

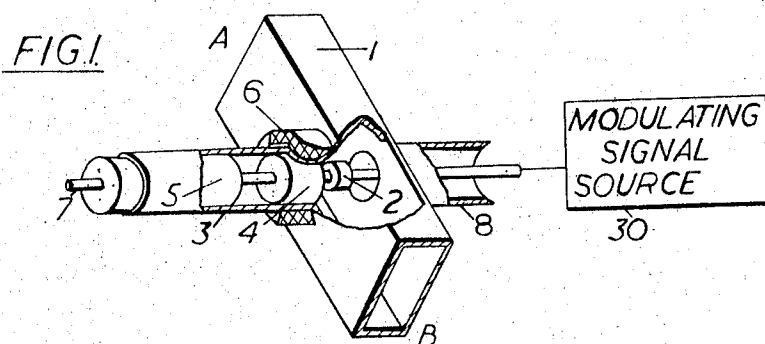
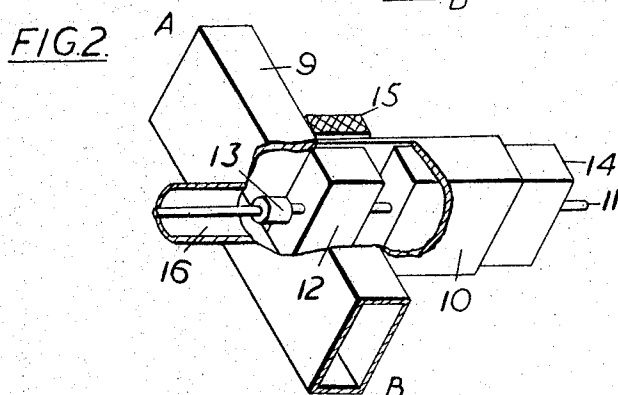
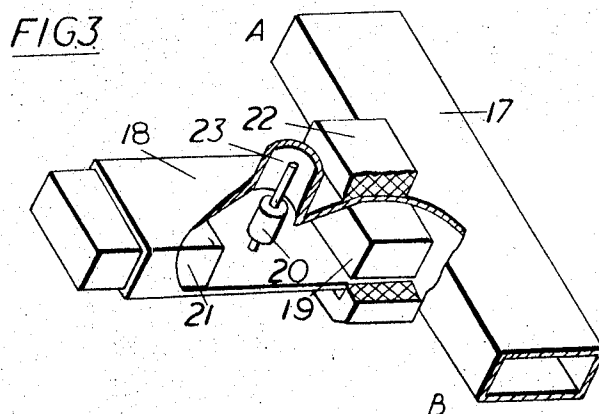
Jan. 17, 1967

AKIO SAEKI ETAL

3,299,372

ISOLATOR-MODULATOR

Filed Feb. 26, 1964



Inventor

A. SAEKI - T. HORIGUCHI

By *R. F. Morris*
Attorney

1

3,299,372

ISOLATOR-MODULATOR

Akio Saeki and Yutaka Horiguchi, Tokyo, Japan, assignors
to Nippon Electric Company, Limited, Tokyo, Japan,
a corporation of Japan

Filed Feb. 26, 1964, Ser. No. 347,426

Claims priority, application Japan, Apr. 2, 1963,

38/16,242

1 Claim. (Cl. 332—51)

This invention relates to an isolator-modulator for use in the microwave band and more particularly to a high-speed pulse modulator.

Prior art conventional modulators of this type have comprised an isolator or a non-reciprocal device which in turn comprised both a ferrite or other ferromagnetic member and means for providing a variable magnetic field. Varying the magnetic field imposed on the ferrite member, however, is not suitable for very high-speed pulse modulation (hereinafter called "switching") because of the inductance of the exciting coil, etc. Moreover, microwave modulators comprising a crystal diode are not non-reciprocal and consequently cannot provide excellent isolation, or large attenuation.

The object of the invention is therefore to provide a microwave modulator operable at high speed with remarkable isolation.

Another object of this invention is to provide a high speed microwave pulse modulator.

According to the invention, a crystal diode is combined in a novel manner with a non-reciprocal electromagnetic-wave transmission device comprising a ferrite member, a microwave modulator which is adapted to high-speed operation which *cannot* be attained by mere use of a ferrite modulator and which provides a better isolation than can be achieved by use of a crystal diode.

The above mentioned and other features and objects of this invention and the means of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of embodiments of the invention taken in conjunction with the accompanying drawings in which:

FIGS. 1 through 3 show perspective views, with parts cut away of three different embodiments of the invention.

Referring to FIG. 1, there is illustrated a modulator according to this invention which comprises a main waveguide 1, a crystal diode 2, a branch coaxial line 3 attached to the main waveguide, a ferrite member 4, an adjustable short-circuiting member 5, an exciting coil or a permanent magnet 6, a center conductor 7 of the coaxial line, and another coaxial line 8 for supplying the crystal diode with bias voltage and with modulating signals from source 30.

The operation of the device of FIG. 1 will now be examined. First assume the ferrite member 4 is not present. The arrangement is thus merely a crystal diode modulator which can effect modulation through the impedance variation of the crystal diode caused by the modulating signal. More particularly, if it is assumed that the electromagnetic wave enters the main waveguide 1 at A and passes out thereof at B and if the negative bias voltage provided by the coaxial line 8 reduces the impedance of the crystal diode, then under these circumstances the parallel disposition of the small impedance of the crystal diode with the main waveguide will reflect most of the electromagnetic wave coming from A to prevent the appearance thereof at B. This corresponds when referring to switching of the modulator by pulses, to the "off" or "open" state. On the other hand, the application of a positive pulse to the coaxial line 8 to overcome the negative bias voltage will increase the impedance of the crystal diode to cause most of the electromagnetic wave

2

which has entered the main waveguide 1 to appear at B. This is the "on" or "closed" state of the modulator. Thus, modulation is effected by the crystal diode. However, it should be noted that it is preferable in a modulator that the switching ratio or the ratio of the intensities of the electromagnetic wave appearing at B under the "off" and the "on" states be as large as possible.

Next assume that the ferrite member 4, is present in FIG. 1, but that the crystal diode is omitted. The disposition of the ferrite member 4 in the manner shown in FIG. 1 makes the device illustrated in said figure (without crystal diode 2) serve as an isolator wherein a branch coaxial line is attached to the main waveguide. It is believed that this isolation effect is due to the fact (where the dimensions of the ferrite member are somewhat larger than the wavelength) that the electric and the magnetic fields are distorted from the normal TEM mode so as to create the so-called circularly polarized wave, which in turn provides the non-reciprocal effect in which the transmission loss differs for the electromagnetic waves which travel from A and from B. The effect is adjustable by means of the short-circuit member and the magnetic field. It is therefore possible with the device of FIG. 1 (without crystal diode 2) to effect modulation by varying the magnetic field, but it is nevertheless impossible to provide sufficiently rapid switching operation.

On the other hand, both fairly rapid switching operation and good isolation can be obtained with a novel combination shown in FIG. 1 of a crystal diode and an isolator. In FIG. 1 the operation of the isolator is controlled by the variation in the impedance of the crystal diode. More particularly, if the electromagnetic wave enters at A and goes out at B (as assumed in the foregoing discussion), and if the isolator is in its "off" state or in the lower-impedance state of the crystal diode, and if the adjustable short-circuit member 5 and the exciting current in the exciting coil 6 are adjusted so that an isolator is formed which provides very large attenuation to the electromagnetic wave which has come in at A, then the "off" operation of the modulator will become deeper. On the other hand, if the isolator is in its "on" state so that the crystal diode is in its higher-impedance state, then the adjustable short-circuit member and the exciting current which have both been adjusted to the "off" state do not attenuate the electromagnetic wave travelling from A to B. Tests indicate that the switching ratio at the 24 Gc. band is more than 40 db, which is 10 to 20 db better than the switching ratio attained with a mere crystal diode modulator. Also, since the modulating signal is applied to the crystal diode, the modulator can respond to a fairly rapid signal as compared with prior art modulation in which a signal is applied to the exciting coil.

Referring to FIG. 2, another embodiment of the invention is illustrated wherein the branch coaxial line 3 of FIG. 1 is replaced with an E-branch waveguide 10 having a center conductor 11. The isolator-modulator of FIG. 2 also includes a ferrite member 12, a crystal diode 13, an adjustable short-circuit member 14, an exciting coil 15, and a coaxial line 16 for applying a modulating signal to the crystal diode. The arrangement serves, if the crystal diode is *not* present, as an isolator, as described heretofore and operates, when combined with the crystal diode as an isolator-modulator in the manner explained hereinabove.

Finally, referring to FIG. 3, still another embodiment of this invention is illustrated wherein the branch waveguide of FIG. 2 is replaced with an H-branch waveguide 18. The isolator modulator of FIG. 3 also includes waveguide 17, a ferrite member 19, a crystal diode 20, an adjustable short-circuit member 21, an exciting coil

22, and a coaxial line 23 for supplying the crystal diode with a modulating signal.

If the crystal diode of FIG. 3 is omitted, the arrangement serves as an isolator having an H-branch waveguide. It is believed that this is due to the fact that the H-branch waveguide attached to the main waveguide and short-circuited at its tip forms a sort of resonator and establishes the non-reciprocal effect for the electromagnetic waves travelling from A and from B because of the presence of the ferrite member in the resonator. The state of the non-reciprocal resonance varies with the adjustable short-circuit member and the magnetic field. When the crystal diode 20 is disposed in the device of FIG. 3 as indicated, the variations in the impedance thereof in turn causes variation in the resonance state of the H-branch waveguide whereby a modulator is formed.

While the combinations of a crystal diode and an isolator comprising a ferrite member disposed within the branch have been illustrated in the drawings, it should be understood that a similar effect can be obtained with the combination of a crystal diode and a conventional isolator in which the ferrite member is placed within the main waveguide. It is particularly effective to arrange such a device so that the resonance state or resonating isolator can be controlled by varying the impedance of a crystal diode.

Thus, in its broadest aspects, our invention provides a crystal diode in combination with an isolator comprising a ferrite member or other microwave non-reciprocal element. This combination makes it possible to obtain excellent modulation characteristics from an uncomplicated arrangement. Although the devices of this invention have been described as an isolator-modulator, it is to be noted that the isolator-modulator can also be used

as a variable attenuator or merely as an isolator in the microwave region.

While we have described above the principles of our invention in connection with specific embodiments, it is to be clearly understood that this description is made only by way of example, and not as a limitation to the scope of our invention as set forth in the objects thereof and in the accompanying claim.

What is claimed is:

10 A microwave isolator-modulator comprising: a main waveguide, an isolator including, a branch stub waveguide attached at one end of said main waveguide, an adjustable short closing the other end of said stub waveguide, a ferromagnetic member substantially codimensional with the inside stub waveguide dimensions positioned in said stub waveguide, excitation means for said ferromagnetic member; a modulating signal source; and a crystal diode connected to said modulating signal source and positioned in one of said waveguides to control the operation of said isolator in response to variations of the impedance of the crystal produced by the modulating signals from the source.

References Cited by the Examiner

UNITED STATES PATENTS

2,769,960 11/1956 Mumford ----- 332-51

FOREIGN PATENTS

30 891,650 3/1962 Great Britain.

NATHAN KAUFMAN, *Primary Examiner.*

A. L. BRODY, *Assistant Examiner.*