Aug. 29, 1950 E. G. LINDER 2,520,602

MICROWAVE MODE CHANGER AND INTEGRATOR

Original Filed April 30, 1947

Fig. 2.

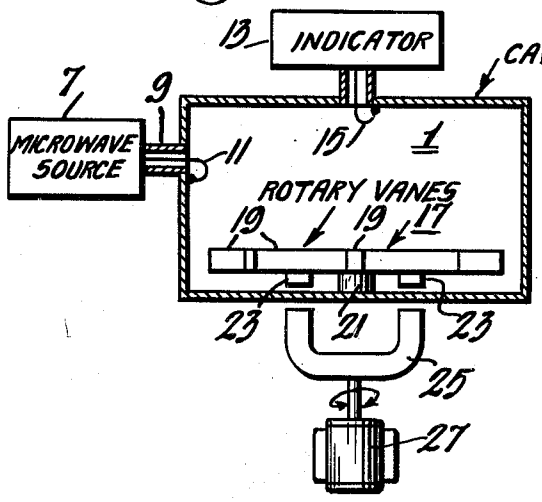


Fig. 1.

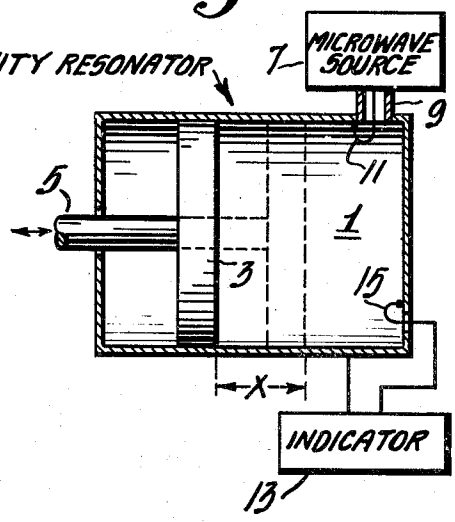


Fig. 4.

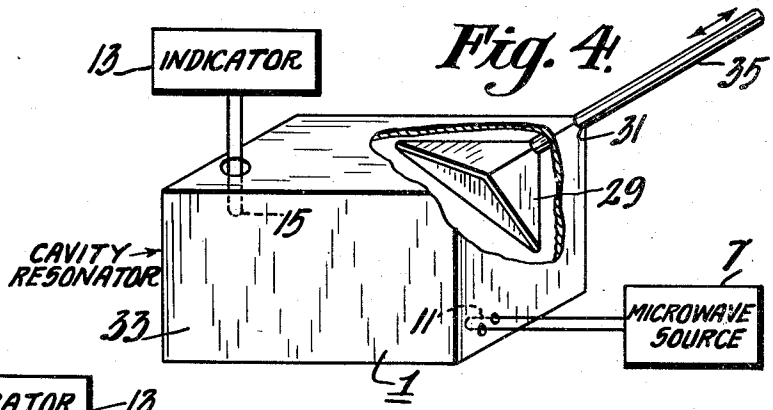
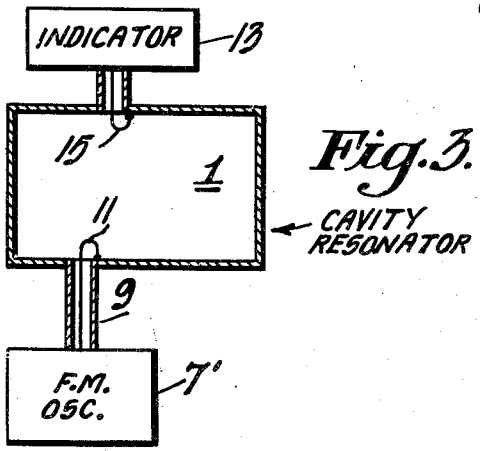


Fig. 3.



INVENTOR
Ernest G. Linder
BY J. L. Whittaker
ATTORNEY

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MICROWAVE MODE CHANGER AND INTEGRATOR

Ernest G. Linder, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

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3 Claims. (Cl. 175—183)

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This application is a division of my copending application Serial Number 745,029, filed April 30, 1947 entitled "Microwave Mode Changer and Integrator," and assigned to the same assignee as the instant application.

This invention relates generally to microwave apparatus and more particularly to methods of and means for effectively integrating microwave energy in shielding enclosures having numerous higher order microwave modes for indicating the average microwave energy distribution within said enclosure.

In measuring microwave energy absorption in gases or other microwave absorptive media, it frequently is necessary to employ a shielding enclosure for the material under observation wherein the enclosure is of such size and the measuring frequency sufficiently high that numerous higher order microwave modes are encountered. Such standing wave distribution within the shielding enclosure heretofore has necessitated the utilization of a large number of microwave detectors spaced at various points within the shielding enclosure, and integrating means for deriving an average indication of the microwave energy detected at the numerous spaced points. Frequently, it is impracticable to space numerous microwave detectors at a sufficiently large number of points within the media under observation or to move a single microwave detector to a plurality of points within said enclosure.

The instant invention contemplates an improved method of and means for effectively changing the microwave modes within a relatively large shielding enclosure at a relatively rapid rate so that a single microwave detector having a relatively long time constant effectively integrates the microwave energy distribution throughout the shielding enclosure. A first embodiment of the invention utilizes a reciprocating piston or similar device for varying one of the internal dimensions of the microwave enclosure at a sufficiently high rate to provide effective integration of the microwave energy within the enclosure by a microwave detector and indicator having a relatively long time constant.

A second embodiment of the invention utilizes a plurality of rotating vanes or propellor blades which are rotated within the microwave enclosure by means of a shaft or magnetic coupling coupled to a driving motor located outside of the microwave enclosure. By proper shaping of the rotating vanes and control of their rotational speed, a much more effective integration of the

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microwave energy may be provided than is possible with a reciprocating piston device. A modification of said first embodiment of the invention having a reciprocating element within the microwave enclosure utilizes a hollow pyramidal shielding element having sides parallel to and adjacent to the sides of the microwave enclosure adjacent to one of the corners thereof wherein the hollow pyramidal element is reciprocated on an axis extending substantially from opposite corners of the hollow rectangular microwave enclosure. Thus each of the dimensions of the microwave enclosure may be varied simultaneously.

A third embodiment of the invention effectively provides rapid variation of the microwave moding in a microwave enclosure by energizing the media within the enclosure by frequency-modulated microwave energy, the modulating frequency being higher than the modulation response frequency of the microwave detector coupled into the enclosure.

Among the objects of the invention are to provide improved methods of and means for measuring microwave energy. Another object is to provide improved methods of and means for effectively integrating microwave energy having a plurality of higher order modes within a microwave enclosure. An additional object of the invention is to provide improved methods of and means for effectively integrating microwave energy within a shielding enclosure having a plurality of microwave modes wherein the modes are varied at a higher rate than the response rate of a microwave detector coupled into said enclosure. A still further object of the invention is to provide improved methods of and means for effectively integrating microwave energy in a shielding enclosure by rapidly mechanically varying at least one internal dimension of said enclosure at a rate higher than the response frequency of a microwave detector and indicator coupled within said enclosure. Another object of the invention is to provide an improved method of and means for effectively integrating microwave energy within a shielding enclosure by introducing frequency-modulated energy into said enclosure, the modulation frequency being higher than the response frequency of a microwave detector and indicator coupled into said enclosure. Still another object of the invention is to provide improved methods of and means for effectively integrating the absorption of microwave energy in a microwave absorptive medium within a microwave shielding enclosure.

The invention will be described in greater detail by reference to the accompanying drawing of which Figure 1 is a cross-sectional, elevational view of a first embodiment of the invention employing a movable piston device, Figure 2 is a cross-sectional plan view of a second embodiment of the invention employing a rotatable microwave fan, Figure 3 is a schematic circuit diagram of a third embodiment of the invention employing frequency-modulated microwave irradiation of a media within a microwave enclosure, and Figure 4 is a partially cross-sectional perspective view of a modification of said first and second mechanical embodiments of the invention. Similar reference characters are applied to similar elements throughout the drawing.

Referring to Figure 1 of the drawing, a preferably cylindrical microwave cavity resonator 1 includes a longitudinally movable piston device 3 actuated by a shaft 5 coupled to a reciprocating mechanism, not shown. It should be understood that the internal dimension of the resonator may be varied in any other known manner, such as by a movable or deformable wall section either contiguous with the remaining resonator structure, or connected thereto by a Sylphon bellows. The travel of the reciprocating system is indicated by the dimension x. A source 7 of microwave energy is coupled into the cavity resonator 1 through a transmission line 9 and a coupling loop 11. A medium, such as a microwave absorptive gas or other material, may be introduced into the cavity resonator 1 for observation of its microwave absorption characteristics. The cavity resonator 1 must, of necessity, be large with respect to the operating wavelength for many microwave absorption measurements in order to provide the required sensitivity. The reciprocating action of the piston 3 varies the microwave modes in the resonator 1 at a relatively high frequency so that the electric field at all points, except at the resonator inner walls, passes through all values from zero to maximum several times during each cycle of the piston, and the resonator consequently shifts through numerous electrical modes. A microwave detector and indicator 13 coupled into the cavity resonator through an output loop or other pickup device 15 has a time constant which is long with respect to the electrical mode changing period. Thus microwave energy detected and indicated will effectively be integrated to provide indications of the average energy transfer of the resonator, and the higher order modes of the resonator are effectively eliminated insofar as the indications are concerned.

Figure 2 illustrates a second mechanical embodiment of the invention wherein the microwave resonator 1 includes a rotary device 17 having a plurality of rotatable conductive vanes 19, each of which has a dimension which is at least one wavelength at the operating frequency. The rotating structure 17 is supported on a center bearing 21 and, if desired, may be driven directly by coupling its center shaft to an external motor. As illustrated, the rotary structure 17 includes magnetic iron pole pieces 23 which are driven by an external permanent magnet device 25 rotated by a motor 27. The resulting induction drive by the magnet 25 of the pole pieces 23 and vane supporting structure 17 is effective through the copper or brass external shell 29 of the cavity resonator 1. The vanes 19 may be shaped in any desired manner to provide maximum variation of the microwave modes within the resonator 1. The speed of rotation of the rotary vanes 19 should be sufficiently high to vary the electric field at all points within the resonator through all values from zero to maximum at a rate higher than the time constant of the microwave detector and indicator circuit. Thus the indicator will provide indications of the average microwave energy transfer of the resonator and will be substantially independent of microwave moding therein.

Figure 3 illustrates schematically a method and apparatus for accomplishing integration of microwave energy transfer through a cavity resonator enclosing a gas or other material to be analyzed, wherein the material-irradiating microwave energy source comprises a frequency-modulated microwave generator 7' coupled through the input transmission line 9 and the input coupling loop 11 into the cavity resonator 1. The modulation frequency of the frequency-modulated microwaves should be sufficiently high to provide effective integration of the irradiating microwave energy for a microwave detector and indicator of any selected time constant. By utilizing an indicator of the cathode ray tube having a sweep or timing frequency synchronized with the modulating frequency, a complete spectrum of the microwave modes may be observed. Then by substituting an indicator having a relatively long time constant, the modes may be effectively integrated and the average energy transfer of the cavity resonator may be indicated.

Figure 4 illustrates a modification of the embodiments of the invention illustrated in Figs. 1 and 2 wherein a hollow pyramidal conductive element 29 enclosed within the cavity resonator 1 is caused to move along an axis extending from opposite corners 31, 33 of the resonator by means of a reciprocating shaft 35 coupled to a reciprocating mechanism, not shown. The shaft 35 extends through any suitable bearing in the corner 31 of the cavity resonator, and reciprocating motion thereof causes all three of the inner dimensions of the resonator to be varied simultaneously thereby providing maximum variation of the microwave modes within the resonator. The frequency of the reciprocating motion of the pyramidal conductive element 29 must be sufficiently high to provide effective integration of the microwave energy transfer of the resonator for a microwave detector and indicator of predetermined time constant. It should be understood that the hollow pyramidal reciprocating element 29 may be varied in shape as desired to provide the desired variation of microwave moding and to minimize resonance effects of the reciprocating element.

Thus the invention described and claimed herein includes novel methods of and means for varying the electrical characteristics of a microwave resonator for effectively providing integration of microwave energy transferred therethrough, wherein the moding variation period is short as compared to the time constant of the microwave detector and indicating circuits. In each of the electromechanical embodiments of the invention described heretofore, the movable mechanical element for disturbing the microwave energy moding may be of conductive or dielectric material and preferably should be at least as large as one wavelength at the operating microwave frequency.

I claim as my invention:

1. In combination, a cavity resonator having at least one internal dimension exceeding a wave-

length at an operating microwave frequency, means for introducing frequency-modulated microwaves into said resonator to provide rapidly varying microwave moding therein, and a wave detector coupled into said resonator, said detector having a time constant substantially greater than the period of variation of microwave moding in said resonator to provide detected signals characteristic of the integrated value of signals of a plurality of said modes in said resonator.

2. Apparatus according to claim 1 including a microwave energy absorptive gas enclosed within said resonator.

3. Apparatus according to claim 2 wherein said

frequency-modulated microwaves include a frequency range to excite molecular resonance absorption effects in said enclosed gas.

ERNEST G. LINDER.

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