

[54] COAXIAL LINE TO MICROWAVE
COUPLER

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[51] Int. Cl. G01n 27/78
[58] Field of Search 324/0.5 A, 0.5 AC, 0.5 AH,
324/58 C, 58.5 C; 333/83, 24 G

[56] References Cited
UNITED STATES PATENTS

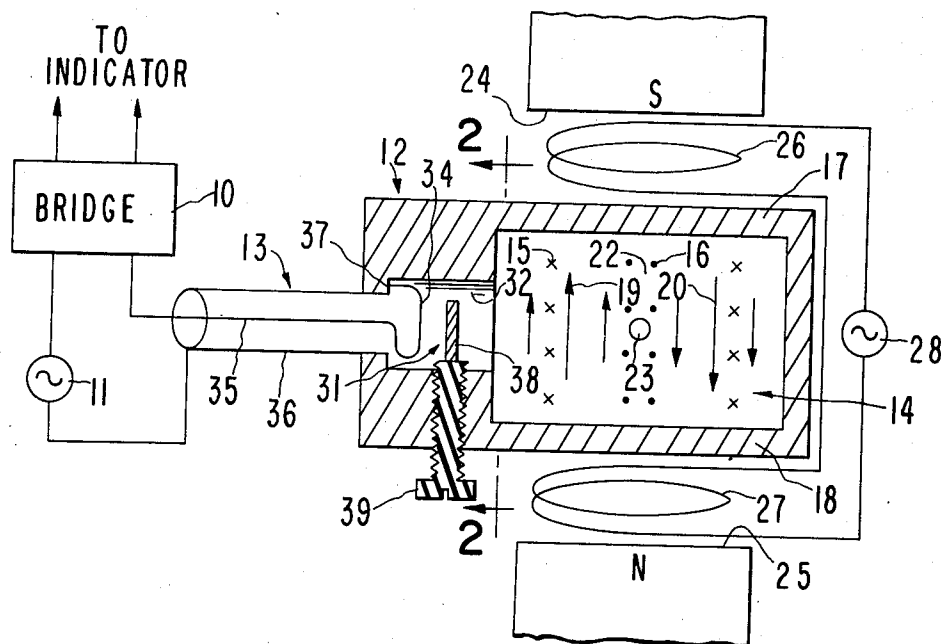
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Attorney, Agent, or Firm—Stanley Z. Cole; Gerald M. Fisher

[57] ABSTRACT

A variable microwave coupler between a coaxial line and an EPR microwave cavity. A housing includes the resonant cavity as well as a section dimensioned to be a waveguide. Energy from the coaxial line is coupled into this section. The section is dimensioned to be a waveguide beyond cutoff and it has an opening into the resonant cavity. A planar loop located in the section is connected to be excited by the energy in the line. The loop is rigidly positioned so that its plane is substantially at right angles to a microwave magnetic field in the cavity. A microwave energy radiator is positioned in the section to be inductively coupled with the microwave energy from the loop. The radiator is positioned in the section, adjacent an intersection between the section and cavity, to electromagnetically radiate the energy inductively coupled to it into the cavity. Inductive coupling between the loop and the radiator is selectively controlled to vary the amount of energy electromagnetically radiated by the radiator into the cavity.

4 Claims, 3 Drawing Figures



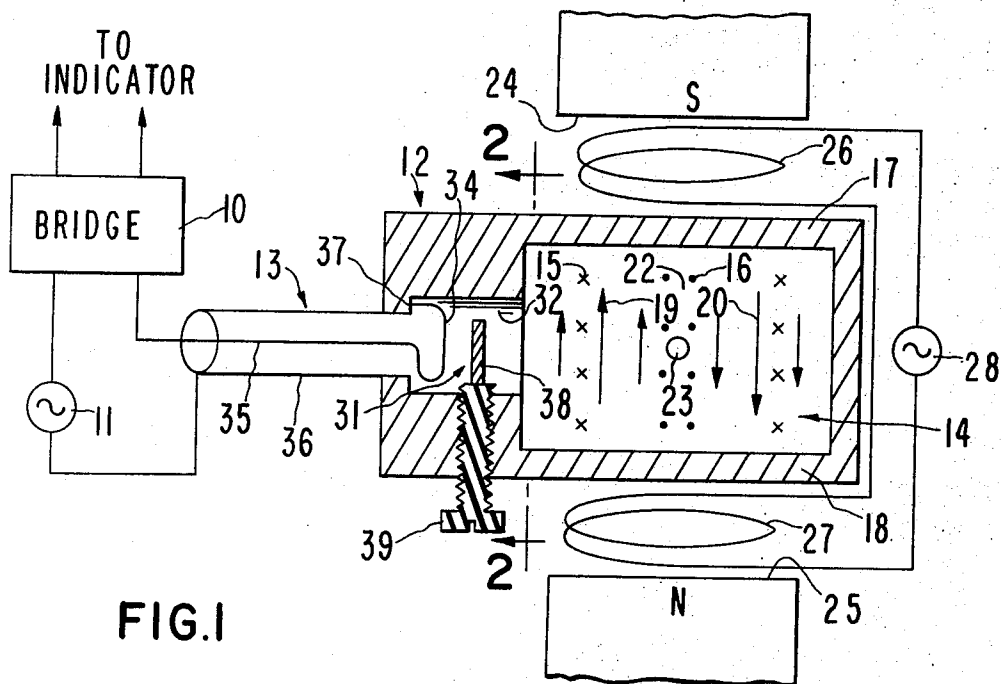


FIG. 1

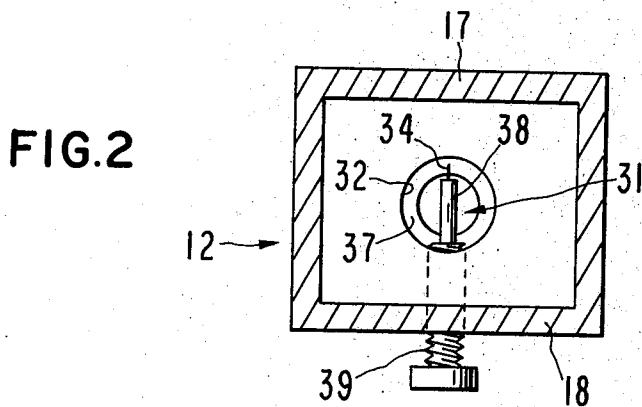


FIG. 2

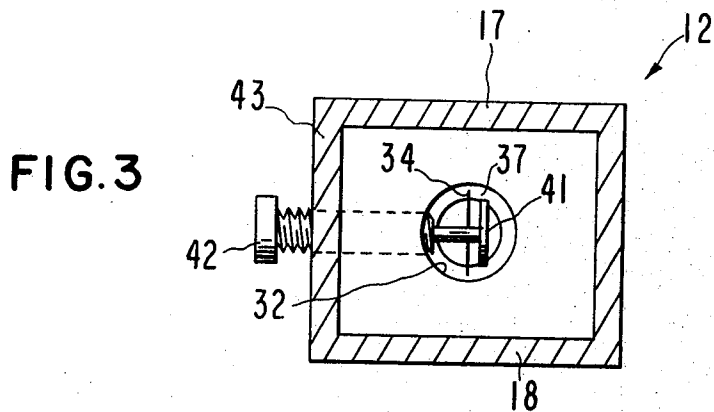


FIG. 3

COAXIAL LINE TO MICROWAVE COUPLER

FIELD OF THE INVENTION

The present invention relates generally to microwave couplers between coaxial lines and microwave cavities and, more particularly, to a coupler wherein an electromagnetic microwave radiator for the cavity is inductively coupled to a termination of the coaxial line.

BACKGROUND OF THE INVENTION

Variable couplers between coaxial lines and microwave cavities, such as resonant cavities or waveguides, typically employ rotating loops as a termination for the coaxial line. The rotating loop varies the polarization angle of microwave energy coupled between the coaxial line and microwave cavity, thereby varying the degree of coupling between the line and cavity. U.S. Pat. No. 3,214,684 assigned to the present assignee is exemplary of such rotating loop couplers. Rotating loops require use of a sliding contact between the rotating element and the coaxial line. Such contacts introduce noise and attenuation in the coupled energy and are relatively susceptible to open circuiting.

SUMMARY OF THE INVENTION

In accordance with the present invention there is provided a new and improved coaxial line to microwave cavity variable coupler that does not require movable elements that are electrically connected to any portion of the coaxial line, thereby obviating the need for brushes. The result is achieved by providing the cavity with a section that is electrically coupled to a termination of the coaxial line. The termination is rigidly connected in situ between the coaxial line center conductor and shield and functions as an inductive radiator for the electromagnetic energy. The section is dimensioned so that it is effectively a waveguide having a cut-off frequency beyond the frequency propagating in the coaxial line, whereby electromagnetic wave transmission is strongly attenuated in the section. Positioned in the section and inductively coupled to the coaxial line termination is an electromagnetic wave radiator that excites the cavity with the microwave energy induced therein from the coaxial line termination. Variations in the inductive coupling between the radiator and coaxial line termination are provided by adjusting the position of the radiator in the waveguide beyond cutoff section to control the coupling between the coaxial line and cavity. Variable coupling can be provided by forming the radiator as a metal stud that is inserted to differing extents in the section or by forming the radiator as a rotatable disc that variably intercepts different amounts of energy from the coaxial line termination.

In a preferred embodiment the coaxial line termination is a planar loop extending between the coaxial line center conductor and outer conductor. The loop, in combination with the radiator, excites the cavity so that a magnetic field subsists in the cavity at right angles to the plane of the loop.

It is accordingly an object of the present invention to provide a new and improved coupler between a microwave cavity and a coaxial line.

Another object of the present invention is to provide a variable, relatively noise-free coupler between a coaxial line and a microwave cavity, which coupler is not

susceptible to open circuits between a moving element and the coaxial line.

Another object of the invention is to provide a new and improved variable coupler between a coaxial line and a microwave cavity, which coupler does not require any moving parts to be connected to the coaxial cable.

Still another object of the invention is to provide a new and improved variable coupler between a coaxial line and a microwave cavity, which coupler does not employ sliding contacts.

A further object of the invention is to provide a microwave coupler between a coaxial line and a microwave cavity wherein energy is inductively coupled between a termination of the coaxial line and a radiator into the cavity.

An additional object of the invention is to provide a new and improved microwave coupler between a coaxial line and an EPR spectrometer resonant cavity.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of several specific embodiments thereof, especially when taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a side sectional view of one preferred embodiment of the invention;

FIG. 2 is a side sectional view taken along the line 2-2 of FIG. 1; and

FIG. 3 is a side sectional view of another embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWING

Reference is now made specifically to FIGS. 1 and 2 of the drawing wherein there is illustrated a preferred embodiment of the variable coupler of the present invention for feeding microwave energy of oscillator 11 to a microwave cavity 12 via bridge 10 and coaxial line 13. In the preferred embodiment, cavity 12 includes a rectangular resonant cavity section 14 formed as a right parallelepiped in which there are excited oppositely polarized and orthogonal magnetic and electric field vectors. The oppositely polarized magnetic field vectors are indicated by the crosses 15 and dots 16 that are directed, in the cross-sectional view of FIG. 1, in planes parallel to the upper and lower walls 17 and 18 of resonant cavity 14. The oppositely polarized electric field vectors 19 and 20 extend at right angles to and between walls 17 and 18, with a null electric field vector being provided substantially along a medium plane 22 of the resonant cavity 14. The microwave electric and magnetic field vectors 15, 16, 19 and 20 thereby excite resonant cavity 14 in the rectangular TE₁₀₂ mode. Positioned midway between wall 17 and 18 on medial plane 22 is a hollow dielectric sample holder 23 which is preferably formed as a capillary tube for a liquid sample to be analyzed by EPR spectroscopy techniques. It is to be understood that resonant cavity 14 can take other geometrical configurations (e.g., cylindrical), that the resonant cavity can be excited to other modes, and that sample holder 23 can have other configurations and positions in the cavity.

To enable the EPR spectroscopy analysis of the sample in holder 23 to be performed, a modulation field is coupled to the sample, with the magnetic field lines of

flux extending in planes parallel to and including the electric field vectors 19 and 20. A strong polarizing magnet including oppositely polarized pole faces 24 and 25 is provided, with the pole faces being disposed parallel to walls 17 and 18 of resonant cavity 14. In a gap between pole faces 24 and 25 and cavity walls 17 and 18, coils 26 and 27 are respectively disposed. Coils 26 and 27 are driven by a relatively low frequency AC source 28, typically having a frequency on the order of 100KHz to modulate the DC magnetic field provided by pole faces 24 and 25. To provide an indication of the spectral lines of the sample in holder 23, bridge 10 is provided to couple energy from microwave source 11 to coaxial line 13 and to be responsive to energy reflected from resonant cavity 14. Bridge 29 includes detector circuitry which drives an indicator in a manner well known to those skilled in the art.

The structure of FIGS. 1 and 2 described to the present is well known to those skilled in the art and does not form a particular part of the present invention. The present invention is concerned with an improved device for variably coupling microwave energy from coaxial line 13 to resonant cavity 14.

The improved variable coupler preferably includes a section 31 formed as a cylindrical section at one end of cavity 12. Alternatively, section 31 could be other shapes, such as a parallelepiped. Section 31 is, in essence, a relatively short length of waveguide dimensioned so that the waveguide cutoff frequency is greater than the frequency of source 11 that drives coaxial line 13 and the resonant frequency of resonant cavity 14. Various manuals provide the formula for calculating the cutoff frequency for waveguides, i.e., for cylindrical waveguides see *Microwave Engineers' Handbook*, Horizon House, 1971, Vol I, p 34. Accordingly, microwave energy of source 11 coupled into section 31 cannot be supported in section 31 for electromagnetic wave propagation and is rapidly attenuated in section 31.

Microwave energy from source 11 is coupled into section 31 by providing coaxial cable 13 with a termination in the form of fixedly mounted planar loop 34 that is connected between center conductor 35 and shield 36 of coaxial line 13. The connection to shield 36 is provided by short circuiting one end of loop 34 to terminating wall 37 of section 13 and by short circuiting shield 36 to the exterior of metal cavity 12. Loop 34 is rigidly positioned in section 31 so that the loop lies in a plane that is substantially at right angles to walls 17 and 18 as well as microwave magnetic field vectors 15 and 16. In response to the microwave current flowing in loop 34 there is a microwave magnetic field induced in section 31 at right angles to the plane of the loop and in the same plane as the microwave magnetic field vectors 15 and 16 in resonant cavity 14. Attenuation of section 31 for the energy of source 11 is such that with screw 39 withdrawn transmission line 35 is a few db undercoupled to resonator 14. Insertion of samples with dielectric loss through opening 23 causes the resonator to become more overcoupled and subsequent insertion of screw 39 permits matching of the transmission line 35 to the resonator 14.

The magnetic field derived from loop 34 is coupled to metallic stud 38 that is positioned in section 31 close to the mouth of the section where the section intersects resonant cavity 14. Metal stud 38 functions basically as a dipole radiator for the microwave energy to electro-

magnetically excite resonant cavity 14 at the same frequency as the energy induced in the radiator from loop 34. Stud 38 is preferably fabricated of a non-ferromagnetic metal, such as silver or aluminum, so that it does not distort the magnetic lines of flux coupled to the resonant cavity by magnet pole faces 24 and 25 in combination with coils 26 and 27. Stud 38 is positioned in section 31 so that its longitudinal axis is coplanar with the plane of loop 34 and generally perpendicular with the microwave magnetic field vectors 19 and 20.

To control the amount of microwave energy coupled into resonant cavity 14, the length of stud 38 in section 31 is adjustable. To this end, stud 38 is mounted on the end of a dielectric screw 39 which is movable in a threaded bore of cavity 12, which threaded bore extends at right angles to and through cavity wall 18. In response to screw 39 being turned to drive stud 38 so that it is inserted to a greater extent into section 31, there is a greater amount of coupling from loop 34 to stud 38. In response to the coupling in stud 38, the stud functions as a dipole radiator to excite cavity 14 to provide the microwave electric and magnetic field vectors 15, 16, 19 and 20. In response to screw 39 being rotated so that stud 38 is withdrawn from section 31, the induced current in stud 38 decreases and the intensity of the microwave fields in cavity 14 is accordingly reduced. Thereby, variable insertion of stud 38 in section 31 controls the amount of microwave energy coupled from coaxial line 13 to resonant cavity 14 without having any physical connection to the coaxial line, all parts and connections to which are rigidly connected in situ at all times.

In accordance with a modification of the invention, as illustrated in FIG. 3, inductive coupling between loop 34 and the dipole radiator for cavity 14 is obtained by providing a rotatable non-ferrous metal disc 41 that is rotatable about an axis that is at right angles to the plane of loop 34. To this end, one end of disc 41 is rigidly connected to one end of dielectric screw 42 that is coaxial with the disc axis of rotation. Screw 42 fits in a threaded bore extending through cavity wall 43 that is disposed at right angles to cavity walls 17 and 18. In response to rotation of screw 42, disc 41 is correspondingly rotated and translated to vary the amount of magnetic coupling between the disc and loop 34 and thereby vary the degree of coupling between coaxial line 13 and resonant cavity 14.

While there have been described and illustrated several specific embodiments of the invention, it will be clear that variations in the details of the embodiments specifically illustrated and described may be made without departing from the true spirit and scope of the invention as defined in the appended claims. For example, the principles of the invention are not necessarily limited to use in connection with EPR spectrometer resonant cavities and the coupler can be employed between any coaxial line and any microwave cavity capable of electromagnetically supporting the frequency in the line. Thereby, the term microwave cavity is to be construed to cover waveguides as well as resonant cavities.

What is claimed is:

1. An EPR spectrometer comprising a cavity for supporting a sample to be analyzed, means for providing a relatively low frequency magnetic field in the sample, a microwave energy source having a frequency for electromagnetically exciting said cavity to resonance,

5

a coaxial line coupling said microwave source and the cavity, and means for variably coupling microwave energy from the coaxial line to the resonant portion of the cavity, said variable coupling means including: a section in a portion of said cavity, said section being dimensioned so that it is a waveguide beyond cutoff for the frequency propagating in said line, a nonferromagnetic, metallic electromagnetic radiator for the energy, said radiator being positioned in the section to electromagnetically excite the cavity with the energy, a fixedly mounted termination for said line connected to the line to be excited by the energy propagating in said line, said termination being positioned in the section to be inductively coupled with said radiator, and means for controlling the inductive coupling between the termination and the radiator to control the amount of said energy radiated by the radiator into the cavity.

6

2. The coupler of claim 1 wherein the means for controlling includes means for moving the radiator relative to the termination.

3. The spectrometer of claim 1 wherein the termination is a planar loop, said radiator comprising a metal stud mounted with a longitudinal axis coplanar with the loop and at right angles to the plane of magnetic flux lines inductively coupling the loop and the stud, and the means for controlling comprises means for varying the length of the stud in the section.

4. The spectrometer of claim 1 wherein the termination is a planar loop, said radiator comprising a metal disc mounted for rotation about an axis at right angles to the plane of the loop, and the means for controlling comprises means for rotating the disc about the axis.

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