

Feb. 26, 1963

E. J. HICKEY

3,079,570

NONRECIPROCAL WAVE GUIDE JUNCTION

Filed Jan. 25, 1961

Fig. 1

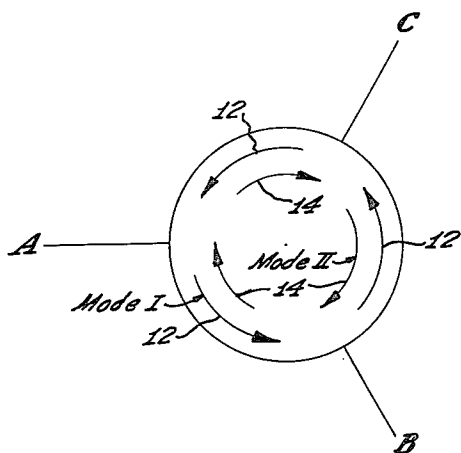
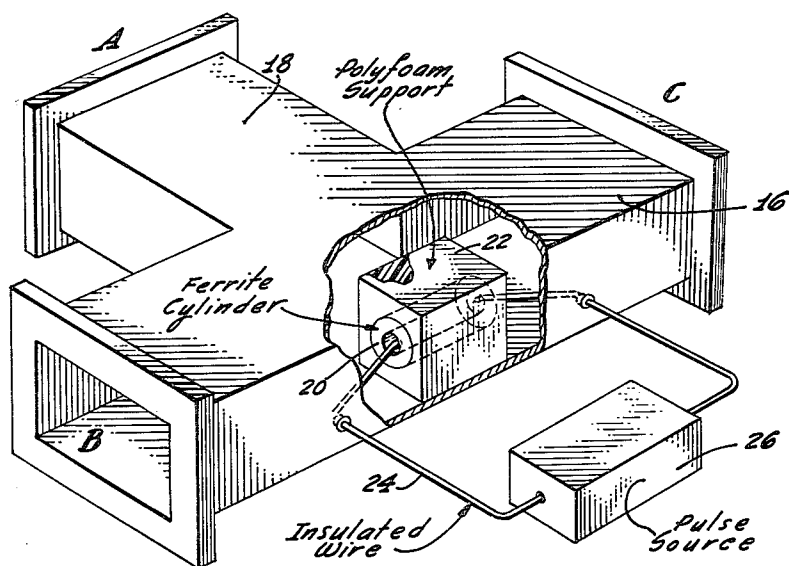


Fig. 2



INVENTOR:
Edward J. Hickey

By Alan C. Rose
Attorney

1

3,079,570

NONRECIPROCAL WAVE GUIDE JUNCTION

Edward John Hickey, Union, N.J., assignor to

Airttron, Inc., Morris Plains, N.J.

Filed Jan. 25, 1961, Ser. No. 84,822

1 Claim. (Cl. 333—1.1)

This invention relates to wave guide junctions and more particularly, to nonreciprocal junctions employing ferromagnetic materials.

Wave guide junctions are well-known in the microwave field. Typical reciprocal junctions are shown in page 234 of text entitled "Principles and Applications of Waveguide Transmission" by George C. Southworth, D. Van Nostrand Co., Inc., New York, 1950. Nonreciprocal wave guide connections or junctions were first disclosed in an article entitled "The Ferromagnetic Faraday Effect at Microwave Frequencies and Its Applications," subtitled "The Microwave Gyrotator," by C. L. Hogan, published in Bell System Technical Journal, Vol. 31, pp. 1-31, January 1952. Many forms of nonreciprocal junctions have been proposed since that time. However, these junctions are often relatively complex and are normally fixed in the nature of the switching action which is employed.

Accordingly, a principal object of the present invention is to provide a simple nonreciprocal wave guide junction in which the coupling between the wave guides can readily be switched.

Another object of the present invention is to eliminate the need for a biasing current in a nonreciprocal wave guide junction switch.

In accordance with the present invention, the foregoing objects are achieved through the use of a cylinder of ferromagnetic material located in the junction of the wave guides. In accordance with one specific embodiment of the invention, a T wave guide junction is formed by the intersection of two wave guides along the narrower side wall of one of the guides. The cylinder of ferrite is located within the junction opposite the branch wave guide connection. It may, for example, be mounted in position by transparent dielectric material such as polyfoam. A single copper wire may extend through the cylinder and the walls of the wave guide to a suitable pulse source, to selectively reverse the magnetic polarization of the ferrite cylinder.

The cylindrical form of the ferromagnetic element has the advantage that it is readily permanently magnetized to a high level. Thus, with a brief pulse of approximately one microsecond duration applied through the single turn, microwave energy may be switched from one mode of transmission through the junction to another. Because of the advantageous geometry provided by a cylinder, the residual magnetic force present in the structure after the switching pulse is sufficient to maintain the desired nonreciprocal action.

The novel features which are believed to be characteristic of the invention both as to its organization and method of construction and operation, together with further objects and advantages thereof, will be better understood from the following description when taken in connection with the accompanying drawing in which an illustrative embodiment of the invention is disclosed by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only and does not define limitations of the invention.

In the drawing:

FIG. 1 is a schematic diagram indicating the two modes of operation of the circulator in accordance with the present invention; and

FIG. 2 represents a typical nonreciprocal wave guide junction in accordance with the invention.

2

With reference to the drawings, FIG. 1 is a diagram of a three-terminal circulator. The lines A, B and C each represent one terminal of the circulator. In the operation of a circulator, energy applied to one terminal is coupled to a second terminal and energy applied to the second terminal is coupled to a third terminal, rather than back to the first terminal as would be the case for a reciprocal structure. For a three-terminal circulator, energy applied to the third terminal is coupled back to the first terminal.

Normal circulator action is indicated by the outer arrows designated 12 in FIG. 1. In accordance with Mode I operation, therefore, microwave energy is circulated between terminals A, B and C. When the circulator of the present invention is switched, however, it operates in accordance with arrows 14 which designate Mode II. In the case of Mode II, energy applied to terminal A is coupled to terminal C; energy applied to terminal C is routed to terminal B and microwave signals applied to terminal B are circulated back to terminal A. Thus, the circulator may be switched between Modes I and II as developed below.

FIG. 2 shows an apparatus for implementing the circulator structure shown in FIG. 1. In the structure of FIG. 2, a principal wave guide 16 has a branch wave guide 18 coupled to it at one of the narrower side walls of wave guide 16. Within wave guide 16 a cylinder of ferrite material 20 is mounted in position by a block 22 of polyfoam. The polyfoam has a very low dielectric constant so that it will support the cylinder 20 without materially interfering with the propagation of electromagnetic waves.

In one representative example, the wave guide cross-section was one inch by two inches in cross-section, and the ferrite cylinder 20 was mounted in wave guide 16 directly opposite the branch wave guide 18. The ferrite cylinder had an outer diameter of one-half inch, an inner diameter of three-sixteenths inch, and was three-quarters inch long. The ferrite cylinder was centered between the upper and lower broad walls of the wave guide 16 and was located approximately one-sixteenth inch from the back wall of wave guide 16.

The cylinder of ferrite 20 must be magnetized in order to provide nonreciprocal coupling between the three terminals A, B and C. In the example shown in FIG. 2, this is accomplished by the single turn 24 of insulated wire which extends through the cylinder 20. The pulse source 26 supplies signals of opposite polarity to the wire 24 to change the direction of cylindrical peripheral magnetization of the cylinder 20. When biased in one direction, the microwave energy from wave guide A was coupled directly to wave guide output C. When the ferrite cylinder 20 was magnetized in the opposite peripheral direction, however, microwave energy applied to the wave guide A was coupled to output B.

Good energy transfer was obtained between the wave guides which were intercoupled, and a high degree of isolation of the de-energized wave guide was obtained with this geometry. Specifically, the junction operated over a five percent frequency band centered at 5550 megacycles per second with an insertion loss of less than one-half of one decibel, and isolation exceeding twenty decibels. These results were obtained in both switching states, with five amperes of switching current being applied successively, in opposite directions, through a single turn of No. 19 wire.

The cylinder 20 is advantageously fabricated from ferrite material having a moderately square hysteresis loop. The many known microwave ferrites having this desired characteristic include the magnesium manganese ferrites. When these materials are used, following magnetization, a high magnetic field strength is retained in the cylinder 20. It is therefore not necessary to have a continued flow

3

of current in the winding 24. When lower speeds of switching of the cylinder 20 may be tolerated, several turns of wire may be passed through the cylinder 20.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention. Thus, by way of example, and not of limitation, the ferrite element may be of a rectangular, oval, or square cross-section with a hole through it; and a ferrite element of any of these various configurations may be employed as the non-reciprocal element in a junction having other forms than that shown in the drawings associated with the present specification. Thus, wave guide junctions of many known forms, such as those disclosed in the Southworth text cited above, may be adapted for nonreciprocal switching purposes by the addition of an apertured ferromagnetic element. Suitable matching and tapering constructions may also be employed in the practice of the present invention. Accordingly, from the foregoing remarks, it is to be understood that the present invention is to be limited only by the spirit and scope of the appended claim.

What is claimed is:

A pulse operated microwave switching device comprising:

a T-waveguide junction consisting of first and second waveguide sections of equally dimensioned rectangular cross section, with broad and narrow walls, said sections being interconnected at right angles to one another with the first waveguide at one end thereof being connected to the second waveguide by an opening in one of the narrow walls of the second waveguide corresponding in dimension with the cross sectional area of the first waveguide, the other end of the first waveguide section providing an input port to receive an input signal and the opposite ends of the second waveguide section selectively providing output ports of the microwave switch,

an elongated hollow ferrite member mounted within said second waveguide with its longitudinal axis generally parallel to the central axis of the second waveguide but offset therefrom,

4

said ferrite member being disposed adjacent the other narrow wall of the second waveguide section and being symmetrically disposed with respect to the central axis of the first waveguide section,

said ferrite member having a high remanent magnetization and adapted to be permanently magnetized at a level close to its saturation levels,

a conductor extending through said hollow ferrite member,

insulated conductor means passing through the narrow wall of the second waveguide section that are located proximate to the ferrite member and being electrically connected to the conductor within said ferrite member to provide a continuous electrical circuit therethrough,

said insulated electrical conductor means being energizable by pulse producing means located external to second waveguide section to selectively apply electrical pulses of opposite polarity thereto to reverse the magnetic polarization of said ferrite member, whereby each pulse permanently magnetizes the ferrite in a direction controlled by its polarity,

said ferrite member being exclusively magnetized by said pulses independently of any other magnetizing source,

means for supporting said ferrite member within said second waveguide,

means for coupling said first waveguide section to receive said input signal and guide the signal in a propagating direction through said first section and transverse to the axis of said ferrite member,

and said microwave switch means selectively propagating said signal in one direction or the other through said second waveguide section in a direction parallel to the axis of said ferrite member.

References Cited in the file of this patent

UNITED STATES PATENTS

2,849,683 Miller ----- Aug. 26, 1958

OTHER REFERENCES

Swanson et al.: "1958 IRE WESCON Convention Record, Part 1," pages 151-156.