Aug. 30, 1960 A. D. BERK ET AL 2,951,215

WAVEGUIDE COUPLING DEVICE WITH SWITCHING ARRANGEMENT

Filed Feb. 2, 1956

Fig. 1.

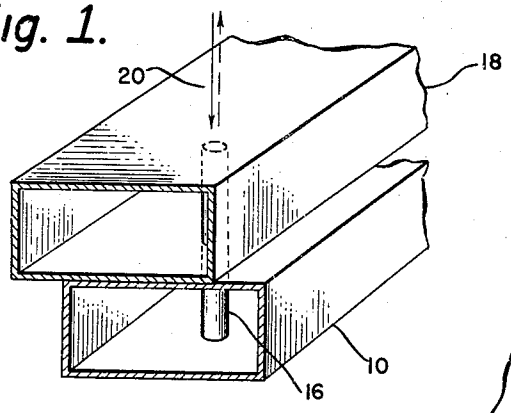


Fig. 5.

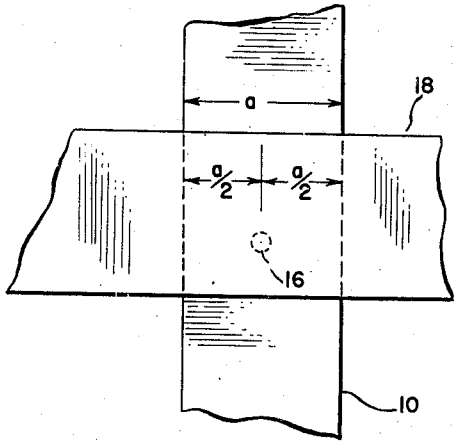


Fig. 2.

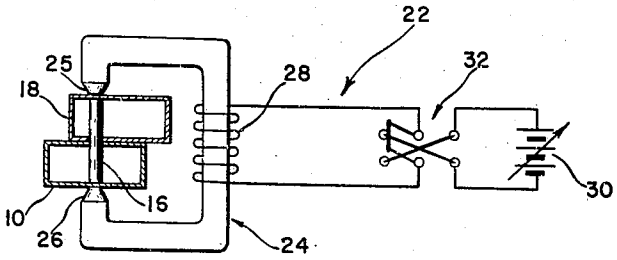
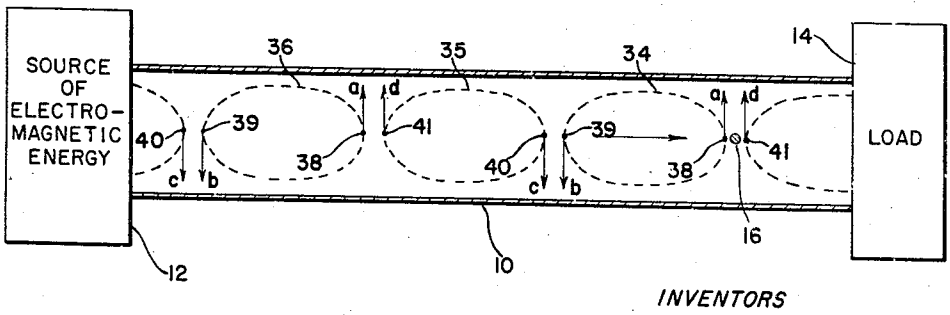


Fig. 3.



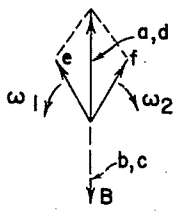


Fig. 4.

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WAVEGUIDE COUPLING DEVICE WITH SWITCHING ARRANGEMENT

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1 Claim. (Cl. 333—7)

This invention relates to waveguide coupling devices and more particularly to a device incorporating a ferrite rod for coupling a portion of the electromagnetic energy propagated by a main waveguide to an auxiliary waveguide and for launching the energy thus coupled to the auxiliary waveguide in a direction therealong determinable by the polarity of current flow in an electrical circuit.

It is generally known that a ferrite material provides a medium throughout which numerous spinning electrons are distributed. These spinning electrons may be considered to be magnetic dipoles. When the ferrite material is immersed in a direct-current magnetic field, the magnetic dipoles are aligned parallel to the magnetic field, i.e., the axes of rotation of the rotating electrons are parallel to the magnetic field. Further, a circularly polarized magnetic field that is transverse to the direct-current magnetic field causes the magnetic dipoles to precess about the lines of force of the direct-current magnetic field. When the frequency of precession, which is equal to the frequency of the microwave field, approaches a certain value determined by the strength of the direct-current magnetic field, a phenomenon occurs that is known as ferromagnetic resonance or simply as gyro-resonance. When ferromagnetic resonance exists the magnetic dipoles tend to precess about the magnetic lines of force at progressively increasing angles and in so doing constitute "magnetic currents."

In accordance with the present invention, one portion of a ferrite rod is inserted transversely through the center of a broad side of a main waveguide and another portion of the rod inserted transversely through the broad side of an auxiliary waveguide intermediate the center line and one side thereof. In operation, a direct-current magnetic field is produced through the ferrite rod of an intensity to produce gyro-resonance in the ferrite material at approximately the frequency of the electromagnetic energy of the main waveguide. The precessing magnetic dipoles in the main-waveguide portion of the ferrite will set the magnetic dipoles in the remainder of the ferrite rod in precession. These precessing magnetic dipoles, when properly located in the auxiliary waveguide, will launch a wave propagating either in one or the other direction of the waveguide, depending on the sense of rotation of the precessing dipole and therefore on the sense of the direct-current magnetic field. The said proper location is at a point where the mode of propagation in the auxiliary waveguide has a circularly polarized magnetic field. Therefore, it is possible to pick up a portion of the electromagnetic energy in the main waveguide and send it in the auxiliary waveguide either in one or in the other direction merely by controlling the direction of the direct-current magnetic field. Conversely, if an electromagnetic wave propagates in the "auxiliary" waveguide only in one direction, the ferrite rod will couple energy to the "main waveguide" or will not, depending on whether the direct current magnetic field is of the proper sense or not. When

energy is coupled to the "main waveguide" it will travel in both directions simultaneously.

It is therefore an object of the present invention to provide an improved waveguide coupling device.

Another object of the present invention is to provide a device capable of coupling electromagnetic energy from a waveguide and radiating it as a wave having a circularly polarized magnetic field of selected polarity.

Still another object of the invention is to provide a device for coupling a portion of the energy propagated by a main waveguide irrespective of the direction of propagation in the main waveguide, to an auxiliary waveguide and launching it therealong in a direction determinable by the direction of current flow in an electric circuit.

A further object of the invention is to provide a device for selectively coupling either one or the other direction of propagation in the auxiliary waveguide to the main waveguide wherein energy is launched in both directions simultaneously.

The novel features which are believed to be characteristic of the invention, both as to its structural organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawing in which an embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only, and is not intended as a definition of the limits of the invention.

Fig. 1 is a perspective view of an embodiment of the invention;

Figs. 2 and 3 are cross-sectional views of the device of Fig. 1 together with associated apparatus;

Fig. 4 is an explanatory vector diagram; and

Fig. 5 is a plan view of an alternative arrangement of the device of Fig. 1.

Referring now to the drawing, Fig. 1 is a schematic representation of the device of the present invention in perspective whereas Figs. 2 and 3 are cross-sectional views of the device of Fig. 1 together with associated apparatus. As shown in these figures, the device of the present invention comprises a main waveguide section **10** which, in the general case, is employed to propagate electromagnetic energy from a source **12** to a load **14**. A ferrite rod **16** having a length equal to approximately twice the thickness of the waveguide employed is disposed transversely through an aperture in the center of a broad side of the waveguide section **10**. The ferrite rod **16** preferably has a circular cross-sectional area which, for the X-band range of frequencies, has a diameter of the order of 0.080 inch. The portion of the ferrite rod **16** projecting out of the waveguide section **10** is then inserted transversely through an aperture disposed intermediate the center line and one side of a broad side of an auxiliary waveguide section **18**.

Thus, a broad side of the auxiliary waveguide section **18** is disposed immediately adjacent a broad side of the main waveguide section **10**. The waveguide section **10**, **18** may run parallel with each other or, as shown in Fig. 5, may be at an angle such as, for example, 90° with respect to each other. In accordance with the invention, however, it is necessary that the ferrite rod **16** be disposed in the center of the main waveguide section **10**. That is, if the section **10** has an inner width "*a*," then the distance from the center of the rod **16** to each side is *a*/2. The position of the rod **16** within the auxiliary waveguide section **18**, however, is at a point of circular polarization of the desired mode of propagation in the auxiliary waveguide. In the case of the $TE_{0,1}$ mode, this point is approximately midway between a center

line and one edge of a broad side of the auxiliary waveguide.

In operation, a reversible magnetic field **20** of an intensity to cause gyro-resonance to occur at a frequency in a region corresponding to the frequency of the electromagnetic energy provided by the source **12** is produced lengthwise through the ferrite rod **16**. An apparatus **22** for producing the reversible magnetic field **20** is shown in Fig. 2. The apparatus **22** includes a U-shaped yoke **24** which is composed of a ferromagnetic material and has pole pieces **25**, **26** disposed opposite the extremities of the ferrite rod **16**, as shown in the drawing. A solenoid coil **28** is disposed about the yoke **24** and is connected across a variable potential source **30** through a double-pole double-throw polarity reversing switch **32**. The potential of source **30** is adjusted to effect a current flow through the coil **28** to make the magnetic field **20** through the ferrite rod **16** of sufficient intensity to cause gyro-resonance to occur at a frequency in the region of the frequency of operation. When it is desired to reverse the direction in which the electromagnetic wave is launched in the auxiliary waveguide **18**, it is only necessary to reverse the direction of current flow through the solenoid coil **28** by means of the reversing switch **32**. This reversal of current may, of course, be accomplished automatically.

In the operation of the device of the present invention, electromagnetic energy is propagated from the source **12** to the load **14** by the main waveguide section **10** in the $TE_{0,1}$ mode of propagation. To illustrate more clearly the manner in which the ferrite rod **16** is coupled to the propagated electromagnetic wave by means of the gyro-resonance phenomenon, reference is made to Figs. 3 and 4. In Fig. 3, dashed lines **34**, **35**, **36** represent the magnetic lines of force of the electromagnetic wave propagated through the waveguide section **10** which have a velocity known as the group velocity, V_g. It is apparent that the ferrite rod **16** will be continuously immersed in the successive portions of the magnetic field as they pass. Therefore, as shown in the figure, the ferrite rod **16** will be successively in magnetic fields which are presently shown at points **38**, **39**, **40**, **41**, **38**, **39**, . . . and represented by the vectors *a*, *b*, *c*, *d*, *a*, *b*, . . . , respectively. Thus, as illustrated in Fig. 4, a linearly polarized magnetic field is presented to the ferrite rod **16**. This linearly polarized magnetic field, as is generally known, can be resolved into two vectors, *e* and *f*, which rotate in opposite directions with the same angular velocities $W_1=W_2$.

As was previously mentioned, the direction of the magnetic field **20** through the ferrite rod **16** determines the direction of precession of the magnetic dipoles within the ferrite material. Therefore, irrespective of the precessional direction of the magnetic dipoles, either vector *e* or *f* will be rotating in the proper direction to couple to the precessing magnetic dipoles. By means of dipole-dipole coupling, all the magnetic dipoles along the length of the rod **16** are caused to precess which precession constitutes "magnetic" currents which, in turn, cause electromagnetic wave propagation in the auxiliary waveguide section **18** in a direction consistent with the polarization of the wave thus generated. A reversal of the magnetic field through the rod **16** will cause the magnetic dipoles to precess in the opposite direction whereby they will be

coupled to the other component of the rotating magnetic fields as represented by the vectors *e* or *f*. It is to be noted that the ferrite rod **16** couples equally well to energy being propagated in both directions by the main waveguide section **10** as there is always one component of the linearly polarized magnetic field that is rotating so as to couple to the magnetic dipoles irrespective of the direction in which the wave is being propagated. In the auxiliary waveguide section **18**, however, a transverse electric wave will be launched in a direction dependent on the orientation of the rod **16** therein with respect to the center line of a broad side thereof and on the direction of the magnetic field **20** through the ferrite rod **16**. Thus, for a fixed orientation of the rod **16** in the waveguide section **18**, the direction in which the wave is launched may be reversed by changing the direction of current flow through the solenoid coil **28**.

In view of the above, it is evident that the device of the present invention need not be restricted to a rectangular waveguide as it is only necessary to have a waveguiding structure capable of propagating an electromagnetic wave having a transverse linearly polarized magnetic field component at the location of the ferrite rod **16**.

What is claimed is:

An electromagnetic wave device comprising a main rectangular waveguiding structure for propagating a transverse-electric wave in a TE_{01} mode; a ferrite rod inserted in said main waveguiding structure transversely through an aperture in the center of at least one broad side thereof, a remaining portion of the length of said ferrite rod being external to said main waveguiding structure; an auxiliary rectangular waveguiding structure disposed with one broad side thereof contiguous to said one broad side of said main waveguiding structure and with said remaining portion of said ferrite rod projecting into said auxiliary waveguiding structure through an aperture located in said one broad side thereof intermediate its center line and one side; and means for maintaining a direct-current magnetic field of selected polarity lengthwise through said ferrite rod of an intensity to produce gyro-resonance at a frequency substantially equal to the frequency of said wave thereby to launch a wave corresponding to said wave propagated by said main waveguiding structure along said auxiliary waveguide in a direction dependent on the polarity of said magnetic field.

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