Oct. 24, 1950 W. W. MUMFORD 2,527,146

BROAD BAND COAXIAL LINE TO WAVE GUIDE COUPLER

Filed March 27, 1945

FIG. 1

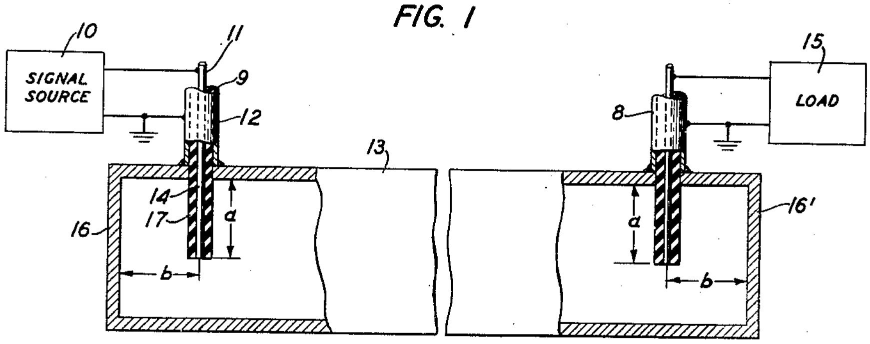


FIG. 2

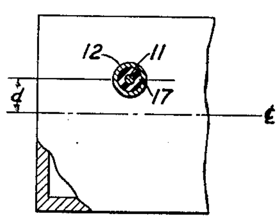


FIG. 3

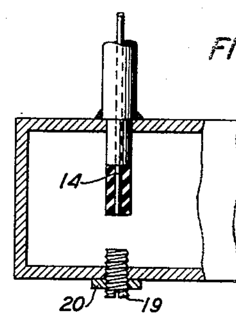


FIG. 4

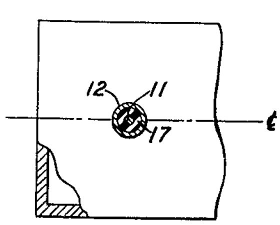
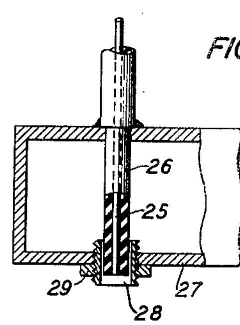


FIG. 5



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BROAD BAND COAXIAL LINE TO WAVE GUIDE COUPLER

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12 Claims. (Cl. 178—44)

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This invention relates to transmission coupling apparatus, and particularly to a coaxial line-to-wave guide transducer for use in a multifrequency microwave signaling system.

Heretofore in microwave signal systems, a tuner of the piston type has been embodied in a wave guide for matching the impedance of the wave guide and that of the coaxial conductor line connected therewith. Such piston tuning tends to provide the system substantially with a single frequency versus impedance characteristic. In other words, the frequency versus impedance characteristic of the coaxial-to-wave guide coupling tends to peak sharply at a particular operating frequency. Hence, reflection effects tend to be introduced in the signal system as the operating frequency varies from the particular frequency. This requires, at least, tuning the system for each different operating frequency. One way proposed heretofore to overcome such single frequency characteristic has been to extend the bare inner conductor of the coaxial conductor line entirely across the interior of the wave guide so that the free end of the inner conductor projects outside the wave guide. This tends to provide the coaxial-to-wave guide coupling with a frequency versus impedance characteristic which was substantially flat over a limited band width.

The present invention contemplates a coaxial line-to-wave guide transducer provided with a frequency versus impedance characteristic which is substantially flat over a wider band width than any obtained heretofore.

The main object of the invention is to match the impedance of a coaxial conductor line and a wave guide over a broad band of signal frequencies.

Another object is substantially to eliminate reflection effects over a broad band of signal frequencies.

In a specific embodiment of the present invention which is disclosed in connection with a conventional microwave signaling system described hereinafter, the inner conductor of the coaxial line and the insulation thereon are extended substantially one-fifth wavelength in the interior of the wave guide, each end wall of the wave guide has its inner surface located substantially one-fifth guide-wavelength from the vertical axis of the inner conductor positioned in proximity of each end wall, and a vertical plane embodying a vertical axis of the inner conductor is spaced from a vertical plane including the longitudinal axis of the wave guide. It has been found in practice that this coaxial-to-wave guide coupling is provided with a substantially flat frequency versus impedance characteristic for a ± 9 per cent band at a frequency of the order of 3,000 megacycles.

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In an alternate embodiment of the invention, the inner conductor and the insulation thereon are extended substantially one-fifth wavelength into the interior of the wave guide, each end wall of the wave guide has its inner surface located substantially one-quarter wavelength from the vertical axis of the inner conductor positioned in proximity thereof, and a vertical plane embodying the vertical axis of the inner conductor coincides with a vertical plane including the longitudinal axis of the wave guide. It has been found in practice that this coaxial-to-wave guide coupling exhibits a substantially flat frequency versus impedance characteristic for a ± 12 per cent band at a frequency of the order of 3,000 megacycles.

In both foregoing embodiments of the invention, a tuning plug is, or may be provided, movably mounted in one wall of the wave guide in axial alignment with the dielectric-covered inner conductor. A further embodiment of the invention concerns the extension of the insulation-covered inner conductor entirely across the interior of the wave guide, and the mounting of a tubular tuning plug in a movable manner in a wall of the wave guide in proximity of the free end of the insulation-covered inner conductor and in coaxial relation therewith. Such tuning plugs provide a variable capacity effect which tends to nullify any inductive effect inherent in the insulation-covered inner conductors and thereby further tends to widen the frequency versus impedance characteristics of the coaxial-to-wave guide coupling.

The invention will be readily understood from the following description taken together with the accompanying drawing, in which:

Fig. 1 is a schematic circuit diagram of a microwave signaling system illustrating the specific embodiment of the invention and showing an elevational view of the wave guide element partly in cross-section;

Figs. 2 and 4 are fragmentary plan views of the wave guide element in Fig. 1 shown partly in cross-section;

Fig. 3 is a fragmentary view of the wave guide element of Fig. 1, showing a modification of the invention, and

Fig. 5 is a fragmentary view of the wave guide element of Fig. 1 showing a further modification of the invention.

Herein, the term "wavelength" employed to identify the length of a dielectric-covered inner conductor in the interior of a wave guide relates to wavelength in free air; the term "guide-wavelength" designates distance in the interior of the wave guide; and the term "microwave" denotes a wave having a length less than one meter, and as short as one centimeter or one millimeter.

One known device for coupling a coaxial line to a wave guide and utilizing pistons for tuning such device to a particular operating frequency, and another known coupling device for the same purpose and extending a bare inner conductor of the coaxial line entirely transversely of the interior of the wave guide to establish a substantially flat frequency versus impedance characteristic over a limited frequency range in such coupling device are both disclosed in the copending application of A. C. Beck, Serial No. 429,358 filed February 3, 1942, which has matured into Patent No. 2,408,032 granted September 24, 1946.

Referring to Fig. 1, a source 10 of signal microwaves extending over a preselected frequency range is connected to an inner conductor 11 and an outer conductor 12 both of which constitute a coaxial conductor line 9. At the left-hand end of wave guide 13, the outer conductor 12 is electrically connected thereto, and a portion 14 of the inner conductor 11 covered with a suitable dielectric 17 extends into the interior of the wave guide 13 through an opening in the upper side wall thereof. The dielectric-covered portion 14 serves to effect transmission between the coaxial line 9 and wave guide 13 in the well-known manner. At the right-hand of wave guide 13, a similar coaxial line 8 effects transmission between wave guide 13 and load 15.

In accordance with the present invention as illustrated in Fig. 1, the portion 14 and the dielectric 17 thereon are both extended a distance a into the interior of wave guide 13, and the vertical axis of the dielectric-covered portion 14 is located a distance b from the inside surface of left-hand end wall 16 of wave guide 13. Referring to Fig. 2, the vertical axis of the dielectric-covered portion 14 lies in a vertical plane which is spaced a distance d from a vertical plane through the longitudinal axis of wave guide 13. The foregoing structure is duplicated for the coaxial line 8 and end wall 16′ located at the right-hand end of wave guide 13.

In one embodiment of Figs. 1 and 2, the size of the wave guide 13 was 1¼ by 2½ inches, and the coaxial lines 8 and 9 individually included an inner conductor 11 of No. 22 AWG tinned copper wire, an outer conductor 12 of two braided shields of No. 36 AWG tinned copper wire, and a dielectric 17 of low capacity rubber of approximately 0.196 inch in diameter enveloping the inner conductor and concentrically spacing the inner and outer conductors. The source 10 supplied microwaves having a wavelength in the range of 9.0 to 10.95 centimeters. It has been found in practice that the distance a for the dielectric-covered portion 14 in the interior of the wave guide was of the order of one-fifth wavelength, and the distance b for the location of the end walls 16 and 16′ with reference to the respective dielectric-covered portions 14 was of the order of one-fifth guide-wavelength. This embodiment was found to provide a substantial impedance match for microwaves in the wavelength range of 9.0 to 10.95 centimeters with a reflection loss of less than 0.02 decibel. This involved a frequency range of the order of ±9 per cent relative to the mid-frequency of the transmitted band. Accordingly, the embodiment of the coaxial-to-wave guide transducer of Figs. 1 and 2 had a frequency versus impedance characteristic which was substantially flat over a band of approximately 600 megacycles in a preselected frequency range of the order of 2,740 to 3,333 megacycles.

In Fig. 3 a tuning plug 19 is disposed in a lower side wall of wave guide 13 which is opposite to that through which the dielectric-covered portion 14 extends. The plug 19 has an axis in diametrical alignment with an axis of the dielectric-covered portion 14, and is preferably provided with a cross-section which is substantially equal to that of the dielectric-covered portion 14. The plug 19 is movably mounted in a suitable manner in the wave guide 13, and adjustments of its position serve to vary the distance and thereby the effective capacity between the inner surface of the wave guide 13 and the adjacent end of the dielectric-covered portion 14. This tends to nullify any inductive effect inherent in the dielectric-covered portion 14. The amount of the plug adjustment depends on the relative cross-sections of the dielectric-covered portion 14 and plug 19. A nut 20 maintains the plug 19 in place after individual adjustments thereof. Thus, the plug 19 tends to widen still further the frequency versus impedance characteristic obtainable in Figs. 1 and 2.

In another embodiment of Fig. 1, the vertical axis of the dielectric-covered portion 14 is located in a vertical plane which coincides with a vertical plane embodying the longitudinal axis of the wave guide 13 as shown in Fig. 4. The source 10 now supplies microwaves having a wavelength in the range of 8.94 to 11.4 centimeters. The size of the wave guide 13 is 1½ by 3 inches. The coaxial conductor lines are identical with those mentioned above. It has been found in practice that the distance a for the dielectric-covered portion 14 in the interior of the wave guide 13 was substantially 0.214 wavelength, and the distance b for the location of the end walls 16 and 16′ with reference to the respective dielectric-covered portions 14 was substantially 0.223 guide-wavelength. This embodiment was found to provide a substantial impedance match for microwaves in the wavelength range of 8.94 to 11.4 centimeters, with a reflection loss of approximately 0.033 decibel. This involved a frequency band of the order of ±12 per cent relative to the mid-frequency of the transmitted band. Thus, the embodiment of the coaxial-to-wave guide transducer of Figs. 1 and 4 had a frequency versus impedance characteristic which was substantially flat over a band of approximately 730 megacycles in a preselected frequency range of the order of 2,630 to 3,360 megacycles. The tuning plug 19 in Fig. 3 may also be used with Figs. 1 and 4 as desired.

The dimensions a and b in Figs. 1, 2 and 4 may increase or decrease from the foregoing specified distances depending on the frequency range of the transmitted signals, the variations of the sizes of the wave guide and/or the cross-section of the dielectric-covered portion of the inner conductor in the interior of the wave guide, and the on or off-center location of the dielectric-covered inner conductor with reference to the longitudinal axis of the wave guide. It has been found in practice that for Figs. 1, 2 and 4 the dimension a varied from approximately one-seventh wavelength to approximately one-quarter wavelength, and the dimension b varied approximately between one-seventh and one-quarter guide-wavelength. Within such dimensional variations, it has been found in practice that the coaxial-to-wave guide transducer had the frequency versus impedance characteristics mentioned hereinbefore.

In Fig. 5 the inner conductor **25** and solid dielectric **26** thereon are extended entirely across the interior of the wave guide **27** so that the lowermost ends of both the inner conductor and dielectric lie exteriorly of the outer surface of the wave guide. A tubular metallic member **28** suitably mounted in the wave guide is disposed coaxially with the lowermost end of the dielectric-covered inner conductor. Adjustments of the position of the member **28** relative to the end of the dielectric-covered inner conductor tend to vary the effective capacity between the wave guide and the inner conductor and dielectric. This tends to nullify any inductive effect inherent in the inner conductor and dielectric in the interior of the wave guide. A nut **29** holds the member **28** in position after each adjustment. The arrangement of Fig. 5 may be substituted for the coaxial conductor lines of Fig. 1.

In Fig. 1, for rectangular wave guides having the dimension ratio of one to two, for example, ⅝ by 1¼, ½ by 1, 1¼ by 2½, 1½ by 3 inches, etc., the distance d can be determined fairly closely with the following equation:

$$\frac{d}{\lambda}=\frac{6.5\lambda}{Z_0W}$$

where Z_0 is the characteristic impedance of the coaxial line **40**, d is the distance off-center, W is the width (inside dimension) of the wave guide **41**, λ the wavelength of the wave lying in the middle of the transmitted band, d, λ and W being in like units. This equation may be used for determining the off-center location of the portion **14** in Fig. 1.

What is claimed is:

1. In combination, a wave guide, and a coaxial line having its outer conductor connected to said guide and its inner conductor extending into the interior of said guide through an opening in one side wall thereof, said inner conductor being imbedded in a solid dielectric substantially throughout its entire length in the interior of said guide, and said inner conductor being positioned off the longitudinal axis of said guide.

2. In combination, a wave guide, a coaxial line having its outer conductor connected to said guide and its inner conductor extending into the interior of said guide through an opening in one side wall thereof and terminating in the interior of said guide, and a solid dielectric gripping substantially the entire longitudinal surface of said inner conductor in the interior of said guide, said inner conductor and said dielectric thereon extending into the interior of said guide to a distance lying between one-seventh and one-quarter wavelength, and said inner conductor having its vertical axis lying in a vertical plane spaced from a vertical plane embodying the longitudinal axis of said guide.

3. A combination according to claim 2 in which said inner conductor has its vertical axis lying in a plane which coincides with a plane embodying the longitudinal axis of said guide.

4. In combination, a wave guide, a coaxial line having its outer conductor connected to said guide and its inner conductor extending into the interior of said guide through an opening in one side wall thereof and terminating in the interior of said guide, a solid dielectric engaging substantially the entire length-wise area of said inner conductor in the interior of said guide, and a wall for closing the end of said guide in proximity of said inner conductor, said end wall having its inner surface located a distance which is greater than one-seventh guide-wavelength but less than one-quarter guide-wavelength from an axis of said inner conductor.

5. A signal system comprising a wave guide, a wall for closing one end of said wave guide, an electrical apparatus, a coaxial conductor line connected to said apparatus, said line having its outer conductor connected to said wave guide in proximity of said one end thereof and its inner conductor extending into the interior of said wave guide through an opening in one side wall thereof and terminating in the interior of said guide, a solid dielectric substantially surrounding said inner conductor in said wave guide, and means for providing said system with a substantially flat frequency versus impedance characteristic over a band width of at least 600 megacycles in a preselected range of the frequencies of the signaling waves being transmitted in said system, comprising said inner conductor and dielectric extending substantially one-fifth wavelength in the interior of said wave guide, said end wall having its inner surface located substantially one-fifth guide-wavelength from the vertical axis of said inner conductor, and said inner conductor having its vertical axis lying in a vertical plane spaced from a vertical plane embodying the longitudinal axis of said wave guide.

6. A circuit comprising a wave guide, a wall for closing one end of said wave guide, electrical apparatus for waves whose frequencies extend over a broad band, a coaxial conductor line having its inner and outer conductors connected to said apparatus, said line having its outer conductor connected to said wave guide in proximity of said one end wall and its inner conductor projecting into the interior of said wave guide through an opening in a side wall thereof and terminating in the interior of said guide, a solid dielectric substantially surrounding said inner conductor in the interior of said guide, and means for providing said circuit with a substantially flat frequency versus impedance characteristic over a band width of at least 730 megacycles in a preselected range of the frequencies of the signaling waves being transmitted in said circuit, comprising said inner conductor including said dielectric thereon projecting substantially one-fifth wavelength in the interior of said wave guide, said end wall having its inner face located substantially one-quarter guide-wavelength from the vertical axis of said inner conductor, and said inner conductor having its vertical axis disposed in a vertical plane coinciding with a vertical plane embodying the longitudinal axis of said wave guide.

7. In combination, a wave guide, a coaxial line having its outer conductor connected to said guide and its inner conductor extending across the interior of said guide through diametrically aligned openings in opposite side walls thereof, said inner conductor being entirely surrounded with a solid dielectric along its axial length, and a hollow conducting member movably mounted on one side wall of said wave guide in coaxial relation with the free end of said inner conductor.

8. In combination, a wave guide, a coaxial line having its outer conductor connected to said

guide and its inner conductor extending into the interior of said guide through an opening in one side wall thereof, a solid dielectric engaging substantially the entire longitudinal area of said inner conductor in the interior of said guide, and a member movably mounted in a further side wall of said guide, said further side wall being opposite said one side wall, said inner conductor and member having axes in diametrical alignment, said member being movable along its axis aligned with said inner conductor.

9. In combination, a wave guide, a coaxial line comprising an outer conductor connected to said guide and an inner conductor extending into the interior of said guide through an opening in a side wall thereof, a non-conductive sleeve engaging substantially the entire length-wise surface of said inner conductor in the interior of said guide, and a wall for closing the end of said guide nearest to said inner conductor, said wall having its inner surface spaced from an axis of said inner conductor a distance which is at least approximately one-seventh but substantially less than one-quarter guide-wavelength at the mid-frequency of the frequency band of signaling waves transmitted in said guide.

10. A combination according to claim 1 which includes a member movably mounted in a side wall of said guide opposite said one side wall, said inner conductor and member having axes in alignment, said member being movable with respect to said inner conductor along its axis aligned with said inner conductor.

11. A combination according to claim 1 which includes said inner conductor terminating in the interior of said guide, and a member movably mounted in a side wall of said guide opposite said one side wall, said inner conductor and member having axes in diametrical alignment, said member being movable with respect to said inner conductor along its axis aligned with said inner conductor.

12. A broad band coupler for wave guide of elongated rectangular cross section and a coaxial line having a solid dielectric filling the space between its inner and outer conductors, comprising a reflecting barrier in said guide, said line having its outer conductor connected to and terminating at a broader side wall of said guide adjacent said barrier and its inner conductor projecting into the interior of said guide and terminating therein, said dielectric continuing into the interior of said guide as a sheath for said projecting inner conductor, said last-mentioned dielectric being substantially coextensive with said projecting inner conductor, and said inner conductor being positioned substantially off the center of said broader side wall.

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