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[54] **COAXIAL MICROWAVE MODULATOR**
5 Claims, 3 Drawing Figs.
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325/442, 329/161, 332/52, 333/21 A
[51] Int. Cl. **H04b 1/26**
[50] Field of Search 329/160-164;
325/442, 445, 446, 448, 449; 332/52;
333/21 A; 343/756

ABSTRACT: A microwave modulator is disclosed which takes the form of a microwave transmission line segment having a pair of diametrically opposed longitudinal slots cut in its outer conducting sheath. Nonlinear impedance means are positioned in the sheath and connected to the sheath at two points each of which is equidistant from all four slot extremities. Modulating waves applied across the nonlinear impedance means modulate microwaves traversing the segment.

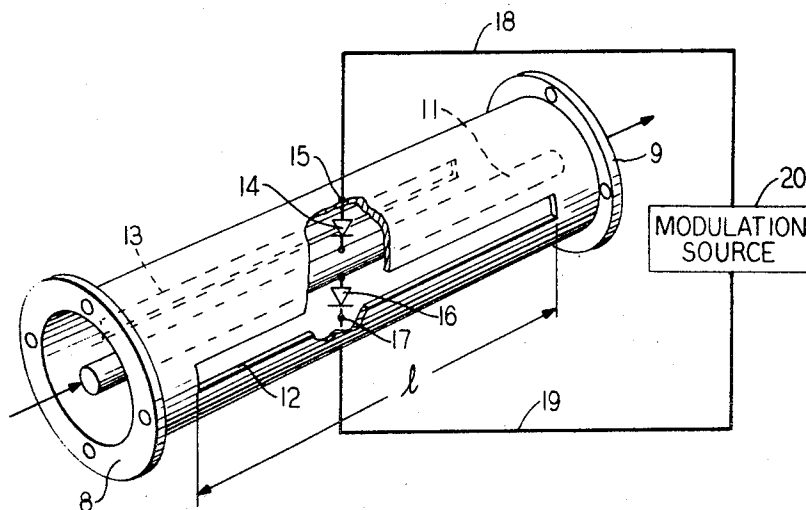


FIG. 1

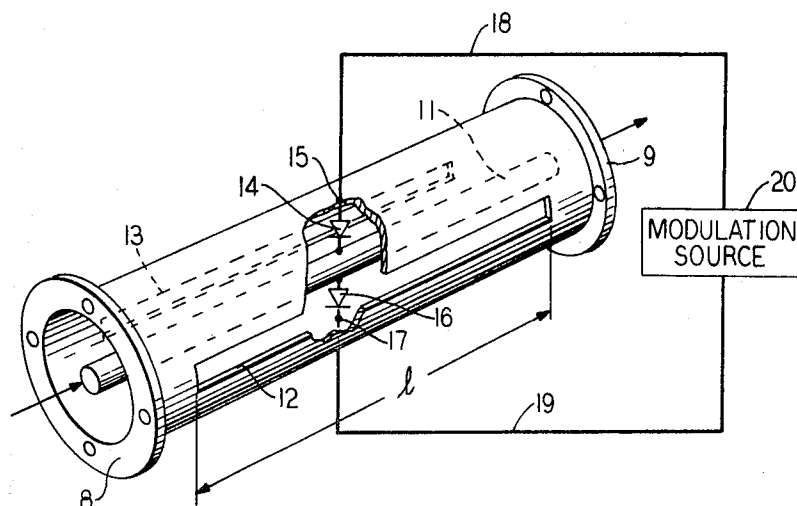


FIG. 2

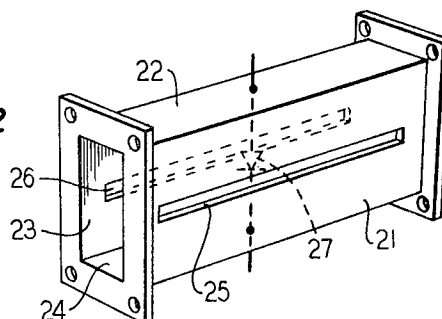
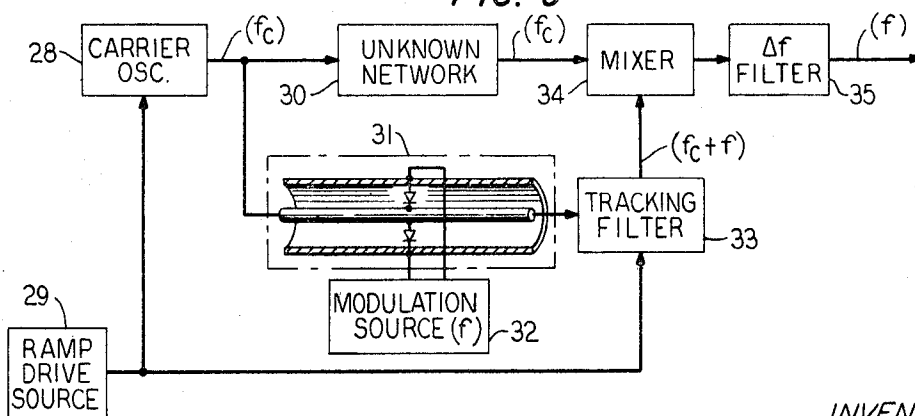


FIG. 3



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COAXIAL MICROWAVE MODULATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to electromagnetic wave modulators, or converters, wherein microwaves are modulated by lower frequency waves to produce waves at frequencies different from those of the input waves.

2. Description of the Prior Art

The prior art discloses various microwave modulators comprising waveguide and/or coaxial line structures with diodes mounted therein. In general, the bandwidths of the microwaves modulated by these modulators are limited because of structural configurations. These limitations are, however, acceptable in many applications, as for example, when modulating a fixed frequency carrier wave.

There are occasions when modulation of broader bandwidth microwaves is required. Such modulation is required, for example, when measuring the transmission characteristics of networks as discussed hereinafter. To the best of applicant's knowledge, the prior art does not disclose any relatively simple microwave modulators which exhibit this characteristic.

SUMMARY OF THE INVENTION

An object of the invention is to use relatively simple structures to modulate a carrier microwave whose frequency can change or vary over a bandwidth limited only by the transmission bandwidths of coaxial or waveguide transmission lines.

This and other objects are achieved by a modulator comprising a microwave transmission line segment having in its outer conducting sheath a pair of diametrically opposed longitudinal slots which are parallel to the center line of the segment. The slots are each substantially equal in length to one-half the wavelength of the fundamental frequency of a modulating wave. When the transmission line comprises a coaxial line segment, a first nonlinear impedance device, such as a diode, is connected between the inner conductor of the segment and a first point on the outer conductor substantially equidistant from the four extremities of the slots. A second nonlinear impedance device, such as a diode, is connected between the inner conductor and a second point on the outer conductor substantially diametrically opposite the first point. The diodes are poled for easy current flow from the first point to the second point on the outer conductor.

When the transmission line comprises a waveguide segment, a single diode is connected between first and second points as defined in the previous paragraph.

In accordance with the invention, a modulating sinusoidal wave applied between the two points causes the devices to change their conductivity which in turn modulates a higher frequency wave traversing the microwave line segment. These embodiments may also be used with a step-function input voltage applied to the two points on the outer conducting sheath. Such a voltage causes a traveling wave to progress up and down the slots which causes the conductivity of the devices to be changed, thereby modulating the wave traversing the microwave line segment.

A feature of the invention is that the slots do not interfere with transmission in the transmission line segment so that the modulation feed connected to the diodes is, in essence, transparent to waves in the line segment. Because of this transparency, embodiments of the invention may be used to modulate microwaves having frequencies anywhere in the transmission bandwidth of the line segment. Furthermore, microwave energy is not fed into the modulating feed circuit thus eliminating the need for isolating chokes or filters.

Another feature of the invention comprises the slots and the modulating wave center feed which establish a hereinafter described resonant condition. This condition eliminates the necessity of providing special modulation wave feed-through devices in the outer conducting sheath.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 are perspective views of embodiments of the invention; and

FIG. 3 shows a block diagram of a transmission measuring combination which includes the embodiment of FIG. 1.

DESCRIPTION OF THE DISCLOSED EMBODIMENTS

The embodiment shown in FIG. 1 includes a coaxial line segment having connectors 8 and 9 mounted on each end thereof and comprising an outer conductor 10 and an inner conductor 11. A pair of identical longitudinal slots 12 and 13 each of length 1 are cut in outer conductor 10 so as to be diametrically opposite one another. A first diode 14 is radially connected between center conductor 11 and outer conductor 10 so that one extremity of diode 14 passes through and makes direct current contact with outer conductor 10 at a point 15 which is equidistant from the four extremities of slots 12 and 13. A second diode 16 is radially connected in a similar manner between inner conductor 11 and a second point 17 which is diametrically opposite point 15. Diodes 14 and 16 are poled for easy current flow from point 15 to point 17. A pair of leads 18 and 19 are connected between the protruding extremities of diodes 14 and 16, respectively and a modulating source 20.

Modulating source 20 may apply a sinusoidal wave to diodes 14 and 16. In this case, length 1 of slots 12 and 13 is nominally equal to one-half of the wavelength of that wave. The two portions of outer conductor 10 which are between slots 12 and 13 may be visualized as two conductors shorted together at their extremities and excited at their midpoints by source 20 to form a cavity which is resonant at the modulating frequency. The potential between these two portions therefore oscillates in polarity with the modulating wave. Diodes 14 and 16, in turn, are turned ON and OFF by this potential to periodically short circuit the coaxial line segment. The diodes therefore alternately block and pass microwave energy attempting to traverse the line segment, thus modulating the microwave.

A segment of 7 millimeter air dielectric coaxial line was used in constructing an embodiment of the invention. Slots which measured $3/16$ inch $\times$ 9.3 inches were machined in this segment. The cavity produced thereby had a resonant frequency of 0.6 GHz. The diodes comprised hot carrier (Schottky-Barrier) X-band diodes. These diodes have an ON state resistance of approximately 10 ohms so some of the higher frequency, or carrier, wave appeared at the output because of incomplete shunting. In the OFF state, the diodes differed from an open circuit by approximately 0.2 pfd. of case and depletion capacitance. A conversion loss which varied between 11 and 14 db. was obtained for a 0.6 GHz. modulating wave and a 2.25 to 12.25 GHz. carrier wave. By increasing the modulation drive level, conversion losses in substantially the same range were obtained while varying the modulation frequency over a band of frequencies. An increase, for example, in the drive level by 6 db. over the minimum level acceptable for a 0.6 GHz. modulating wave permitted the same conversion loss range to be obtained over a modulating frequency range of 0.45 to 0.75 GHz. Additional drive is needed, of course, to accommodate the reactive appearance of the cavity at frequencies to either side of its resonant frequency.

It should be noted that only the transmission line bandwidth and the diode characteristics limit the range of carrier frequency operation as the parallel slots make the modulation feed circuit invisible to the carrier waves traveling inside the coaxial line.

A step-function voltage may also be applied by source 20 to forward bias diodes 14 and 16. In this case, a wave front travels from the center of slots 12 and 13 to their extremities and back to the center. The diodes remain ON and the carrier is blocked for the period of time required for the wave front to make the round trip.

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The embodiment of FIG. 2 comprises a waveguide segment having four conductive walls 21 through 24 with longitudinal slots 25 and 26 cut in walls 21 and 23. As in the embodiment of FIG. 1, these slots are diametrically opposite one another. One extremity of a diode 27 passes through and makes direct current contact with wall 22 at a first point equidistant from the four extremities of slots 25 and 26. The other extremity of diode 27 passes through and makes direct current contact with wall 24 at a second point diametrically opposite the first point of wall 22. Operation of this embodiment is similar to that of the embodiment of FIG. 1.

Embodiments of the invention find use, for example in measuring apparatus as shown in FIG. 3. This apparatus includes a carrier oscillator 28 which produces a carrier wave whose frequency f_c sweeps over a frequency band in response to the drive from a ramp drive source 29. The output of oscillator 28 is simultaneously applied to an unknown network 30 and an embodiment 31 of the invention. This embodiment is the same as that shown in FIG. 1. A modulation source 32 applies a sinusoidal wave at frequency f to embodiment 31. The output of embodiment 31 is tracked by a tracking filter 33 so that substantially only the portion of the embodiment at the frequency ($f_c + f$) appears as the filter output. Tracking filter 33, which is electronically tunable, is also driven by ramp drive source 29 and may taken the form of the one disclosed in "A 500-to-1,000 MHz. Magnetically Tunable Bandpass Filter Using Two YIG-Disk Resonators," by L. Young and D. B. Weller, pp. 72-86 of the Feb. 1967 issue of IEEE Transactions of Microwave Theory and Techniques. The outputs from unknown network 30 and tracking filter 33 are mixed in a mixer 34. The output of mixer 34 is filtered by a filter 35 so as to pass substantially only that portion at the frequency f . The output of filter 35 contains information relating to unknown network 30 produced as a result of the varying frequency carrier wave passing through the network.

What is claimed is:

1. A combination for modulating a carrier wave with a second wave to produce a modulated output, said combination comprising
 - a microwave transmission line segment having an outer conducting sheath,
 - said sheath having two diametrically opposed longitudinal slots cut therein parallel to the centerline of said sheath with said slots each having a length equal to one-half of

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the fundamental frequency portion of said second wave and, furthermore, said sheath having two diametrically opposite points therein each of which is equally located from the four extremities of said slots,

nonlinear impedance means positioned in said sheath and direct current connected between said points, input means connected to one extremity of said segment to receive said carrier wave, input means connected to said point to receive said second wave, and output means connected to the remaining extremity of said segment to make available said modulated output.

2. A combination in accordance with claim 1 in which said microwave transmission line segment comprises a coaxial line segment having a center conductor and the midpoint of said nonlinear impedance means is direct current connected to said center conductor.

3. A combination in accordance with claim 2 in which said nonlinear impedance means comprises a pair of diodes connected in series and poled in the same sense.

4. A combination in accordance with claim 1 in which said microwave transmission line segment comprises a waveguide segment and said nonlinear impedance means comprises at least one diode.

5. A combination for modulating a carrier frequency wave with a modulating wave, said combination comprising, a coaxial transmission line segment having inner and outer conductors with said outer conductor having cut therein a pair of diametrically opposed longitudinal slots parallel to the centerline of said segment and substantially equal in length to one-half the wavelength of the fundamental frequency of said modulating frequency wave, a first diode connected between said inner conductor and a first point on said outer conductor substantially equidistant from the four extremities of said slots, a second diode connected between said inner conductor and a second point on said outer conductor substantially diametrically opposite said first point, means connected to said first and second points for applying said modulating wave, means connected to one end of said segment to receive said carrier frequency wave, and means connected to the other end of said segment to make available the output from said combination.

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