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WAVEGUIDE

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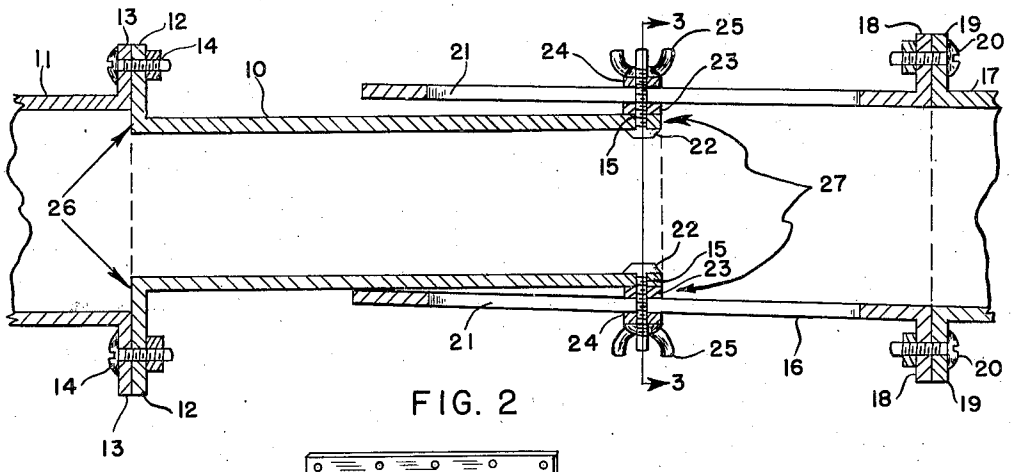


FIG. 2

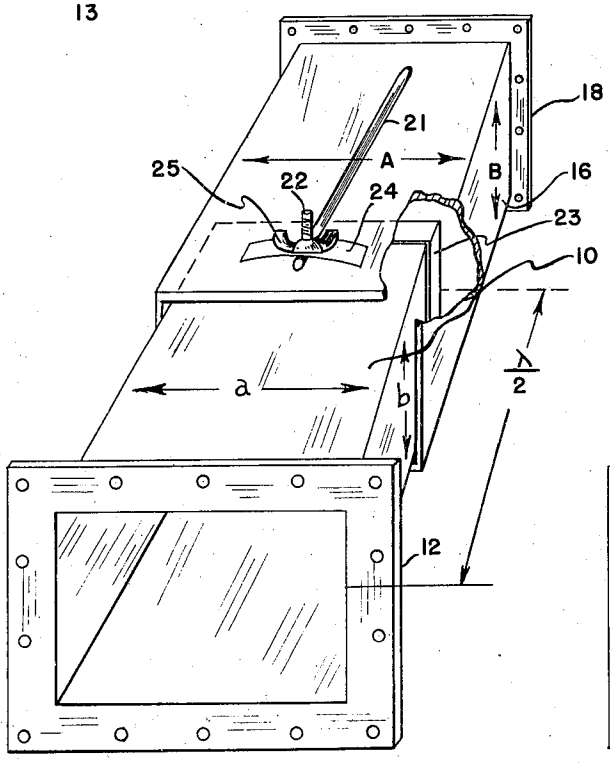


FIG. 1

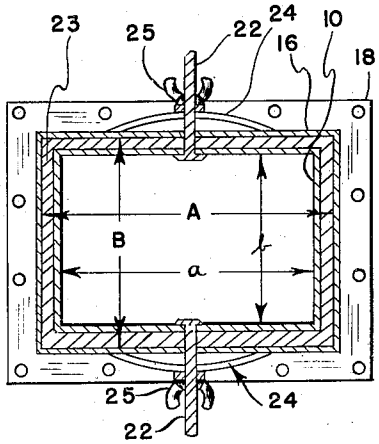


FIG. 3

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WAVE GUIDE

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This invention relates generally to the transmission of radio frequency energy. More particularly it relates to waveguides and the provision of a section of waveguide adjustable in length and permitting change in direction.

Due to the rigidity of the materials used and the type of construction that has been necessary, installations of waveguides for the transmission of high frequency energy have been confined to those of a permanent or semi-permanent nature. This has greatly restricted their use because in many types of installations where waveguides would have been of great advantage over cables or some other type of flexible transmission line the use of the latter has been dictated by the requirements of retaining flexibility and adjustability of length after the installation has been completed.

It is an object of this invention to devise a section of waveguide that is flexible and adjustable.

A further object of the invention is to devise a flexible and adjustable section of waveguide which will not introduce any electrical discontinuity that would cause excessive reflection or excessive standing wave ratios.

Generally a device made in accordance with the principles of this invention comprises a section of waveguide composed of two telescoping parts each having relative internal cross-sectional dimensions designed so that each section has substantially the same characteristic impedance.

Other objects, features, and advantages of this invention will suggest themselves to those skilled in the art and will become apparent from the following description of the invention taken in connection with the accompanying drawings in which:

Fig. 1 is an end perspective view partially cut away of one embodiment of the invention in its extended position.

Fig. 2 is a longitudinal cross-section of the same embodiment of the invention connected to a rigid waveguide system; and

Fig. 3 is a cross-section on line 3—3 of Fig. 2.

Part 10 is of rectangular shape and has internal cross-sectional dimensions slightly smaller than those of rigid waveguide section 11 to which it is attached by any suitable means such as flanges 12 and 13 and bolts 14. The internal cross-sectional dimensions of part 10 are designed so that its characteristic impedance will be equal to that of rigid waveguide section 11. In J. C. Slater's, "Microwave Transmission," published by McGraw-Hill Book Company, Inc., 1942, page 185, the formula for the characteristic impedance of a rectangular waveguide is given as follows:

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$$Zeq=\sqrt{\frac{u}{\epsilon}}\cdot\frac{1}{\sqrt{1-\left(\frac{\lambda_0}{2a}\right)^2}}\cdot\frac{b}{a}$$

where:

Zeq is the equivalent or characteristic impedance of a rectangular waveguide in the $TE_{(0,1)}$ mode

u is the permeability of the dielectric used

ϵ is the dielectric Constant of the dielectric used

λ_0 is the wave length in free space corresponding to the operating frequency

b is the smaller internal dimension

a is the larger internal dimension

In the design of the instant waveguide it is desired that the characteristic impedance of the part 10 be equal to that of rigid waveguide section 11. If a and b are the respective larger and smaller dimensions of the part 10, and if we call A and B the respective larger and smaller dimensions of the rigid waveguide section 11, then by equating we obtain:

$$\sqrt{\frac{u}{\epsilon}}\cdot\frac{1}{\sqrt{1-\left(\frac{\lambda_0}{2a}\right)^2}}\cdot\frac{b}{a}=\sqrt{\frac{u}{\epsilon}}\cdot\frac{1}{\sqrt{1-\left(\frac{\lambda_0}{2A}\right)^2}}\cdot\frac{B}{A}$$

$$\therefore b=a\frac{\sqrt{1-\left(\frac{\lambda_0}{2a}\right)^2}}{\sqrt{1-\left(\frac{\lambda_0}{2A}\right)^2}}\cdot\frac{B}{A}$$

Similar formulas may be used for other modes of operation and other types of waveguides.

The length of part 10 is equal to one-half the waveguide wavelength corresponding to the operating frequency. The end of part 10 has two two holes 15, 15 to connect part 10 to part 16 as explained hereinbelow.

Part 16 may be of any desired length but preferably is longer than part 10 and has internal cross-sectional dimensions the same as those of rigid waveguide section 11. It is connected at one end to a rigid waveguide section 17 by flanges 18 and 19 and bolts 20, similar to those connecting part 10 to rigid waveguide section 11, or by any other suitable method. The sides of part 16 where the current flow is longitudinal, the top and bottom as shown in the drawings, are provided with centrally located longitudinal slots 21, 21. Slots 21, 21 are adapted to receive adjustable clamping devices comprising bolts 22, 22, contact spacer 23, springs 24, 24, and wing nuts 25, 25. Bolts 22, 22 fit in holes 15, 15 in part 10,

It is obvious that the relative positions of parts 10 and 16 may be adjusted and then fixed by tightening nuts 25, 25 on bolts 22, 22 in slots 21, 21. Contact spacer 23 consists of a rectangular conductive member having inner cross-sectional dimensions so that it fits tightly over the end of part 10 and has outer cross-sectional dimensions a little smaller than the corresponding internal cross-sectional dimensions of part 16.

From the above description of a device embodying this invention it is obvious that a flexible and extendable section of waveguide has been provided.

The length of the section is determined by the amount of telescoping of part 10 into part 16 which is adjusted by the position of bolts 22, 22 in slots 21, 21. Angular displacement in both vertical and horizontal directions is made possible by the fact that the outer dimensions of contact spacer 23 is smaller than the internal dimensions of part 16 thus providing clearance on all sides and by the fact that part 10 is appreciably smaller than part 16 thus allowing large clearance where part 10 enters part 16.

It will now be shown how a section embodying the principles of this invention reduces electrical discontinuity to a minimum. Considering the energy to be passing from left to right, it encounters a discontinuity at the shoulder 26 formed by flange 12 since the dimensions of the path of the field are appreciably reduced at that point. This discontinuity arises solely from this physical change and not from any change in characteristic impedance because, as above stated, part 10 is so designed that it has the same characteristic impedance as that of rigid waveguide section 11. Therefore, reflections arising at this point are kept at a minimum.

As the energy continues, the next place at which it is possible for reflections to arise due to a discontinuity is at the shoulder 27 formed at the end of part 10 which is telescoped into part 16 because at this point there is again a change in dimensions. However, the change in dimensions here is of the same magnitude as that at shoulder 26 and in the opposite direction, that is, from small to large. The resultant reflections, therefore, are of substantially equal magnitude. Since part 10 is one-half of a waveguide wavelength long, shoulders 26 and 27 at which these two discontinuities occur are separated by one-half the wavelength of the operating frequency and any reflections arising therefrom will offset each other. The result is that, although there will be standing waves along part 10, these will not be transmitted along the waveguide in either direction. Since the characteristic impedances of parts 10 and 16 are the same, there is no discontinuity arising due to any change of impedance.

In analyzing the operation of this telescoping section it is convenient to consider the discontinuities presented at shoulder 26 and at shoulder 27 as lumped impedances at those points having substantially the same magnitude which are conjugates of each other and which are separated by one-half wavelength of the operating frequency.

Placing slots 21, 21 in the walls of the part 16 which carry currents in a longitudinal direction causes a minimum interference in current flow since they do not cut across the current path. The tightening of bolts 22, 22 in cooperation with springs 24, 24 assures good contact between contact spacer 23 and the portion of the top and

bottom walls of part 16 where the longitudinal flow of current is of highest value. Contact at the side walls of part 16 is not necessary because the current flow on those walls is transverse, that is, up and down these sides, and no current passes along those walls from one telescoping part to the other.

It has been explained that the internal cross-sectional dimensions of part 10 are made somewhat smaller than the corresponding dimensions of rigid waveguide section 11. These dimensions, however, should not be made so much smaller that energy is unable to pass through part 10 in the same mode in which it is transmitted through rigid section 11. An additional reason for not making these dimensions a great deal smaller than those of rigid section 11 is that the larger the change in dimensions the greater the reflections at shoulders 26 and 27. These dimensions should be made as close to those of rigid waveguide section 11 as fitting of the parts and operation of the device will allow.

It is thus seen that a device employing the principles of the present invention presents a flexible and adjustable waveguide section all elements of which have the same characteristic impedance, the points of electrical discontinuity of which are spaced so that reflections offset each other, and a minimum of interruption of current flow is caused by adjustment and setting means.

Several of these adjustable sections may be used together to achieve a considerable cumulative change in the physical direction of the waveguide or in the amount of adjustment of length.

The embodiment herein described and explained is based on the usual mode of operation of a rectangular waveguide, but it is to be understood that the principles of this invention apply with equal effect to and result in similar advantages for other modes of operation and apply to waveguides of various shapes and types.

While there has been here described what is at present considered to be the preferred embodiment of this invention it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the scope of the invention.

What is claimed is:

1. In a waveguide system, a flexible waveguide section comprising first and second relatively adjustable parts adapted to telescope one into the other, each of said parts being of rectangular cross-section, said first part having internal dimensions equal to those of said system, said second part having both internal cross-sectional dimensions smaller then those of said first part and determined by the formula

$$b=a\frac{\sqrt{1-\left(\frac{\lambda}{2a}\right)^2}}{\sqrt{1-\left(\frac{\lambda}{2A}\right)^2}}\cdot\frac{B}{A}$$

in which b is the smaller of the two internal dimensions of said second part, a is the larger internal dimension of that part, B and A are the corresponding internal dimensions of the part having the same internal dimensions as the waveguide system and λ is the wavelength in free space corresponding to the operating frequency, said second part having a length of one-half waveguide wavelength of the operating frequency.

2. The device according to claim 1, which further includes longitudinal slots formed in said first part in those walls thereof wherein current flow is in a direction that is parallel to the longest

axis of said part and clamping means extending through said second part and said slots whereby said wave guide parts may be fixed relative to each other.

3. The device according to claim 1, and contact spacer means positioned about that end of said second part that is telescoped into said first part, said contact spacer means having smaller external dimensions than the internal dimensions of said first part whereby said parts may be angularly adjusted.

4. The device according to claim 3, and clamping means extending through said second part, said contact spacer means and said first part whereby said wave guide parts may be fixed relative to each other.

5. The device according to claim 1, which further includes longitudinal slots formed in said first part in those walls thereof wherein current flow is in a direction that is parallel to the longest axis of said part, contact spacer means positioned about that end of said second part that is telescoped into said first part, said contact spacer means having smaller external dimensions than the internal dimensions of said first part whereby said parts may be angularly adjusted, and clamping means extending through said second part, said contact spacer means and said slots whereby said wave guide section parts may be fixed relative to each other.

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