinusoidal waveguide **4** provided with straight sided portions which form an apex beyond the extremities of the common interconnecting wall, the portions extending beyond the common interconnecting wall forming a compensating loop so as to substantially match the phase velocities of the waveguides **1** and **4**. The angle of inclination θ of the sides of the waveguide **4** is given by the equation:

$$\beta TE_{01}^{\frown}\cdot L-\beta TE_{10}^{\square}\cdot L/\cos\theta=0$$

where L = the length of half the period of the sinusoidal waveguide **4**.

The coupling slots **7** or holes are arranged and dimensioned in accordance with known principles and are typically spaced apart at their centres and have a length or diameter slightly less than a quarter of the wavelength of the geometric mean of the top and bottom extremities of the band of frequencies required to be coupled. As is well known the important factor is that the distance between the slots or holes is less than one half the waveguide wavelength at the highest frequency to be coupled. Where a frequency selective coupler is required, additionally to a careful selection of aperture size, the guide into which energy is being coupled will normally be arranged to be cut-off at approximately 20 percent below the lowest wanted coupled frequency.

Although the foregoing description has been applied to couplers for coupling from a relatively low phase velocity guide **1** to a relatively high phase velocity guide **4** the converse coupling action is of course also applicable. Those skilled in the art will now realise that the couplers in accordance with this invention are capable of coupling between any two waveguides where the relative phase velocities are different and require to be matched. Thus coupling may be performed between, for example, rectangular and triangular waveguide or elliptical and ridged rectangular waveguide, and also, between either the broad walls or narrow walls of rectangular waveguide and a further geometrically dissimilar waveguide, assuming of course that the slots or holes are laterally spaced in the waveguide walls so as to cut the waveguide wall surface currents.

As has already been shown the length of guide having the higher cut-off frequency need not be truly sinusoidal but only approximately sinusoidal. Thus a series of oppositely phased semi-circles may also be used to approximate to the sinusoidal shape.

Because couplers in accordance with this invention having one section that is sinusoidal in shape effectively slow the waves in the sinusoidally shaped guide in the longitudinal direction, such couplers are typically only 12 inches in length.

Couplers as hereinbefore described may be used in a band branching network, and such a network will now be described with reference to FIG. **7**. Referring to FIG. **7** a transitional section of waveguide **14** known per se transfers energy of the TE_{01}° mode from circular waveguide at its input **15** to semi-circular waveguides at its output **16**. The output **16** is connected to two serially connected couplers **17** and **18** which are in accordance with this invention and which provide coupling from semi-circular waveguide to rectangular waveguide. The couplers **17** and **18** have rectangular ports

19 and 20 respectively and rectangular output ports 21 and 22 respectively. The ports 19 and 20 are connected to matched loads (not shown) so that any undirected power in the couplers 17 and 18 may be absorbed. The semi-circular end of coupler 18 that is distant from coupler 17 is connected to a known slot coupler 23 which is capable of converting energy from semi-circular waveguide to rectangular waveguide since its semi-circular waveguide portion is arranged to have the same cut-off frequency as its rectangular waveguide portions. The coupler 23 is provided with a rectangular port 24 which is connected to a matched load (not shown) and with a rectangular output port 25. The semi-circular end of coupler 23 remote from coupler 18 is terminated in a matched load 26 known per se.

In a practical embodiment, energy of the TE_{01}° mode in circular waveguide and in the frequency range 30–90 Ghz is applied at input 15. This energy is then transferred to semi-circular waveguide by the transitional section 14. The coupling slots (not separately shown) in the coupler 17 are dimensioned so as to couple into the approximately sinusoidal rectangular portion thereof frequencies in the range 70–90 Ghz. Because energy in the remaining 30–70 Ghz must pass through the semi-circular portion of coupler 17 with the minimum of disturbance the coupling slots are made as small as possible to be consistent with the required 70–90 Ghz coupled band of frequencies. So that greater attenuation to low frequencies is produced by the rectangular portion of coupler 17 the rectangular portion of coupler 17 is arranged to be cut-off to frequencies below 70 Ghz. The coupler 17 is thus frequency selective and energy in the frequency range 70–90 Ghz in the $TE_{10}^{\square}$ mode is taken from the rectangular output port 21. Coupler 18 is similar to coupler 17 but transfers energy in the semi-circular portion thereof in the frequency band 50–70 Ghz to the rectangular portion thereof. Thus $TE_{10}^{\square}$ mode energy in the range 50–70 Ghz is taken from rectangular output port 22. The remaining frequency band in the semi-circular waveguide is coupled into rectangular waveguide by the slot coupler 23, thus, the coupler 23 is not required to be frequency selective. Energy of the $TE_{10}^{\square}$ mode in the remaining frequency band 30–50 Ghz is taken from rectangular output port 25.

I claim:

1. A waveguide coupler for coupling energy between two lengths of waveguide each capable of supporting electromagnetic waves having phase velocities different from those supportable by the other, a common interconnecting wall between said two lengths which is such that one of the waveguides has a non-rectilinear form in the longitudinal direction such that the ratio of the non-rectilinear length of said one waveguide to the length of the other waveguide is substantially equal to the ratio of their respective phase velocities and wherein coupling apertures are provided in the common interconnecting wall so that energy from an incident electromagnetic wave in said non-rectilinear length of waveguide is capable of being coupled to the other waveguide, or vice versa, to produce a coupled output electromagnetic wave therein.

2. A band branching system comprising first and second serially connected couplers as claimed in claim 1 for converting energy from a semi-circular sectioned waveguide to a rectangular sectioned waveguide, both first and second serially connected couplers being capable of operating at predetermined different ranges of frequencies and each capable of coupling from semi-circular sectioned waveguide to rectangular sectioned waveguide; a transitional section waveguide that is capable of transferring energy at one end thereof from a circular section waveguide to a semi-circular sectioned waveguide at the other end thereof; a slot coupler capable of operating at a lower range of frequencies than the serially connected couplers and also capable of coupling from a semi-circular sectioned waveguide to rectangular sectioned waveguide; and a load; wherein the semi-circular end of the transitional section waveguide is connected to the first serially connected coupler which possesses the higher frequency coupling apertures whilst the second serially connected coupler is connected to the slot coupler, the slot coupler in turn being connected to the load, the combination being capable of operating such that an incident wave possessing the TE_{01}° mode in circular waveguide is transferred to semi-circular waveguide by the transitional section waveguide, high frequency energy is coupled into rectangular section waveguide operating in the $TE_{10}^{\square}$ mode by the first serially connected coupler, mid-band frequency energy is coupled into rectangular section waveguide operating in the $Te_{10}^{\square}$ mode by the second serially connected waveguide, and the remaining low frequency energy is coupled into the rectangular section waveguide operating in the $TE_{10}^{\square}$ mode by the slot coupler.

3. A waveguide coupler for coupling energy between two lengths of waveguide each capable of supporting electromagnetic waves having phase velocities different from those supportable by the other, and having a common interconnecting wall therebetween which is such that the length of waveguide capable of supporting waves having the higher phase velocities is approximately sinusoidally shaped in the longitudinal direction and is provided with coupling apertures in the common interconnecting wall so that energy from an incident electromagnetic wave in one of said lengths of waveguide is capable of being coupled to the other length of waveguide to produce a coupled output electromagnetic wave therein.

4. A waveguide coupler as claimed in claim 3 wherein the overall dimensions of the apertures is just less than the spacing between the apertures, and the apertures and sinusoidal guide are dimensioned such that the apertures do not extend over the side walls of the sinusoidal guide, said overall dimensions of the apertures being made equal to a quarter of the wavelength of the geometric mean frequency of the extreme frequencies to be present in the waveguide intended to support the electromagnetic wave from which energy is to be coupled into the other guide.

5. A waveguide coupler as claimed in claim 3 wherein the sinusoidally shaped length of waveguide is of a rectangularly sectioned waveguide, and the other length of waveguide is a semicircularly sectioned length of waveguide, the common longitudinal wall between the two lengths of waveguide forming the flat wall of the semi-circularly sectional length of waveguide.

6. A waveguide coupler as claimed in claim 3 wherein the waveguide capable of supporting waves having the higher phase velocities is a true sinusoid.

7. A waveguide coupler as claimed in claim 6 wherein the coupling apertures are in the form of longitudinally disposed slots positioned such that the centre

of each slot lies substantially on the zero axis of the sinusoid midway between adjacent oppositely phased peaks of the sinusoid.

8. A waveguide coupler as claimed in claim **3** wherein the waveguide capable of supporting wave having the higher phase velocities is a succession of inclined straight line portions.

9. A waveguide coupler as claimed in claim **8** wherein the coupling apertures are in the form of longitudinally disposed slots positioned such that the centre of each slot lies substantially on the zero axis of the sinusoid midway between adjacent oppositely phased peaks of the sinusoid.

10. A waveguide coupler as claimed in claim **3** wherein the waveguide capable of supporting waves having the higher phase velocities is a succession of straight line portions having a common longitudinal axis with the waveguide capable of supporting waves having the lower phase velocities, and connected between the straight line portions are curved portions providing a compensating loop so as to substantially match the differing phase velocities between the two lengths of waveguide.

11. A waveguide coupler as claimed in claim **10** wherein the coupling apertures are provided along the common longitudinal axis and are slots.

12. A waveguide coupler as claimed in claim **10** wherein the coupling apertures are provided along the common longitudinal wall and are circular holes.

13. A waveguide coupler as claimed in claim **3** wherein the waveguide capable of supporting waves having the higher phase velocities is a ture sinusoid with a compensating loop provided in the region of maximum amplitude of the sinusoid so as to substantially match the differing phase velocities of the two lengths of waveguide.

14. A waveguide coupler as claimed in claim **13** wherein the coupling apertures are slots.

15. A waveguide coupler as claimed in claim **3** wherein the waveguide capable of supporting waves having the higher phase velocities is a true sinusoid which extends beyond the common interconnecting wall, the extended portion providing a compensating loop to substantially match the differing phase velocities of the two lengths of waveguide.

16. A waveguide coupler sa claimed in claim **15** wherein the coupling apertures are slots.

17. A waveguide coupler as claimed in claim **3** wherein the waveguide capable of supporting waves having the higher phase velocities is a succession of inclined straight line portions with a compensating loop provided in the region of maximum amplitude of the sinusoid so as substantially to match the differing phase velocities of the two lengths of waveguide.

18. A waveguide coupler as claimed in claim **17** wherein the coupling apertures are slots.

19. A waveguide coupler as claimed in claim **3** wherein the waveguide capable of supporting waves having the higher phase velocities is a succession of inclined straight line portions which extend beyond the common interconnecting wall, the extended portion providing a compensating loop substantially to match the differing phase velocities of the two lengths of waveguide.

20. A waveguide coupler as claimed in claim **19** wherein the coupling apertures are slots.

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