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RESONANT CAVITY WAVEMETER FOR
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3 Claims. (Cl. 333—83)

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The present invention relates to microwave resonator systems, and is particularly concerned with an improved wavemeter system for microwave energy.

Calibrated cavity resonators are often employed for the determination of the wavelength or the frequency of energy at microwaves, and particularly at frequencies of the order of 10^{10} cycles per second. A usable structure for this purpose may comprise a cylindrical shell closed at one end, and an adjustable piston element for use as the other end boundary of the resonator. The piston usually is provided with a precision drive mechanism, and is calibrated to enable the user to make frequency or wavelength determinations from the indicated position thereof.

In some prior cavity resonator wavemeters, direct friction contact pistons have been used. These suffer the disadvantage that the contact may become erratic, or may develop appreciable resistance due to surface scoring, or due to foreign matter, or to corrosion or oxidation of the surfaces.

As set forth in U. S. patent application Serial No. 102,276, filed June 30, 1949, in the names of E. L. Ginzton and F. L. Salisbury, these problems may be avoided by use of a series of impedance-transforming transmission line sections, wherein the cylindrical outer surfaces of the piston are spaced slightly from the inner surface of the outer shell, and cooperate therewith as transmission line sections of very low impedance. Intermediate transmission line sections of higher characteristic impedance are provided in the piston. These transmission line sections of alternately low and high characteristic impedance, in cooperation, sometimes referred to as "traps," serve to provide an extremely low effective impedance value across the gap at the periphery of the face of the piston, enabling it to work substantially as though an ideal direct connection were provided thereat.

A difficulty arises, however, when a condition of resonance exists in the space at the opposite end of the piston. This may occur at one or more frequencies in the tuning range of the wavemeter, and can result in ambiguities and/or discontinuities in the calibration of the wavemeter.

A principal object of the present invention is to provide a wavemeter system free from the vulnerability of friction contacts to wear, corrosion, and foreign matter; and free from the spurious response effects which arise from use of a series of alternate transmission line sections.

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A further object is to provide a reliable wavemeter of economical construction, with a simple and effective spurious mode suppressor.

A preferred embodiment of the invention is shown in the appended drawings, wherein Fig. 1 is a side elevation, partly in section, of the wavemeter system, and Fig. 2 is a cross-sectional view taken on the line 2—2 in Fig. 1.

Referring now to Fig. 1, the wavemeter of the present invention comprises an outer cylindrical shell 11 of conductive material, and a longitudinally movable piston 13 therein. Both of these elements are made of highly conductive material such for example as brass, which may be silver plated if desired for very high conductivity. Calibrated means are provided for effecting gradual longitudinal movement of piston 13, and for accurately noting the position thereof, for translation into wavelength or frequency. Such means may comprise a screw drive mechanism, including a large diameter micrometer thimble 15 provided with a scale of divisions around the end thereof, the shell 11 being provided with an index mark therefor and with a longitudinal scale of divisions, to be referred to along with the angular divisions in the manner of the calibration system ordinarily employed for micrometers.

An input coupling such as a coaxial line connector 17 with a coupling loop 19 formed in the inner conductor thereof is provided for introducing energy into the wavemeter system 11, 13. An additional coupler may be provided for the resonator, including a further coupling loop 21 and a housing and radio-frequency by-pass capacitor 23 for a crystal detector element. Output connections from the crystal detector and the shell of the housing and by-pass unit 23 extend to an indicating galvanometer such as a milliammeter or microammeter 25.

If the cavity resonator formed in the left-hand end of the shell 11 is to be coupled to a wave guide, either a coaxial line adapter may be used in conjunction with the coupler 17, or an aperture coupling may be provided in the end of the shell 11 instead of the coaxial coupler system 17, 19.

A microwave energy source such as a klystron 29 is shown connected to the input energy coupler 17, 19 for supplying microwave energy to the cavity resonator.

The piston 13 comprises two large-diameter sections 31 and 33, separated by a section 35 of relatively small diameter. Section 31, which is nearly as great in diameter as the inside diameter of shell 11, cooperates with the adjacent in-

ner surface of the shell 11 as a quarter-wave-length coaxial transmission line section of very low characteristic impedance. Section 33 similarly cooperates with the adjacent inner surface of shell 11 as a further coaxial transmission line section of very low characteristic impedance. The small diameter section between these two sections of piston 13, providing radial current conduction paths of substantially quarter-wave-length extent, serves the purpose of an intermediate quarter-wavelength transmission line section of relatively high characteristic impedance.

The alternate coaxial line sections of low characteristic impedance and radial line section of high characteristic impedance serve the purpose of a "non-contacting shorting system," i. e., they are provided for the purpose of achieving substantially the same effect as though the end face 37 of piston 13 were in direct contact with the inner surface of the shell 11 throughout the periphery of the end face.

The structural features as thus far described are closely related to the systems shown and described in the aforementioned application S. N. 102,276 in the names of E. L. Ginzton and F. L. Salisbury.

In accordance with the present invention, the piston 13 is so arranged as to prevent spurious resonance effects arising from microwave energy fields in the region back of piston 13, i. e. the region bounded at the left-hand end in Fig. 1 by end 39 of piston 13. It has been found that microwave energy fields existing in this region can cause considerable disturbance to the continuity and smoothness of the calibration of the wavemeter system, and can cause some ambiguity of the calibration thereof.

In addition, circumferential resonances occur along the section of coaxial line formed by the non-contacting piston 13 and shell 11 of the TEM mode type, which resonances occur where the circumference of the piston is of the order of a wavelength or multiple thereof. Two such resonances have been found over the tuning range of the wavemeter without the mode suppression of the present invention.

To overcome these resonance effects, relatively deep slots are milled diametrically through the rear end of the piston 13 prior to its assembly on the drive screw 41, and slabs 43 of lossy material are inserted therein. The preferred material for this purpose is "polyiron," a material which was developed primarily for use as cores of transformers and other inductance devices, for high permeability and relatively low eddy-current loss at moderately high frequencies. This is composed of finely divided particles of ferromagnetic material suspended in a dielectric binder. At the microwaves, such material introduces both dielectric losses and eddy-current losses, and is quite effective for suppressing local voltage and current concentrations.

With the "polyiron" slabs 43 arranged as indicated in Figs. 1 and 2, there is appreciable resistance to circular currents around the end surface 39, and likewise around the cylindrical surface at the rear end of the piston 13, and accordingly, such currents are substantially suppressed. Therefore, the region to the right-hand side of piston 13 (as viewed in Fig. 1) is prevented from supporting a resonant field condition and causing objectionable interaction to the principal cavity resonance in the left-hand end of the system.

The circumferential currents associated with

the coaxial-type parasitic resonances, occurring along the piston 13 as mentioned above, are attenuated by the exposed attenuating surfaces formed by the ends of the slabs 43 along the cylindrical surface of the piston, since the circumferential currents must flow across these exposed surfaces. At the same time, by virtue of their limited area in the outer cylindrical surface of the piston, the slabs 43 do not attenuate currents associated with the axial flowing TEM wave, and so have negligible effect on the TEM impedance of the piston.

The slabs 43 of lossy material can be wedge-shaped, if desired, so that the interfaces between these slabs and the brass body of piston 13 would all be radially disposed. However, for economy of construction with the retention of the desired effectiveness, provision of the rectangular slabs is preferred, particularly for simplicity of the milling operations in the end of the piston.

A table of dimensions is set forth below as a guide to construction of a wavemeter system for operation throughout a frequency range of 2575 to 3780 mc.

Inside diameter of shell 11	3.125 inches.
Outside diameter of piston 13	3.000 inches.
Overall length of piston 13	2.220 inches.
Length of section 31 of piston 13	0.840 inch.
Length of section 33 of piston 13	1.130 inches.
Diameter of section 35 of piston 13	1.380 inches.
Diameter of shaft 41	1.500 inches.
Thickness of elements 43	0.125 inch.
Axial length of elements 43	0.400 inch.
Material of elements 43	Grade D-1 Polyiron (H. L. Crowley & Co.).

In addition to the slabs or elements of "polyiron" arranged as spokes in the end of piston 13, and having exposed narrow faces in the end surface and the cylindrical surface thereof, an annular "polyiron" element is provided in the "back-cavity" space surrounding screw-shaft 41. While a ring of this high-loss material could be recessed in the end surface of the piston, intersecting the exposed surfaces of the slabs 43, it is simpler to attach the annular body to the opposite fixed surface as shown at 45 in Fig. 1. This annular body may be secured to the right-hand interior surface of the shell 11 by screws and cement.

The annular "polyiron" body 45 not only contributes somewhat to the suppression of circumferential currents, but also it is particularly effective in the suppression of the mode of oscillation involving radial currents therein, longitudinal currents along the screw-shaft 41 and the inner cylindrical surface of the shell 11, and radial currents in the rear end surface 39 of the piston 13. Since the spokes are so oriented as to contribute relatively little to suppression of these modes, the back plate body 45 and the set of spokes 43 complement each other in rendering the wavemeter system substantially free from spurious response effects.

Since many changes could be made in the above construction and many apparently widely dif-

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ferent embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A tunable cavity comprising a cylindrical conductive shell having first and second conductive ends, a conductive cylindrical piston of slightly smaller diameter than the inner diameter of the shell and longitudinally movable within the shell, one end of the shell and the adjacent end of the piston combining with the shell to define a cavity resonator, the piston having a reduced diameter portion positioned intermediate the ends of the piston forming an annular groove having a radial depth of substantially a quarter wavelength at the mid-band operating frequency, the reduced diameter portion dividing the piston into two regions, each of which provides in combination with the shell a coaxial line section of relatively low characteristic impedance and of the order of a quarter wavelength in length, means for coupling microwave energy through the shell into the resonator, a drive shaft extending axially through the end of the shell opposite the end defining the cavity resonator and secured at one end thereof to the end of the piston opposite the end thereof defining the cavity resonator, the drive shaft combining with the outer shell to provide a coaxial line section of relatively high characteristic impedance, the end of the piston connected to the drive shaft having a plurality of radially extending slots therein that extend through the outer cylindrical surface of the piston, the slots having an appreciable depth as measured parallel to the longitudinal axis of the piston, inserts of high-loss material positioned in the slots, the inserts providing axially extending exposed surfaces in the cylindrical surface of the piston adjacent one end thereof, and an annular body of high-loss material surrounding the drive shaft and secured to the inner surface of the end of the shell through which the drive shaft extends.

2. A tunable cavity comprising a cylindrical conductive shell having first and second conductive ends, a conductive cylindrical piston having a portion thereof extending axially a distance of the order of a quarter wavelength, said portion having a slightly smaller diameter than the inner diameter of the shell, the piston being longi-

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tudinally movable within the shell, one end of the shell and the adjacent end of the piston combining with the shell to define a cavity resonator, a drive shaft extending axially through the end of the shell opposite the end defining the cavity resonator and secured at one end thereof to the end of the piston opposite the end thereof defining the cavity resonator, the drive shaft combining with the outer shell to provide a coaxial line section of relatively high characteristic impedance, the end of the piston connected to the drive shaft having a plurality of radially extending slots therein that extend through the outer cylindrical surface of the piston, the slots having an appreciable depth as measured parallel to the longitudinal axis of the piston, and inserts of high-loss material positioned in the slots, the inserts providing axially extending exposed surfaces in the cylindrical surface of the piston adjacent one end thereof.

3. A tunable cavity comprising a cylindrical conductive shell having first and second conductive ends, a conductive cylindrical piston having a portion thereof extending axially a distance of the order of a quarter wavelength, said portion having a slightly smaller diameter than the inner diameter of the shell, the piston being longitudinally movable within the shell, one end of the shell and the adjacent end of the piston combining with the shell to define a cavity resonator, the end of the piston opposite the end defining the resonant cavity having a plurality of radially extending slots therein that extend through the outer cylindrical surface of the piston, the slots having an appreciable depth as measured parallel to the longitudinal axis of the piston, and inserts of high-loss material positioned in the slots, the inserts providing axially extending exposed surfaces in the cylindrical surface of the piston adjacent one end thereof.

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