

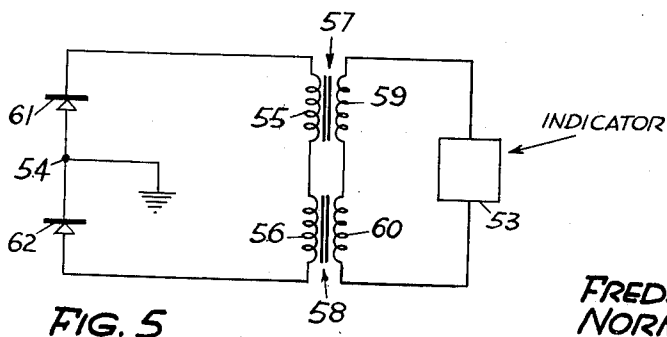
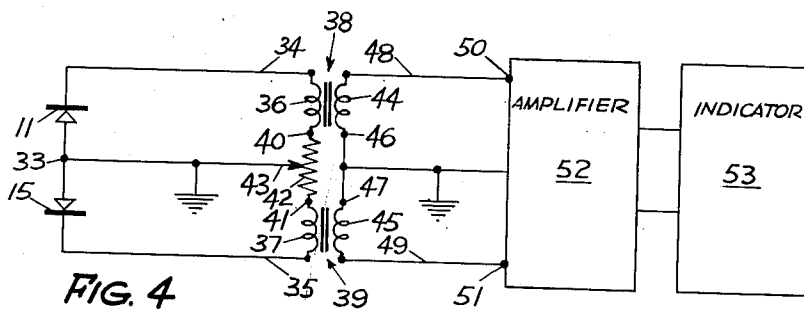
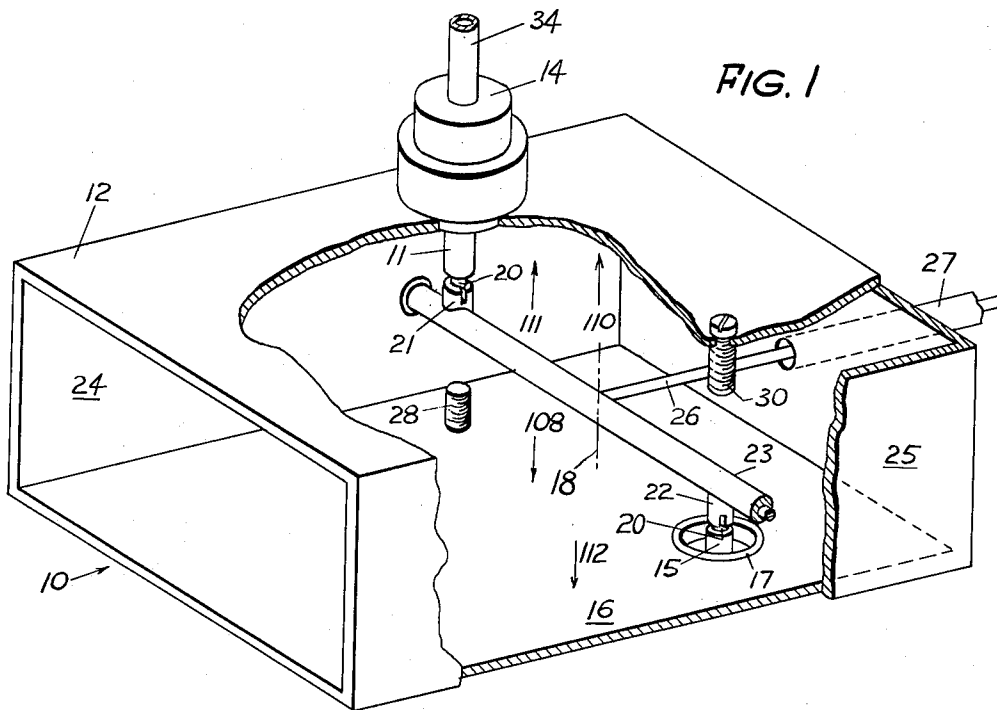
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F. A. JENKS ET AL
BALANCED DETECTORS

2,713,636

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2 Sheets-Sheet 1



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FIG. 2

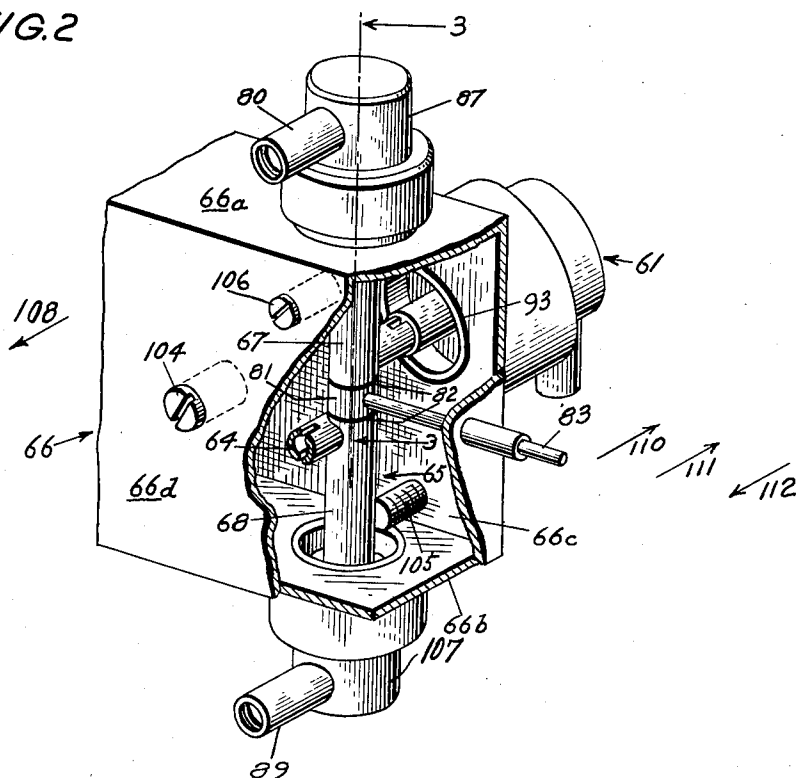
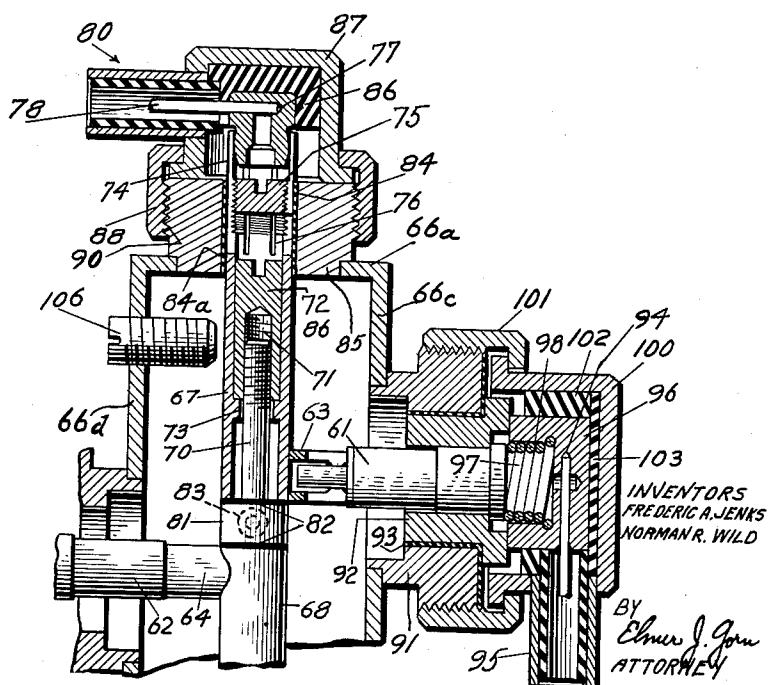


FIG. 3



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BALANCED DETECTORS

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This invention relates to balanced detectors for detecting microwave energy in wave guides.

Heretofore it has been customary to make a wave guide-coaxial transition unit and then locate the detectors in the coaxial arms in order to obtain a good match. Usually a magic tee configuration is used to get push-pull injection of the signal and parallel injection of the local oscillator output. This technique, however, is space consuming and, therefore, not suitable for compact equipment design.

Such a compact design could be achieved by locating the detectors on or in the wave guide. In order to obtain a balanced output from the detectors they are introduced in the same plane transverse to the wave guide. The introduction of the detectors modifies the impedance of the wave guide. This impedance must be balanced by one of equal amount and opposite sign. Such a balancing impedance is created by inserting a screw in the wave guide in the same plane as the detector and from the opposite wall. This screw serves another purpose. The protruding detector tends to set up a resonant path for the microwave energy within the wave guide. The screw breaks this path up and broadens the frequency response curve of the device.

A cross bar of conductive material is mounted across the wave guide in the same plane as the detectors and the detectors connected to this cross bar. For parallel-connected D. C. output this cross bar is solid. For series-connected D. C. output a more complicated structure is used for the cross bar. The last-mentioned cross bar is formed of a rod and two concentric tubes supported on the rod but insulated from it by suitable insulating material. Thus the parts are insulated from each other at D. C. and connected at radio frequencies. Small R. F. by-pass capacitances are built into the D. C. series cross bar to keep the microwave energy and the D. C. current along the respective proper paths.

The result is a broad band match with a voltage standing wave ratio under two to one over such a range of frequencies as 4200 to 4400 megacycles. This is accomplished with a small compact device not requiring carefully selected crystals but permitting the signal to be applied push-pull and the oscillator energy in parallel to the detectors.

Other and further advantages of this invention will be apparent as the description thereof progresses, reference being had to the accompanying drawings, wherein:

Fig. 1 is an isometric view of one embodiment of the invention;

Fig. 2 is an isometric view of another embodiment of the invention as modified for the D. C. series connection of the crystals;

Fig. 3 is a section taken along the line 3—3 of Fig. 2; Fig. 4 is a schematic diagram of the D. C. equivalent circuit of the parallel-connected embodiment; and

Fig. 5 is a schematic diagram of the D. C. equivalent circuit of the series-connected embodiment.

In Fig. 1 a wave guide is represented generally by the

reference number 10. A crystal detector 11 is inserted into the top surface 12 of the wave guide 10 by means of a crystal holder 14. A second crystal detector 15 is inserted into the bottom surface 16 of the wave guide 10 by means of a second crystal holder 17. These crystals are positioned in a common transverse plane and displaced from the vertical center line 18 of the plane by an equal amount. The detector units are described herein as crystals but they could also be electrical discharge devices and bolometers with suitable modifications.

The tip 20 of each crystal 11 and 15 is set in cylindrical contactors 21 and 22, respectively, which are electrically and mechanically connected to a cross bar 23 of conductive material. This cross bar is fixed in the walls 24 and 25 of the wave guide along the middle of the above-mentioned transverse plane. The center conductor 26 of coaxial cable 27 is connected to the center of cross bar 23. This coaxial line serves to introduce energy from the local oscillator for mixing purposes.

In order to counteract the resonant effects of each crystal 11 and 15, as explained above, anti-resonant posts 28 and 30 are placed in the wave guide walls 16 and 12, respectively, opposite each crystal 11 and 15.

The distinction between the series and parallel arrangements will be best understood with reference to the schematic diagrams of Figs. 4 and 5. Fig. 4 shows the parallel arrangement with crystals 11 and 15. It will be seen that the crystals are connected back-to-back with the common point 33 connected to ground. The other ends of the crystals are connected through coaxial cables 34 and 35, respectively, to the primaries 36 and 37 of transformers 38 and 39, respectively. The other terminals 40 and 41 of the primaries are connected in series through a potentiometer 42 with a movable contact 43 connected to ground. The purpose of this potentiometer 42 is to assure that the currents through the two primaries 36 and 37 are equal. The secondaries 44 and 45 have terminals 46 and 47 connected together and to a reference potential. The other terminals 48 and 49 are connected, respectively, to the inputs 50 and 51 of the amplifier 52 associated with the detector circuit 53.

In the series arrangement the crystals 61 and 62 are connected in series with a point 54 between them connected to ground. The primaries 55 and 56 of the transformers 57 and 58 are connected in series with each other and the crystals 61 and 62. The secondaries 59 and 60 are connected in series and to the input of the amplifier of the detector circuit 53.

It will be seen from Fig. 1 that one terminal 20 of each crystal 11 and 15 is connected to the cross bar 23, corresponding to the common point 33 of Fig. 4. The other ends of the crystals 11 and 15 are brought out separately to the center conductors of coaxial lines 34 and 35, respectively, through connectors 14 and 17. The details of a suitable connector for this purpose are shown in Fig. 3 and will be described later.

The physical arrangement of the D. C. series modification is shown in Figs. 2 and 3. In this modification the crystals 61 and 62 are inserted into receptacles 63 and 64, respectively, on the special cross piece 65 mounted in the walls 66a and 66b of the wave guide 66. This cross piece 65 is formed of two pieces of tubing 67 and 68 held together by a double-ended screw 70. Each threaded end of the screw 70 is received in a tapped hole 71 in a plug 72 of insulating material. The threaded ends of screw 70 are each one-quarter wave length long and form an open transmission line with their respective tubes 67 and 68. Each of these plugs 72 fits inside its respective tube 67 or 68, and rests against a ridge 73 extending radially inward from the inside surface of the tubes 67 and 68. As the plugs 72 are pulled together by action of the screw 70, they carry with them the tubes 67 and 68 because of

the ridges 73. The outer end 74 of each tube 67 or 68 is threaded to receive a spreading plug 75 of conductive material. The tube ends are also split by saw cuts 76 to permit a spring contact to be made with a plug 77 of conductive material. These plugs 77 are adapted to receive the center conductor 83 of a coaxial cable 89. The central head 81 of the screw 79 is insulated from the tubes 67 and 68 by washers 82 of insulating material to form a capacitive path for the microwave energy between the central head 81 and the tubes 67 and 68 while preventing the flow of direct current between these parts. This capacitive path is reinforced by a low impedance from the quarter wave open-circuited transmission line formed by the tubes 67 and 68 and the screw 79. The center conductor 83 of a coaxial cable is electrically connected to the head 81 of the screw 79. The end 74 of the tube 67 is received in a hole 84 in a bushing 85 of conductive material inserted into the wave guide wall 66a. The hole 84 is lined with an insulating material 48a, such as polystyrene tape. The expansion plug 75, as it is screwed down into the tube 67, expands the tube to form a tight mechanical contact with the bushing 85 while insulated from it by the insulation 84a. This forms a capacitive path for microwave energy while isolating the direct current. The plug 77 is set in a cap 86 of insulating material which is itself set in a cap 87 of conductive material that receives the coaxial cable 89 and is attached to the bushing 85 through the threaded connector 88 by threads 99. The other end of the cross bar 65 is connected to a coaxial cable 89 by similar means.

Radio frequency energy is prevented from propagating out along cables 89 and 89 by the quarter wave open transmission line formed by the screw 79 and the tubes 67 and 68.

This connector cap construction, together with the special construction of the cross bars 67 and 68, prevents any leakage of microwave energy down the cable 89. The tight mechanical connections of the screw 79 with the sleeves 67 and 68 and of the sleeves 67 and 68 to the bushing 85, while at the same time providing a capacitive path through insulated washers 82 and 84a, prevent microphonics in the circuit as would be caused by looser mechanical connections when the equipment was used in the presence of considerable vibration as in mobile equipment.

The crystal 61 is inserted through the wave guide wall 66c by means of a bushing 91 of conductive material adapted to receive an insert member 92 separated from the bushing by a layer 93 of insulating material, such as polystyrene tape. When the crystal 61 is inserted in the bushing 91, it is electrically connected to the central conductor 94 of the coaxial cable 95 through a cap 96 of conductive material adapted to receive the central conductor 94 and a spring 97 of conductive material fitted into a recess 98 in the cap 96. The cap 96 and spring 97 are pressed down on the crystal 61 by a cap 100 that is fastened to the bushing 91 by a threaded sleeve member 101 and insulated from the cap 96 by an annular ring 102 and a disk 103, both made of insulating material. The second crystal 62 is similarly mounted in the wave guide and connected between tube 68 and the coaxial cable 89. This construction provides a rigid microphonic free mounting for the detector element while providing a shorting path through insulation 93 for any microwave energy that might otherwise leak out along cable 95.

In addition to the cross bar 65 and the crystals 61 and 62, a matching post 104 for matching the impedance of the crystals and cross bar is introduced into the field. This matching post, preferably a metallic plug, is inserted into wall 66d of the wave guide 66 along the center line of the wide dimension and at a quarter wave length in front of the crystals 61 and 62. In addition, anti-resonant posts 105 and 106 are mounted one on each wall 66c and 66d in the same plane with the crystals 61 and 62 and displaced from the center by approximately equal amounts

but in the opposite direction in order to balance out the reactance added by the insertion of the crystals and to broaden the band width over which the equipment may be used effectively, as explained above.

In the series resonant structure shown in Figs. 2 and 3, there are two D. C. paths. One runs from the coaxial cable 89 through plug 77, tube 67, connector 63, crystal 61, spring 97 and coaxial cable 95. The other D. C. path runs from coaxial cable 89 through the connector 107, tube 68, crystal connector 64, crystal 62 and its associated coaxial cable. These two paths may be connected in series, if desired, or used separately. The series connection of the crystals 61 and 62 shown in Fig. 5 is represented in Figs. 2 and 3 by the coaxial cable 89, the connector plug 77, tube 67, connector 63, crystal 61, connector structure 96, 97 and coaxial cable 95 which may be connected to coaxial cable 89 of Fig. 2, and through connector assembly 107 to tube 68 through connector 64 to crystal 62. The output of these two crystals in series may be connected to the input of an indicator device 53 directly as shown in Fig. 5 or through an amplifier 52 as shown in Fig. 4.

The series structure shown in Figs. 2 and 3 can also be connected for parallel operation of the crystals by connecting both lines 89 and 89 together and to ground and the rectifiers 61 and 62 to an external circuit. The connections could also be reversed. The rectifiers 61 and 62 could be connected together and to ground with the lines 89 and 81 connected to the external circuit.

The coaxial center conductor 83 is fed from a local oscillator, and at a particular instant produces voltage vectors in the directions indicated by arrows 108 and 110. The energy in the wave guide could be energy picked up by a receiving antenna, such as a horn (not shown), and led into the wave guide 66, to produce an electrical vector at that instant in the direction indicated by arrows 111 in Figs. 1 and 2, which is in phase with the vector 110 of local oscillator energy in the upper portion of the guide, but 180 degrees out of phase with the local oscillator energy vector indicated by the arrows 108 in the lower portion of the wave guide. The result would be that the vector difference in energy is transmitted through the lower crystal 15, and the vector sum of the energies through the upper crystal 11 in the D. C. parallel version of Fig. 1. When the directions of the vectors reverse on the next alternation, the lower crystal 15 would conduct the vector sum of the energies and the upper crystal 11, the vector difference of the energies. In the series case illustrated in Figs. 2, 3 and 5, local oscillator energy produces vectors in the direction of arrows 108 and 110 to set up currents through the crystals 61 and 62 outward from the central nut 81. When the vectors reverse on the next alternation, the polarities are wrong for conduction through the crystals and little or no current flows.

Obviously, the present invention could be applied wherever it is required to extract and rectify energy from a wave guide over a wide band of frequencies and with a maximum of efficiency for a minimum of bulk and weight of equipment.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. A balanced detector of electromagnetic energy comprising a section of waveguide, a conductive rod mounted between and electrically contacting the conductive walls of the waveguide, a pair of detector elements mounted on but insulated from the waveguide with one end of each in electrical contact with said rod inside said waveguide and their axes of conduction in the same transverse plane as the rod and perpendicular to it, and means to apply high frequency energy to the center of the rod.

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2. A balanced detector of electromagnetic energy comprising a section of waveguide, a conductive rod mounted between and electrically contacting the conductive walls of the waveguide, a pair of detector elements mounted on but insulated from the waveguide with one end of each in electrical contact with said rod inside said wave guide at points displaced equally from the center of said rod and their axes of conduction in the same transverse plane as the rod and perpendicular to it, and means to apply high frequency energy to the center of the rod.

3. A balanced detector of electromagnetic energy comprising a section of waveguide, a conductive rod mounted between but insulated from the side walls of the waveguide, a pair of conductive tubes mounted concentrically on but insulated from said conductive rod, a pair of detector elements mounted with one end of each in electrical contact with an associated one of the tubes and their axes of conduction in the same transverse plane as the rod and perpendicular to it, and means to apply high frequency energy to the center of the rod.

4. A balanced detector of electromagnetic energy comprising a section of waveguide, a conductive rod mounted between but insulated from the side walls of the waveguide, a pair of conductive tubes mounted concentrically on but insulated from said conductive rod, a pair of detector elements mounted with one end of each in electrical contact with an associated one of the tubes at points displaced equally from the center of said rod and their axes of conduction in the same transverse plane as the rod and perpendicular to it, and means to apply high frequency energy to the center of the rod.

5. A balanced detector of electromagnetic energy comprising a section of waveguide, a conductive rod mounted

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between and electrically contacting the conductive walls of the waveguide, a pair of detector elements mounted with one end of each in electrical contact with said rod inside said waveguide at points displaced equally from the center of said rod and their axes of conduction in the same transverse plane as the rod and perpendicular to it, means to counteract the unbalance introduced into the electromagnetic field by the detecting elements, and means to apply high frequency energy to the center of the rod.

6. A balanced detector of electromagnetic energy comprising a section of waveguide, a conductive rod mounted between but insulated from the side walls of the waveguide, a pair of conductive tubes mounted concentrically on but insulated from said conductive rod, a pair of detector elements mounted with one end of each in electrical contact with an associated one of the tubes at points displaced equally from the center of said rod and their axes of conduction in the same transverse plane as the rod and perpendicular to it, means to counteract the unbalance introduced into the electromagnetic field by the detecting elements, and means to apply high frequency energy to the center of the rod.

References Cited in the file of this patent

UNITED STATES PATENTS

2,413,939	Benware	Jan. 7, 1947
2,420,892	McClellan	May 20, 1947
2,469,222	Atwood	May 3, 1949
2,527,910	Braden	Oct. 31, 1950
2,550,524	Braden	Apr. 24, 1951
2,552,052	Matare	May 8, 1951
2,576,481	Rodwin	Nov. 27, 1951