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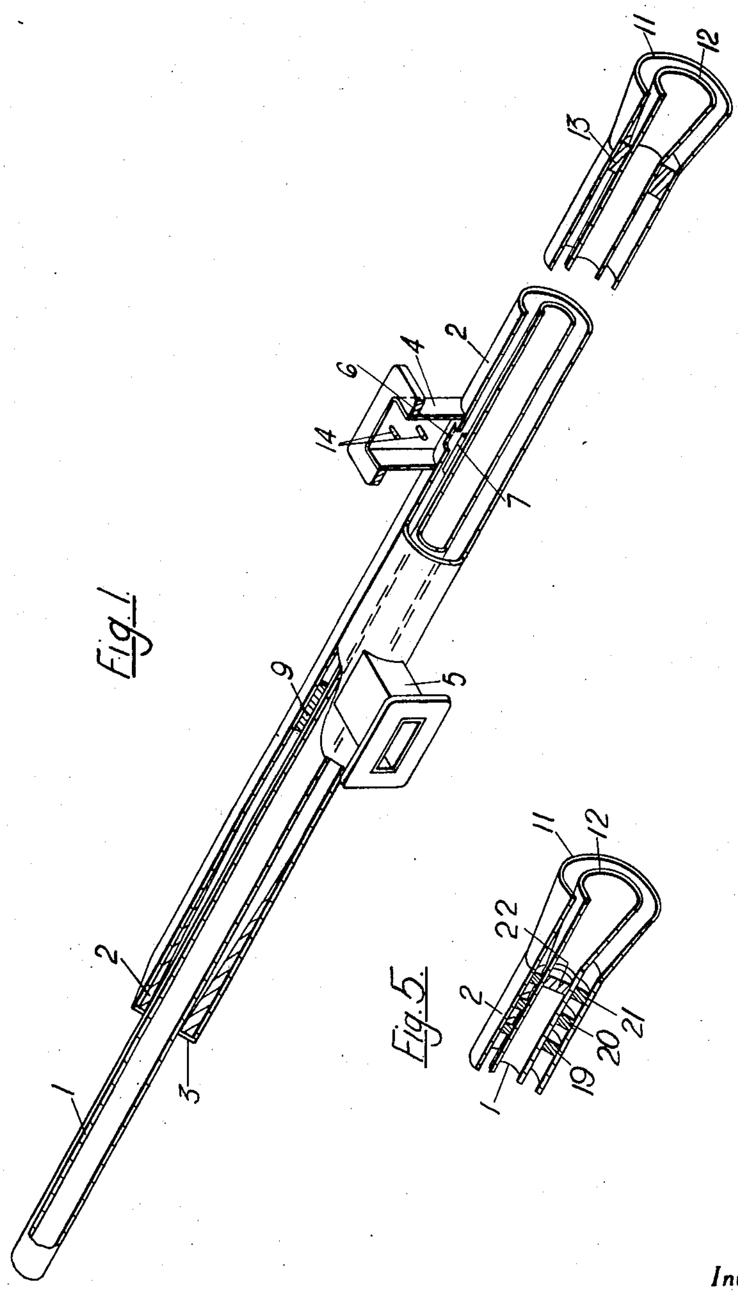
COAXIAL HORNS WITH CROSS-POLARIZED FEEDS
OF DIFFERENT FREQUENCIES

Filed May 5, 1967 2 Sheets-Sheet 1



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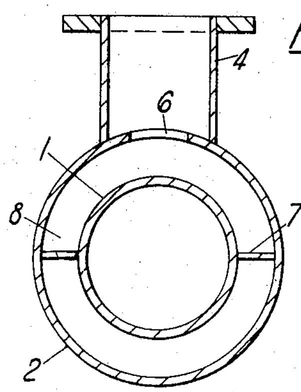

Fig. 2.

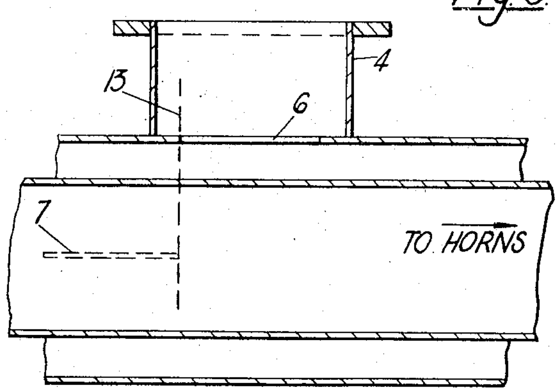

Fig. 3.

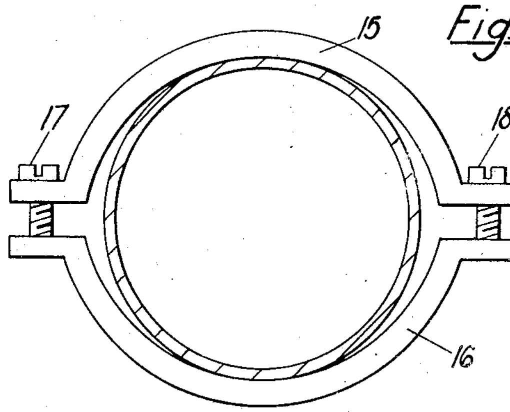

Fig. 4.

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COAXIAL HORNS WITH CROSS-POLARIZED FEEDS OF DIFFERENT FREQUENCIES

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U.S. Cl. 343—776 17 Claims

ABSTRACT OF THE DISCLOSURE

A waveguide junction for combining four independent microwave signals and feeding them to a common load. Two circular waveguides are mounted coaxially with respect to each other and two signals lying in an upper frequency band and having orthogonal planes of polarization are fed into the inner waveguide. Two mode converters are coupled to the outer waveguide to convert two respective input signals lying in a lower frequency band into two H_{11} coaxial mode signals having orthogonal planes of polarization. The two lower frequency band signals are transmitted between the two waveguides. Horns are provided at the ends of the waveguides for feeding to a common load, such as an antenna.

BACKGROUND OF THE INVENTION

This invention relates to waveguide junctions, and more particularly to a waveguide junction for combining a plurality of independent microwave signals and feeding them to a common load, such as a microwave antenna.

Microwave antennae and towers to support them are generally large and expensive structures. It is therefore desirable to reduce the number of antennae on a given radio link route to a minimum. One method reducing the number of antennae on a given radio link is to use a single antenna to radiate or receive two or more microwave signals occupying separate frequency bands. This type of system is well known in the art. Furthermore, a parabolic reflector can be used which can accommodate signals lying in a given frequency band, but having mutually perpendicular planes of polarization.

Therefore, the main object of this invention is to provide a waveguide junction for combining more than two independent microwave signals and for feeding them to a common load, such as a microwave antenna.

SUMMARY OF THE INVENTION

According to the invention there is provided a waveguide junction for the transmission of up to four multiplex microwave signals, two of said signals lying in an upper frequency band and two of said signals lying in a lower frequency band, the two signals in each of said bands having mutually perpendicular planes of polarization. The junction comprises an inner circular waveguide for transmission of the signals in the upper frequency band and an outer circular waveguide for transmission of the signals in the lower frequency band, the two waveguides forming a coaxial structure. Apparatus is coupled to the outer waveguide for converting the lower frequency signals into respective H_{11} coaxial mode signals having mutually perpendicular planes of polarization and for launching said H_{11} coaxial mode signals within the outer circular waveguide.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partly sectioned perspective view of the junction according to the invention;

FIGS. 2 and 3 are transverse and axial sections through one of the mode converters of the junctions; and

FIG. 4 is a diagrammatic view of a clamp; and

FIG. 5 is a partly sectioned perspective view of a portion of the junction of FIG. 1 which is modified according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a central waveguide **1** of circular cross section is located inside an outer waveguide **2**, also of circular cross section, and is axially aligned with the latter. The outer waveguide **2** has a non-reflecting termination **3** at one end thereof.

Two rectangular waveguides, **4** and **5**, having their larger dimension parallel to the longitudinal axis of the coaxial structure are joined to the outer waveguide **2**. The longitudinal axes of these rectangular waveguides **4** and **5** are normal to each other and also to the common axis of the coaxial waveguide structure. At each junction of one of the rectangular waveguides with waveguide **2**, the wall of the outer waveguide **2** is provided with a rectangular aperture **6** having dimensions smaller than the corresponding dimensions of the broad and narrow walls of the waveguides **4** and **5**. These apertures **6** form resonant irises in the rectangular waveguides. The aperture for waveguide **5** is not shown in the drawings for the sake of clarity and it is pointed out here that it is similar to the aperture shown for waveguide **4**.

Associated with each junction of the rectangular waveguides **4** and **5** and the outer circular waveguide **2** are two conducting planes or septa **7**, **8**, **9** and **10**, of which only **7** and **9** are visible in FIG. 1. Septum **8** is visible in FIG. 2. The two septa associated with a particular rectangular waveguide interconnect the outer and inner circular waveguides, both said septa lying in a plane which includes the axis of the inner waveguide, but is normal to the axis of the associated rectangular waveguide. The exact axial position of the septa is determined by experiment, but in general the narrow edges of the septa nearest to the horns **11** and **12** will approximately coincide with a narrow edge of the resonant iris which is furthest from the horns **11** and **12** at the right end of the coaxial waveguides. The approximate position of the septa relative to the resonant iris of a mode converter is indicated by the dashed line **13** in FIG. 3. The axial length of each septum is substantially equal to one half wavelength of the mean frequency of the signals lying in the lower band.

The inner and outer circular waveguides, **1** and **2**, respectively, terminate in horns **11** and **12** which radiate energy from the circular waveguides to a microwave aerial, not shown. The inner and outer waveguides **1** and **2** near the horns are kept in coaxial alignment by a separator **13** made of insulating material.

The operation of the junction will now be described.

Two signals, representing two respective communication channels, lying in an upper frequency band are transmitted through the central, circular waveguide **1**. Each of these signals is propagated as a H_{11} circularly polarized wave, but the planes of polarization of these waves are normal to each other. These two waves are derived from two separate H_{01} waves by well known mode conversion means, not shown, which are connected to the central waveguide **1** at the end opposite to the horn **12**.

Two signals, representing two other respective communication channels, occupy a lower frequency band and are transmitted as H_{11} coaxial mode waves in the annular space between the two waveguides **1** and **2**. The separation of these second two waves is based on the use of waves having planes of polarization which are normal to each other. These two waves are derived from two H_{01} waves transmitted in rectangular waveguides (not shown) which are connected to rectangular waveguides **4** and **5**. The orientation of these not shown waveguides is such that the direction of the vector representing the electric field is normal to the axis of the circular waveguides **1** and **2**. The resonant irises at the junctions of the rectangular waveguides **4** and **5** and outer circular waveguide **2** compensate for any impedance irregularities introduced by the junction and reduce reflections. To correct for residual discontinuities, capacitive trimmer screws **14** are provided on both rectangular waveguides. For clarity, only the tirmmer screws **14** associated with waveguide **4** are shown in FIG. 1. If required additional screws may be used on the circular waveguide, the axis of these screws lying in the plane of the E vector.

The H_{11} coaxial mode wave launched in the outer circular waveguide **2** would normally propagate in both directions. Since propagation is desired only in the direction towards the horns **11** and **12**, two metal septa **7, 8** and **9, 10** are placed in the space between the two circular waveguides **1** and **2** and behind the wall aperture **6** forming the resonant iris. The plane in which the septa **7, 8** and **9, 10** lie is parallel to the direction of the electrical field of the signal. The septa are in electrical contact with both circular waveguides **1** and **2** and present an effective short circuit to the H_{11} coaxial mode wave propagating to the left. See FIGS. 2 and 3 for more detailed cross-sectional views of the construction of a typical waveguide junction in the vicinity of rectangular waveguide **4**. For optimum performance the axial length of the septa is chosen to be approximately equal to $\lambda/2$ of the wave corresponding to the mean frequency of the signal. The wave is thus reflected by the septa towards the horns **11** and **12** and the propagation of the wave in the opposite direction is prevented.

The second wave in the lower frequency band is launched in a similar manner as the first wave in the lower frequency band, except that the rectangular waveguide, the iris and the septa are circumferentially displaced by 90° relative to the first mode converter. It should be noted that this H_{11} coaxial mode wave propagates past the septa of the first converter substantially without attenuation, since the plane of the septa of the first converter is normal to the direction of the electric field of the wave launched by the second converter.

The axial separation of the two rectangular waveguides **4** and **5** is not critical, but interaction between the two waves in the lower frequency band is reduced if this separation is not less than a wavelength of the signal.

In order to reduce or eliminate distortions which might arise due to reflections of waves propagated in the outer waveguide in the unwanted direction past the septa, a nonreflecting termination **3** is provided to absorb these unwanted waves.

In the mode converters described with reference to FIG. 1 the direction of the electrical vectors in each of the rectangular waveguides **4** and **5** was normal to the axis of the circular waveguide. It is however, also possible to achieve the same results if each of the rectangular waveguides **5** and **6** and the resonant irises are turned round their axes through 90°, so that the direction of the electrical vector is parallel to the axis of the circular waveguide. In this case however the plane containing each pair of septa is also rotated round the axis of the circular waveguide through 90°.

In order to improve the coupling between the coaxial waveguides and the microwave antenna used for radiating or receiving the signals, the circular waveguides **1** and **2** are terminated in horns **11** and **12**, which are designed by known methods to give the desired pattern of radiation and impedance match. In order to provide rigidity, and to maintain the coaxial relationship of waveguides **1** and **2**, the two coaxial horns **11** and **12** are separated by an insert **13** made of insulating material having low dielectric losses. The axial position of separator **13** is chosen to satisfy two separate requirements.

The first of these requirements is that the reflection caused by separator **13** should substantially reduce the reflection caused by the impedance discontinuity at the mouth of the horn. The optimum axial length and position of separator **13** are therefore determined by experiment. The second requirement for the separator **13** is that while it must transmit freely waves lying in the lower frequency band, it must reflect waves lying in the upper frequency band. This requirement arises from the need to reduce crosstalk between channels radiated by the inner horn into the outer horns. For this reason the separator **13** must have a transmission characteristic corresponding to a lowpass filter. This type of characteristic is obtained by placing a number of dielectric obstacles **19, 20** and **21** (see FIG. 5) in the space between the waveguides **1** and **2**, the separation between two adjacent obstacles being substantially equal to one quarter wavelength at the frequency of the signal to be passed, and half a wavelength of the frequency of the signal to be stopped. The separator **13** as shown in FIG. 1 will therefore in practice be replaced by a plurality of insulating washers **19, 20, 21** as illustrated in FIG. 5. Of course it is possible to simplify the design by separating the filter and reflection compensating functions referred to above. In this case the disc shaped obstacles **19, 20** and **21** would only perform the filter function, the reflection compensating function being performed by other and independent means, for example obstacles made of conducting material.

A dielectric obstacle **22** may also be placed in the central waveguide **1** in the vicinity of horn **12**. In this case, however, its sole function is to compensate for unwanted reflections generated at the mouth of horn **12**. As will become apparent later, the filter function of the obstacle **22** in this case is not required. The obstacles in both waveguides **1** and **2** perform a further important function of sealing the overall waveguide structure against atmospheric influences.

If the minimum and maximum frequencies defining the lower frequency band are designated by f_A and f_B, and the minimum and maximum frequencies defining the upper frequency band are designated by f_C and f_D respectively, then the following considerations apply for the choice of diameters of the inner and outer circular waveguides, **1** and **2**, respectively. The inner diameter d_0 of the inner waveguide **1** is chosen so that signals lying in the upper frequency band will propagate, but that signals lying in the lower frequency band cannot be propagated in it. In practice d_0 would be chosen to satisfy the inequality:

$$\frac{2\lambda_D}{3.412} \leq d_0 \leq \frac{2\lambda_C}{2.057}$$

where λ_D is the wavelength at frequency f_d and λ_C is the wavelength at frequency f_c.

Let d_1 be the external diameter of the inner waveguide **1** and d_2 be the internal diameter of the outer waveguide **2**. d_1 and d_2 would, in practice, be chosen to permit propagation in the H_{01} mode between the frequencies f_c and f_d and to suppress propagation of all other waveguide modes. Therefore d_1 and d_2 are chosen to satisfy the inequality:

$$\frac{2\lambda_B}{1.873\left(\frac{\pi}{2}\right)} \leq (d_1+d_2) \leq \frac{2\lambda_A}{1.025\left(\frac{\pi}{2}\right)}$$

where λ_B is the wavelength at frequency f_b and λ_A is the wavelength at frequency f_a.

When imperfect circular waveguides are used to transmit waves in two orthogonal polarizations some conversion of signals of one polarization into the other will take place. Such signal conversion should be reduced to a minimum since it will introduce distortion into the signal channels. The most serious defect met with in circular waveguides is their departure from true circularity due to various causes. These geometrical distortions may vary in magnitude and direction along the length of the waveguide and it is impossible to correct them individually.

In the present junction, therefore, polarization crosstalk is compensated for by providing distorting means to introduce deliberate geometrical distortion at one point along the axis of at least one of the circular waveguides. The purpose of the distorting means is to cause a signal to be generated within the waveguide which has a magnitude and phase angle opposite to that of the spurious signals generated in the waveguide due to the inherent geometrical distortions of the waveguide. The magnitude of the introduced geometric distortion and the circumferential position of the distorting means determines the magnitude and phase of the signal which is being introduced to cancel out the spurious signals generated due to irregularities in the waveguide.

Any arrangement which will exert a compressive force acting along a diameter of the waveguide and will cause the cross section of the waveguide to become elliptical will be satisfactory provided that the magnitude and direction of the deformation can be adjusted as required. A simple clamp meeting these requirements is shown in FIG. 4. It comprises two semicircular clamps **15** and **16** each having a radius of curvature slightly larger than the radius of the waveguide **2** with which it is to be used. The two clamps **15** and **16** are pressed against the waveguide by means of screws **17** and **18**. The clamp of FIG. 4 may also be provided for waveguide **1**, but that this may easily be designed by one ordinarily skilled in the art within the spirit of this invention and is therefore not illustrated or described in detail herein.

The four independent channels provided by the junction can be used either for transmission or for reception. In general however they will be used to provide two bidirectional communication channels.

It is to be understood that the foregoing description of specific examples of this invention is made by way of example only and is not to be considered as a limitation on its scope.

What we claim is:

1. A waveguide junction for transmitting a plurality of microwave signals, two of said signals lying in an upper frequency band and two of said signals lying in a lower frequency band, the two signals in each of said bands having mutually perpendicular planes of polarization, said junction comprising:

an inner circular waveguide for transmission of said signals in said upper frequency band;

an outer circular waveguide for transmission of said signals in said lower frequency band;

means for mounting said inner waveguide coaxially within said outer waveguide;

means for applying signals in said upper frequency band to said inner circular waveguide;

means for applying said signals in said lower frequency band to said waveguide junction including means coupled to said outer waveguide for converting said lower frequency signals into respective H_{11} coaxial mode signals having mutually perpendicular planes of polarization; and

filter means coupled between said outer and inner waveguides for transmitting signals lying in said lower frequency band annd for substantially reflecting signals lying in said upper frequency band.

2. A waveguide junction according to claim **1** wherein said means for applying said lower frequency signals includes first and second mode converting means coupled to said outer waveguide, each said mode converting means being adapted to convert respective H_{01} coaxial mode microwave signals in rectangular waveguides into respectice H_{11} coaxial mode signals having mutually perpendicular planes of polarization.

3. A waveguide junction according to claim **1** wherein said inner and outer waveguides each terminate in a horn at one end thereof for radiating said signals lying in said upper and lower frequency bands.

4. A waveguide junction according to claim **3** further comprising a nonreflecting termination coupled to said outer waveguide at the end thereof opposite to said horn.

5. A waveguide junction according to claim **1** further comprising means coupled to said waveguide to compensate for undesired signals having a spurious plane of polarization within said circular waveguides.

6. A waveguide junction according to claim **2** wherein said first and second mode converting means includes first and second rectangular waveguide sections, respectively, coupled to said outer waveguide.

7. A waveguide junction according to claim **6** wherein the respective axes of each of said two rectangular waveguide sections are normal to the longitudinal axis of said circular waveguides and wherein said rectangular waveguide sections have a circumferential separation of 90° on said outer waveguide.

8. A waveguide junction according to claim **6** further comprising:

a first resonant iris formed by a first aperture in the wall of said outer waveguide for matching the impedance of said first rectangular waveguide to said outer circular waveguide; and

a second resonant iris formed by a second aperture in the wall of said outer waveguide for matching the impedance of said second rectangular waveguide to said outer circular waveguide.

9. A waveguide junction according to claim **1** further comprising means coupled to said waveguides for causing each of said two H_{11} coaxial mode signals to be transmitted substantially in only one direction within said outer waveguide.

10. A waveguide junction according to claim **9**, wherein said means for causing said signals to be transmitted substantially in only one direction includes:

a first conducting septum coupled to said waveguides and extending in a plane parallel to the plane of the vector of the electric field of one of said lower frequency signals; and

a second conducting septum coupled to said waveguides and extending in a plane parallel to the plane of the vector of the electric field of the other of said lower frequency signals.

11. A waveguide junction according to claim **10** wherein the axial lengths of said first septum are substantially equal to one half the wavelength of the mean frequency of one of said lower frequency signals and wherein the axial lengths of said second septum are substantially equal to one half the wavelength of the mean frequency of the other of said lower frequency signals.

12. A waveguide junction according to claim **1** wherein the inner diameter of said inner waveguide is dimensioned so that the cut-off frequency of said inner waveguide lies above the upper frequency of said lower frequency band.

13. A waveguide junction according to claim **1** wherein said filter means comprises a plurality of dielectric washers mounted between said inner and outer circular waveguides, said washers having an axial separation from each other substantially equal to one half the wavelength at the midband frequency of the upper frequency band, said filter further providing a mechanical support between the inner and outer circular waveguides.

14. A waveguide junction according to claim **1** wherein an obstacle is mounted within each of said two circular waveguides adjacent to said horns and in a position such that reflections caused by said obstacle substantially cancel reflections caused by the impedance discontinuities at the mouths of said horns.

15. A waveguide junction according to claim **5** wherein said compensating means comprises:

means coupled to at least one of said circular waveguides for distorting the circumferential shape thereof; and

means for adjusting said distorting means to vary the magnitude and angular position of the distortion provided by said distorting means;

said distorting means causing a signal to be generated which will substantially cancel any spurious signals generated within said waveguides due to the inherent deviations from true circularity of said waveguides.

16. A waveguide junction according to claim **14** wherein each said distorting means includes:

first and second arcuate portions having respective radii of curvature larger than that of its associated circular waveguide; and

means for coupling said first and second arcuate portions together and around the periphery of one of said waveguides.

17. A waveguide junction according to claim **3** further comprising a dielectric means mounted between said first and second waveguides in the vicinity of said horns for maintaining the coaxial relationship between said waveguides.

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U.S. Cl. X.R.

333—21; 343—786