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MICROWAVE MODULATOR

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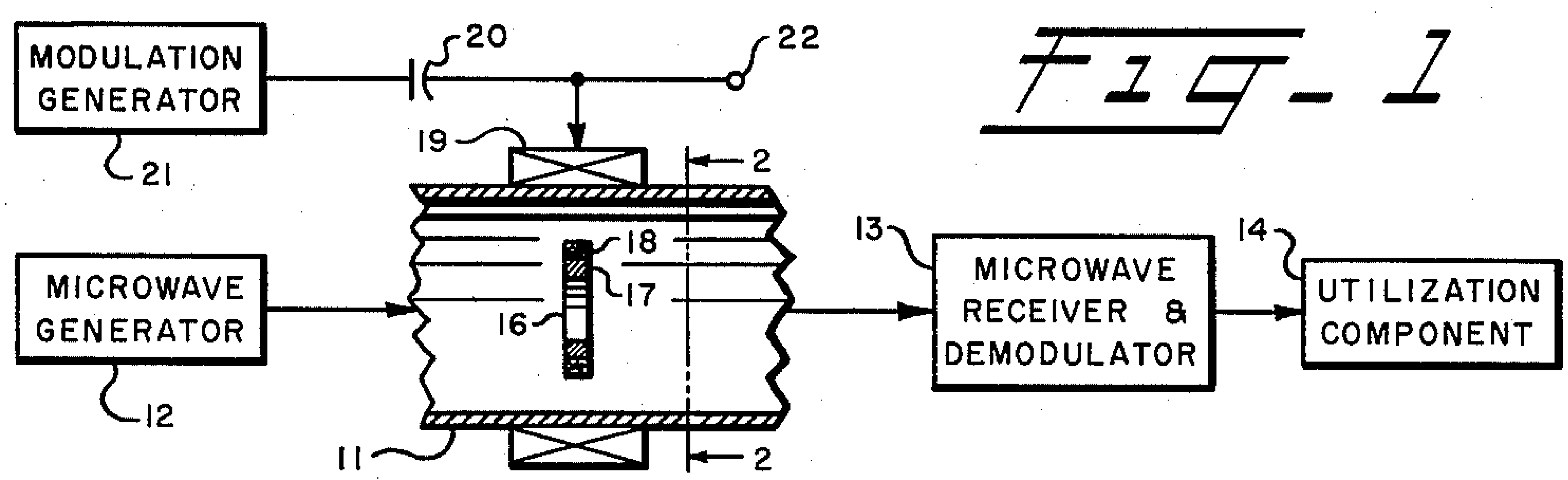

FIG. 1

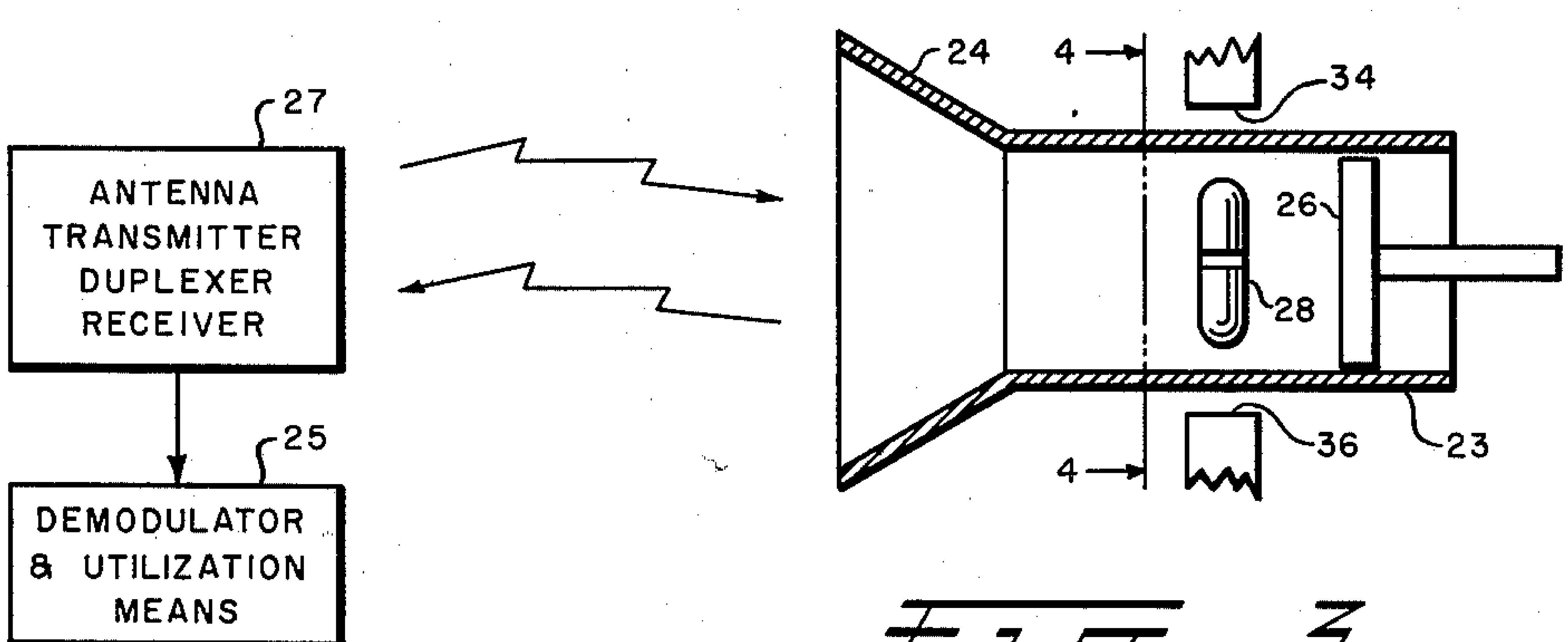

FIG. 3

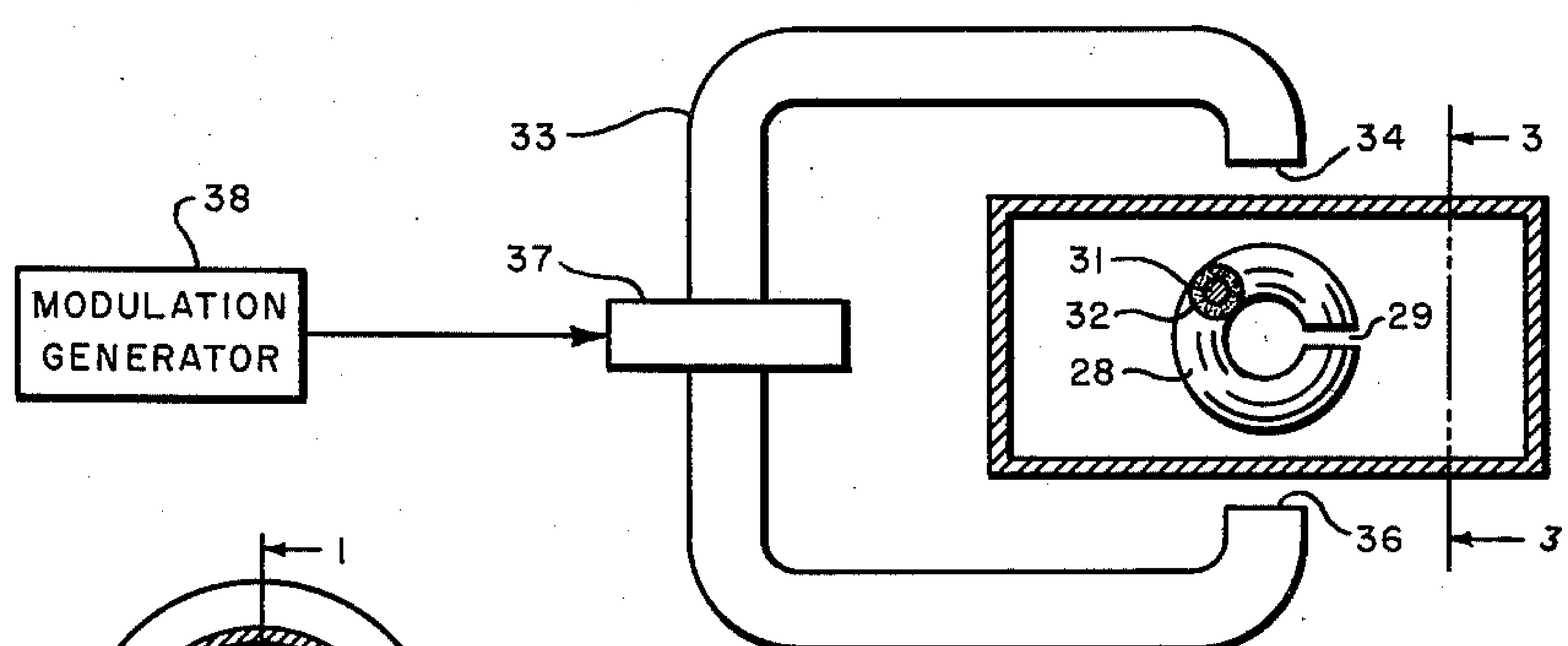

FIG. 4

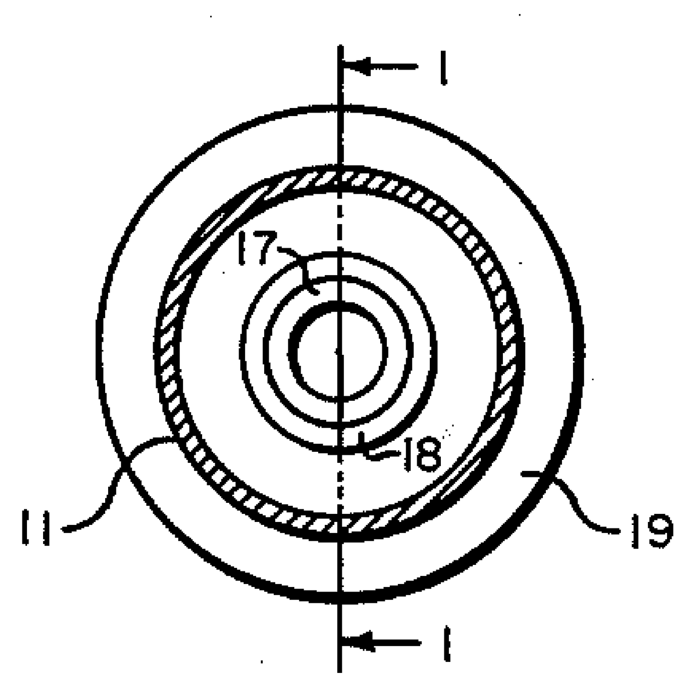

FIG. 2

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MICROWAVE MODULATOR

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This invention relates to modulators of microwave energy.

The apparatus of this invention includes a microwave-resonant conductive ring having a ferrite component. This ring assembly is immersed in a modulating magnetic field and also in a field of the microwave energy which is to be modulated. The interaction of the ring and of the magnetic field on the microwave field causes modulation of the latter at the frequency of variation of the modulating magnetic field.

A particular embodiment of the invention employs a round waveguide inside which is placed, transversely, a composite round ring made of metal and one of the microwave ferrites. This composite ring has such dimensions as to be resonant, or approximately resonant, at the microwave frequency employed. A microwave generator is connected to apply microwave energy to one end of the waveguide and a microwave receiver, detector, and modulation indicator is connected to the other end. A coil surrounding the round wave guide is connected for excitation by an audio-frequency generator. The modulation indicator indicates that the received microwave energy has been modulated at a function of the audio frequency.

The several components of this apparatus may take various forms and may be combined in several ways. The resonant ring may be solid or split, the conductive part may have any cross section such as circular, rectangular or other form and may be surrounded, in cross section, either partly or completely by the ferrite material. Alternatively, the ferrite material may simply be in close proximity or adjacent to the conductive ring material. The ferrite material may be of various compositions, one being, for example, that termed ferramic R–1 manufactured by the General Ceramics Corporation, Keasbey, New Jersey. The ferrite material is, however, restricted to that class termed microwave ferrites, as defined by E. Albers-Schornberg in the Journal of Applied Physics for February, 1954.

The resonant ring assembly is positioned transversely in the center of a round or rectangular waveguide, or in a coaxial waveguide, or may be positioned somewhere within an enlarged portion of a waveguide forming a tuned or tunable microwave cavity. In all cases, however, one purpose of the resonant or non-resonant component in which the resonant ring is positioned is to apply a microwave field to the ring. The ring may even be positioned in an unbounded microwave field instead of one of the guiding structures mentioned. One way in which this can be done is to position the ring structure at or just outside of one of the individual radiators of a microwave antenna such as a linear array or planar array antenna. If the individual radiator consists of a slot, the resonant ring structure may consist of the edge of the slot itself in association with a coating or layer of ferrite material secured thereon or adjacent thereto.

The modulating magnetic field in which the resonant ring assembly is immersed may have the same direction as the ring axis, a direction perpendicular thereto, any intermediate direction, or the field may be curved so as to follow the curvature of the periphery of the ring. When the ring is enclosed in a waveguide, for example, the field may be coaxial, as when generated by a coaxial coil, may be transverse, to the waveguide and therefore in the plane of the ring, or may be generated by current in a single conductor running through the resonant ring to form a field in and around the ring cross section and concentric with the axis of the ring.

The type of modulation provided by the modulator of this invention may be changed by adjustment from almost pure amplitude modulation, through a combination of amplitude and frequency modulation to almost pure frequency modulation. This is done simply by slightly changing the frequency of resonance of the resonant ring relative to the frequency of the impinging microwave energy, or vice versa.

The principal purpose of this invention is to provide a microwave modulator including a resonant ring composed of conductive material and microwave ferrite material, and immersed in a modulated magnetic field.

Another purpose of this invention is to provide a modulator including a microwave waveguide containing a relatively thin resonant ring including microwave ferrite material positioned in a waveguide transverse plane, a modulating magnetic field being applied to the ring.

A more detailed description of the invention follows with drawings, in which:

FIGURE 1 is a view of one embodiment of the invention taken partially in section on the line 1—1 of FIGURE 2.

FIGURE 2 is a sectional view taken on the line 2—2 of FIGURE 1.

FIGURE 3 is a view of another embodiment of the invention taken partially in section on the line 3—3 of FIGURE 4.

FIGURE 4 is a sectional view taken on the line 4—4 of FIGURE 3.

Referring now to FIGURE 1, a round hollow microwave waveguide 11 is connected between a microwave generator 12 and a microwave receiver and demodulator 13. The microwave frequency employed may be, for example, 8800 mc. p.s., and the diameter of the round waveguide 11 is such as to transmit this microwave frequency in the dominant mode. The generator 12 may comprise a klystron or magnetron and, for example, generates continuous-wave unmodulated energy. The microwave receiver and demodulator 13 may consist merely of a crystal mixer, such as is described in volume 1 of the Radiation Laboratory series, Radar System Engineering by Ridenour, on page 416. The output of the mixer is utilized in a component 14 which may comprise, for example, an oscilloscope.

A resonant ring 16 is suspended coaxially in the round waveguide 11 by means not shown. As shown in FIGURE 2, the ring is round and, as shown in the sectioned view of FIGURE 1, its cross section is rectangular and composite. The inner part, 17, is a ring made of a highly conductive metal such as brass. The outer part, 18, is a ring made of a microwave ferrite and is in contact with the inner part around its periphery. As a specific example of such a composite resonant ring for use in this invention in the apparatus of FIGURES 1 and 2, the ring length is 0.060 inch, the radial dimension of the brass cross section is 0.032 inch, the radial dimension of the ferrite cross section is 0.036 inch and the outer diameter of the ferrite ring is 0.443 inch. Such a composite ring is found to be electrically resonant in the vicinity of the chosen frequency of 8800 mc. p.s.

A wire coil 19 is positioned around the outside of the round waveguide 11, so that when energized its magnetic field is coaxial at the ring 16. The coil 19 is energized by an alternating current modulation generator 21 coupled through a capacitor 20. The frequency and waveform of this generator are not limited in this invention except by the wire coil structure and associated structure. As an example, the output of this generator is sinusoidal and has a frequency in the audible range. To increase efficiency, especially at high frequencies, it may be desirable to slot the waveguide.

In the operation of this embodiment, when the composite ring 16 is exactly tuned to the microwave energy impinging on it from the generator 12, substantially all of the microwave energy is reflected back to the source. When the ring 16 is completely detuned from the microwave frequency it reflects very little energy and its reflection as a discontinuity in the waveguide can be tuned out if desired. When, however, the ring is almost exactly tuned to the microwave frequency and the ring is subjected to an alternating field in addition to the microwave field, the microwave properties of the ferrite component, particularly its dielectric constant and permeability at microwave frequencies, are cyclically changed at the alternating field rate or, if not biased as hereinafter described, at twice that rate. This modification of microwave properties in turn affects the microwave reflectivity of the ring so that microwave energy is returned to the source with cyclic variation at the modulating frequency or at twice that frequency. That field not reflected is transmitted to the receiver 13 and similarly undergoes the cyclic variation. Thus, modulated microwave energy is received at the receiver 13, is demodulated and the modulation made evident at the oscilloscope 14.

In order to eliminate frequency doubling either the ring is slightly detuned or a direct-current bias may be applied to the coil 19 from a direct-current source 22.

FIGURES 3 and 4 illustrate an embodiment differing in a number of details. A rectangular waveguide 23 is provided with a radiating horn 24 at one end and a tuning piston 26 at the other. A microwave system 27 consisting of a transmitter together with an antenna, duplexing component and receiver is positioned at a distance from the horn 24 and is adapted to transmit microwave radiation to the horn and to receive radiation of the same order of frequency from the horn. A demodulator with utilizing equipment, 25, is connected to the receiver. A resonant split ring 28 is positioned coaxially in a transverse plane of the waveguide 23. The ring gap 29 is so positioned, facing one of the narrow waveguide sides, that the ring is reflective when resonant to the impinging microwave energy. The ring is round in its cross section, the core 31 being made of brass and the material 32 surrounding the core consisting of a microwave ferrite. A transverse magnetic field is applied to the ring by a magnetic yoke structure 33 having pole faces 34 and 36 and provided with a magnetizing coil 37 excited from a modulation generator 38.

In the operation of the embodiments of FIGURES 3 and 4, the coil 37 is supplied with alternating current from generator 38. The piston 26 is spaced from the ring 28 by approximately an odd number of quarter wavelengths in the waveguide of the microwave energy generated by generator 27.

This embodiment has the great practical advantage that, in addition to the primary function of the piston 26, its adjustment can be changed to compensate for small departures of the ring dimensions from the resonant dimensions.

When microwave energy is radiated from the transmitter and antenna of the component 27 the energy so radiated is received by the horn 24 and impinges on the ring 28. Part of this energy passes the ring and is reflected by the piston 26 toward the source. Thus in the several passages of the energy past the ring 28 modulation of the energy is augmented. This modulated energy is radiated by the horn 24. The energy reradiated by horn 24 is separated from the transmitted energy by the duplexer of component 27 and is impressed on the receiver thereof as energy modulated at the frequency of generator 38 or at double that frequency. The received signal representing the energy radiated from the horn is demodulated by the component 25 and the demodulated signal is indicated on an oscilloscope or is otherwise utilized.

What is claimed is:

1. A microwave modulator comprising a resonant ring structure including a metal ring member and an adjoining microwave ferrite ring member, said resonant ring structure being electrically resonant at a selected microwave frequency, means for generating an alternating magnetic space field having a selected lower frequency less than said selected microwave frequency, said resonant ring structure being immersed in said alternating magnetic space field, means generating and propagating electromagnetic field energy at approximately said selected microwave frequency, said resonant ring structure being immersed in said electromagnetic field energy, the plane of said resonant ring structure being normal to the direction of propagation of said electromagnetic field energy, whereby the electromagnetic field energy propagated past the resonant ring structure is modulated at a rate which is a function of said selected lower frequency.

2. A microwave modulator comprising means generating microwave energy at a selected microwave frequency, microwave electromagnetic field bounding means, means propagating said microwave energy bounded by said field bounding means, a microwave resonant ring structure tuned to substantially said selected microwave frequency, said ring structure including an inner metal ring and an outer microwave ferrite ring in engagement with each other throughout the circumference of each, said ring structure being contained within said bounding means, means generating an alternating magnetic field at a selected frequency in the space occupied by said ring structure, whereby the microwave energy impinging upon said resonant ring structure is modulated at a function of said selected frequency.

3. A microwave modulator comprising, a microwave waveguide, means propagating electromagnetic field energy having a selected microwave frequency through said waveguide, a microwave-resonant ring structure positioned coaxially in a transverse plane of said waveguide, said ring structure including an inner metal ring and an outer microwave ferrite ring having complete mutual circumferential engagement, said ring structure being tuned approximately to said selected microwave frequency, means applying an alternating magnetic field having a selected frequency to said ring structure whereby said field energy is modulated.

4. A microwave modulator comprising a microwave waveguide, means propagating electromagnetic energy into one end of said waveguide in the dominant mode, said energy having a selected microwave frequency, a microwave-resonaant ring positioned coaxially in a transverse plane of said waveguide, said ring having a metal inner cylinder and a microwave ferrite outer cylinder fitted tightly thereto, said ring being resonant at a frequency approximating said selected microwave frequency, means applying an alternating magnetic field having a selected frequency to said ring whereby said energy is modulated.

5. A microwave modulator in accordance with claim 4 in which the direction of said alternating magnetic field is the direction of the ring axis.

6. A microwave modulator in accordance with claim 4 in which the direction of said alternating magnetic field is in said transverse plane.

7. A microwave modulator in accordance with claim 4 in which said microwave waveguide is circular.

8. A microwave modulator in accordance with claim 4 in which said microwave waveguide is rectangular.

9. A microwave modulator comprising a microwave waveguide having a conductive adjustable piston short circuiting one end, means applying electromagnetic field energy to propagate into the other end of said waveguide, said field energy having a selected microwave frequency, a microwave-resonant ring positioned coaxially within said waveguide in a transverse plane thereof, said transverse plane being positioned at a distance from said piston of approximately an odd number of quarter wavelengths of field energy in the waveguide, said ring including a conductive core surrounded by microwave ferrite ma-

terial, said ring being interrupted in its circumference by a gap, said interrupted ring having such dimensions as to be approximately resonant to said selected microwave frequency, means applying an alternating magnetic field having a selected frequency to said ring whereby said energy is modulated.

10. A microwave modulator in accordance with claim 9 in which the direction of said alternating magnetic field is in said transverse plane.

11. A microwave modulator in accordance with claim 9 in which said microwave waveguide is rectangular.

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