July 8, 1958 S. HOPFER 2,842,665

CRYSTAL DETECTOR ASSEMBLY

Filed Dec. 29, 1955

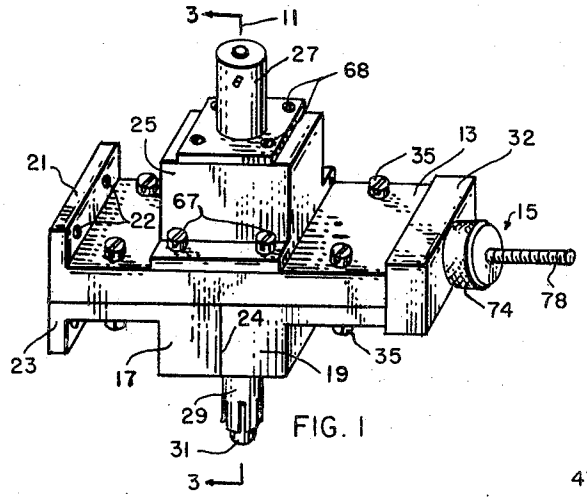


FIG. 1

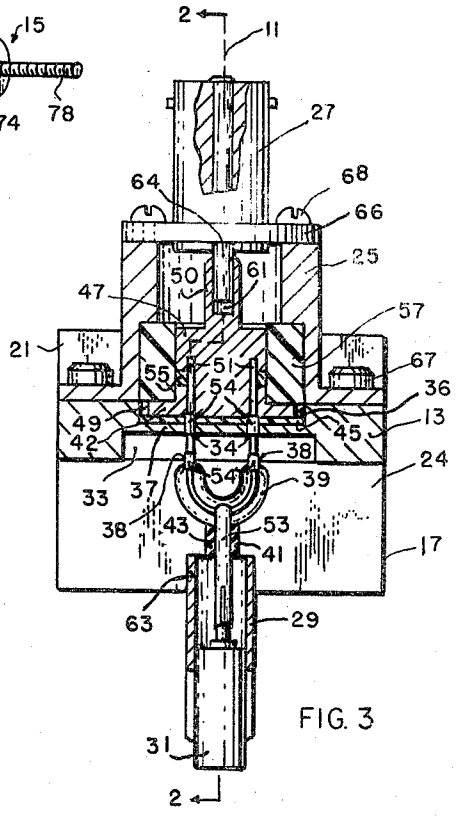


FIG. 3

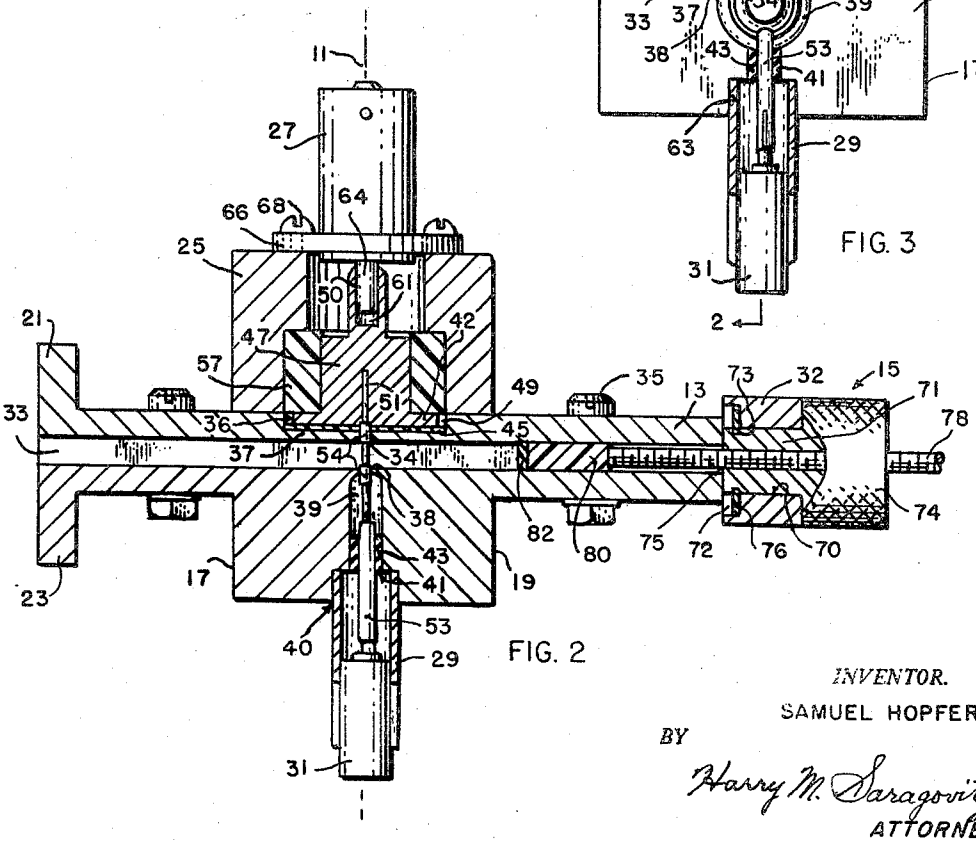


FIG. 2

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2,842,665

Patented July 8, 1958

2,842,665

CRYSTAL DETECTOR ASSEMBLY

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Application December 29, 1955, Serial No. 556,376

10 Claims. (Cl. 250—31)

This invention relates to a novel crystal detector assembly for use in conjunction with a hollow rectangular waveguide in a broad band of microwave frequencies.

It is well known in the art that all waveguides act as high-pass filters. In a rectangular waveguide, with a height H and a width W, the cut-off frequency F_c of the transverse electric mode TE_{mn} or the transverse magnetic mode TM_{mn} of the microwave energy traversing said guide is given by the formula

$$F_c = C\sqrt{\left(\frac{m}{2H}\right)^2+\left(\frac{n}{2W}\right)^2}$$

where C is the speed of light, and m and n are integers.

The dominant mode, i. e., the mode having the lowest cut-off frequency, is usually used to transmit the power in a range of frequencies between the cut-off frequencies of the dominant and the next permissible higher order mode. If a broad band of frequencies is propagated, only those higher order modes having cut-off frequencies within said band can theoretically occur. For example, in the range extending from 10,000 mc./sec. to 40,000 mc./sec., with $L=0.74''$ and $W=0.14''$, using the above formula it is found that only the TE_{10}, TE_{20}, TE_{30} and TE_{40} modes can exist, all other modes being attenuated.

In most practical applications of a rectangular waveguide it is desired to propagate the power only in the dominant mode and avoid the generation of any higher order modes. In general, if the dominant mode is initially propagated it remains pure unless there is present within the guide a reflecting discontinuity. When a broad band of frequencies is used, some higher order modes in general are propagated by any reflecting discontinuity. There can be generated only those higher order modes whose cut-off frequencies, as computed by the above formula using the dimensions of the particular waveguide, are within the range of frequencies being propagated in the guide; while all other higher order modes are attenuated.

It is often desirable to utilize a crystal detector to measure and translate the power propagated inside a hollow waveguide. The use of a crystal detector assembly in conjunction with a rectangular waveguide necessitates the introduction of reflecting discontinuities, such as probes which traverse the waveguide and the apertures required for said probes in the waveguide walls, and which cause the generation of undesirable higher order modes.

Accordingly, it is an object of this invention to provide a novel crystal detector assembly which minimizes the generation of higher order modes in a broad band of frequencies in a rectangular waveguide.

It is a further object to minimize higher order mode generation caused by the introduction inside a waveguide of detecting probes.

It is still a further object to minimize higher order mode generation caused by the apertures in the walls of a waveguide used to introduce therein detecting probes.

It is still a further object to provide means to couple energy from a rectangular waveguide to a coaxial waveguide with a minimum higher order mode generation.

In accordance with the invention a detector assembly

includes a section of a hollow rectangular waveguide and a conducting forked probe structure having thin tines branching from a common base. The tines traverse the waveguide in the nodal planes of those modes whose generation is to be minimized. The tines may also be postioned symmetrically about the plane bisecting the width of the waveguide section to minimize the higher even order modes. Insulation is positioned between the outside surfaces of said tines and the boundaries of the apertures in the waveguide walls wherein said tines penetrate to fill in said apertures. This assembly may then be adapted to couple microwave energy from the rectangular waveguide section to another branch, such as a coaxial waveguide through the use of coaxial terminals connected to the forked probe and the coaxial waveguide.

This assembly may also be used to measure microwave energy propagated in the rectangular waveguide section through the addition of a crystal detector connected to the base of the probe and electrical terminals which are connected to the crystal detector and the tines of the probe.

Other objects and advantages will be apparent from the following detailed description and the accompanying drawing, wherein:

Figure 1 is a perspective view of a crystal mount embodiment constructed in accordance with the principles of the invention;

Figure 2 is a sectional view of the crystal mount, taken along the line 2—2 of Figure 3; and

Figure 3 is a sectional view of the crystal mount taken along the line 3—3 of Fig. 2.

The particular embodiment described herein is for use with a rectangular waveguide of given dimensions within a prescribed broad band of frequencies such that the only modes which can exist are the first four transverse electric modes, i. e., the TE_{10}, TE_{20}, TE_{30} and TE_{40} modes.

The detector assembly is divided into three major structures, an upper plate member structure **13**, a tuning structure **15**, and a lower structure comprising lower plate elements **17** and **19**.

The upper plate member **13** is formed with an upwardly extending flange **21** at one of its ends. The lower plate element **17** is formed with a downwardly-extending flange **23** at its corresponding end. The flanges **21** and **23** which cooperate to form a unitary flange structure, when the plate elements **13** and **17** are assembled as shown, have holes **22** and appropriate fastening means (not shown) to enable it to be joined to a waveguide structure through which the input energy is supplied to a waveguide section formed by the three major structures.

The lower plate elements **17** and **19** are fastened to the upper member **13** by suitable fastening means such as machine screws **35**. One end of plate element **19** abuts the end of lower plate element **17** which is remote from its flange **23**. The abutting ends of the two plate elements **17** and **19** are closely fitted together at a plane of contact **24**.

The upper member **13** is composed of a material of high conductivity such as brass and has a longitudinal slot **33** of rectangular cross section extending along its lower surface the total length of the plate. The walls of the longitudinal slot **33** form the top and side walls of a rectangular waveguide section having cross sectional dimensions which are identical with those of the waveguide to which the detector assembly is to be joined by the flanges **21** and **23**. The lower wall of the waveguide section is formed by the uppermost portions of the aligned lower plate elements **17** and **19** which should also be composed of a highly conductive material, such as brass.

The upper member **13** has in its upper surface a cylin-

drical bore 36 which is symmetrical about the vertical central axis 11 lying in the plane of contact 24. The bore 36 is sufficiently shallow to leave a thin portion 37 of the upper member 13 located between the lower surface of the bore and the upper surface of the longitudinal slot 33.

Two holes 38 extend vertically in the lower structure starting from its upper surface and terminating in the extremities of a U-shaped slot 39. As is best shown in Fig. 3 of the drawing, the holes 38 are positioned symmetrically about the plane of contact 24 and are respectively spaced on opposite sides of the vertical axis 11 a distance equal to one third the width of the longitudinal slot from a side wall of the longitudinal slot; in other words, each hole is centered in one of the nodal planes of the TE_{30} mode of the microwave energy propagated in the waveguide. The U-shaped slot 39 connecting the holes 38 has a circular cross section and is positioned symmetrically about the plane of contact 24.

A counterbore 40 positioned symmetrically about axis 11 extends upward from the lower surface of the lower structure. A cylindrical bore 41 having a diameter less than the diameter of the counterbore 40 is positioned symmetrically about the axis 11 and connects the lower extremity of the U-shaped slot 39 to the upper extremity of the counterbore 40.

A cylindrical conducting sleeve 29 is positioned in the counterbore 40. The sleeve forms a mount for a crystal detector 31, such as a germanium crystal of the 1N26 type. The sleeve is slotted at its lower extremity to provide spring fingers which insure a good mechanical and electrical connection to the crystal detector 31. The sleeve 29 is electrically and mechanically connected to the lower plate structure by a press fit within the counterbore 40. A supporting bushing 43 of insulating material such as polystyrene is situated within the bore 41 surrounding the base 53 of the fork and connects the lower elements 17 and 19 to the base 53.

A plug composed of a conducting material such as beryllium having a stepped configuration and comprising three cylindrical sections 42, 47 and 50 of progressively decreasing diameter, respectively, is positioned in cylindrical bore 36. A thin disc 45 of insulating material such as mica is positioned in the aperture below this plug and serves to insulate it from the thin portion 37 of the upper member 13. The lowermost section 42 has a diameter a little less than the inside diameter of bore 36 leaving an annularly shaped insulating space 49 between the lowermost section and the side walls of the bore 36.

Two holes 34, which are vertically aligned with holes 38, extend through the thin portion 37, the thin disc 45, the lowermost section 42, and part of the intermediate section 47.

Two thin tines 51 branch upward from a common base 53 traversing the aligned apertures 34 and 38 and the longitudinal slot 33. The tines 51 should be thin compared to the width of the waveguide section. For example, tines which have been found suitable for the specific waveguide whose dimensions are hereinabove given are formed of .031 inch diameter steel wire. The crystal detector 31 is connected to the lower extremity of the shaft 53 of the fork.

The U-shaped slot 39 has a cross sectional diameter which is considerably larger than the width of the tines 51; while the cross sectional diameter of the cylindrical bore is considerably larger than the thickness of the shaft 53. The shaft extends coaxially through the cylindrical bore 41 while the tines extend coaxially through the U-shaped slot 39 to leave a considerable space separating the fork from the lower plate elements 17 and 19.

In the vicinity of the longitudinal slot the portions of the holes 34 and 38 remaining between the tines and the inner walls of the holes is filled with insulation such as an insulating coating 54 of a suitable material such as varnish on the outside surfaces of the tines 51 to completely fill in the four holes 34 and 38 and insulate the tines from the waveguide walls. The tines extend from the U-shaped slot 39 through the holes 38, across the entire height of the waveguide section formed by the longitudinal slot 33, through the holes 34 in the thin portion 37, through the holes in the thin disc 45 and terminate in the middle section 47 of the plug. The tines are fastened and connected to the plug near their upper ends by a suitable conducting joint 55 formed, for example, by solder.

The uppermost section 50 of the plug has a slotted bore in its upper extremity to form a press fit receptacle 61 for the lower end of the center conductor 64 of a coaxial upper terminal 27. The lower portion 66 of the outer conductor of the upper terminal 27 forms a plate which rests on a hollow block 25 composed of sturdy conducting material such as brass, and is connected thereto by suitable fastening means such as screws 68.

An annular collar 57 composed of an insulating material such as polystyrene surrounds the middle section 47 and insulates the plug from the block 25 and the upper member 13.

On the side opposite the flanges 21 and 23 a support block 32 abuts the upper member 13 and lower plate element 19. The support block 32 is composed of a sturdy conducting material such as brass and carries the tuning structure. As shown best in Fig. 2, the support block 32 has therein a central bore 70 completely traversing it and a larger concentric counterbore 72 located at the surface abutting the upper member 13 and the lower plate element 19. The bore 70 is completely filled by an adjusting nut 71 which has an enlarged knurled outer end 74 and an internal central threaded bore 75 which completely traverses it. The adjusting nut 71 is held within the bore 70 by a retaining washer 76 located in the aligned annular slots formed by the counterbore 72 and an annular groove 73 in nut 71. The nut 71 is thus free to rotate about its axis but is prevented from longitudinal movement with respect to the support block 32 by the retaining washer 76 at one end and the enlarged knurled portion 74 at its other end.

The adjusting nut 71 carries a screw member 78 within its internal threaded bore 75. The screw member 78 is attached to a block 80 which is composed of an insulating material and which is dimensioned to have a close internal fit within longitudinal slot 33. The block 80 is faced with a strip 82 composed of a conducting material, such as brass, on the end remote from the end attached to screw member 78. Conducting strip 82 is dimensioned to have a sliding fit within the longitudinal slot 33. Adjustment of nut 78 moves metal strip 82 longitudinally and varies the effective length of the cavity to tune the waveguide.

In operation, the conducting probes transmit to crystal 31 the microwave energy from the waveguide section formed by the longitudinal slot 33. The probes constituted by the two tines 51, extend along the nodal planes of the TE_{30} mode of the microwave energy traversing the waveguide section.

Assuming that only the TE_{10}, TE_{20}, TE_{30} and TE_{40} modes can exist in the given broad frequency range within which said microwave energy lies, and that initially only the fundamental mode, the TE_{10} mode, is applied to the waveguide section, the higher order modes, i. e., the TE_{20}, TE_{30} and TE_{40} modes will, in general, be generated due to the presence of reflecting discontinuities. Such discontinuities are formed by the tines 51 and the holes 34 and 38 in the walls of the waveguide section.

Any obstacle discontinuities which are positioned symmetrically about the center plane bisecting the width of a waveguide section do not cause the generation of any higher even order modes such as the TE_{20} or TE_{40}

modes. The nodal planes of the TE_{30} mode are located symmetrically about this plane. The tines 51 are positioned symmetrically about the nodal planes of the TE_{30} mode; therefore the resultant amount of each of the TE_{20} and TE_{40} modes consequently generated is minimized. Also the TE_{30} mode generation is minimized because the tines are located at the nodal planes of this mode.

The use of only one crystal minimizes higher order mode generation which would result from the use of a plurality of crystals and the resulting impedance asymmetry about the vertical axis 11. The higher order mode generation due to the discontinuities caused by apertures 34 and 38 has been minimized by the expedient of completely filling in the holes with insulating coatings 54. Even if all four propagating modes are incident in the waveguide, the dual tine arrangement will couple only to the fundamental mode. This follows from the fact that the location of the tines will prevent detection of the third mode, and the second and fourth modes, being 180 degrees out of phase, will be short circuited across the symmetrically positioned crystal line so that no power will reach the crystal.

The above structure can be readily modified and converted to a device to couple energy from a rectangular to a coaxial waveguide by eliminating the crystal and connecting the shaft 53 of the fork to the center conductor of the coaxial line.

What is claimed is:

1. In combination with a rectangular waveguide, a pair of probes traversing said waveguide and respectively positioned in the vicinity of the trisecting planes the width of said waveguide, means for combining the outputs of said probes, to provide a resultant output equal to the sum of said outputs, and means to supply said resultant output to a utilization circuit.

2. The combination set forth in claim 1, wherein the axes of said probes lie in said planes.

3. The combination set forth in claim 1, wherein said planes intersect said probes.

4. A crystal detector assembly comprising a rectangular waveguide section adapted to pass microwave energy therethrough, a crystal detector mounted externally to said waveguide section, means connecting said crystal detector to said rectangular waveguide section, said means comprising a pair of probes traversing said waveguide section with their axes respectively positioned substantially in the nodal planes of the TE_{30} mode of said microwave energy, said planes trisecting the width of said waveguide, and means connecting said probes to said detector.

5. A crystal detector assembly comprising a crystal detector, a rectangular waveguide section having walls with apertures therein, means connecting said crystal detector to said rectangular waveguide section comprising a conducting forked structure having a pair of tines branching from a common base, and means electrically connecting said base to said crystal detector, said tines traversing said apertures with their axes positioned substantially in the planes trisecting the width of said waveguide section.

6. A crystal detector assembly comprising an upper structure having a longitudinal slot in one face thereof, a lower structure fastened to said face to form with said slot a rectangular waveguide section, a crystal detector attached to said lower structure, a conducting forked structure having a pair of tines branching from a common base, said upper and lower structures having aligned apertures therein, said tines passing through said apertures with their respective axes substantially in the nodal planes of the TE_{30} mode of said waveguide, said planes trisecting the width of said waveguide, and means electrically connecting said common base to said crystal detector.

7. A crystal detector assembly comprising an upper structure having a longitudinal slot in one face thereof, a lower structure fastened to said face, a tuning structure attached to both said upper and lower structures at one end of said slot to vary the effective length of said slot, a crystal detector attached to said lower structure, a conducting forked structure having a pair of tines branching upwards from a common base and connected at the upper end thereof, said upper and lower structures having aligned apertures therein, said tines passing through said apertures with their axes respectively positioned substantially in the planes trisecting the width of the said slot, and insulating material disposed in and completely filling in said apertures between said tines and the boundaries of said apertures.

8. A device to couple energy from a rectangular waveguide to a coaxial waveguide comprising a conducting forked structure having a pair of tines branching from a common base, a rectangular waveguide section adapted to pass microwave energy therethrough, said waveguide section having walls with apertures therein which are larger than the thickness of said tines, a coaxial waveguide section, means connecting said conducting forked structure to said rectangular waveguide section, coaxial transmission means connecting both said base and said tines to said coaxial waveguide section, said tines traversing said apertures and said waveguide at the nodal planes of the TE_{30} mode of said rectangular waveguide section, said nodal planes trisecting the width of said rectangular waveguide section, and insulation positioned to fill in said apertures around said tines, whereby the excitation of higher order modes of said energy is reduced.

9. A crytal detector assembly comprising a crystal detector, a rectangular waveguide section adapted to pass microwave energy therethrough having walls with apertures therein, means connecting said crystal detector to said rectangular waveguide section, said means comprising a conducting forked structure having a pair of tines branching from a common base and connected at the ends thereof, said tines being thinner than the width of said apertures, means electrically connecting said common base to said crystal detector, said tines traversing said waveguide section with their axes positioned respectively in the planes trisecting the width of said waveguide section and insulating coatings on said tines filling the spaces between said tines and the walls of said apertures.

10. A crystal detector assembly comprising an upper structure having a longitudinal slot in one face thereof, a lower structure fastened to said upper structure and forming with said slot a rectangular waveguide, a tuning structure comprising movable means at one end of said longitudinal slot to vary the effective length of said rectangular waveguide, a crystal detector attached to said lower structure, a terminal attached to and insulated from said upper structure, a conducting forked structure having a pair of tines branching from a common base and connected at the ends thereof, said upper and lower structures having aligned apertures located therein at the nodal planes of the TE_{30} mode of said waveguide, said nodal planes trisecting the width of said waveguide, said tines extending through said apertures and through said waveguide with their axes respectively in said nodal planes, means electrically connecting the ends of said tines to said terminal, and means electrically connecting said common base to said crystal detector.

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