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M. D. FISKE

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GAS DISCHARGE COUPLING DEVICE FOR WAVEGUIDES

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Fig. 1.

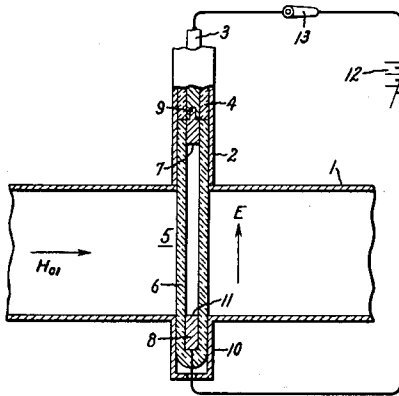


Fig. 2.

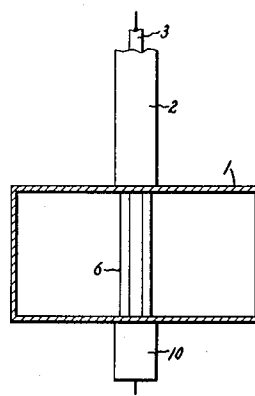


Fig. 3.

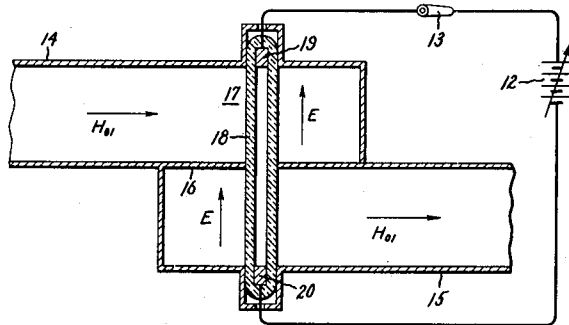
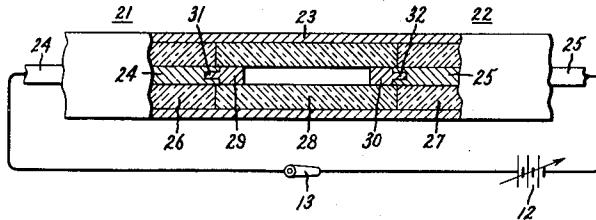


Fig. 4.



Inventor:
Milan D. Fiske,
by *Paul A. Frank*
His Attorney.

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GAS DISCHARGE COUPLING DEVICE FOR WAVEGUIDES

Milan D. Fiske, Burnt Hills, N. Y., assignor to General Electric Company, a corporation of New York

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Divided and this application December 23, 1949; Serial No. 134,789

10 Claims. (Cl. 333—7)

This present application is a division of my copending application S. N. 484,736, filed April 27, 1943, and relates to apparatus and methods for coupling ultra high frequency systems; and more particularly to apparatus and methods for coupling dielectric wave guides of the hollow-pipe type, or interconnecting wave guides and coaxial transmission lines.

It is an object of my invention to provide a new and improved coupling device for ultra high frequency systems.

It is a further object of my invention to provide a new and improved device for coupling a dielectric wave guide of the hollow-pipe type to a coaxial or concentric transmission line.

It is a still further object of my invention to provide a new and improved coupling means for interconnecting dielectric wave guide sections or concentric transmission lines.

It is a still further object of my invention to provide a new and improved apparatus and methods for coupling or tuning elements or parts of ultra high frequency systems.

It is a still further object of my invention to provide a new and improved device whereby the coupling effect between elements of an ultra high frequency system may be readily controlled.

Briefly stated, in accordance with a general aspect of my invention, I provide new and improved apparatus and methods for coupling elements or parts of high frequency systems, such as systems designed for the utilization of ultra high frequency electromagnetic waves or microwaves. A confined or localized region of charged electrical particles is employed as a coupling element or electrode, the density of which may be controlled to establish or control the coupling between elements or parts of the high frequency system. Where a high coupling coefficient is desired, the density of the particles comprising the discharge is controlled so that in effect the discharge path acts as a conductor, serving as an element or electrode for the interconnection of related parts of the system. By controlling the electric discharge path, this apparatus may be employed to accomplish a variety of results. Some of the uses to which it may be put are the provision of a continuously variable attenuator, a simple on-off control of the coupling between elements or units, or a controllable tuning element.

The above-described discharge path may be furnished by an electric discharge device, either of the high vacuum type or of the type employing an ionizable medium, and in which a dielectric evacuated envelope encloses a plurality of electrodes between which the electric discharge is established or provided.

In accordance with a still further feature of my invention, the discharge device may be of peculiar configuration to accomplish the above-described coupling effect, while minimizing reflections of electromagnetic waves due to interconnection of the system parts. For example, where the coupling device which I provide is employed for the interconnection of a concentric or coaxial transmission

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line and a dielectric wave guide, the enclosing envelope is preferably of relatively small longitudinal cross sectional area relative to the transverse cross sectional area of the guide. The enclosing envelope may be adapted to be inserted within an outer conductor of a concentric transmission line and provided with an electrode, or electrodes, at each end thereof to permit ready connection to an inner conductor of a coaxial transmission line.

For a better understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims. Fig. 1 illustrates an embodiment of my invention as applied to a system for coupling a dielectric wave guide of the hollow-pipe type and a concentric transmission line, and Fig. 2 is a transverse cross sectional view of the guide showing the position of the coupling device therein. Fig. 3 is another modification of my invention showing an arrangement for coupling a pair of dielectric wave guides of the hollow-pipe type. Fig. 4 shows the manner in which my invention may be applied to a system for controlling the coupling between two concentric transmission lines.

Referring now more particularly to Fig. 1, I have there illustrated my invention as applied to an ultra high frequency system, peculiarly adapted for transmitting microwaves and which may comprise a dielectric wave guide of the hollow-pipe type defined by a conductive or metallic member 1 defining therein a region through which the electromagnetic waves are propagated dielectrically. While it is to be appreciated that my invention is applicable to systems for controlling the propagation of electromagnetic waves of either the transverse electric or the transverse magnetic type, I have chosen to represent my invention as applied to a system where H_{01} type waves may be utilized. A concentric or coaxial transmission line comprising an outer conductor 2, preferably metallic in nature, and an inner conductor 3 is connected to the dielectric wave guide through the coupling device explained immediately hereinafter, and may be connected to other elements of a high frequency system (not illustrated). Conductors 2 and 3 are separated and maintained in spaced relation by means of a tubular insulator 4, and the outer conductor 2 is preferably arranged to provide therein a recess to receive one end of a coupling device described immediately hereinafter.

The coupling device which I provide comprises means, such as an electric discharge device, for establishing within the region defined by member 1 a confined or localized region of charged electrical particles, such as electrons or ions, which controls the coupling effect or the coefficient of coupling between the wave guide and the coaxial transmission line. This means may comprise an electric discharge device 5 including a dielectric or vitreous envelope 6, preferably of elongated tubular form and supporting a plurality of electrodes, such as a pair of electrodes 7 and 8, between which an electric discharge is established. The longitudinal cross sectional area of the electric discharge device 5 with respect to the transverse cross sectional area of the dielectric wave guide is relatively small as illustrated in Fig. 2 which is a partial transverse cross sectional view of the guide and the transmission line.

Either, or both, of the electrodes 7 and 8 of the discharge device 5 may be adapted to facilitate connection to an external conductor, such as the inner conductor, of a coaxial transmission line, in which case the electrodes, such as electrode 7, constitute a part of the end of the discharge device having an externally accessible area which is placed in juxtaposition to the conductor with which it is desired to make connection. It will be noted that electrode 7 immediately engages inner conductor 3 of the transmission line and, as illustrated, may be provided with a centrally positioned cylindrical protuberance 9

which is inserted within a recess provided by inner conductor 3.

So that the connection between the coupling device and a concentric transmission line may be continuous, the transverse dimensions or diameters of the electrode 7 and the envelope 6 may be made substantially equal to the diameters of inner conductor 3 and tubular insulator 4, respectively, so that the interconnection of the coupling device to the line presents substantially no discontinuities, thereby minimizing reflection of the electromagnetic waves.

The discharge device 5, and particularly the enclosing envelope 6, may be of sufficient length to extend through the dielectric wave guide and having one extremity thereof supported by a cylindrical cup 10 comprising a part of member 1. Furthermore, in order to minimize discontinuities offered to the transmission of electromagnetic waves within the guide, the electrodes, such as electrode 8, may be positioned so that the upper surface 11 is in the same plane with the bottom inner surface of the member 1 which defines the region through which the waves are propagated.

In accordance with one aspect of my invention, I contemplate the provision of a coupling means, such as a column or region of charged electrical particles, either electrons or ions, the density of which may be sufficient so that the discharge path or the electric column serves as a conductor to effect coupling between the parts of the high frequency system. In accordance with a further feature, I contemplate the provision of an electric discharge path of controllable density to control the coupling effect or the coefficient of coupling between such parts. For example, the discharge device 5 may include an ionizable medium and the electrodes 7 and 8 of discharge device 5 may be energized from a controllable source of voltage or current, such as a battery 12, the magnitude of the voltage impressed across the electrodes determining the density of the charged electrical particles within envelope 8. I have found that the coupling effect between the coaxial transmission line and the dielectric medium of the wave guide is a function of the density of the charged electrical particles, the coupling effect increasing as the density increases. An arrangement such as that shown in Fig. 1 may be employed as a simple on-off coupling control, in which instance a suitable circuit controlling means, such as a switch 13, may be interposed between the battery 12 and the coupling device, the coupling being substantially zero in the absence of an electric discharge.

Upon the establishment of an electromagnetic wave within the wave guide having a direction of propagation indicated, for example, by the arrow H_{01} , the electric component of the incident electromagnetic field will be substantially perpendicular to the direction of wave propagation as indicated by the arrow E . Without entering into an extended discussion of the mechanism by virtue of which the coupling is effected between the wave guide and the concentric transmission line, it may be stated that the region of charged electrical particles serves as a wave coupling element between the wave guide and the inner conductor 3 and the outer tubular conductor 2 of the transmission line. I have found that the degree or coefficient of coupling increases as the density of the charged particles increases.

Coupling arrangements such as that shown in Fig. 1 may be employed for tuning an element, or elements, of an ultra high frequency system. In this manner, the electric discharge device 5 comprises an electrically controlled, continuously variable tuning element. In addition, by controlling the density of the discharge within device 5, the device may be employed as a continuously variable attenuator for a dielectric wave guide. A still further application would be the utilization of such an arrangement for bleeding or deriving energy from a dielectric

wave guide, the sink (not shown) being connected to the concentric transmission line.

Fig. 3 diagrammatically illustrates another arrangement to which my invention may be applied, that is, for coupling a pair of dielectric wave guides 14 and 15 which may be overlapping having a common boundary 16. The coupling device may be of a configuration and form generally shown in Fig. 1 and may include an electric discharge device 17 comprising an elongated vitreous or dielectric envelope 18 having therein a pair of electrodes 19 and 20 between which an electric discharge is established. The electrodes 19 and 20 may be positioned so that the surfaces thereof lie in substantially the same plane with the associated members defining the wave guide, thereby minimizing reflections of the electromagnetic waves which are to be controlled.

The system of Fig. 3 operates in substantially the same way as that explained above in connection with Fig. 1, the degree of coupling or the coefficient of coupling between dielectric wave guides 14 and 15 being a function of the density of the electric discharge established between electrodes 19 and 20.

A still further modification of my invention is illustrated in Fig. 4 wherein a pair of concentric or coaxial transmission line sections 21 and 22 are interconnected through a coupling device. The transmission line sections 21 and 22 may include a common outer tubular conductor 23 and may include inner conductors 24, 25 and tubular insulators 26 and 27, respectively.

The coupling device which I provide in this connection is also of the continuously variable type wherein the coupling effect or coefficient of coupling between the concentric transmission line sections 21 and 22 is obtained by establishing a controllable electric discharge path between the respective sections. The controllable discharge path may be provided by an electric discharge device including a tubular dielectric or vitreous member 28 supporting a pair of spaced electrodes 29 and 30 which may comprise part of the end sealing structures for the device as a whole, which is in end-to-end contact with the transmission line sections. In such an arrangement, the electrodes 29 and 30 may be of cylindrical cross section being sealed to the vitreous member 28. Furthermore, electrodes 29 and 30 may be provided with cylindrical extensions 31 and 32 which are inserted within appropriately formed recesses in the ends of inner conductors 24 and 25. The coupling between transmission line sections 21 and 22 is increased as the density of the charged electrical particles is increased. In this manner the energy flow between the two sections of the transmission line may be controlled completely throughout a predetermined range, or the coupling between the sections may be reduced to substantially zero by extinguishing the electric discharge between the electrodes 29 and 30 by decreasing the voltage applied to the electrodes, such as that effected by opening switch 13.

It will be apparent that I may employ in systems such as shown in Figs. 1, 3 and 4 an electric discharge device wherein the initiation of current flow between the electrodes or the value of the current which flows is controlled by means of interspaced control members, such as electrostatic control grids, in which instance the density of the charged electrical particles may be determined or controlled by the potential impressed on such grids, thereby controlling the coupling between the various parts of the high frequency systems.

The electric discharge devices comprising elements of the coupling devices described above in connection with several embodiments of my invention may be either of the high vacuum type or of the type employing an ionizable medium, such as a gas or a vapor. In such instances, the electric discharge devices may employ a thermionic cathode which comprises one element or electrode of the devices. Alternatively, the electric discharge devices may be of the type comprising a hot or thermionic

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cathode in conjunction with another electrode serving as an anode or in combination with an anode and a single or a plurality of control electrodes, such as electrostatic control grids.

While I have shown my invention as applied to ultra high frequency systems including specific parts or elements and as employing an electric discharge device of particular form, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, a dielectric wave guide of the hollow-pipe type, a concentric transmission line having an inner conductor decoupled from said guide comprising an inner conductor and an outer tubular conductor separated by a tubular insulator, said outer conductor being electrically connected to said wave guide and means for coupling energy between said guide and said transmission line comprising a gas-filled, elongated dielectric member extending into said guide for establishing a localized region of charged electrical particles, a plurality of electrodes within said envelope one of which is electrically connected to and forming a portion of said inner conductor, said electrodes being positioned outside said guide on different sides thereof and external means for varying the potential applied to said electrodes.

2. In combination, a dielectric wave guide of the hollow-pipe type, a concentric transmission line comprising an inner conductor and an outer tubular conductor the latter of which is electrically connected to said guide, a gas-filled, elongated dielectric envelope having at least a part extending into said guide and extending an appreciable distance within said outer tubular conductor, a plurality of electrodes external to said guide on different sides thereof and within said envelope for establishing an electrical discharge therein, one electrode being electrically connected to and forming a portion of said inner conductor, and means external to the guide and the line for applying a variable potential across said electrodes.

3. In a coupling system for a dielectric wave guide and a concentric transmission line comprising an inner conductor and an outer tubular conductor separated by a tubular insulator, the combination comprising an electric discharge device extending into said wave guide and comprising a gas-filled dielectric envelope for defining a localized region of charged electrical particles and comprising a pair of electrodes external to said guide on different sides thereof, the thickness of said envelope being substantially equal to the thickness of said tubular insulator and the diameter of one of said electrodes being substantially equal to that of the cooperating inner conductor, said one electrode being positioned to form an extension of said cooperating conductor, and means external to said guide and said line for varying the potential applied across said electrodes.

4. In combination, a dielectric wave guide of the hollow-pipe type defined by a conductive member, a concentric transmission line comprising an inner conductor and an outer tubular conductor separated by a tubular insulator, said outer conductor being connected electrically to said member and said inner conductor and said tubular insulator being displaced from said member providing a recess adjoining said wave guide, and a coupling means comprising an electric discharge device including a gas-filled, elongated dielectric envelope insertable within said recess and comprising a pair of electrodes positioned outside said guide on different sides thereof for establishing a localized region of charged electrical particles which serve as a coupling electrode, and external means for varying the potential applied across said electrodes.

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5. In combination, a pair of overlapping, decoupled, dielectric wave guides having a common conductive boundary, and means for coupling said guides comprising an electric discharge device of elongated nature extending transversely through both said guides and including a gas-filled dielectric envelope, and a plurality of electrodes positioned outside said guides on opposite sides thereof for establishing a discharge therebetween which serves as a coupling element, said discharge being exposed to and linking the electromagnetic fields of both of said guides substantially completely throughout the entire length of said envelope in said guide and said guides being constructed and arranged to shield said region from fields external to said guide, and means external to said guides for varying the potential across said electrodes.

6. In a coupling system for a pair of dielectric wave guides having overlapping ends, the combination comprising an elongated electric discharge device extending transversely through both guides and comprising a gas-filled dielectric envelope containing a pair of electrodes positioned outside said guides on opposite sides thereof for establishing an electric discharge therebetween which serves as a coupling element, and means supported by each of said guides for engaging the ends of said envelope, said discharge being exposed to and linking the electromagnetic fields of both of said guides substantially completely throughout the entire length of said envelope in said guide, and external means for varying the potential applied across said electrodes.

7. In combination, an ultra high frequency system comprising a pair of decoupled dielectric wave guides, means for coupling said guides for transmission of electromagnetic waves therebetween comprising an electric discharge device of the gas-filled type including a plurality of enclosed electrodes positioned on opposite sides of said guides and defining therebetween an electric discharge path, means for impressing a difference of potential between said electrodes of an intensity to cause said discharge path to act essentially as a conductor, said path linking the electromagnetic field of each of said wave guides and being shielded by said guides from fields external thereto, and means external to the guides for varying the discharge to vary the coupling between said guides.

8. In combination, an ultra high frequency system comprising a pair of dielectric wave guides of the hollow pipe type, means for coupling said guides for transmission of electromagnetic waves therebetween comprising an electric discharge device of the gas-filled type including a plurality of enclosed electrodes positioned on opposite sides of said guides and defining therebetween an electric discharge path, means for energizing said discharge device including means for selectively establishing a discharge of sufficient intensity so that the discharge path serves as a coupling electrode, said path linking a portion of the electromagnetic field of each of said wave guides and being shielded by said guides from fields external thereto, and means external to said guides for varying the intensity of said discharge to vary said coupling.

9. In combination, a dielectric wave guide of the hollow-pipe type, a high frequency circuit external to and decoupled therefrom, and a device for coupling said guide and said circuit comprising a dielectric member for defining a gas-filled space containing a pair of electrodes positioned on opposite sides of said guide and a region of charged electrical particles which serve as a coupling electrode, said region being wholly contained within said guide and said circuit and said electrical particles linking the electromagnetic fields of both said guide and said circuit means shielding said region from external fields, and means external to the guide and the circuit for controlling the density of the particles.

10. In combination, a dielectric wave guide of the hollow-pipe type and a device for coupling energy therefrom to an external high frequency circuit comprising a dielec-

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tric member defining a space containing a pair of electrodes positioned on opposite sides of said guide and a region of charged electrical particles extending substantially completely across a transverse dimension of said guide and which serve as a coupling electrode, means 5 external to the wave guide and the circuit for controlling the density of said particles to control the degree of coupling and means shielding said region from external fields.

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