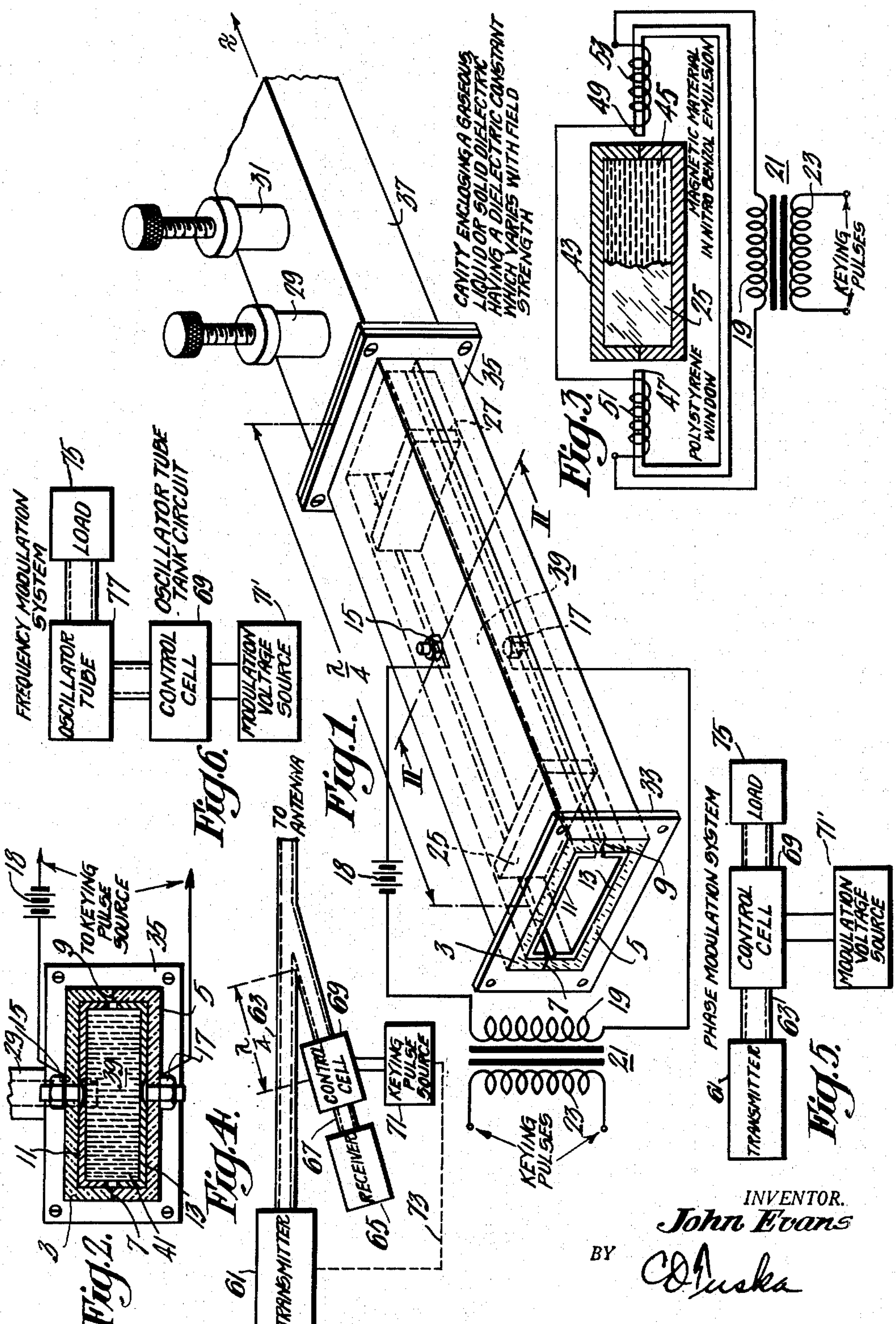
Nov. 28, 1950 J. EVANS 2,532,157

VARIABLE REACTIVE MICROWAVE DEVICE

Filed Oct. 31, 1944



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Patented Nov. 28, 1950 2,532,157

UNITED STATES PATENT OFFICE

2,532,157

VARIABLE REACTIVE MICROWAVE DEVICE

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Application October 31, 1944, Serial No. 561,277

12 Claims. (Cl. 178—44)

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This invention relates generally to microwave transmission systems and more particularly to an improved method of and means for adjusting reactance or attenuation in a microwave communication system.

It has been found that the effective dielectric constant of certain gases, liquids and solids varies as a function of the electric or magnetic field to which the dielectric is subjected. This effect is believed to be caused by the orientation of molecular or crystalline dipoles of the particular material in planes which are parallel to the direction of the applied field. In dielectrics wherein the molecular dipoles are of substantially insulating material, the orientation of the molecular diploes may be produced by means of an applied electrostatic field. In materials which include comminuted or molecular conducting particles, such, for example, as comminuted iron, the orientation of the particles may be produced by means of an applied magnetic field.

In the absence of an applied field, the molecular dipoles of the dielectric material have random orientation. However, in the presence of a biasing field, the orientation of the molecular dipoles in planes parallel to the field produces a secondary field which will oppose the propagation of microwaves through the dielectric material. Hence, a dielectric of any of the types described may be enclosed within a conventional waveguide transmission system to provide a waveguide section having reactance, phase rotation, or attenuation which vary as a function of an applied biasing electrostatic or magnetic field, depending upon the dielectric material employed.

A variable reactive waveguide section of the type described may be employed for controlling the phase, amplitude or frequency of microwaves transmitted through an otherwise conventional waveguide system.

Among the objects of the invention are to provide an improved method of and means for varying reactance in a waveguide transmission system. Another object of the invention is to provide an improved method of and means for adjusting attenuation in a waveguide transmission system. A further object of the invention is to provide an improved method of and means for phase modulating microwave energy. An additional object is to provide an improved method of and means for amplitude modulating microwave energy. Another object of the invention is to provide an improved method of and means for frequency modulating microwave energy.

A still further object of the invention is to

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provide an improved method of and means for adjusting the dielectric constant of a dielectric enclosed within a section of a waveguide transmission system. Another object of the invention is to provide an improved microwave variable reactance comprising a section of waveguide enclosing a material of which the dielectric constant may be varied as a function of an applied field. Other objects of the invention will become apparent in view of the more detailed description which follows, considered in combination with the appended claims.

The invention will be described in greater detail by reference to the accompanying drawing of which Figure 1 is a perspective view of one embodiment of the invention; Figure 2 is an elevational cross-sectional view, taken along the section line II—II, of the device illustrated in Figure 1; Figure 3 is a cross-sectional elevational view of an optional cross-sectional structure for the device illustrated in Figure 1; Figure 4 is a schematic circuit diagram of one system embodiment of the invention; Figure 5 is a schematic circuit diagram of a second system embodiment of the invention; and Figure 6 is a schematic circuit diagram of a third system embodiment of the invention. Similar reference characters are applied to similar elements throughout the drawing.

Referring to Figures 1 and 2 of the drawing, a preferred embodiment of the invention comprises a pair of U-shaped insulating channel members 3, 5, of polystyrene or other insulating material, joined together on the lines 7, 9, to provide a waveguide of rectangular cross-section. The inner surfaces of the insulating dielectric channels 3, 5 are coated with conductive layers 11, 13 except in the immediate vicinity of the joints 7, 9. A conductive coating may be applied to the polystyrene walls by employing an ethylene dichloride and styrol cement in combination with powdered silver to provide a continuous silver coating having high electrical conductivity. Since the conductive layers 11, 13 on the insulating waveguide walls 3, 5 are insulated from each other by the gaps adjacent the joints 7, 9, the opposing conductive elements may be employed for establishing a dielectric field in a vertical plane within the waveguide. Contacts 15, 17, extending through the dielectric waveguide walls 3, 5 respectively, and electrically connected to the conductive layers 11, 13, respectively, may be connected, for example, through a biasing battery 18 to the secondary winding 19 of a pulse transformer 21, to the primary winding 23 of which may be applied keying pulses or other modulation signals from a source not shown. If the use of a modulation transformer is not practicable, the modulation signals may be applied directly or through any other known means to the contacts 15, 17.

Polystyrene windows 25, 27 extending across the entire inner cross-section of the waveguide section adjacent the ends thereof, provide a sealed chamber 39 in which a predetermined gas, liquid, or solid dielectric material having a variable dielectric constant may be enclosed. The length of the enclosed chamber within the waveguide section may be selected to be of the order of ¼ or ½ wavelength as desired. However, the length of the adjustably reactive chamber may be otherwise selected to conform with the reactive requirements of the particular associated microwave circuit. In order to minimize microwave reflections due to the discontinuities provided by the polystyrene windows 25, 27, one or more reactive tuning plugs 29, 31 may be provided in the connecting waveguide adjacent each end of the variably reactive waveguide section. Both ends of the variably reactive waveguide section may include conductive flanges 33, 35 for connection to adjacent conventional rectangular waveguides as, for example, the waveguide 37 including the tuning plugs 29 and 31.

The enclosed chamber 39 between the polystyrene windows 25, 27 may be filled either with a gaseous, liquid or solid dielectric in which the dielectric constant varies with the strength of an applied field. A typical liquid having these characteristics comprises nitrobenzol having quinine crystals emulsified therewith. Under the stress of an applied electrostatic field, the quinine crystals are oriented in planes parallel to the applied field. Various other materials may be employed either singly or in combination with neutral supporting liquids such as nitrobenzol.

A typical solid in which the molecular dipoles may be oriented by the application of a dielectric field is titanium dioxide (TiO_2). In the case of both the liquids and the solids enumerated heretofore, the dielectric field may be modulated directly by means of the modulating potentials to provide a section of waveguide having variable reactive or attenuating characteristics to microwaves propagated therethrough. It should be understood that the variations in dielectric constant, in the liquid or solid mediums employed, provides a corresponding variation in the propagation velocity of microwaves transmitted therethrough.

Certain gases such, for example, as ammonia, also may be employed as variable microwave absorptive dielectric materials since these gases absorb microwave energy within predetermined frequency ranges. For example, ammonia gas absorbs microwave energy at wavelengths in the region of 3.2 centimeters and 1.1 centimeter. Thus, the modulation applied to the control cell terminals 15, 17 may comprise 3.2 centimeter wavelength which are modulated by means of the desired low frequency keying or modulating signals. The variable dielectric constant or loss characteristics of the gas due to phase rotation thence may be employed to modulate microwaves having a wavelength, for example, of the order of two centimeters which are propagated through the waveguide system. Thus, it is seen that the variable dielectric constant or loss characteristics of various gases, liquids, or solids may be modified in accordance with the modulating potentials to vary the reactance, or attenuation, of a waveguide section forming a control cell portion of a microwave waveguide system. Insofar as liquid dielectrics are concerned, the speed of response to applied modulation signals is a function of the viscosity of the liquid. This effect has not been fully investigated with gases or solid dielectrics.

Figure 2 illustrates schematically the parallel orientation of the molecular dipoles 41 of an insulating material in response to an applied electrostatic field established between the conductive waveguide surfaces 11, 13.

Figure 3 illustrates a modification of the device described in Figures 1 and 2 wherein the waveguide section includes conventional conductive walls 43 closed at each end by a polystyrene window as illustrated at 25. A portion of the window 25 is shown broken away to illustrate the use of a magnetically sensitive dielectric 45 within the space between the dielectric windows 25, 27. A pair of magnetic pole pieces 47, 49, including serially-connected windings 51, 53, respectively, connected to the secondary winding 19 of the modulation transformer 21, provide a magnetic field transversely of the waveguide section which may be employed to vary the dielectric constant of the enclosed material 45.

A dielectric in which the dielectric constant may be varied in response to an applied magnetic field may, for example, comprise nitrobenzol having finely comminuted iron dust in emulsion therewith. Application of a transverse magnetic field between the pole pieces 47, 49 causes the comminuted iron particles to arrange themselves in planes parallel to the magnetic field, thereby changing the effective dielectric constant of the emulsion in the same manner as described heretofore for the embodiment of the invention employing a modulating dielectric field. It should be understood that the use of nitrobenzol as a support for the comminuted iron particles is purely illustrative, and that various other neutral supporting liquids may be employed in a similar manner.

Also, it should be understood that other magnetic materials, such as comminuted nickel, may be substituted for the comminuted iron in the magnetically sensitive emulsion. The modification of the invention illustrated in Figure 3 has the advantage that a conventional section of waveguide, having continuous metallic walls, may be employed for the variable reactance control cell device.

Since the reactance or attenuation of the devices thus described may be varied within wide limits, they are ideally adapted to provide modulating elements for conventional microwave transmission systems. For example, as illustrated in Figure 4, the control cell comprising the invention may be interposed between a microwave receiver and a microwave antenna in a waveguide coupling system wherein a microwave transmitter is connected through an auxiliary waveguide to the same microwave antenna. A transmitter 61 is connected through a waveguide 63 to a microwave antenna. Similarly, a microwave receiver 65 is connected through a receiver waveguide 67 to the same antenna as, for example, in radar systems. The control cell 69 may be interposed in the receiver waveguide 67 at a point, for example, ¼ wavelength from the junction with the transmitter waveguide 63. The source of keying pulses 71 which keys the transmitter 61, as indicated by the dash line 73, also may be connected to the control cell 69 to block signals in the receiver waveguide 67 when the transmitter 61 is keyed on. The keying pulses from the keying pulse source 71 thus may provide an effective short circuit across the control cell 69 when the transmitter is keyed on, thereby providing a relatively high impedance looking into the receiver waveguide 67 at the point where it joins the transmitter waveguide 63. In the absence of transmitter keying pulses, the control cell efficiently transmits to the receiver the signals derived from the antenna.

Figure 5 illustrates schematically the manner in which the control cell 69 may be serially interposed in a waveguide transmission system 63 connecting a microwave transmitter 61 to a load 75. Since the control cell provides variable delay of microwave signals applied therethrough to the load 75 due to the variations in microwave propagation velocity, the modulation voltage source 71' may be connected to the control cell to vary the phase of signals applied to the load 75. The effective length of the control cell and/or the magnitude of the modulating signals may be selected to provide the desired phase shift in response to modulation potentials.

Figure 6 schematically illustrates the manner in which the control cell 69 may be employed for frequency-modulating a source of microwave oscillations. In this modification of the invention, the control cell may comprise, for example, all or a portion of a cavity resonator forming the tank circuit of the oscillation source. The effective reactance of the control cell 69 may be varied by means of the modulation voltage source 71' in the same manner as described heretofore, thereby providing corresponding variations in the frequency of the microwave oscillations generated by the oscillator tube 77. The output of the oscillator 77 is applied directly, or through suitable coupling circuits, to the load 75. It should be understood that the structure and conformation of the control cell may be varied in any manner known in the microwave art to provide the desired type of oscillator tube tank circuit. The rectangular waveguide structure described and specifically illustrated herein is intended purely for the purpose of illustration, since the control electrostatic or electromagnetic fields may be applied to an enclosed field-responsive dielectric in any other structure or manner known in the art.

Thus the invention described comprises an improved method of and means for varying reactance or attenuation in a microwave transmission system wherein predetermined dielectrics, having dielectric constants dependent upon an applied field, are employed to provide variable reactance, delay, or loss chracteristics in a waveguide transmission system.

I claim as my invention:

1. In combination with a waveguide transmission system, a variable reactive device comprising a section of waveguide containing a pliant dielectric, particles of solid material mixed with said dielectric, means for establishing a field transversely of said waveguide section for orienting said particles, and means for selectively varying said field to vary the reactive properties of said device.

2. In combination with a waveguide transmission system, a variable reactive device comprising a section of waveguide containing a liquid dielectric, comminuted particles of solid material forming an emulsion with said liquid dielectric, means for establishing a field transversely of said waveguide section for orienting said particles, and means for selectively varying said field to vary the reactive properties of said device.

3. In combination with a waveguide transmission system, a variable reactive device comprising a section of waveguide containing a pliant dielectric, comminuted particles of solid magnetic material forming an emulsion with said dielectric, means for establishing a magnetic field transversely of said waveguide section for orienting said particles, and means for selectively varying said field to vary the reactive properties of said device.

4. In combination with a waveguide transmission system, a variable reactive device comprising a section of waveguide containing a pliant dielectric, comminuted particles of solid dielectric material forming an emulsion with said pliant dielectric, means for establishing an electric field transversely of said waveguide section for orienting said particles, and means for selectively varying said field to vary the reactive properties of said device.

5. In combination with a waveguide transmission system, a variable reacting device comprising a section of waveguide having insulating walls and containing a liquid dielectric, crystalline particles of solid dielectric material forming an emulsion with said liquid dielectric, means including relatively insulated conductive inner surfaces of said insulating waveguide walls for establishing an electric field transversely of said waveguide section for orienting said particles, and means for selectively varying said field to vary the reactive properties of said device.

6. In combination with a waveguide transmission system, a variable reactive device comprising a section of waveguide containing a liquid dielectric, comminuted particles of solid magnetic material mixed with said liquid dielectric, means including a magnetic structure having pole pieces disposed adjacent opposite sides of said waveguide section for establishing a magnetic field transversely of said waveguide section for orienting said particles, and means for selectively varying said field to vary the reactive properties of said device.

7. A variable reactive device comprising a section of waveguide containing a pliant dielectric, particles of solid material mixed with said dielectric, and means for establishing a field transversely of said waveguide for orienting said particles to vary the reactance of said device.

8. A variable reactive device comprising a section of waveguide containing a liquid dielectric, comminuted particles of solid material mixed with said liquid dielectric, and means for establishing a field transversely of said waveguide for orienting said particles to vary the reactance of said device.

9. A variable reactive device comprising a section of waveguide containing a pliant dielectric, comminuted particles of solid magnetic material mixed with said dielectric, and means for establishing a magnetic field transversely of said waveguide for orienting said particles to vary the reactance of said device.

10. A variable reactive device comprising a section of waveguide containing a liquid dielectric, crystalline particles of solid dielectric material mixed with said liquid dielectric, and means for establishing an electric field transversely of said

waveguide for orienting said particles to vary the reactance of said device.

11. A variable reactive device including a section of waveguide containing nitrobenzol comprising a liquid dielectric, crystalline particles of quinine mixed with said liquid dielectric, and means for establishing an electric field transversely of said waveguide for orienting said particles to vary the reactance of said device.

12. In combination with a waveguide transmission system, a variable reactive device comprising a section of waveguide containing a pliant dielectric including particles of solid material of the group including solid dielectric material, magnetic material, and crystalline quinine, means for establishing a field transversely of said waveguide section for orienting said particles, and means for selectively varying said field to vary the reactive properties of said device.

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