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CENTIMETER WAVE APPARATUS

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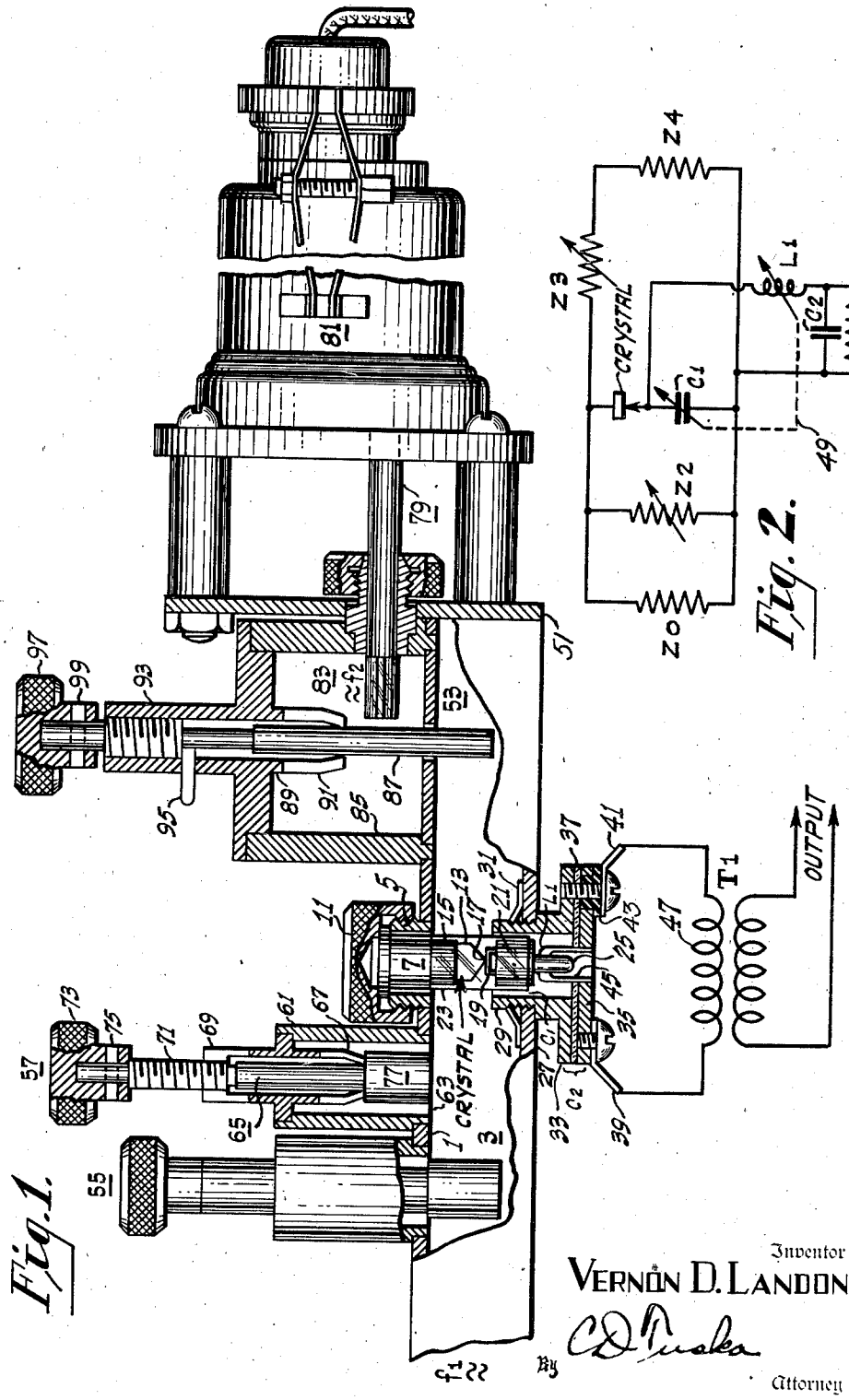


Fig. 1.

Fig. 2.

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CENTIMETER WAVE APPARATUS

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10 Claims. (Cl. 178—44)

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This invention relates generally to centimeter wave apparatus and more particularly to an improved method of and means for tuning and coupling in waveguide microwave transmission systems.

Heretofore, waveguide transmission systems and cavity resonators have been tuned by means of micrometer operated tuning plungers or by means of various types of tuning screws. One of the principal disadvantages in tuning systems of these types is that erratic contact inherent in all screw-fed or sliding contact devices provides a variable contact resistance which is especially objectionable wherever high microwave current values occur. Since the sliding contact or threaded joint in many known devices is situated adjacent to the waveguide walls, it will be seen that this location coincides with conditions of high microwave currents.

The instant invention contemplates a tuning screw which may be employed either for tuning a resonant cavity or waveguide or for providing adjustable coupling between two such devices. The proportions of the apparatus to be described hereinafter are such that the region of coincidence of the tuning screw or coupling element with the adjacent wall of the waveguide or resonant cavity is maintained substantially at ground potential. Furthermore, the device is proportioned so that all threaded or sliding contacts occur at regions of minimum microwave currents whereby contact resistance variations do not introduce objectionable variations in the current distribution in the conductors.

The features of the instant invention mentioned heretofore are accomplished by providing a supporting structure for the tuning screw or coupling element which forms a concentric line therewith having a length of the order of any predetermined multiple of ½ wavelength at the operating microwave frequency. The contact points between the supporting element and the tuning screw or coupling element are permitted to touch the tuning screw or coupling element only at points disposed distances of the order of odd multiples of ¼ wavelength at the operating microwave frequency from the ends of the half wave concentric line. Preferably, the contact means include flexible contact elements providing low resistance joints. Supplemental threaded means may be included with one or more of the contact elements to provide convenient screw feed for the movable element.

One of the embodiments of the invention to be described hereinafter comprises an improved tuning screw for tuning a waveguide or cavity

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resonator. Another embodiment of the invention, also to be described hereinafter, comprises an improved adjustable coupling device for coupling microwave energy from a cavity resonator to a waveguide transmission system. Both of the embodiments utilize substantially the same means for providing movable electrical contacts at points of minimum microwave current distribution.

Among the objects of the invention are to provide an improved method of and means for reactively coupling to a microwave transmission system. Another object of the invention is to provide an improved method of and means for tuning a microwave transmission system. An additional object of the invention is to provide an improved tuning screw for a waveguide transmission system wherein the movable contacts are disposed at points of minimum microwave current distribution. A further object of the invention is to provide an improved method of and means for providing fixed microwave coupling to a cavity resonator and providing adjustable microwave coupling between said resonator and a waveguide transmission system. A further object of the invention is to provide an improved method of and means for tuning a microwave waveguide transmission system, introducing modulated microwaves to said system, providing variable coupling between a source of local oscillations and said waveguide transmission system, and mixing and detecting said modulated signals and said local oscillations to derive desired signal modulation components.

The invention will be further described by reference to the accompanying drawing of which Figure 1 is an elevational cross-sectional view of the complete system including all of the embodiments thereof described hereinafter. Figure 2 is a schematic circuit diagram of the equivalent electrical circuit of the complete system. Similar reference characters are applied to similar elements throughout the drawing.

Wave detector

Referring to Figure 1, one of the walls 1 of a rectangular waveguide 3, is apertured to receive a threaded cylindrical sleeve 5 for supporting one terminal 7 of a tubular crystal detector of the type comprising a wedge-shaped silicon crystal having a tungsten wire "catwhisker" disposed in contact therewith and normal to the wedge apex. A cylindrical conductive cap 11, threaded to engage the threads in the cylindrical sleeve 5, retains the detector terminal 7 in engagement with the cylindrical sleeve 5, thereby providing

electrical contact between the detector terminal 7 and the waveguide wall 1.

A silicon crystal 13 is electrically connected to and supported by a cylindrical projection 15 of the detector terminal 7. The crystal 13 has a knife edge 17 which engages a tungsten wire "catwhisker" 19. The tungsten wire "catwhisker" 19 is supported by a second cylindrical detector terminal 21. The cylindrical conductive members 15, 21, and the crystal 13 and "catwhisker" 19 are enclosed within a glass, ceramic or suitably insulated sleeve 23. A cylindrical prong 25 projects coaxially from the outer end of the second cylindrical supporting member 21. This type of microwave crystal detector is disclosed and claimed in a copending U. S. application of William D. Larue, Serial No. 432,818 filed February 28, 1942, and assigned to the same assignee as the instant application.

The wall 27, of the waveguide 3, opposite the waveguide wall 1, includes a threaded aperture for receiving a second threaded sleeve 29 which surrounds the prong 25 and the second cylindrical terminal 21. The penetration of the threaded sleeve 29 into the waveguide interior may be varied by rotation thereof in the threaded aperture in the waveguide wall 27. A flexible contact ring 31, which may be suitably secured to the wall 27, provides uniform electrical contact between the second threaded sleeve 29 and the waveguide wall 27. If fixed filtering is desired, the sleeve 29 may be fixed in position by soldering it to the waveguide wall 27.

The second threaded sleeve 29 is terminated in an annular ring portion 33. A flat plate 35 is separated from the annular ring 33 by a layer of mica, or other dielectric, 37 to provide a relatively large capacitor which is indicated in Figure 2 as the capacitor C2. A terminal 39 provides an output connection to the flat plate 35 while a second terminal 41 and insulated bushing 43 provide an output terminal for the annular ring 33. A flexible cylindraceous contact element 45, electrically connected to the flat plate 35 adjacent an aperture in the center thereof, provides a sliding electrical contact with the prong 25. The cavity formed between the prong 25, the second threaded sleeve 29, and the flat plate 35 may be proportioned to be substantially anti-resonant to the microwave operating or carrier frequency.

It will be seen that the effective inductance L1 provided by the prong 25 and the flexible contact element 45 may be varied by rotating the entire capacitor supporting structure within the threaded aperture in the waveguide wall 27. The effective bypassing of microwave signal components derived from the detector is accomplished by a capacitor provided between the inner surface of the second threaded sleeve 29 and the outer surface of the conductive second cylindrical detector terminal 21. This capacitor is C1 of Figure 2, and also may be effectively varied simultaneously with the inductance L1 by rotating the second threaded sleeve 29 to project more or less of the sleeve 29 into the interior of the waveguide.

The output terminals 39, 41 may be connected to any desired modulation utilization circuit such as, for example, the primary winding 47 of an intermediate frequency transformer T1. It should be understood that modulated microwave signals and unmodulated local oscillations both may be introduced into the waveguide 3 to provide intermediate frequency modulated signals at the output terminals 39, 41 of the capacitor C2. The means for introducing and tuning the waveguide 3 to the source of modulated microwave frequencies, and means for introducing and adjustably coupling the source of local oscillations to the waveguide 3 will be described in detail hereinafter.

Operation

The operation of the crystal detector is apparent from the schematic equivalent circuit diagram of the system illustrated in Figure 2. The crystal detector 9 is illustrated as interposed in series between an impedance Z_0, representing the waveguide characteristic impedance, and an impedance Z1, representing the output load impedance. The variable capacitor C1, connected between the load terminal of the crystal and the common terminals of the waveguide and load impedances, represents the main bypass capacitor for the microwave signal components passing through the crystal detector. The variable inductive element L1, corresponding to the inductance interposed by the center prong and contacts 25, 45 is effectively connected in series with the crystal and one terminal of the load impedance Z1. The capacitor C2 is effectively connected directly across the load impedance Z1. The dash line 49 is indicative of the fact that the capacitor C1 and the inductor L1 are adjustable simultaneously. It will be seen that the network effectively connected between the crystal detector and the load impedance Z1 represents a low-pass filter having a relatively large bypass capacitor C1 on the input thereof for bypassing the microwave signal components. The Q of the filter network is relatively high, since the network elements are essentially pure reactances. The wave detector system thus disclosed is described and claimed in a copending U. S. application of Wendell L. Carlson, Serial No. 507,755, filed October 26, 1943, entitled Centimeter wave detector, and is assigned to the same assignee as the instant application.

Tuning screws

Again referring to Figure 1, the waveguide 3 is terminated at one end by a conductive plate 51. The resultant resonant cavity 53 may be tuned by one or more tuning screws 55, 57 to resonate at either the modulated signal carrier frequency, the local oscillator frequency or the mean frequency of the carrier and local oscillation frequencies. All tuning screws may be identical and may be spaced predetermined fractions of the operating wavelengths.

The tuning screw 57 therefore may be taken as typical. It comprises a cylindrical supporting shell 61 having one end secured to and surrounding an aperture 63 in the wall 1 of the waveguide 3. The supporting shell 61 forms a half wave concentric line with the tuning screw element 65 which is disposed coaxially therewith. The length of the conductive shell 61 may be any predetermined multiple of ½ wavelength at the operating frequency. Clearance is provided between the tuning screw 65 and the supporting shell 61 except at points removed any predetermined odd multiples of ¼ wavelength from the ends of the supporting shell 61. At such protruding and reentrant points, the supporting shell includes flexible contact elements 67, 69 which provide electrical contact between the supporting shell and the tuning screw at current nodes or points of minimum microwave circulat-

ing currents. The protruding contacts 69 may include threaded portions which engage complementary threads 71 in the exterior portion of the tuning screw 65. An adjusting knob 73 may be keyed to the outer end of the tuning screw 65 by means of a key 75. The inner end of the tuning screw 65 may include an enlarged cylindrical portion 77 having a diameter providing ample clearance with the supporting shell 61 and the aperture in the waveguide wall 1. The length of the enlarged cylindrical end of the tuning screw 65 may be of the order of ¼ wavelength, or any odd multiple thereof, depending upon the proportions of the supporting shell and the reentrant portion thereof.

It will be seen that the half wave line provided by the supporting shell 61 and the tuning screw 65, 77 provides a point of substantially ground potential in the region of the waveguide aperture. Furthermore, the points of contact of the flexible contacts 67, 69 on the surface of the tuning screw 65 are at multiples of ¼ wavelength from the point of ground potential and correspond to regions of minimum microwave current.

Variable microwave coupler

A source of oscillations derived from, for example, the output line 79 of a Shepard tube oscillator 81 supported on the end terminating plate 51 of the waveguide 3, is introduced into a cavity resonator or concentric line 83 which comprises an outer conductive wall 85 and an inner movable cylindrical rod 87. Shepard oscillator tubes are representative of the well known type of microwave generators having a thermionic cathode and a negatively biased reflector electrode housed within a cavity resonator. Tuning of the cavity resonator, for example, by distortion of the resonator walls, varies the output frequency. Output energy is derived from a short coaxial output line coupled to the resonator. The length of the cavity resonator 83 is selected to be of the order of any multiple of ½ wavelength at the oscillator frequency. A reentrant portion 89 of the cavity resonator 83 includes flexible contacts 91 which engage the cylindrical central rod 87 at a point removed substantially ¼ wavelength from either end of the cavity resonator 83. A protruding portion 93 of the cavity resonator 83 may be of the order of ½ wavelength at the oscillator frequency. At a point ¼ wavelength removed from the end of the cavity resonator 83, a second flexible contact 95 engages the shank of the cylindrical rod 87. The remainder of the protruding portion 93 of the cavity resonator 83 may be threaded to engage complementary threads in the output portion of the cylindrical rod 87. A third control knob 97 may be keyed by means of a key 99 to the outer end of the cylindrical rod 87. The waveguide wall 1 is apertured to provide clearance for the cylindrical rod 87 whereby the inner end of the rod may be introduced into the interior of the waveguide 3. The degree of penetration of the inner end of the cylindrical rod 87 into the waveguide 3 may be adjusted by rotating the third control knob 97. As illustrated, the spacing between the cylindrical rod 87 and the output line 79 of the Shepard tube 81 remains fixed, thereby providing fixed capacitive coupling between these elements. It will be seen that the coupling from the Shepard tube 81 to the waveguide 3 and the crystal detector 9 may, therefore, be adjusted readily by rotating the third control knob 97.

Referring again to Figure 2, the operation of the complete system may be defined as follows: Modulated microwave signals having a carrier frequency $f1$ may be introduced into the waveguide 3 in any known manner effectively across the waveguide characteristic impedance Z0. The tuning screws 55, 57 are represented by the variable impedance Z2, effectively connected in shunt with the characteristic impedance Z0. The Shepard tube local oscillator provides a local microwave energy source having a frequency $f2$. The variable coupling between the Shepard tube and the waveguide is denoted by the series connected variable impedance Z3 while the Shepard tube is represented by the impedance Z4. The crystal detector with its filter network C1, C2, L1 provides effective bypassing of the microwave components $f1$, $f2$ and $f1+f2$ and provides a modulated intermediate frequency signal $f1-f2$ across the load impedance Z1.

It should be understood that the tuning screws and the adjustable microwave coupler may be employed in any other manner known in the microwave art, and that the particular proportions thereof disclosed herein may be employed in other types of microwave apparatus wherein the adjustment of reactive circuit elements involves movable electrical contact between conductive circuit elements.

Thus the invention described comprises several modifications of improved reactive circuit elements wherein erratic contact effects are substantially overcome by locating the movable contacts in the region of microwave current nodes. An improved tuning screw, a variable microwave coupler and a complete system including a microwave converter have been described in combination with said tuning screws and coupler.

I claim as my invention:

1. Microwave apparatus for a waveguide transmission system including a threaded screw member, support means engaging said screw member for introducing said screw member through an apertured waveguide wall, said member and said means being proportioned with respect to the operating frequency and engaging at a predetermined distance from said apertured wave guide wall to maintain the portion of said member in the immediate region of said waveguide aperture substantially at ground potential, and contact means interconnecting said member and said support means and providing said engaging means for said threaded portion of said member at a current node on said member.

2. A microwave coupling device including a resonant concentric line comprising a threaded screw member, conductive support means engaging said screw member concentric with respect to said member for introducing said member through an apertured waveguide wall, said member and said means being proportioned with respect to the operating frequency and engaging at a predetermined distance from said apertured waveguide wall to maintain the portion of said member in the immediate region of said waveguide aperture substantially at ground potential, and contact means providing said engaging means interconnecting said member and said support means at current nodes on said member, means for coupling a source of microwave energy to said line, and means for adjusting the penetration of said member through said waveguide aperture for varying the microwave coupling to said waveguide.

3. A microwave coupling device including a waveguide having an apertured wall, a resonant

concentric line comprising a threaded screw member, conductive support means engaging said screw member mounted upon said wall adjacent said aperture and concentric with respect to said member for introducing said member through said apertured waveguide wall, said member and said means being proportioned with respect to the operating frequency and engaging at a predetermined distance from said apertured waveguide wall to maintain the portion of said member in the immediate region of said waveguide aperture substantially at ground potential, and contact means providing said engaging means interconnecting said member and said support means at current nodes on said member, means for coupling microwave energy to said line, and means for adjusting the penetration of said member through said waveguide aperture for varying the microwave coupling to said waveguide.

4. A tuning screw for a microwave waveguide including a threaded screw member, support means engaging said screw member for introducing said screw member through an apertured waveguide wall, means proportioned with respect to the operating frequency and engaging at a predetermined distance from said apertured waveguide wall for maintaining the portion of said screw member in the immediate region of said waveguide aperture substantially at ground potential, and contact means providing said engaging means connecting said screw member and said support means at current nodes on said tuning screw.

5. A tuning screw for a microwave waveguide including a threaded screw member, support means threaded to said screw member for introducing said screw member through an apertured waveguide wall, means proportioned with respect to the operating frequency and engaging at a predetermined distance from said apertured waveguide wall for maintaining the portion of said screw member in the immediate region of said waveguide aperture substantially at ground potential, and contact means providing said engaging means connecting said screw member and said support means at current nodes on said tuning screw.

6. Microwave apparatus for tuning a waveguide system comprising a waveguide having an aperture in one of the walls thereof, and a tuning screw operable through said wall aperture to tune said waveguide as a function of the penetration of said tuning screw into said waveguide, means combined with said tuning screw forming therewith a concentric line having a length of the order of a predetermined multiple of one half wavelength at the operating microwave frequency, said means having one end thereof secured to said waveguide and surrounding said aperture, contacts connecting said tuning screw and said means at points of the order of predetermined odd multiples of one quarter wavelength from the junction of said means and said waveguide, and means for rotating said tuning screw to vary the penetration thereof within said waveguide.

7. Microwave apparatus for tuning a waveguide system comprising a waveguide having an aperture in one of the walls thereof, and a tuning screw including, in combination, a hollow cylindrical conductive element having a length of the order of a predetermined multiple of one half wavelength at the operating microwave frequency

and having one end thereof secured to said waveguide and surrounding said aperture, an apertured concentric cylinder having a reentrant portion and a protruding portion each extending lengths of the order of predetermined odd multiples of one quarter wavelength coaxially from the remaining end of said element and each being terminated in flexible contact elements, a threaded cylindraceous conductive member contacting said contact elements and coaxially spaced from the intermediate portions of said concentric cylinder, and means for rotating said member to vary the penetration of one end of said member within said waveguide.

8. Microwave apparatus for tuning a waveguide system comprising a waveguide having an aperture in one of the walls thereof, and a tuning screw including, in combination, a hollow cylindrical conductive element having a length of the order of one half wavelength at the operating microwave frequency and having one end thereof secured to said waveguide and surrounding said aperture, a hollow concentric cylinder having a reentrant portion and a protruding portion each extending lengths of the order of one quarter wavelength coaxially from the remaining end of said element and each being terminated in flexible contact elements, a threaded cylindraceous conductive member contacting said contact elements and coaxially spaced thereby from the intermediate portions of said concentric cylinder, and means for rotating said member to vary the penetration of one end of said member within said waveguide.

9. Microwave apparatus for tuning a waveguide system comprising a waveguide having an aperture in one of the walls thereof, and a tuning screw including, in combination, a hollow cylindrical conductive element having a length of the order of one half wavelength at the operating microwave frequency and having one end thereof secured to said waveguide and surrounding said aperture, an apertured concentric cylinder having a reentrant portion and a protruding portion each extending lengths of the order of one quarter wavelength coaxially from the remaining end of said element and each being terminated in flexible contact elements, a threaded cylindraceous conductive member contacting said contact elements and coaxially spaced from the intermediate portions of said concentric cylinder, threaded means coaxial with said protruding concentric cylinder portion engaging said threaded cylindraceous member, and means for rotating said member to vary the penetration of one end of said member within said waveguide.

10. Apparatus of the type described in claim 3 including a wave detector disposed in said waveguide, means for introducing energy from a second source of microwave energy into said waveguide, and means for deriving from said detector currents having predetermined modulation components of said two sources of microwave energy.

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REFERENCES CITED

The following references are of record in the file of this patent:

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