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Zaleski

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[54] **PASSIVE MODULATING COMPONENT**

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[52] **U.S. Cl.** .... **343/7.6;** 325/18; 332/30; 332/56; 333/82 B; 343/18 D

[51] **Int. Cl.** **G01s 9/02**

[58] **Field of Search** .... 343/6.5, 6.8, 100.10, 18.4, 343/7.6; 332/29 M, 54, 56, 30; 250/6 A; 325/18, 175; 333/82 B

[56] **References Cited**

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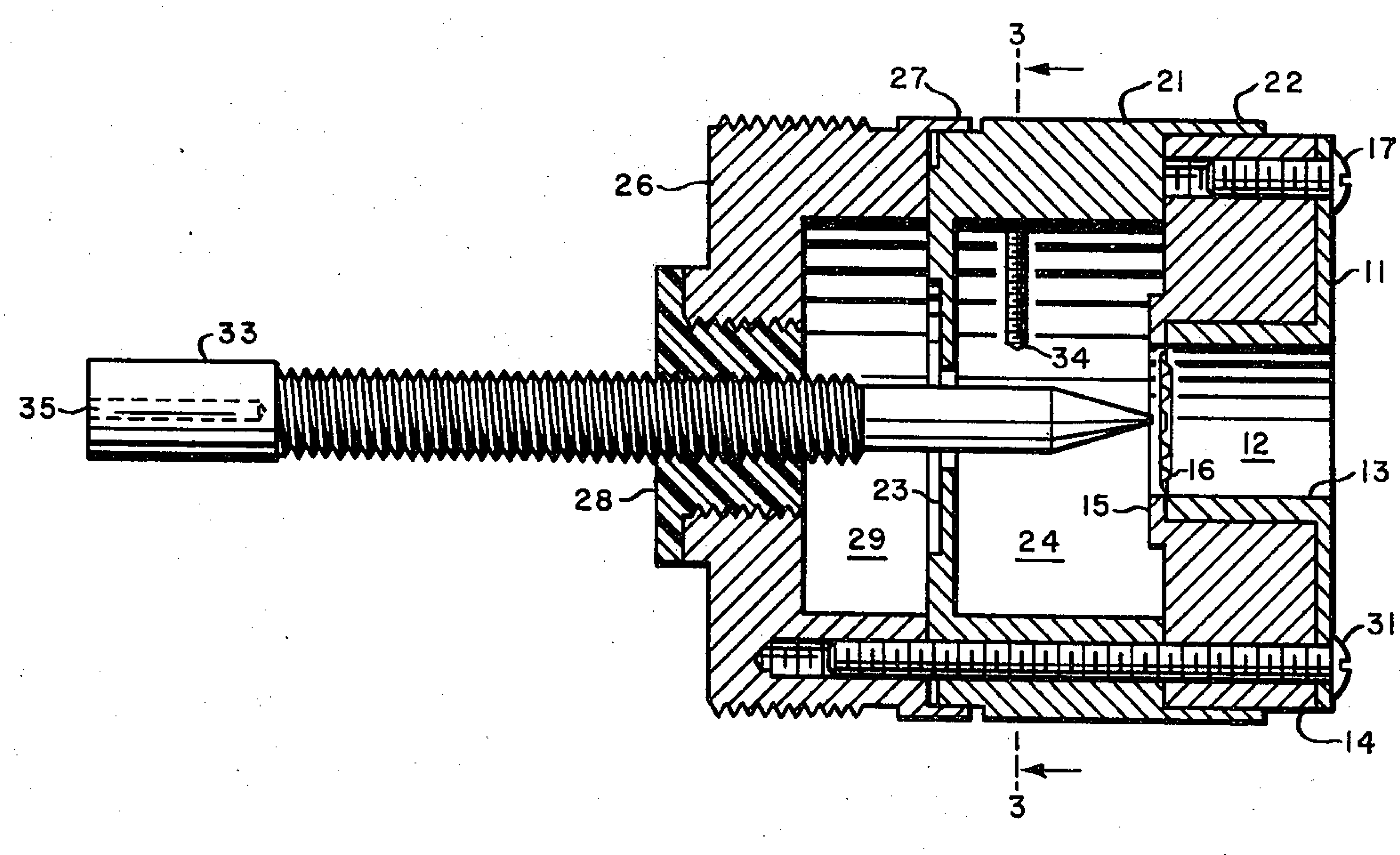
Attorney, Agent, or Firm—T. W. Kennedy

EXEMPLARY CLAIM

1. A passive modulating component comprising, a hollow conductive body, the interior surface of said body defining a cavity in the shape of a figure of revolution, a flexible conductive diaphragm mounted to constitute a portion of said body and positioned on the axis of said figure, a conductive septum perpendicular to said axis fastened to said body and having an axial aperture, and a conductive member positioned on said axis extending through but insulated from said body at a point opposite said diaphragm, and passing through said aperture in said septum.

12 Claims, 6 Drawing Figures



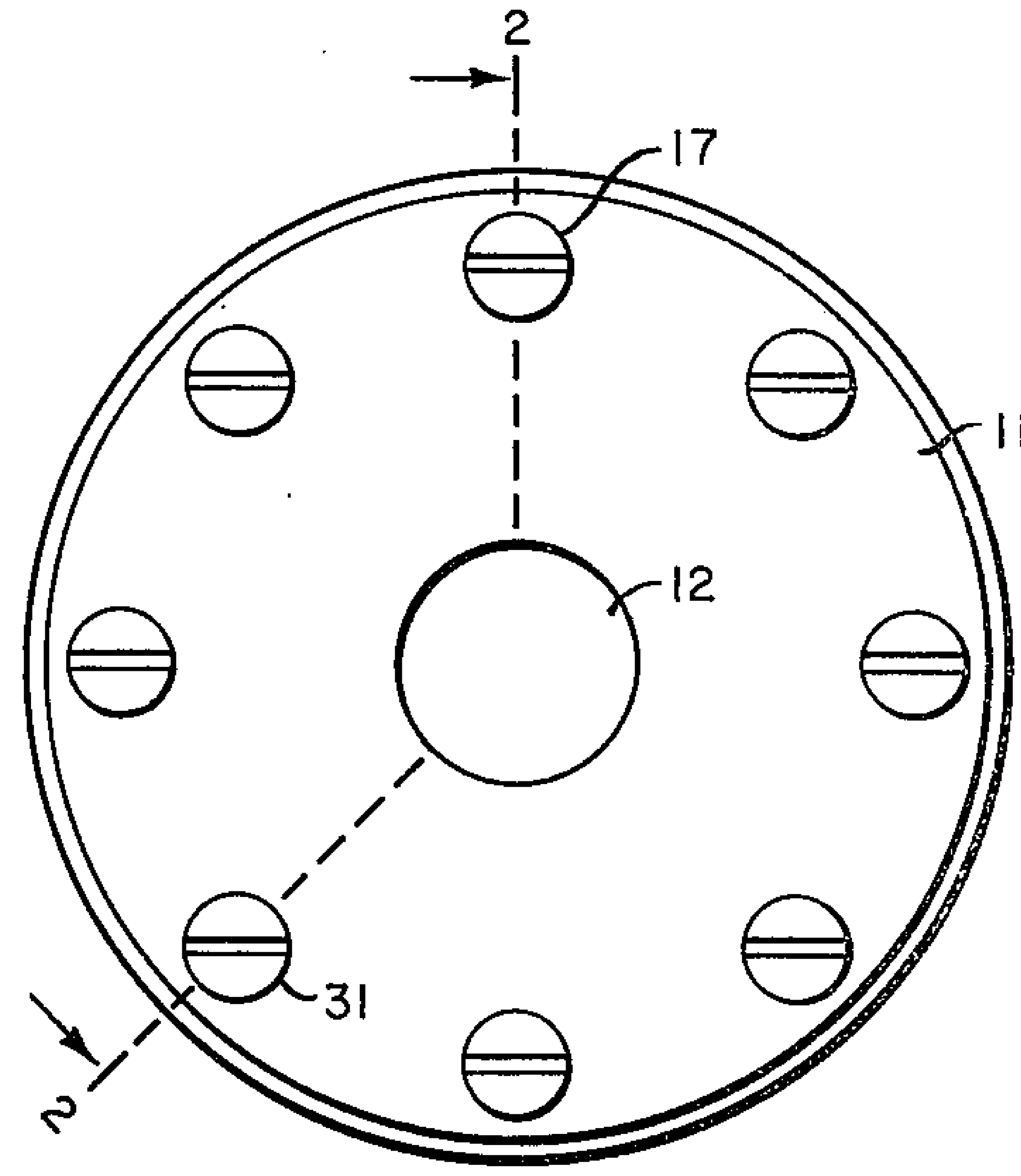


FIG. 1

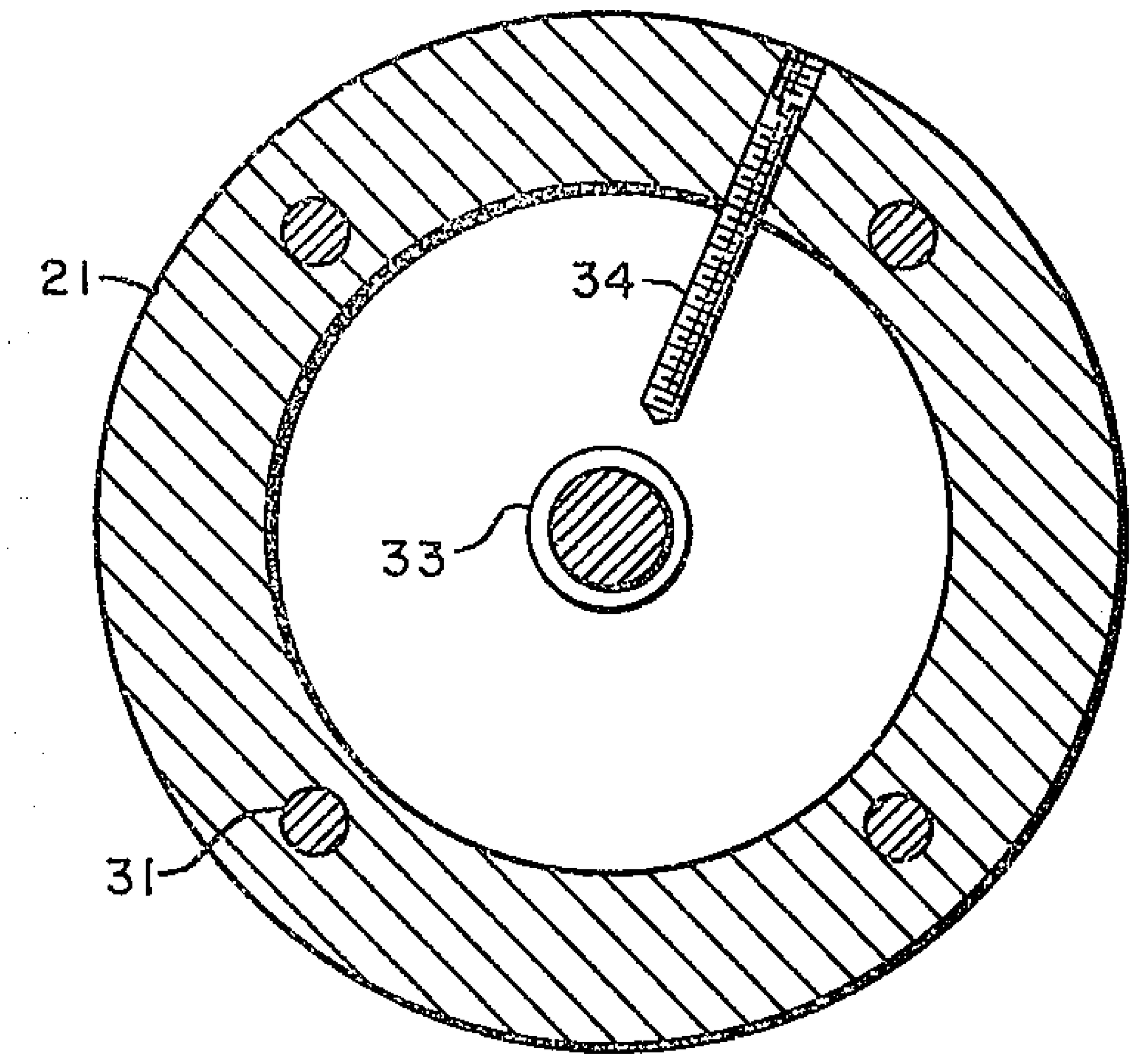


FIG. 3

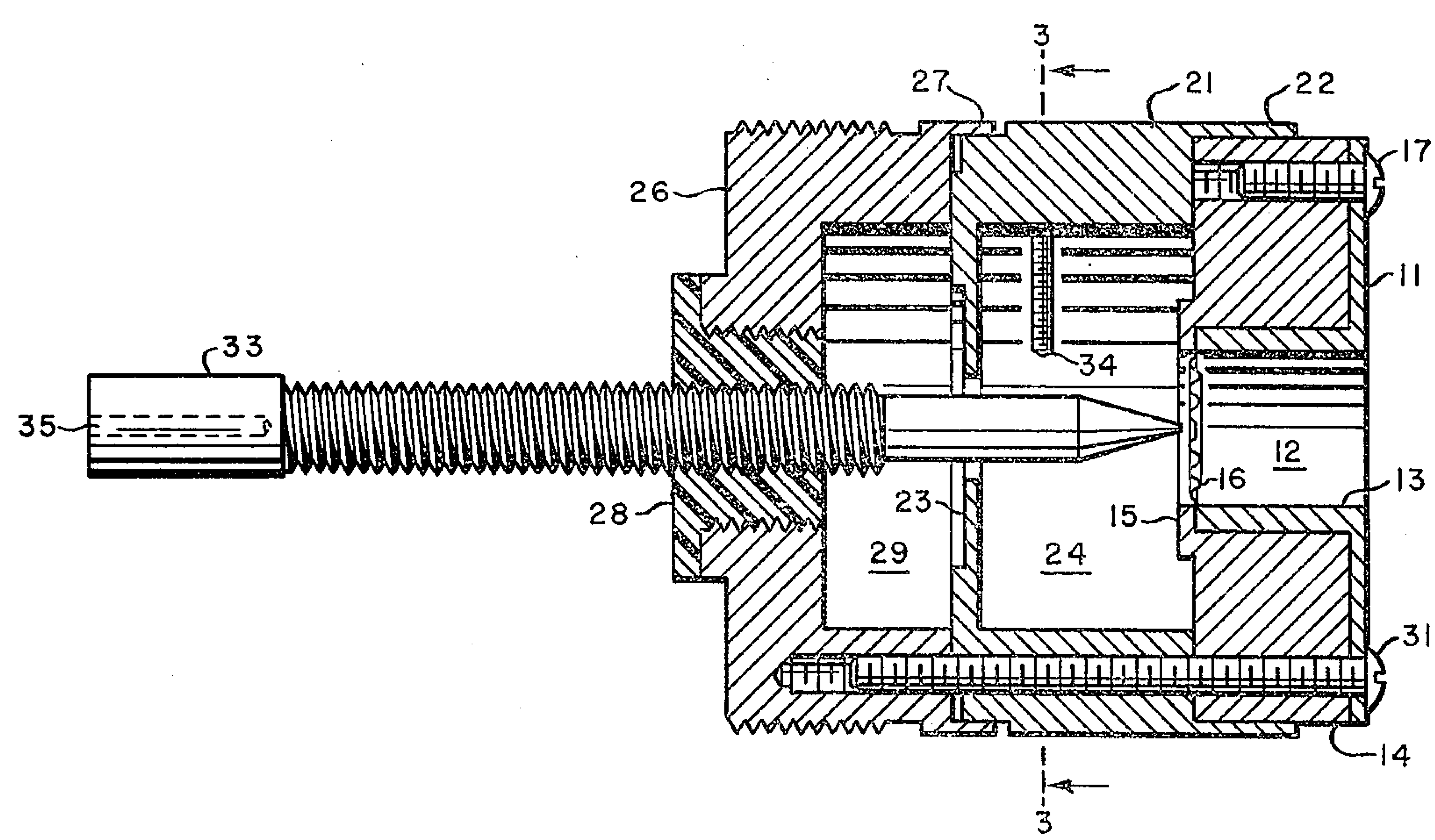


FIG. 2

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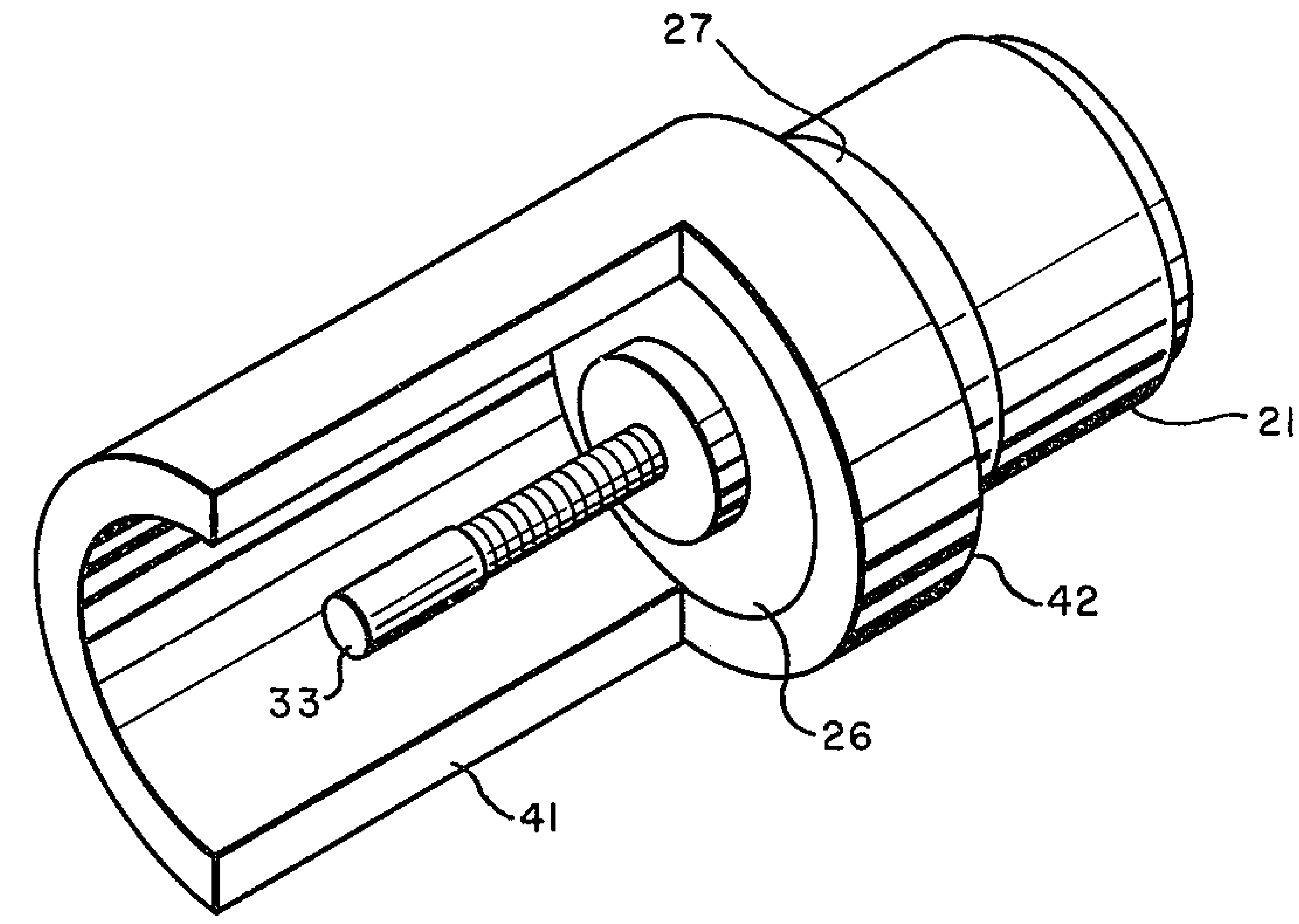

FIG. 6

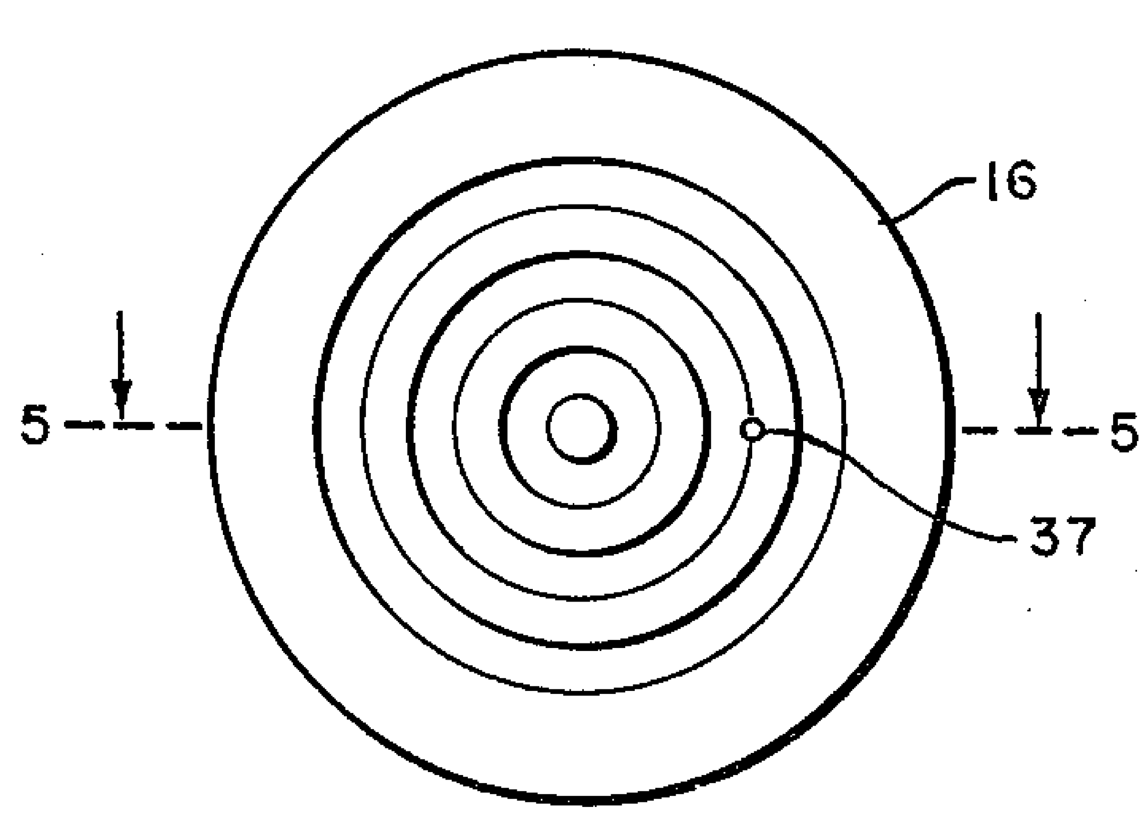

FIG. 4

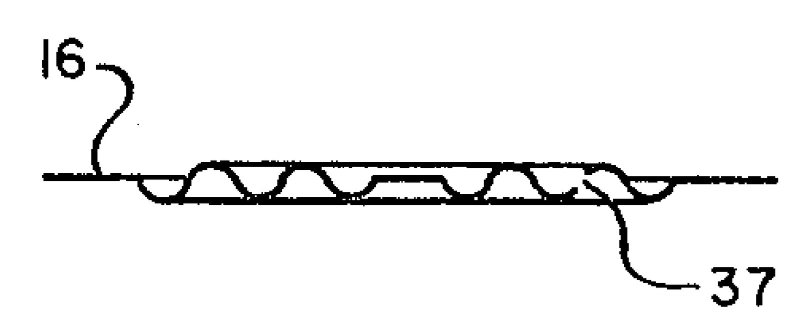

FIG. 5

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PASSIVE MODULATING COMPONENT

This invention relates generally to apparatus for modulating electromagnetic wave energy with intelligence and particularly to a passive component capable of modulating incident radio frequency energy with incident acoustic energy.

The usual method of modulating radio frequency energy with acoustic signals requires the conversion of the acoustic signals to corresponding electric signals which in turn are employed to modulate a radio frequency carrier. Recently considerable attention has been directed to passive components capable of modulating a radio frequency carrier directly by acoustic signals thereby eliminating the apparatus required for the acoustic-electric conversion and its attendant power supplies. The small size, light weight, and absence of trailing wires makes such a component attractive for many applications such as use by a reporter moving through a crowd or use for monitoring sounds occurring in an explosive atmosphere where power supplies would be hazardous.

Passive components for modulating radio frequency energy with acoustic energy have been known in the past and in general comprise a resonant circuit such as a cavity resonator one parameter of which is varied by mechanical motion induced by incident acoustic energy. When such a circuit is excited by radio frequency energy of the proper frequency, the energy in the circuit is modulated by the acoustic energy and a portion is reflected along the path by which it entered. One example of such a passive component is described and claimed in the copending application of John F. Zaleski, Ser. No. 605,663 filed Aug. 22, 1956 for Passive Microwave Receiver-Transmitter, now U.S. Pat. No. 3,836,962.

While the passive elements which have been known in the past, such as the one described in the aforementioned application Ser. No. 605,663, have operated remarkably well, they have been subject to certain limitations, especially when excited by radio frequency energy transmitted through space. For example, nearly all practical applications have required the resonant circuit to be coupled to an antenna, and the antenna and its coupling arrangement have been bulkier than desirable. Also, the efficiency has been low, resulting in a low level of the returned signal.

It is a general object of the present invention to provide improved apparatus for modulating radio frequency energy directly by acoustic energy.

Another object is to provide a passive component for modulating radio frequency energy by acoustic energy which is compact and readily coupled to other radio frequency components.

Another object is to provide a passive modulating component complete with antenna which is very compact.

Yet another object is to provide a passive modulating component exhibiting improved operating characteristics.

Briefly stated, the invention comprises a hollow, generally cylindrical conductive body the interior of which is divided into two chambers by means of a septum having an axial aperture. One end wall of the cylindrical body is comprised in part of a flexible conductive diaphragm capable of being moved by acoustic energy impinging thereon. The other end wall includes an axial

insulating bushing through which a conductive rod is threaded. The rod extends through the aperture in the septum and has one end positioned adjacent to the diaphragm. The other end protrudes from the body and constitutes a probe or antenna. Radio frequency energy of the proper frequency reaching the antenna end of the rod is transmitted to the interior where a symmetrical field is set up. Acoustic energy incident on the diaphragm alters the resonant frequency causing modulation of the radio frequency energy, a portion of which is reflected and transmitted to the antenna end of the rod.

For a clearer understanding of the invention references may be made to the following detailed description and the accompanying drawing, in which:

FIG. **1** is an end elevation view of the modulating component;

FIG. **2** is an axial cross sectional view taken on the line **2—2** of FIG. **1**;

FIG. **3** is a transverse sectional view taken on the line **3—3** of FIG. **2**;

FIG. **4** is an enlarged elevation view of the diaphragm, partly schematic;

FIG. **5** is a schematic cross sectional view of the diaphragm, taken on the line **5—5** of FIG. **4**; and

FIG. **6** is a pictorial view of the device with a reflector added.

The modulating component of the invention is generally cylindrical in shape and in the elevation view of FIG. **1** there can be seen an end plate **11**, the heads of the eight bolts which hold the assembly together, and the outline of a cylindrical recess **12** through which the acoustic energy enters. As best shown in FIG. **2**, the end plate **11** comprises the flat circular portion visible in FIG. **1** and an axial sleeve portion **13** which defines the recess **12**. A block **14** has an axial aperture into which the sleeve portion **13** fits and is formed with an annular lip **15** which cooperates with the sleeve portion **13** to hold a thin circular conductive diaphragm **16** in place. The assembly consisting of the end plate **11**, the diaphragm **16** and the block **14** is held together by four bolts, ninety degrees apart, one of which, the bolt **17**, is visible in FIG. **2**.

A central annular member **21** has an external annular lip portion **22** on one end which fits over the outside of the block **14** while the other end has a small portion of the exterior surface cut away. A plate like septum **23** with an axial aperture is formed integrally with the member **21** opposite the cut away portion. The diaphragm **16**, the block **14**, the member **21** and the septum **23** define a first chamber designated generally by the reference character **24**.

A cup shaped member **26** has threads formed on its exterior surface except for one end which has an annular projection **27** which fits into the previously mentioned cut away portion in the member **21**. The base of the member **26** has an axial aperture with internal threads which cooperate with the external threads of a dielectric bushing **28**. The bushing **28** is preferably made of a low loss dielectric, transparent to radio frequency energy, such as one of those sold under the names "Stycast" or "Teflon." The interior surfaces of the cup shaped member **26**, the septum **23**, and the bushing **28** define a second chamber, designated generally by the reference character **29**. The entire assembly including the end plate **11**, the block **14**, the annular member **21**, and the cup shaped member **26** are fastened together by means of four bolts spaced ninety degrees apart, threaded into the member **26.** One of these bolts, the bolt **31,** is visible in FIG. **2.**

The bushing **28** has an axial aperture through which is threaded a conductive rod **33,** the right end of which, as viewed in FIG. **2,** is frustro-conical in shape, having a flattened tip. The rod **33** extends through the chamber **29,** through the aperture in the septum **23,** and through the chamber **24** to a position such that the tip nearly, but not quite, touches the diaphragm **16.** The left end of the rod **33** extends beyond the main body of the apparatus and constitutes a probe or antenna for receiving and transmitting radio frequency energy and additionally is provided with a small axial aperture **35** into which the inner conductor of a coaxial cable may be fitted. The cylindrical walls of the chambers **24** and **29** cooperate with the axial conductive rod **33** to constitute two coaxial cavity resonators, the resonant frequency of which may be adjusted by means of a tuning screw **34** which extends through the cylindrical wall of the member **21** into the chamber **24.** As best shown in FIG. **3,** the screw **34** is angularly positioned so as not to interfere with any of the bolts holding the assembly together.

In operation, the rod **33** is first adjusted so that the flattened tip is very close to the diaphragm **16.** Radio frequency energy incident on the protruding end of the rod is propagated through the coaxial line comprising the rod **33,** bushing **28** and the end of the cup shaped member **26,** to the chambers **29** and **24** where standing waves in the symmetrical TEM mode are set up. The tuning screw **34** is adjusted to match the resonant frequency of the cavities to that of the incident radio frequency energy. Acoustic energy entering the recess **12** causes the diaphragm **16** to move in accordance with the compressions and rarifactions of the acoustic signal. The spacing between the diaphragm **16** and the tip of the rod **33** is likewise varied, thus varying the capacitance between the rod and the diaphragm. The latter variation causes at least two forms of modulation. First, amplitude modulation is produced since when the cavity is resonant at the frequency of the impressed radio frequency a relatively large amount of power is absorbed while only a small mount is reflected. As the capacitance between rod and diaphragm is varied, the resonant frequency varies, causing a greater amount of power to be reflected. Second, phase modulation is introduced since as the resonant frequency varies above and below that of the impressed frequency, the impedance of the cavity changes from capacitative to inductive thereby producing a change in the phase of the reflected energy. It has been found that the reflected signal can be recovered satisfactorily by the use of either an amplitude modulation detector or a phase modulation detector, although the latter is preferred in most instances because of the more favorable signal to noise ratio inherently obtainable.

A specific embodiment of the invention has been constructed for use with microwave energy in the X band range of frequencies. In this embodiment, the internal diameter of the cavities was made 0.500 inch, the internal distance from the block **11** to the septum **23** was made 0.265 inch. the septum **23** was made 0.035 inch thick where it joins the block **21** and **inch** inch thick at the portion nearer the center of the cavities. the internal diameter of the thicker portion was made 0.343 inch, the aperture in the septum was made

inch **0.125** inches in diameter, and the distance from the thicker portion of the septum to the end portion of the block **26** was made 0.220 inch. The rod **33** was 0.125 inch in diameter at the protruding end, the interior portion being reduced to a diameter of 0.093 inch, and the flat tip was made 0.020 inch in diameter. The rod had a total length of 1.343 inches so that it protruded beyond the bushing **28** a distance of about 0.63 inch which is approximately one half wavelength at 9,000 mcps. All of the parts except the diaphragm **16** and the dielectric bushing **28** were made of brass. It was found that a spacing of from 0.001 inch to 0.005 inch between the tip of the rod **33** and the diaphragm **16** provided excellent operation under normal circumstances, although a spacing of as little as 0.0001 inch has been used when extreme sensitivity has been required.

The diaphragm **16** should have a number of properties. It must be of conductive material so as to cooperate with the tip of the rod **34** and to complete the electrical enclosure of the chamber **24.** The diaphragm must be compliant enough to move in response to acoustic energy yet strong enough so as not to be permanently deformed thereby. It must have sufficient resilience to provide a restoring force to maintain the diaphragm in a neutral position in the absence of acoustic signals. It must be thicker than the skin penetration of the radio frequency energy. One form of diaphragm which has been found to be satisfactory is illustrated in FIGS. **4** and **5** and comprises an aluminum disc approximately 0.0002 inch thick and approximately ¼ inch in diameter. The outer 1/32 inch is held between the end plate **11** and the block **14,** leaving an active diameter of about 3/16 inch. The active portion is stiffened by concentric corrugations approximately 0.005 inch deep and approximately 0.010 inch between crests. As best shown in FIG. **5,** these corrugations extend over the active portion of the diaphragm except for a small portion about 0.030 inch in diameter at the center. It has been found that the chambers **24** and **29** constitute too much of an acoustic load for the diaphragm and that performance is improved by forming a small hole **37** about 0.005 inch to 0.010 inch in diameter in the diaphragm. Additionally, the hole **37** equalizes the pressures on opposite sides of the diaphragm. As is obvious from the dimensions given above, FIGS. **4** and **5,** especially FIG. **5,** are not drawn to scale and must be regarded as schematic only.

The resonant frequency of a reentrant cavity, such as the chamber **24,** depends on many factors, such as the length, the diameter, the size of the central conductor, the spacing of the tip of the central conductor from the end wall, and the arrangement for coupling energy into and out of the cavity. No simple formula is known for predicting the resonant frequency for the various possible configurations and accordingly the design of the present invention has necessarily been in part a process of trial and error. It has been found that the chamber **24** with the dimensions given above is resonant at about 9,000 mcps, the exact frequency depending upon the adjustment of the tuning screw **34.** The chamber **29** is not provided with a separate tuning screw but its resonant frequency is affected by the impedance reflected from the cavity **24** so that both cavities may be tuned by the single tuning screw **34.** It has been found that both cavities can be tuned to resonance by the screw

34 over the range from about 8,500 mcps to about 9,500 mcps.

The component of the present invention may be coupled readily to other microwave components, such as a coaxial line or a waveguide, by means of the external threads on the member **26.** In the case of a waveguide, the device may be screwed into a suitable bushing in the wall of the waveguide in which case the protruding end of the rod **33** constitutes a probe for coupling microwave energy in both directions. In the case of a coaxial line, the inner conductor may be clamped to the end of the rod **33,** aided by the hole in the end, while the outer conductor may be held by the exterior threads on the body of the component.

The present invention is also suitable for use in those applications wherein a microwave transmitter and receiver are located at a remote point and in which the microwave energy is transmitted unguided through space to and from the device. When positioned with the protruding end of the rod vertical, the device has omnidirectional characteristics for vertically polarized waves. If directivity is desired, it may be obtained readily by the use of a reflector such as shown in FIG. **6.**

Turning now to FIG. **6,** there is shown to a smaller scale, the component previously described but with a reflector added. The reflector comprises a hollow semicylindrical portion **41** and a full hollow cylindrical portion **42,** both made from a single piece of brass pipe. The portion **42** is provided with internal threads, not visible in the drawing, which engage the external threads on the cup shaped member **26.** One satisfactory reflector had an overall length of about 1¼ inches so that it extended beyond the end of the rod **33,** as shown, although it will be understood that the dimensions are not critical.

A device in accordance with the present invention was compared directly with a device constructed in accordance with the teachings of the aforesaid copending application Ser. No. 605,663. Differences which might have been caused by differences in the directivity patterns of the two antennas were eliminated by exciting both devices directly by a waveguide. With identical carrier and acoustic signals the device of the present invention produced a return signal 6db stronger than that produced by the device of the application Ser. No. 605,663. The improvement is believed to be due largely to the simpler coupling arrangement of the present invention which permits a greater portion of the incident energy to be converted to the symmetrical TEM mode within the cavities.

What is claimed is:

1. A passive modulating component comprising, a hollow conductive body, the interior surface of said body defining a cavity in the shape of a figure of revolution, a flexible conductive diaphragm mounted to constitute a portion of said body and positioned on the axis of said figure, a conductive septum perpendicular to said axis fastened to said body and having an axial aperture, and a conductive member positioned on said axis extending through but insulated from said body at a point opposite said diaphragm, and passing through said aperture in said septum.

2. A passive modulating component comprising, a hollow conductive body, the interior surface of said body defining a cavity having the shape of a plane figure revolved about an axis, a transverse conductive septum mounted on said body within said cavity dividing said cavity into two chambers, said septum having an axial aperture, said body being formed with first and second apertures at points where said axis intersects said body, a flexible conductive diaphragm mounted to cover said first aperture in said body, and a conductive rod insulated from said body extending through said second aperture in said body and through said aperture in said septum, an end of said rod being in proximity to but spaced from said diaphragm.

3. A passive modulating component comprising, a hollow conductive body, the interior surface of said body defining a cavity having the shape of a plane figure revolved about an axis, a transverse conductive septum mounted on said body within said cavity dividing said cavity into two chambers, said septum having an axial aperture, said body being formed with first and second apertures at points where said axis intersects said body, a flexible conductive diaphragm mounted to cover said first aperture in said body, and a conductive rod insulated from said body extending along said axis through said second aperture in said body and through said aperture in said septum, said rod being mounted to be axially adjustable in position.

4. A passive modulating component comprising, a conductive body having a generally cylindrical interior cavity, said body being formed with first and second apertures at points where the axis of said cylinder intersects said body, a flexible conductive diaphragm mounted on said body and covering said first aperture, and a conductive rod insulated from said body extending through said second aperture, one end of said rod being spaced from said diaphragm by a distance less than the transverse dimension of said rod, the other end of said rod projecting outside said cavity beyond said body a distance approximately equal to one half the free space wavelength of electromagnetic wave energy at the resonant frequency of said cavity.

5. A passive modulating component comprising, a conductive wall shaped to define a generally cylindrical cavity, a transverse conductive septum fastened to said wall within said cavity dividing said cavity into two chambers, said septum having an axial aperture, said wall consisting in part of a flexible conductive diaphragm located on the axis of said cylindrical cavity, and a conductive rod on said axis extending through but insulated from said wall, said rod extending through said aperture in said septum.

6. A passive modulating component comprising, a conductive body having a generally cylindrical interior cavity, said body being formed with first and second apertures in those portions constituting the bases of said cylindrical cavity, a flexible conductive diaphragm mounted on said body and covering said first aperture, a transverse conductive plate dividing said cavity into two chambers, said plate having an aperture coaxial with said first and second apertures, and a conductive rod insulated from said body extending through said second aperture in said body and through said aperture in said plate, said rod being mounted to be axially adjustable in position.

7. A passive modulating component comprising, a hollow conductive body, the interior surface of said body defining a generally cylindrical cavity, a transverse conductive septum fastened to said body within said cavity dividing said cavity into two chambers, said septum being formed with a central aperture, said body being formed with first and second apertures on the cylindrical axis of said cavity and aligned with said central aperture in said septum, and a conductive rod extending from the exterior of said cavity through said second aperture in said body and through said aperture in said septum to a point in proximity to said diaphragm, whereby the end of said rod, said diaphragm and the space therebetween constitute a capacitor, said rod being insulated from said body.

8. A passive modulating component comprising, a hollow conductive body, the interior surface of said body defining a generally cylindrical cavity, a transverse conductive septum fastened to said body within said cavity dividing said cavity into two chambers, said septum having a central aperture, said body being formed with first and second apertures one through each base portion of said cylindrical cavity, both aligned with said central aperture, a conductive diaphragm fastened to said body and covering said first aperture, a conductive rod extending through said second aperture in said body and through said aperture in said septum to a position with its end in proximity to said diaphragm, and insulating means in said second aperture for holding said rod radially while permitting axial adjustment thereof.

9. A passive modulating component comprising, a hollow conductive body, the interior surface of said body defining a generally cylindrical cavity, a transverse conductive septum fastened to said body within said cavity dividing said cavity into two chambers, said septum having a central aperture, said body being formed with first and second apertures one through each base portion of said cylindrical cavity, both aligned with said central aperture in said septum, a conductive diaphragm fastened to said body and covering said first aperture, a conductive rod extending from the exterior of said cavity through said second aperture and through said central aperture to a point in proximity to said diaphragm, and a dielectric bushing in said second aperture for preventing radial movement of said rod while permitting axial adjustment throughout a range which includes contact of the end of said rod with said diaphragm.

10. A passive modulating component comprising, a hollow conductive body, the interior surface of said body defining a generally cylindrical cavity, a transverse conductive septum fastened to said body within said cavity dividing said cavity into two chambers, said septum having a central aperture, said body being formed with first and second apertures one through each base portion of said cylindrical cavity, both aligned with said central aperture in said septum, a corrugated conductive diaphragm fastened to said body and covering said first aperture, said diaphragm being formed with an aperture small compared to the width of said diaphragm, a dielectric bushing mounted in said second aperture, and a conductive rod supported by said bushing and extending from the exterior of said cavity through said bushing and through said aperture in said septum to a position with its tip in proximity to said diaphragm.

11. A passive modulating component comprising, a hollow conductive body, the interior surface of said body defining a generally cylindrical cavity, a transverse conductive septum fastened to said body within said cavity dividing said cavity into two chambers, said septum having a central aperture, said body being formed with first and second apertures one through each base portion of said cylindrical cavity, both aligned with said central aperture in said septum, a flexible conductive diaphragm fastened to said body and covering said first aperture, and a conductive rod insulated from said body extending through said second aperture in said body, and through said aperture in said septum, the end of said rod within said cavity being formed with a tip of reduced diameter, said rod being axially positioned with said tip in proximity to said diaphragm.

12. A passive modulating component comprising, a hollow conductive body, the interior surface of said body defining a generally cylindrical cavity, a transverse conductive septum fastened to said body within said cavity dividing said cavity into two chambers, said septum having a central aperture, said body being formed with first and second apertures one through each base portion of said cylindrical cavity, both aligned with said central aperture in said septum, a flexible conductive diaphragm fastened to said body and covering said first aperture, a conductive rod insulated from said body extending from the exterior of said cavity through said second aperture in said body and through said aperture in said septum, said rod being of smaller diameter than said aperture in said septum, and adjustable tuning means in that one of said chambers which is bounded in part by said diaphragm for varying the resonant frequency of said cavity.

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