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2,433,074

HIGH-FREQUENCY COUPLING DEVICE

Filed July 2, 1943

FIG. 1.

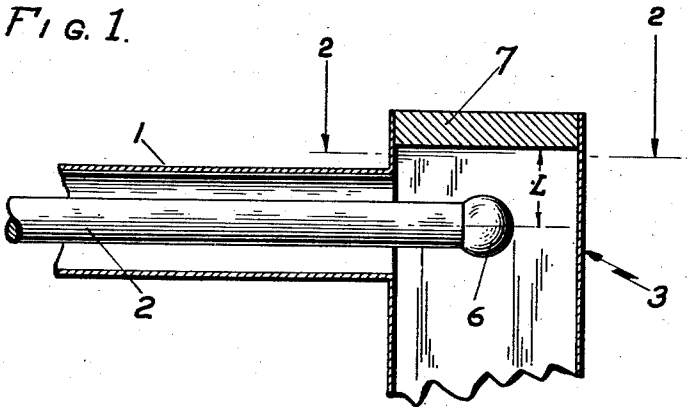
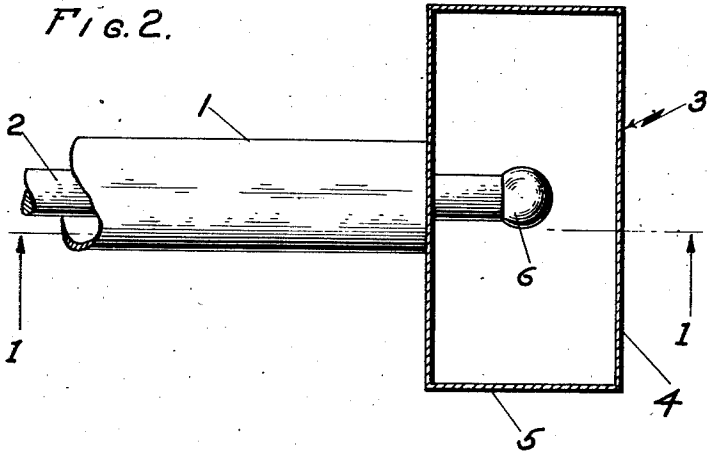


FIG. 2.



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UNITED STATES PATENT OFFICE

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HIGH-FREQUENCY COUPLING DEVICE

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4 Claims. (Cl. 178-44)

1 This invention relates to guided electromagnetic wave transmission, and more particularly to a coupling arrangement between a coaxial conductor transmission line and a dielectric wave guide.

In coupling a coaxial conductor transmission line to a dielectric wave guide, it is desirable that there be no reflection at the point of coupling in order to provide a free and efficient transfer of electromagnetic wave energy from one system to the other.

An object of this invention is to accomplish a coupling of the foregoing type with substantially no reflection at the coupling point.

Another object is to produce such a coupling by a simple and compact structure.

The foregoing and other objects of this invention will be best understood from the following description of an exemplification thereof, reference being had to the accompanying drawing wherein:

Fig. 1 is a section through my novel coupling system taken along line 1-1 of Fig. 2; and

Fig. 2 is a section taken along line 2-2 of Fig. 1.

The coupling system shown comprises a coaxial conductor transmission line consisting of a tubular conductor 1 having a central conductor 2, said transmission line being coupled to a hollow dielectric wave guide 3. The members 1, 2 and 3 are formed of highly conducting material, such as copper or brass. The wave guide 3 is preferably of rectangular cross-section having a long side 4 and a short side 5. One end of the tubular conductor 1 is joined to one long side 4 of the wave guide 3 which is provided with an opening therein substantially of the size of the tubular conductor 1 through which the conductor 2 projects for a substantial distance into the wave guide 3.

When electromagnetic waves of sufficiently high frequency are transmitted along the coaxial conductor transmission line, the above coupling arrangement will excite the wave guide 3 in what is known as the $TE_{0,1}$ mode, and such waves will be propagated down through the wave guide. The $TE_{0,1}$ mode is that mode in which the electric vector of the propagated wave is always transverse to the direction of propagation of the wave in the wave guide. There is a single maximum of field distribution along one side of the wave guide, and no such maximum along the other side of said wave guide. In the arrangements which I have illustrated, the single maximum will occur along the long side of the wave guide. The $TE_{0,1}$ mode is the simplest and most commonly

2 used mode of excitation of wave guides of this type.

In order for the energy of the wave which is propagated along such a system to be effectively and efficiently transferred from the coaxial conductor transmission line to the wave guide, it is desirable that there be no reflections at the point of coupling between these two systems. For this purpose the impedance of the conductor 2 which extends into the wave guide 3 and forms a probe should be matched to the impedance of the coaxial conductor transmission line. I have found that if the probe end of the conductor 2 is terminated by a partial spherical member 6, that is, a spherical member which is flattened in the plane where it meets the probe end of said conductor 2, bearing the proper relationship both to the diameter of the conductor 2 and to the inside diameter of the conductor 1, the impedance of the coaxial conductor transmission line can be matched with the impedance of the probe and thus produce the desired reflectionless coupling. In such an arrangement also a reflecting plate 7 is located in the wave guide 3 at the proper distance behind the probe so as to form a resonant chamber termination for said wave guide.

I have found that using the following notation:

S=diameter of partial sphere 6;

A=diameter of conductor 2;

B=inner diameter of conductor 1;

approximately the following relationship produces the desired matched impedance coupling:

$$\frac{S}{A} = 2.442 - \frac{1}{1.694} \times \frac{B}{A}$$

Thus, for example, in a coupling arrangement in which the inner diameter of the conductor 1 was .812 inch, the diameter of the conductor 2 was .375 inch and the diameter of the partial sphere 6 was .4375 inch, substantially no reflection occurred at the coupling point. In this case the wave guide was 1.344 inches by 2.834 inches in internal cross-section, and the probe extended into the wave guide .965 inch.

A consideration of the above equation shows that as the ratio of B/A increases, the ratio of S/A decreases. Thus, for example, where the internal diameter of the conductor 1 was 1.527 inches and the diameter of the conductor 2 was .625 inch, the diameter of the partial sphere 6 was likewise .625 inch. In order for proper operation, the partial sphere 6 should be attached to the conductor 2 so that the section through the partial sphere in the plane where it is attached to the conductor should be of the same size as the

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cross-section of the conductor. Thus the last example cited represents a limiting case in which the member 6 is a hemisphere. If the ratio of B/A were to be increased beyond that indicated, the ratio of S/A would be less than one, and therefore the condition of matched section of the partial sphere and the cross-section of the conductor would not ordinarily be obtained. However, for conditions of this kind I have found that the end of the conductor 2 as it approaches the partial sphere 6 may be gradually decreased in diameter so as to afford at least a one-to-one ratio between the diameter of the partial sphere and the reduced diameter of the end of the conductor 2.

Coaxial conductor transmission lines and dielectric wave guides, such as I have described above, are usually designed to carry electromagnetic waves of approximately a predetermined wave length in the wave guide, which wave length may be represented by λ . In Fig. 1 I have designated the distance between the reflecting surface of the plate 7 and the center of the probe as L. Theoretical considerations have indicated that L should be about

$$\frac{\lambda}{4}$$

I have found, however, that proper operation is secured in my arrangement when L is approximately

$$\frac{\lambda}{6}$$

I have found that coupling systems constructed in accordance with the foregoing principles have enabled the transmission of substantially increased quantities of electromagnetic power therethrough. Also I have found that such a coupling arrangement remains matched in its impedance to the impedance of the coaxial conductor transmission line over a relatively substantial frequency variation in the electromagnetic wave without further adjustment. It is to be understood that the numerical values of particular systems which I have listed above are given merely by way of example, and it is further understood that the principles of my invention may be applied to a wide variety of coupling systems.

What is claimed is:

1. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow wave guide, said inner conductor extending into said hollow wave guide through an opening in a side wall of said wave guide and forming a probe, said probe being placed in a transverse electric mode-exciting relationship with respect to said hollow wave guide, said outer conductor being connected to said wall, said probe terminating in a member comprising a portion of a sphere, the diameters of said member, said probe and said outer conductor bearing approximately the relation

$$\frac{S}{A} = 2.442 - \frac{1}{1.694} \times \frac{B}{A}$$

where S is the diameter of the member, A is the diameter of the probe and B is the inner diameter of the outer conductor.

2. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow wave guide, said inner conductor extending into said hollow wave guide through an opening in a wall of said wave guide and forming a probe, said probe being placed in a transverse electric mode-

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exciting relationship with respect to said hollow wave guide, said outer conductor being connected to said wall, said probe terminating in a spherical member which is flattened in the plane where it meets said probe, the area of the flattened portion being equal to the cross-sectional area of said probe, and an electromagnetic wave-reflecting plate disposed across said wave guide at one side of said probe and spaced from the center of said probe a distance approximately equal to one-sixth of the wave length of the electromagnetic wave which said wave guide is adapted to transmit.

3. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow wave guide, said inner conductor extending into said hollow wave guide through an opening in a side wall of said wave guide and forming a probe, said probe being placed in a transverse electric mode-exciting relationship with respect to said hollow wave guide, said outer conductor being connected to said wall, said probe terminating in a member comprising a portion of a sphere, the diameters of said member, said probe and said outer conductor bearing approximately the relation

$$\frac{S}{A} = 2.442 - \frac{1}{1.694} \times \frac{B}{A}$$

where S is the diameter of the member, A is the diameter of the probe and B is the inner diameter of the outer conductor, and an electromagnetic wave-reflecting plate disposed across said wave guide at one side of said probe and spaced from the center of said probe a distance approximately equal to one-sixth of the wave length of the electromagnetic wave which said inner guide is adapted to transmit.

4. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a rectangular hollow wave guide, said inner conductor extending into said hollow wave guide through an opening in a side wall of said wave guide and forming a probe, said probe being placed in the TE_{0,1} mode-exciting relationship with respect to said hollow wave guide, said outer conductor being connected to said wall, said probe terminating in a member comprising a portion of a sphere, the diameters of said member, said probe and said outer conductor bearing approximately the relation

$$\frac{S}{A} = 2.442 - \frac{1}{1.694} \times \frac{B}{A}$$

where S is the diameter of the member, A is the diameter of the probe and B is the inner diameter of the outer conductor, and an electromagnetic wave-reflecting plate disposed across said wave guide at one side of said probe and spaced from the center of said probe a distance approximately equal to one-sixth of the wave length of the electromagnetic wave which said wave guide is adapted to transmit.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,147,717	Schelkunoff	Feb. 21, 1939
2,307,012	Barrow	Jan. 5, 1943
2,316,151	Barrow	Apr. 13, 1943

Certificate of Correction

Patent No. 2,433,074.

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WILLIAM G. TULLER

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Column 2, line 42, for "1.344" read *1.334*; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 9th day of March, A. D. 1948.

[SEAL]

THOMAS F. MURPHY,

Assistant Commissioner of Patents.