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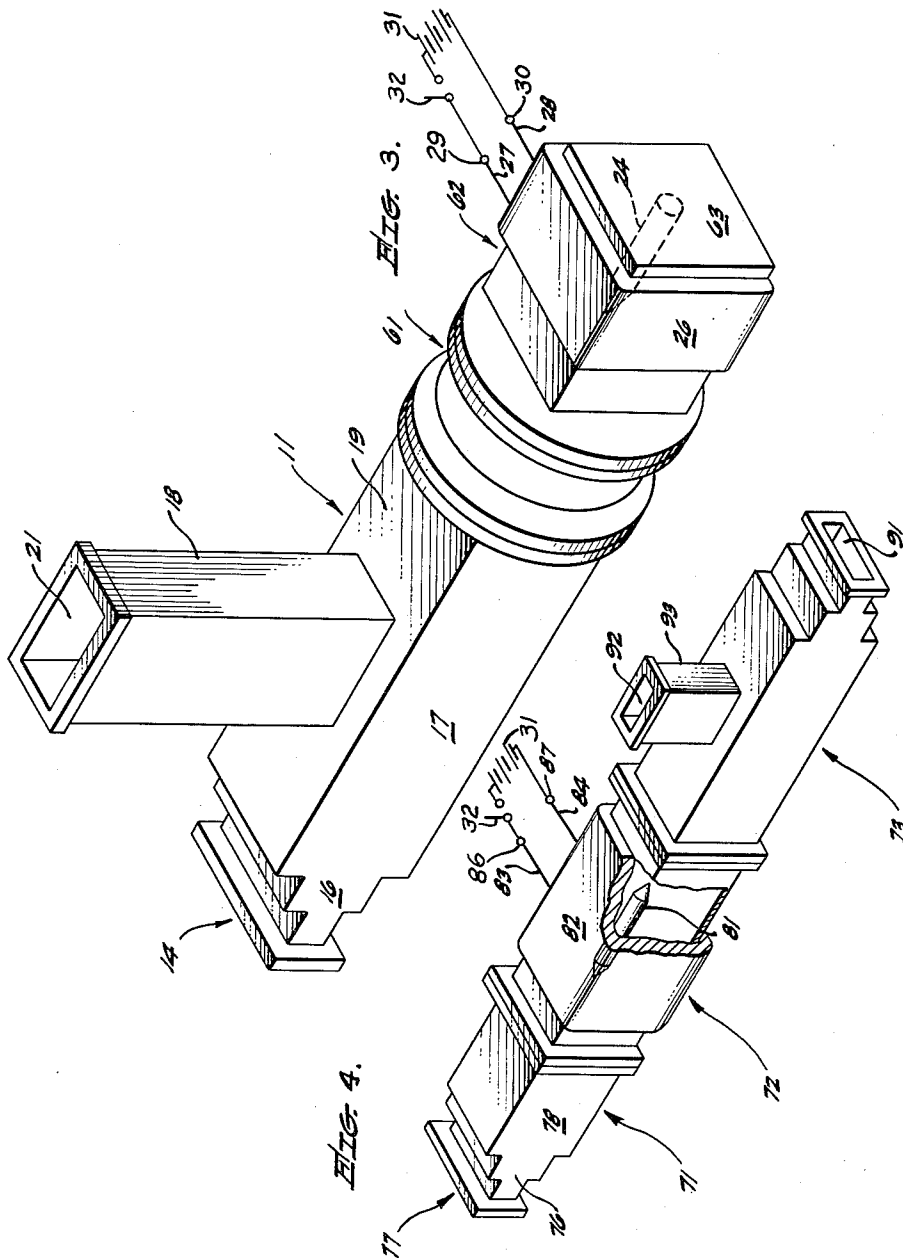
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FAIL-SAFE MICROWAVE FERRITE SWITCH

Filed Sept. 19, 1958

2 Sheets-Sheet 1



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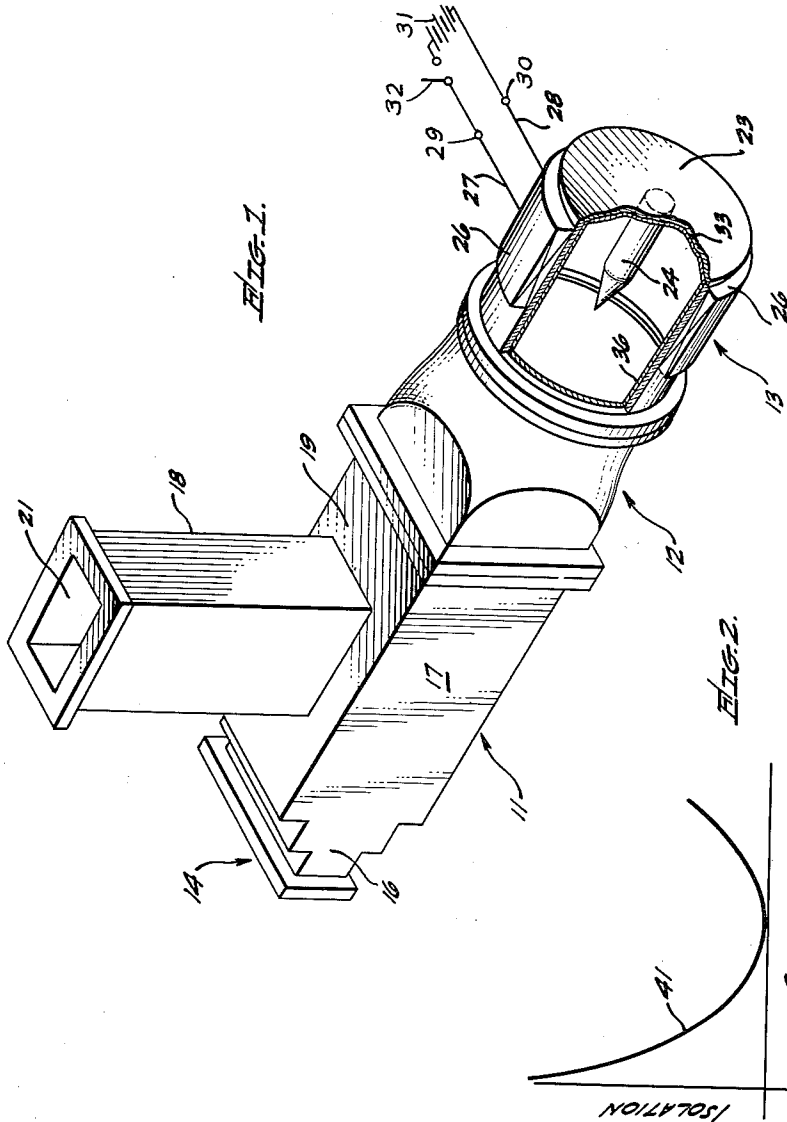
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FAIL-SAFE MICROWAVE FERRITE SWITCH

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4 Claims. (Cl. 333—7)

The present invention relates to a microwave ferrite switch and more particularly to a fail-safe high isolation ferrite switch.

In the past microwave switching has been accomplished by gaseous discharge tubes and such tubes, as developed to date, have inherent disadvantages in that they have a slow recovery time because of the ionization processes in the tube during operation and, therefore, are not capable of operating at high repetition rates. Further, failure of these tubes often results in providing a straight-through electrical circuit, which may readily permit damage to subsequent components.

Recently switches employing gyromagnetic materials have been developed utilizing the attenuation characteristics of the material when subjected to a static magnetic field in the presence of a microwave alternating field of the system in which employed. These switches as presently developed, principally rely on resonance absorption of energy by the gyromagnetic material to provide maximum isolation during an attenuation period and minimum isolation during the remaining period of the cycle of operation. Thus, should some fault or breakdown occur to prevent the necessary attenuation during the period of maximum isolation, subsequent components may be subjected to high values of power that are damaging.

Another disadvantage occurring with respect to the foregoing type of switch is also related to the period of maximum isolation and is embodied in the fact that, even under the best of conditions, the degree of isolation is limited because maximum attenuation is dependent upon absorption in the gyromagnetic material. This dependence, in turn, is dependent upon the current in a coil providing the necessary static magnetic field and upon the amount of such material, as well as other inherent factors. The value of current for the magnetic field required to provide maximum attenuation with a given gyromagnetic material at frequency of the microwave energy is critical and the attenuation is difficult to maintain at the necessary constant value for even a short period.

During the attenuation period, the gyromagnetic material is generally subjected to high values of microwave power, thereby resulting in generation of considerable heat, which must be dissipated to provide suitable cooling. Dissipation of the generated heat requires the employment of additional equipment, such as fans, and the more heat to be dissipated, the more elaborate and bulky the cooling system.

Accordingly, the switch of the present invention comprises, in brief, a single orthogonal mode transducer coupled to a rotator section containing an element of gyromagnetic material and a short-circuit termination. During the high power portion of the operating cycle, substantially no static magnetic field is established through the gyromagnetic material so that the energy is reflected from the short-circuit termination without rotation and with minimum attenuation to be absorbed elsewhere in the system. During the low power portion of the operating cycle, a static magnetic field is applied to the gyromagnetic material to produce a 45 degree rotation of the energy prior to reflection at the short-circuit termination and the reflected power is rotated by another 45 degrees

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in the same direction so that the energy of low power is coupled out of the transducer at a 90 degree port.

Another object is to provide a microwave switch having a gyromagnetic element that produces maximum isolation for minimum values of static magnetic field through the element.

Still another object is to provide a microwave switch that operates in a fail-safe manner.

A further object is to provide a simple and easily constructed microwave switch requiring minimum cooling.

Other objects and advantages will be apparent in the following description and claims considered together with the accompanying drawings in which:

FIGURE 1 is a perspective view, partly in section, of a microwave switch according to the present invention;

FIGURE 2 is a characteristic diagram of isolation versus current during operation of the switch of FIGURE 1;

FIGURE 3 is a perspective view of a variation of the switch of FIGURE 1; and

FIGURE 4 is a perspective view of an embodiment of the switch of FIGURE 1.

Referring to FIGURE 1 in detail, there is illustrated a microwave switch according to the present invention having an orthogonal mode transducer 11 coupled to a square-to-circular transition section 12 which, in turn, is coupled to a circular termination section 13. Input port 14 of transducer 11 is dimensioned to couple to regular rectangular waveguide (not shown) and the transducer itself comprises a stepped impedance matching portion 16 extending from the input port to a square waveguide portion 17. An output waveguide 18 of rectangular dimension is extended from one wall 19 of square waveguide portion 17 and is disposed 90 degrees with respect to input port 14 with the broad walls parallel to the sides of wall 19. Such waveguide 18 has an output port 21 for connecting to a rectangular waveguide similar to that at input port 14. Thus, energy coupled to input port 14 is suitably propagated with minimum attenuation through impedance matching portion 16 and square waveguide portion 17 without electromagnetic coupling to output waveguide 18.

Transition section 12 propagates energy from square waveguide section 17 to circular termination section 13 with minimum attenuation by suitable impedance matching in a conventional manner. Additionally, the mechanical connection between transition section 12 and termination section 13 is made adjustable in any conventional manner (not shown), such as slotted apertures in one connector flange, so that the angular position of the latter section is adjustable with respect to the mode transducer 11 to permit corrections for imperfections in the waveguide and other factors causing minor impedance mismatches.

Termination section 13, illustrated in FIGURE 1 with a portion of the wall broken away, comprises a length of circular waveguide with one end 23 closed by conducting material to provide a short circuit. An element 24 of gyromagnetic material, such as a ferrite rod, is suitably mounted with its axis along the longitudinal axis of termination section 13 and with one end centrally in contact with closed end 23 of the section. To selectively rotate electromagnetic energy in section 13, a coil 26 is wound externally on the section with leads 27 and 28 respectively connected to terminals 29 and 30 for further connection to a conventional source of current, as represented in FIG. 1 by a battery 31 connected in series with a switch 32. According to the invention, the length of the ferrite element 24 is selected to provide a rotation of the energy by 45 degrees when axially magnetized by coil 26. Thus, when coil 26 is suitably energized as by

closing the switch 32, a static magnetic field extends axially through ferrite element 24 and microwave energy entering the terminal section 13 is rotated 45 degrees by the ferrite element before reaching the short-circuit end 23, where the energy is reflected, and then rotated another 45 degrees in the same direction by the ferrite element. In the remaining state of operation, as with the switch 32 in an open position, coil 26 has substantially no exciting current so that the ferrite element 24 is not magnetized and energy entering termination section 13 is propagated without rotation to short-circuit end 23 where the energy is reflected back to input port 14 without rotation.

During that portion of the cycle of operation in which the ferrite element 24 is magnetized, the combination of static and alternating magnetic fields results in heat being generated in the ferrite material and unless adequate means for dissipating the heat is provided, damage to the ferrite may result, or at least the magnetization characteristics are distorted so that the desired energy rotation is not obtained. By mounting the ferrite element 24 in contact with the end 23, the surface of the entire termination section 13 is heated by conduction and thereby provides a substantially large heat-radiating surface to carry off the heat of the element. To improve the foregoing action a termination section 13 may comprise an external layer of insulating material 33, have a high coefficient of heat conduction and radiation, such as glass, and a thin internal layer of conducting material 36, such as vaporized aluminum or silver. Since coil 26 is pulsed during operation, as by a programed opening and closing of the switch 32, the provision of the thin conducting layer 36 also serves to minimize eddy current losses and therefore provides a higher value of magnetization for a given value of current in coil 26.

In operation with the above-described switch suitably connected into a microwave system, high power energy coupled in a linearly polarized mode, such as the TE_{01} mode, to input port 14 is propagated through orthogonal mode transducer 11 and square-to-circular transition section 12 to circular termination section 13. In a system where it is desired to protect components coupled to output waveguide 18 from high power energy, coil 26 remains substantially de-energized, except for possibly establishing a substantially low biasing field in ferrite element 24 to compensate for stray fields and the high power energy is reflected from end 23 back to input port 14 without rotation for absorption elsewhere in the system. Thus, since there is no rotation of the linearly polarized high power energy, there is no coupling of energy to output-waveguide 18.

Low power signals which are to be coupled out waveguide 18 are propagated from input port 14 to the termination section 13 in the same manner set forth for the high power energy. In this instance, however, the current supply connected to terminals 29 and 30 is energized by the closing of the switch 32 to provide current flow through coil 26 which then establishes an axial magnetic field through ferrite element 24. The low power energy is rotated by 45 degrees, reflected from end 23, and then rotated another 45 degrees in the same direction within the termination section 13. The result is that the reflected energy in the orthogonal mode transducer 11 is linearly polarized with a 90 degree angular difference in polarization with respect to energy at the input port 14 and, therefore, readily couples electromagnetically to output waveguide 18 for propagation to other components of system.

Thus, there is set forth in the foregoing a microwave switch that has fail-safe operation in that for no magnetization of the gyromagnetic element 24, there is provided maximum isolation, which is comparable to the open position of a conventional single throw switch at commercial frequencies, and for maximum magnetization of element 24 there is provided minimum isolation, which is comparable to the closed position of such con-

ventional switch. The foregoing characteristic of operation is illustrated in the diagram of isolation versus current of coil 26, as shown by the curve 41 of FIGURE 2. The fail-safe advantage is based upon the fact that should coil 26 or the current source connected to it become inoperative, no energy is coupled to output waveguide 18.

In FIGURE 3 there is shown a modification of the switch of FIGURE 1 wherein a circular square-to-square waveguide transition section 61 is suitably mounted between the orthogonal mode transducer 11 and square termination section 62. The circular transition section 61 is dimensioned for proper impedance matching between the two square waveguide sections at the ends thereof in a conventional manner so that such condition exists for any relative angular positions of the waveguides about their aligned longitudinal axes. The same reference numerals have been used in FIGURE 3 for similar elements previously described with respect to FIGURE 1 and operation of the switch is the same in both instances. Thus, square termination section 62 may be fabricated of an insulating material having an innerconductor coating. Also coil 26 is suitably wound about the external surface of termination section 62 with leads 27 and 28 extended to terminals 29 and 30 for connection to a current source to provide an axial static magnetic field through ferrite rod 24 which is disposed along the axis of the section. As stated previously, operation of the switch of FIGURE 3 is the same as described in FIGURE 1 and energy is reflected back to input port 14 when there is no magnetization of the ferrite rod 24, but the energy is rotated 90 degrees to couple with output waveguide 18 when the ferrite rod is magnetized.

A perspective view of an embodiment of the switch of FIGURES 1 and 3 is illustrated in FIGURE 4 and comprises a rectangular-to-square waveguide transition section 71 for propagation of energy through a square waveguide rotator section 72 to an orthogonal mode transducer section 73. Transition section 71 includes a stepped impedance transformer portion 76 extended from input port 77 to square waveguide portion 78 so that energy is transferred with minimum attenuation through transition section 71. Energy is propagated into rotator section 72 having a gyromagnetic element 81, such as a ferrite rod, suitably mounted with its axis extended along the longitudinal axis of the section. Ferrite rod 81 is dimensioned in this embodiment to provide 90 degrees of rotation in one direction and, to apply a suitable axial static magnetic field through the rod, a coil 82 is wound about the section 72 with leads 83 and 84 respectively extended to terminals 86 and 87 for connection to a source of current. After traversing rotator section 72, high-power energy is propagated through orthogonal mode transducer 73 with the energy emerging at output port 91 and rotated low-power energy emerges at output port 92 of transversely mounted waveguide 93.

Again operation of the switch of FIGURE 4 is similar to that described for FIGURE 1 and the walls of rotator section 72 may be formed in the same manner as described for termination sections 13 and 62. When high-power energy is introduced at input port 77, the static magnetic field is substantially zero so that no rotation of the microwave energy occurs in rotator section 72 and the energy is propagated straight through to output port 91 of orthogonal mode transducer section 73. A static magnetic field of a value producing 90 degrees rotation is established axially through ferrite rod 81 when low-power energy is introduced at input port 77 and waveguide 93 then couples to the rotated energy in orthogonal mode transducer 73 to provide an output at port 92.

The switch of FIGURES 1 and 3 may be readily used in a microwave system between a duplexer and receiver with input port 14 coupled to the duplexer and output port 21 coupled to the receiver. With such connections coil 26 is energized only during the receive cycle of operation so that the input signal of low power at port 14

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is rotated 45 degrees by ferrite element 24, reflected at short-circuit end 23, 63, again rotated 45 degrees, and finally coupled to waveguide 18 of the orthogonal mode transducer 11. During the transmitter pulse of high power, no static magnetic field is applied and the energy is reflected without rotation back to input port 14 for absorption at the duplexer.

The switch of FIGURE 4 may be similarly used with input port 77 coupled to the duplexer, output port 92 coupled to the receiver, and an absorptive load coupled to output port 91 of the mode transducer 73. The operation is the same as described for the switch of FIGURE 1 with the exception that the receiver signal is rotated 90 degrees by the ferrite rod 81 and no magnetic field is applied during the transmitter pulse of high power.

Thus there is provided a microwave switch having minimum heating effects with respect to the gyromagnetic material and maximum isolation with minimum field current to achieve a fail-safe operation. While the salient features of the present invention have been described with respect to several embodiments, it will be apparent that numerous modifications may be made within the spirit and scope of the invention and it is, therefore, not desired to limit the invention to the exact details shown except insofar as they may be set forth in the following claims.

What is claimed is:

1. A microwave switch for a system having a high-power energy cycle and low-power energy cycle, comprising waveguide structure having a termination section with a short-circuit end portion for propagating both of said energies in a linearly polarized mode from an input receiving said energies in similarly polarized modes, an elongated element of gyromagnetic material mounted substantially centrally on said end portion with its longitudinal axis lying substantially along the direction of propagation of said energies, means inductively coupled to said element for establishing a static magnetic field lengthwise through said element substantially parallel to the direction of propagation of energy only during said low-power energy cycle, said magnetic field having a strength to provide substantially 45 degree rotation of low-power energy in either direction, and an output waveguide mounted on said waveguide structure at a ninety degree angle with respect to said input for coupling of only the rotated low-power energy.

2. A microwave switch for a system having a high-power energy cycle and a low-power energy cycle, comprising an orthogonal mode transducer having a rectangular waveguide input, a rectangular waveguide output con-

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nected to said input with a ninety degree angular relationship therebetween, said transducer including a rectangular-to-square waveguide transition section between said input and output, a termination section having a short-circuit end, an elongated element of gyromagnetic material mounted substantially centrally on said end and extended substantially along the direction of propagation of energy, means inductively coupled to said element for establishing a static magnetic field through said element substantially parallel to the direction of propagation of energy only during said low-power energy cycle, said magnetic field having a strength to provide substantially 45 degrees rotation of said low-power energy in either direction, and a transition coupling section mounted between said transducer and said termination section to provide electromagnetic coupling of energy therebetween.

3. The microwave switch of claim 2 wherein said termination section is of circular cross section and said transition coupling means is a square-to-circular waveguide transition section having mechanical coupling adjustment for altering the angular relationship between said transducer and said termination section to provide optimum operation.

4. The microwave switch of claim 2 wherein said termination section is of square cross section and said transition coupling means is a circular square-to-square waveguide transition section providing impedance matching between square waveguides independent of the angular relation of the waveguides.

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