

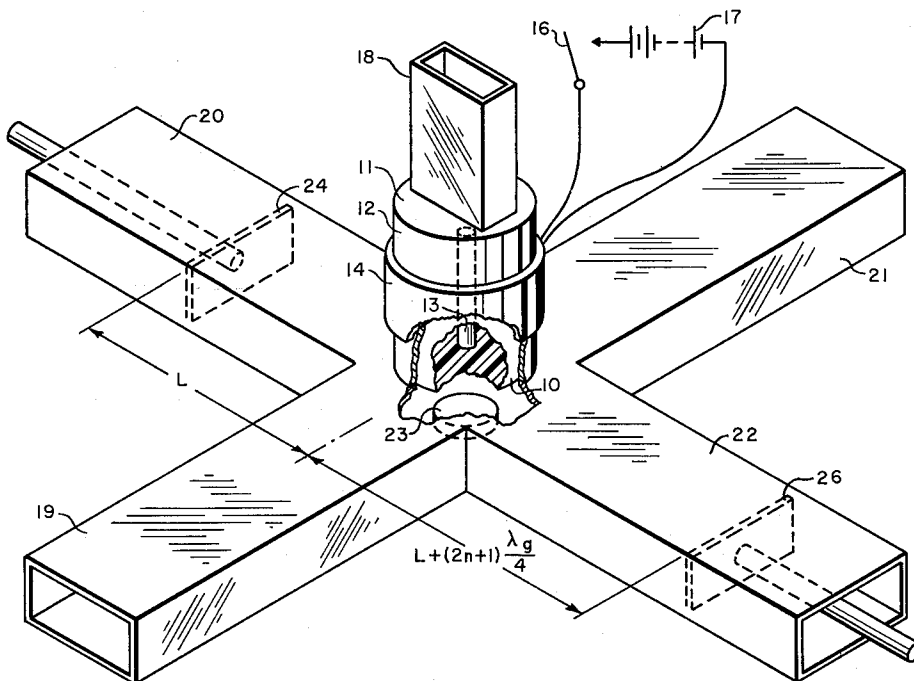
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MICROWAVE SWITCH

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MICROWAVE SWITCH

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This invention relates to microwave switches and particularly to phase-reversing microwave switches.

An example of the use of such switches is in beam-shifting microwave antennas. One form of such antenna consists of a number of elemental radiators arranged in a plane and having two microwave input terminals. When these terminals are fed with inphase microwave energy two beams are radiated by the antenna in two selected directions. The switch for such an antenna should reverse the phase of one of the feeds accurately and rapidly, and should be low-loss during transition from one position to the other. Since the beam directions of such an antenna are highly sensitive to the phases of the inputs, the phases must be controlled with great accuracy.

The present invention provides such a switch. Because the switch is electronic, its speed is limited only by the electrical time constant of its actuating circuit. The loss during switching, as indicated by change of the voltage standing wave ratio, is so small as to be unmeasurable, and either the phases or the amplitudes of the outputs can be matched as closely as may be desired.

The invention provides a turnstile junction combined with a particular form of microwave polarization rotator. The arms of the turnstile junction are short circuited at selected points.

The turnstile junction is described in volume 8 of the Radiation Laboratory Series, entitled Principles of Microwave Circuits, by Montgomery et al., on page 459. A form of rotator is described in U.S. Patent No. 2,719,274.

In the operation of the apparatus of this invention the polarization rotator serves as the microwave input to the round waveguide of the turnstile junction and two unshorted turnstile junction arms constitute the two outputs. When the rotator is not excited the phases of the outputs are opposite, and when the rotator is excited so that it rotates the input polarization by 90°, the output phases are alike.

One purpose of this invention is to provide a switch for changing the phase difference of two microwave energies by 180°.

Another purpose of this invention is to provide a switch having no moving parts which changes the relative phases of two microwave outputs from the same to opposed phases.

Still another purpose of this invention is to provide a phase-reversing switch having no increased loss during the switching transition.

Still another purpose of this invention is to provide a phase-reversing switch which converts any input phase error into an output amplitude error.

A further understanding of this invention may be secured from the detailed description and the drawing in which the single figure illustrates an embodiment of the invention.

Referring now to the single figure, a microwave polarization rotator 11 comprises a round waveguide 12 containing a ferrite rod 13 coaxially positioned within it. The rod 13 may be embedded in a dielectric material 10 filling the interior of the round waveguide and serving

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as mechanical support. The round waveguide 12 is surrounded by a coaxial wire coil 14 having its two terminals connected through a switch 16 to a source of direct current 17. One end of the round waveguide 12 is terminated in a conductive end wall pierced by a rectangular waveguide 18. By choice of dimensions the hollow rectangular waveguide 18 is matched in impedance at its junction with the dielectric-filled round waveguide 12. The round waveguide 12 constituting the outer wall of the polarization rotator is connected at its end opposite waveguide 18 to four rectangular waveguides 19, 20, 21 and 22. Alternatively, the round waveguide 12 of the rotator 11 may be joined through a length of round waveguide to the four waveguides 19, 20, 21 and 22.

The four rectangular waveguide arms 19, 20, 21 and 22 are joined in a four-way H-plane orthogonal junction so that the arms 19 and 21 are collinear and the arms 20 and 22 are collinear. The axis of arms 19 and 21, the axis of arms 20 and 22, and the axis of the round waveguide 12 all intersect at a single point within the junction. The end of the round waveguide 12 which is opposite to that entered by waveguide 18 is secured to the junction of the four arms 19, 20, 21 and 22 so that there is microwave energy communication from the rotator 11 to the four arms. The orientation of waveguide 18 is such that, if continued, it would form an E-plane or series T junction with the arms 19 and 21. The junction of the rotator and the four arms is matched by a button or post 23 secured to the wall of the junction opposite that entered by the rotator 11 and coaxial with the rotator.

The arms 20 and 22 are provided with short-circuiting conductive plugs 24 and 26 which may either be fixed or be adjustable as shown. In either case the distance from plug 24 to the point of axis intersection in the center of the junction is L and the distance from plug 26 to the same point is L plus an odd quarter wavelength of the microwave energy within the waveguide, which may be defined as

$$L + (2n + 1) \frac{\lambda_g}{4}$$

in which n is any positive integer including zero and λ_g is the wavelength in the waveguide.

In the operation of this switch input power is applied to the rectangular waveguide 18 and the outputs are taken from the arms 19 and 21. The rotator 11 is so designed that when switch 16 is closed and the direct-current source 17 has a selected strength, microwave energy entering the rotator from waveguide 18 is rotated through exactly 90° in its transit to the multiarm junction. Reflected energy entering the rotator from arms 20 and 22 will also be rotated 90° so that the quarter-turn polarization will enable the energy to enter waveguide 18 without reflection or loss.

In operation to produce outputs at the arms 19 and 21 which are oppositely phased by exactly 180°, and equal in amplitudes, the switch 16 is opened and the rotator 11 is left unenergized. Microwave energy in the TE₁₀ dominant mode in waveguide 18 enters the rotator 11 and passes through without change of its direction of polarization. At the junction the energy is therefore presented to the arms 19 and 21 exactly as if applied from the stem of an E-plane (series) rectangular waveguide T and is transmitted in two equal amounts, at opposite phases, out the arms 19 and 21. The action is in all respects similar to that in a series T. No energy can enter arm 20 or 22 because the polarization is wrong for such transmission.

The junction is reciprocal in the same sense that a series T is reciprocal, and equal energies with opposite phases applied to the junction through arms 19 and 21 will combine and pass out the waveguide 18.

In operation to produce outputs at the arms 19 and 21 which are identical in phase at equal distances from the junction, the switch 16 is closed, energizing the rotator 11. The direct-current source 17 and the magnetizing coil 14, as well as the design of the other parts of the rotator, are such that the microwave energy applied to the rotator from the waveguide 18 is rotated in polarization by 90°. The direction of rotation is immaterial. Microwave energy in the dominant or TE₁₀ mode entering the rotator from the waveguide 18, being rotated 90°, arrives at the junction with its polarization in such direction that it can enter the two arms 20 and 22 in equal amounts and in opposite phases, as if the rotator together with the arms constituted a series T. The energy cannot now enter arms 19 and 21 directly. The energies are reflected from the short-circuiting plugs 24 and 26 back to the junction, and since the round-trip paths differ by one-half wavelength in the waveguide, the reflected energies are returned to the junction in phase. They cannot reenter the round waveguide because it requires oppositely-phased feeds, but they can enter the arms 19 and 21, the action being analogous to that of a shunt T in which the arms 19 and 21 are analogous to the collinear arms of the T. The two energies from arms 20 and 22 combine by addition, and half of the sum is emitted from each of the arms 19 and 21, the phases being identical at equal distances from the junction along these arms.

This action is reciprocal, microwave energies applied in equal amounts and equal phases from the arms 19 and 21 combining to leave the rotator through the waveguide 18, provided the switch 16 is closed and the rotator is in operation as described. In this reciprocal action the output from waveguide 18 may have a phase reversed 180° from the phase in the case of energy applied to waveguide 18, but such reversed-phase energy is transmitted equally well by the rectangular waveguide 18.

To sum up, when the rotator 11 is completely deenergized the outputs from arms 19 and 21 are equal in amplitude and opposite in phase, and when the rotator 11 is energized to cause a rotation of exactly 90° the outputs from arms 19 and 21 are equal in amplitude and equal in phase.

An advantage of this invention is the opportunity it gives, when the polarizations applied by the rotator to the junction contain any selected angular error, to adjust the lengths L in both arms 20 and 22 in such manner as to translate the error into output relative phase error, or into output relative amplitude error, or into any mixture of these two kinds of error which may be desired.

As an example, let it be supposed that with the coil 14 unenergized, residual magnetism in the ferrite rod 13 causes a small rotation of the voltage vector as the microwave energy passes through the rotator 11. Most of the energy then passes out of arms 19 and 21 in opposite phase, but a small amount which is a function of the sine of the small rotation angle passes into arms 20 and 22, is reflected, and passes out of arms 19 and 21 in phase. This small quantity of energy in, say, arm 19 has a phase relative to the major quantity of energy passing out of the same arm depending on the magnitude of L. L can be selected and the plugs or pistons 24 and 26 adjusted correspondingly so that the output phase of the small quantity of energy in arm 19 is the same as the phase of the larger quantity of energy, is of the opposite phase, or has an intermediate phase. In the first and third cases the outputs will still be exactly 180° apart in phase but will differ in amplitude. In the second case the outputs may be made equal in amplitude but the relative phase difference will be slightly different from

180°. Alternatively, in the second case the distance L may be made such that the outputs will both differ from a 180° relative phase and differ in amplitude.

Other phase errors in applying energy to the junction will produce similar output errors which may be controlled by adjusting the distance L in both of the arms 20 and 22.

It has been found, as a practical matter, that when the invention is employed to shift the beam directions of an antenna, amplitude differences are far less serious in producing system errors than are phase aberrations. This invention thus provides means for an improvement in the operation of such systems by converting a phase discrepancy into an amplitude error.

What is claimed is:

1. A phase reversing microwave switch comprising, four rectangular waveguide sections orthogonally joined together at a common junction with broad sides thereof lying in a common plane providing two pairs of collinearly disposed arms positioned in cruciform orientation, a round waveguide section joined to said rectangular waveguide sections at said common junction and extending in a direction normal to said common plane, reflective terminations for each of the arms of one pair of collinearly disposed arms, the distance from one of said reflective terminations to said common junction exceeding the distance between said common junction and the other reflective termination by an odd number of quarter wavelengths of energy in said waveguide sections, means for introducing linearly polarized energy into said round waveguide section with an orientation such that the E-vectors thereof extend in a direction parallel to the longitudinal axis of one of the pairs of collinearly disposed arms, and means for rotating the orientation of said linearly polarized energy through an angle of 90°.

2. A phase reversing microwave switch comprising, four rectangular waveguide sections orthogonally joined together at a common junction with broad sides thereof lying in a common plane providing two pairs of collinearly disposed arms positioned in cruciform orientation, a round waveguide section joined to said rectangular waveguide sections at said common junction and extending in a direction normal to said common plane, reflective terminations for each of the arms of one pair of collinearly disposed arms, the distance from one of said reflective terminations to said common junction exceeding the distance between said common junction and the other reflective termination by an odd number of quarter wavelengths of energy in said waveguide sections, means for introducing linearly polarized energy into said round waveguide section with an orientation such that the E-vectors thereof extend in a direction parallel to the longitudinal axis of one of the pairs of collinearly disposed arms, a body of gyromagnetic material in said round waveguide section, and means for selectively imposing a magnetic field of such a strength on said gyromagnetic material as to rotate the orientation of said linearly polarized energy through an angle of 90°.

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