Sept. 29, 1959 F. REGGIA ET AL 2,906,974

MICROWAVE MODULATOR AND SWITCH

Filed Aug. 24, 1956

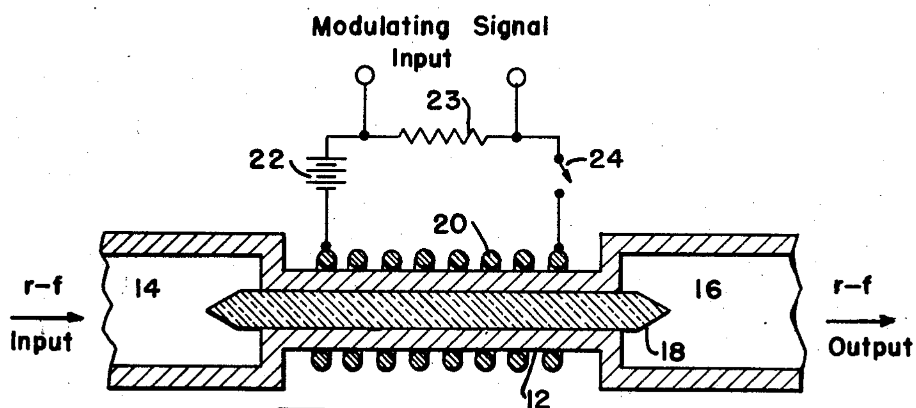

Fig. 1.

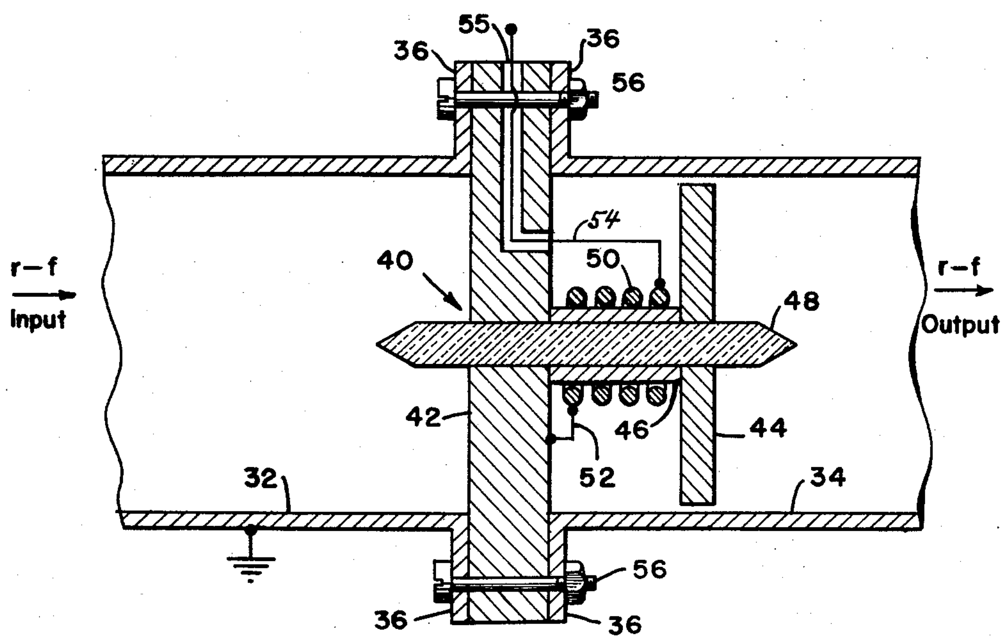

Fig. 2.

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MICROWAVE MODULATOR AND SWITCH

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Application August 24, 1956, Serial No. 606,172

1 Claim. (Cl. 333—98)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment to us of any royalty thereon.

This invention relates to the control of the amplitude of microwave energy flow. More particularly, the invention provides microwave switching arrangements in which the flow of microwave energy of a frequency f_0 through a waveguide section may be controlled by the application of a magnetic field to a ferrite body within the section; application of the magnetic field so affects the effective permeability of the ferrite as to change the effective cut-off frequency of the section from a value above f_0 to a value below f_0, thereby permitting energy flow to the output end of the section.

An object of the invention is to provide a device for controlling the amplitude of microwave energy flow that affords a wide range of attenuations, requires little energy for actuation, and is substantially non-dissipative, fast-acting, reliable, durable, and readily fabricated at low cost.

Other objects, aspects, uses and advantages of the invention will become apparent from the following description and the accompanying drawings, in which:

Fig. 1 is a simplified longitudinal sectional and schematic representation of a form of microwave switch in accordance with the invention.

Fig. 2 is a simplified longitudinal section and schematic representation of another switch in accordance with the invention, mounted between two sections of flanged waveguide.

In Fig. 1 a circular waveguide section **12** is shown integral with an input waveguide section **14** and an output waveguide section **16**. A coaxial ferrite rod **18** is positioned within waveguide **12**. A solenoid **20** is wound around waveguide **12**. A battery **22** is connectable through a resistor **23** to solenoid **20** by means of a single-pole single-throw switch **24**.

With switch **24** open, waveguide **12** has a certain cut-off frequency f_{c1}—i.e., little or no energy of frequencies less than f_{c1} will propagate through waveguide **12**. Let a microwave input signal of frequency f_0, slightly less than f_{c1}, be applied to input waveguide **14**. With switch **24** open, little or none of the f_0 signal will reach output waveguide **16**. Now let switch **24** be closed. The resulting flow of current through solenoid **20** causes a magnetic field to be applied to ferrite **18** and lowers the effective cut-off frequency of waveguide **12** to a new value f_{c2} that is lower than f_{c1} and that may be made lower than f_0. The f_0 energy in waveguide **14** thus becomes coupled through waveguide **12** to output waveguide **16**. It will be understood that the f_0 output from waveguide **16** may be switched on and off at very high rates by switching on and off the current applied to solenoid **20**. Various devices can be coupled to, or substituted for, waveguide **16**. Or waveguide **16** may be omitted; energy will then be radiated from the output end of rod **18**.

If desired, a modulating signal may be applied across

resistor **23**, leaving switch **24** closed. If the current through coil **20** is of the correct value to bring the effective cut-off frequency of waveguide **16** very close to f_0, a high degree of modulation of the microwave output signal from waveguide **16** will be caused by a small modulating signal.

We have constructed and tested practical embodiments of microwave switching devices of the above-disclosed type. For example, we have constructed embodiments using ferrite rods of approximately 1/4 inch diameter and 2 to 4 inches in length. Such switches have provided isolation of greater than 60 decibels in the "off" condition and have required very little current—typically less than 25 milliamperes—to turn the switch "on." It will be apparent that even greater isolations should be obtainable if desired, by making waveguide **12** and rod **18** longer or by using a number of switches in series. Measured insertion loss, using presently available ferrites, has been as low as 1.2 db. When the switch is "on," large changes in current through the coil **20** produce relatively small changes in output from waveguide **16**.

We believe that the lowering of cut-off frequency of waveguide **12** that is observed when current is applied to coil **20** may be explained by the following theory. The f_0 linearly polarized energy entering the input end of waveguide **12** may be considered to be the resultant of two circularly-polarized waves of equal amplitude, one negative and the other positive. With no applied magnetic field the effective permeability of the ferrite **18** for both these waves is identical—typically, approximately 0.8. When a longitudinal magnetic field is applied, however, the effective permeability of the ferrite increases to approximately 1.7 for the negative wave, decreasing at the same time to approximately zero for the positive wave. The effective electrical diameter of waveguide **12** for the negative wave is thus increased sufficiently to permit propagation of the wave. Because of the low insertion loss obtained, we believe that a conversion process occurs at the input and output of the switch whereby an appreciable percentage of the positive wave energy is converted to negative wave energy, and hence propagates.

Fig. 2 shows an arrangment for conveniently mounting a switch in accordance with the invention between two conventional pieces of rectangular waveguide **32** and **34** having flanges **36**.

In Fig. 2 a switch subassembly **40** includes: a main metallic plate **42**, the length and width of which preferably correspond to the outer dimensions of flanges **36**; a metallic ground plate **44** the length and width of which are slightly less than the internal cross-sectional dimensions of waveguides **32** and **34**, plate **44** being parallel to plate **42**; a length of circular waveguide **46** having its axis perpendicular to plates 42 and 44 and extending between plates 42 and 44; a ferrite rod **48** extending coaxially through waveguide **46** and through plates **42** and **44**; a solenoid **50** wound coaxially around waveguide **46**; a wire lead **52** electrically grounding one end of solenoid **50** to main plate **42**; and another wire lead **54** extending insulatedly from the other end of solenoid **50**, through a passageway **55** in main plate **42**, to a point beyond the outer edge of plate 42.

Subassembly **40** is readily mounted by sandwiching main plate **42** between flanges **36** of waveguides **32** and **34**. The complete assembly may be held together by any usual or convenient means such as the screws **56** shown.

From what has been said in connection with Fig. 1, it will be understood that the coupling of microwave energy from waveguide **32** to waveguide **34** can be controlled, within a certain frequency range, by supplying current to solenoid **50** by means of wire lead **54**.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of the invention as defined in the appended claim.

We claim:

A microwave switch for mounting between two sections of standard flanged rectangular waveguide and adapted for use at a frequency f_0, comprising: a rectangular main metallic plate adapted to be mounted between the flanges of said two sections; a rectangular metallic ground plate parallel to said main plate and of lesser length and width than the interior dimensions of said sections so as to be disposable therein; a length of reduced circular waveguide having its axis perpendicular to both of said plates and extending between said plates; a ferrite rod extending coaxially through said circular waveguide and through apertures in said plates and substantially filling said waveguide; a coaxial solenoid around said circular waveguide; and means for applying an electrical current to said solenoid; the dimensions of the elements being selected so that the cut-off frequency of said reduced circular waveguide section with said ferrite rod extending therethrough is slightly higher than f_0 when no current is applied to said solenoid, said means

for applying an electrical current being adapted so that the application of current to the solenoid causes said cut-off frequency to fall below f_0 and thus permit the flow of f_0 energy between said two sections of rectangular waveguide.

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