

March 9, 1954

J. F. ZALESKI

2,671,884

MICROWAVE MAGNETIC CONTROL

Filed Sept. 19, 1950

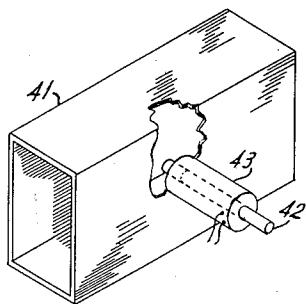
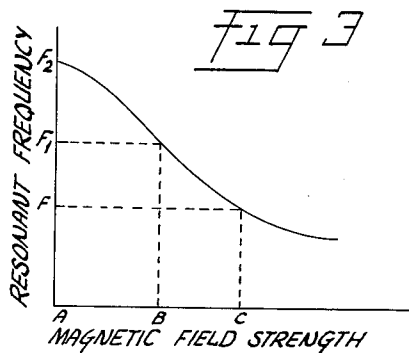
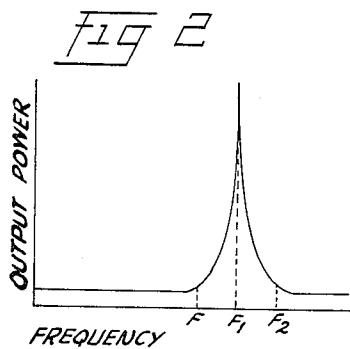
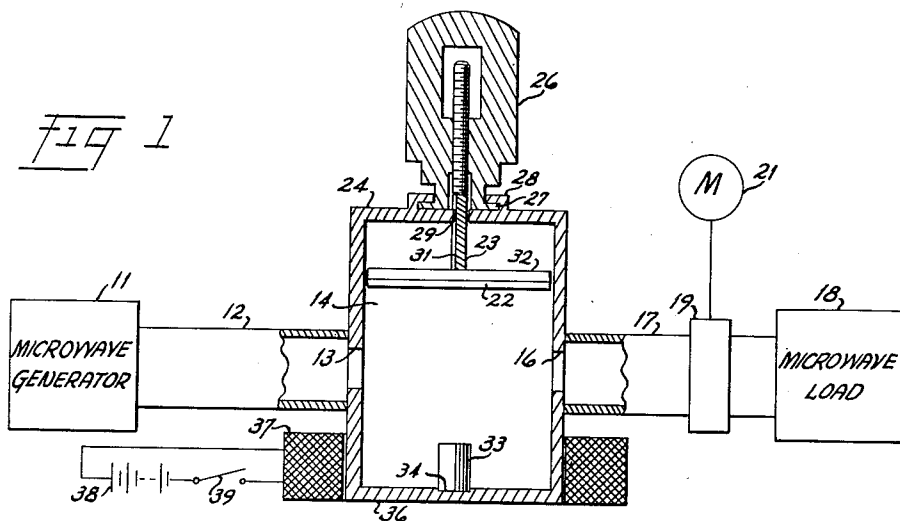


*Fig 4*

INVENTOR.  
JOHN F. ZALESKI  
BY *A. I. Mackay*  
ATTORNEY

## UNITED STATES PATENT OFFICE

2,671,884

## MICROWAVE MAGNETIC CONTROL

John F. Zaleski, Valhalla, N. Y., assignor to General Precision Laboratory Incorporated, a corporation of New York

Application September 19, 1950, Serial No. 185,593

7 Claims. (Cl. 333—98)

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This invention relates to microwave magnetic control circuits for control of microwave energy by means of a magnetic substance.

In the art of control of microwave energy, improved means have been lacking for switching, attenuation and modulation of the energy. The straightforward switching methods of direct-current and low alternating-current practice are not applicable to microwave energy because of the radically different behavior of such energy. Microwave switching means have, therefore, in most cases included wave traps to eliminate radiation losses, precise sliding parts, or accurately made flexible wave guides. Means for attenuation of high power and for modulation are at present correspondingly cumbersome.

The instant invention employs a magnetic substance which may be either ferromagnetic, paramagnetic or diamagnetic. This substance is positioned within a confined microwave field, as within a wave guide, a resonant cavity, or any other microwave transmission component. A solenoid is so positioned that when electrically excited its field magnetizes the magnetic substance, and the resulting change in the magnetic substance changes the impedance which the associated microwave transmission component presents to microwave energy transmitted through it.

The purpose then of this invention is to provide means including a magnetic substance for controlling the magnitude of microwave energy passing through it or near it.

More specifically, the purpose of this invention is to provide magnetic means for changing the impedance of a microwave transmission component.

A further understanding of the invention may be obtained from the detailed description and the drawings, in which:

Figure 1 illustrates a microwave resonant cavity in a circuit embodying the invention.

Figures 2 and 3 illustrate graphically the operation of the invention.

Figure 4 illustrates an alternative embodiment of the invention.

Referring now to Fig. 1, a source of microwave energy is represented by the rectangle 11. This source may be any type of generator such as a magnetron or a hot cathode electric discharge tube, or in general the rectangle 11 may represent any circuit carrying microwave energy. This energy is applied to a microwave guide of any type, such as the rectangular hollow guide 12, of suitable dimensions for transmitting

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microwave energy of the frequency generated by the source 11.

The guide 12 is connected through an appropriate impedance-matching device such as the iris 13 to the interior of a tunable microwave cavity 14. This cavity may have any desired shape, such as that of a hollow right circular cylinder, a sphere, a parallelepiped, a coaxial cylinder, or a partial-coaxial cavity. For the purposes of the present description a hollow right circular cylinder has been chosen, the specific details of which will be more fully described hereinafter.

From the cavity 14 the microwaves are conducted through a matching iris 16 and a rectangular guide 17 to a matched load represented by the rectangle 18. Preceding the load 18 there is connected a microwave power meter 19 which may be any one of the several well-known types, with an associated indicator 21.

Returning now to the cylinder cavity 14, this cavity is tunable by longitudinal adjustment of a piston 22 loosely fitted in the cylinder. The piston 22 is supported by a threaded rod 23 that extends through the end plate 24 and is adjusted by a knurled nut 26 rotatable about the rod and constrained from moving upward by a flange 27 engaging a ring 28 affixed to the end plate 24 of the cavity. The rod is constrained against rotation by a tongue 29 which projects from the end plate 24 into a longitudinal slot or spline 31 cut in the rod 23. The cavity may be of such a size as to support only the principal mode of field configuration at the applied frequency, in which case no microwave energy will leak past the piston 22. If, however, the cavity is made larger to secure the advantage of a larger Q (figure of merit), a higher mode will be supported in addition and some energy will exist in resonations in that mode. This energy will to some extent reach the space behind the piston. In order to absorb this energy, the rear face of the piston is coated with a thick layer 32 of a solid aggregate of finely divided iron in a matrix.

A short rod or stub 33 is pressed into an axial recess 34 in the end disc 36 of the tunable cavity portion of the cylinder, so that the stub projects into the interior space of the tunable cavity. The stub 33 is constructed of a solid aggregate preferably consisting of finely-divided copper-coated iron filings embedded in a matrix of polystyrene. Although the iron particles are numerous and are close together in their matrix, in general each particle is insulated by the polystyrene from the others. Other magnetic materials can be employed, although with less efficiency.

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However, if so, it is preferable that they be in the form of small particles substantially or partly insulated from each other and immobilized in a solid matrix.

Surrounding the cylinder 14 is a wire coil or solenoid 37 in such a position that when energized its field magnetizes the stub 33. The coil 37 is energized by direct current, represented by a battery 38, when the switch 39 is closed.

As is well known, a cavity such as the cylinder 14 resonates at a definite microwave frequency determined by the position of the piston. When microwave energy is transmitted from the guide 12 through the cavity to the guide 17, the cavity acts as a shunt tuned circuit of high quality and rejects incoming energy of all frequencies except that frequency to which it is tuned. Therefore only that frequency is permitted by the cavity to pass from the guide 12 to guide 17, with only a slight reduction in power. All other frequencies are very highly attenuated. This behavior of the cavity is graphically illustrated in Fig. 2, in which when microwave power is applied to the cavity and the resonant frequency of the cavity is varied by adjustment of its piston, the adjustment positions are plotted against the output power, as measured at the meter 21, Fig. 1. A similar resonance curve would be obtained by holding the cavity adjustment constant and varying the frequency of the incident microwave power.

Tests have shown that if a stub of magnetic material, such as the stub 33, is placed in such a cavity in any one of a number of positions, and if the stub be magnetized in any manner such as by energizing a surrounding solenoid, such as the solenoid 37, then the resonant frequency of the cavity is thereby changed. This change of resonant frequency is a nonlinear function, and is represented by the curve of Fig. 3. If the magnetic field strength be varied from A to B on this curve, the resonant frequency of the cavity will change from  $F_2$  to  $F_1$ . Such a change in resonant frequency will permit power to pass through the cavity, as indicated in Fig. 2, so that by increase of the magnetic field of the coil the microwave energy to the load 18, Fig. 1, has in effect been switched on. By proper selection of resonant frequency adjustments the other side of the resonant curve may of course, be used, as for example, in Fig. 2 by adjustment to operate between F and  $F_1$ . Thus the switch 39, Fig. 1 is employed to control the flow of microwave power, and may be alternatively arranged so that when it is moved to its closed position it either starts or stops the flow of microwave power. Because of the high efficiency of any microwave cavity, and because the control of power is effected without mechanical movement within the microwave guides or cavity, this control of microwave power is exceedingly convenient, and is applicable to the lowest microwave powers as well as to the highest.

Another condition occurs when the input microwave frequency is intermediate between the resonant frequency of the cavity with the switch open and that with the switch closed. Then closing or opening the switch results in a momentary pulse of output power as the cavity tuning sweeps past the microwave frequency, and furnishes a method of securing microwave pulses that are exceedingly short. For instance, if in Fig. 3 a field change from A to C be made, causing a frequency change from F to  $F_2$ , then as indicated in Fig. 2 the microwave power will be

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passed while the magnetic field in the coil 37, Fig. 1, is building up, when the cavity resonance sweeps past its peak, but the microwave power will be prevented from passing when the switch is either open or closed. The shortness of the pulse will be limited only by the speed of build-up of the magnetic field of the coil 37. A similar pulse will be transmitted when the switch is opened. By passing periodically changing or alternating current through the coil, pulses of microwave power will of course, be periodically allowed to pass through the cavity.

Instead of placing magnetic material in a cavity as illustrated in Fig. 1, it may be placed directly in a wave guide 41, Fig. 4, as at 42. If placed to form a post projecting into the interior of a rectangular hollow guide through a broad face thereof, it has the properties of a shunt capacitance if shorter than

$$\frac{\lambda}{4}$$

where  $\lambda$  is the free space wavelength of impinging microwave energy, and of an inductance if longer. If it is surrounded by a solenoid 43, changes in the magnetic field thereof will cause changes in the impedance which the post presents to impinging microwave energy, thus controlling to some degree the magnitude of the microwave power passing through the guide. This effect is of course, by no means so marked as is the effect in a resonant cavity but is useful for some purposes because broadband in its frequency transmission characteristics.

What is claimed is:

1. A generator of short microwave energy pulses comprising, a microwave generator producing microwave energy at a selected fixed frequency, a microwave resonant cavity tuned to a frequency which departs from the frequency of said generated energy by a small amount in one sense, means for impressing said generated energy on said cavity, an output circuit connected to said cavity, a member composed of magnetic material positioned in said cavity, means for generating a magnetic field the flux of which links said magnetic member, and means for altering said magnetic field so that when so altered the resonant cavity is tuned to a frequency which departs from the frequency of the generated signal by a small amount in a sense opposite to said first mentioned sense.

2. A generator of short microwave energy pulses as set forth in claim 1 wherein said magnetic material comprises comminuted iron embedded in an insulating matrix.

3. A generator of short microwave energy pulses as set forth in claim 1 wherein said magnetic material consists of comminuted iron having a highly conductive coating embedded in an insulating matrix.

4. A generator of short microwave energy pulses comprising, a microwave generator producing microwave energy at a selected fixed frequency, a microwave resonant cavity tuned to a frequency which differs from the frequency of said generated energy by a predetermined amount in one sense, means for impressing said generated energy on said cavity, an output circuit connected to said cavity, a member composed of magnetic material positioned in said cavity, a solenoid surrounding said cavity and said member, a circuit energizing said solenoid producing a magnetic field of such intensity in said magnetic member that the resonant cavity

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is tuned to a frequency differing from the frequency of said generated energy in a sense opposite from said first mentioned sense, and switching means in said energizing circuit for selectively energizing and de-energizing said solenoid.

5. A generator of short microwave energy pulses as set forth in claim 4 wherein said magnetic material comprises comminuted iron embedded in an insulating matrix.

6. A generator of short microwave energy pulses as set forth in claim 4 wherein said magnetic material consists of comminuted iron having a highly conductive coating embedded in insulating matrix.

7. A magnetic microwave control comprising, a source of microwave energy of a predetermined fixed frequency, a microwave resonant cavity, a transmission circuit interconnecting said source and said resonant cavity, a utilization circuit, a second transmission circuit interconnecting said

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resonant cavity and said utilization circuit, a rod composed of comminuted iron particles having a highly conductive coating embedded in an insulating matrix positioned in said cavity and extending longitudinally of the axis thereof, and means for generating a variable magnetic field the flux of which links said magnetic member.

JOHN F. ZALESKI.

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