

Aug. 8, 1950

R. L. SPROULL

2,517,731

MICROWAVE TRANSMISSION SYSTEM

Filed April 9, 1946

2 Sheets-Sheet 1

Fig. 1

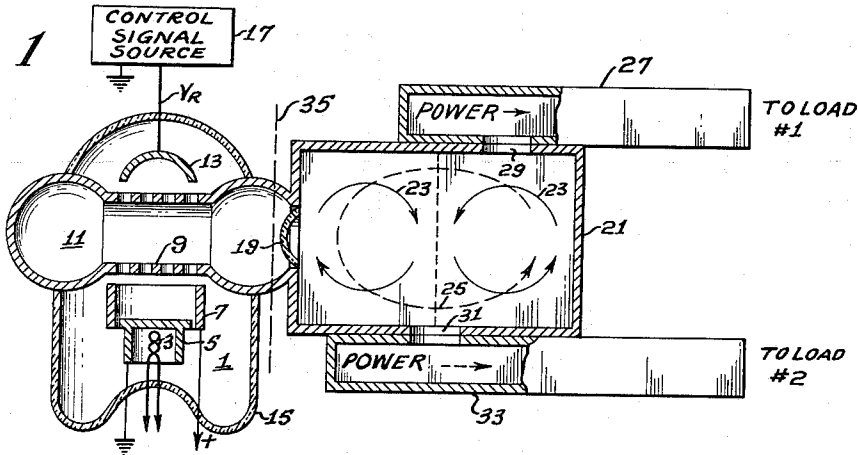


Fig. 2

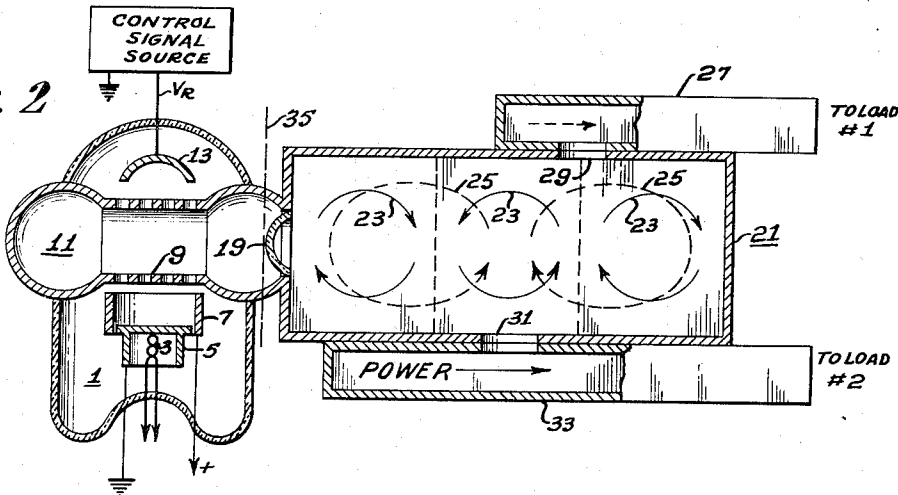
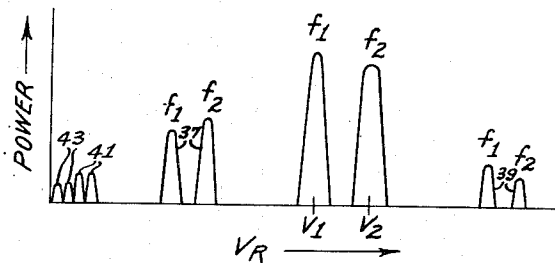


Fig. 3



INVENTOR.
Robert L. Sproull
BY *W. Huska*
ATTORNEY

Aug. 8, 1950

R. L. SPROULL
MICROWAVE TRANSMISSION SYSTEM

2,517,731

Filed April 9, 1946

2 Sheets-Sheet 2

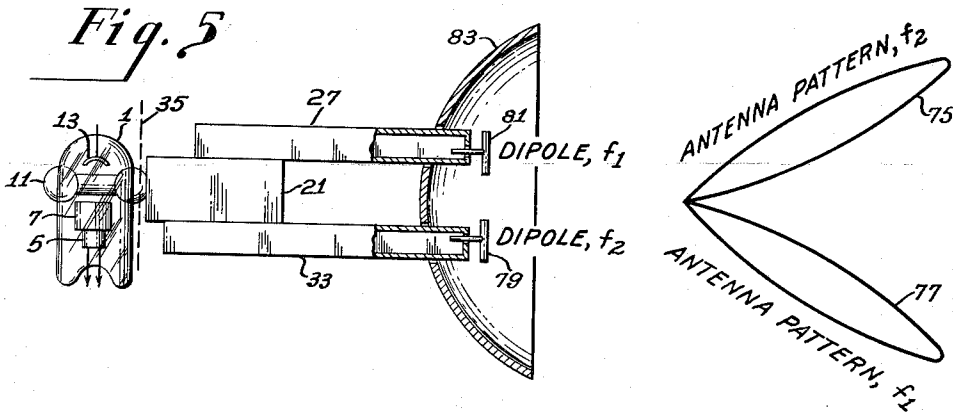
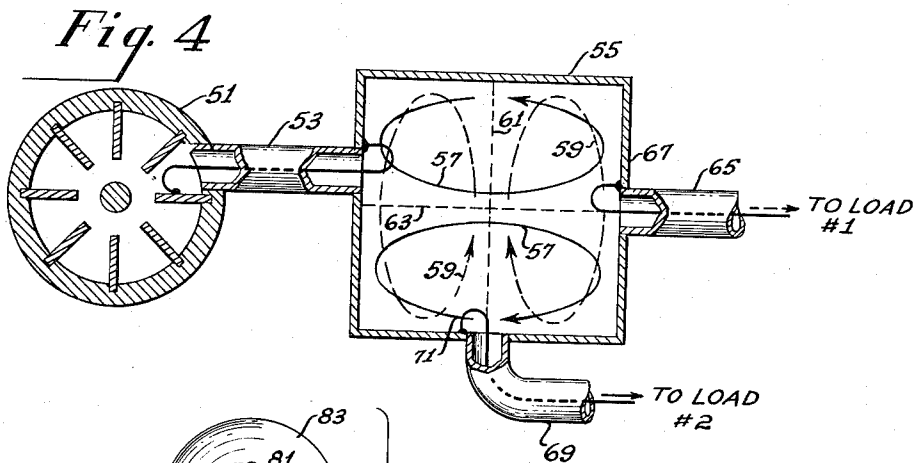
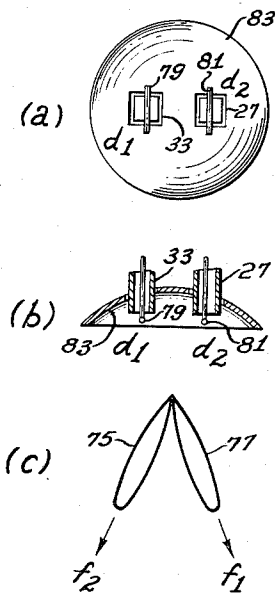


Fig. 6

INVENTOR.
Robert L. Sproull
BY *C. D. Huska*
ATTORNEY

UNITED STATES PATENT OFFICE

2,517,731

MICROWAVE TRANSMISSION SYSTEM

Robert L. Sproull, Ithaca, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application April 9, 1946, Serial No. 660,594

8 Claims. (Cl. 250—17)

1

2

This invention relates generally to microwave transmission systems and more particularly to improved methods of and means for switching a microwave generator between a plurality of load circuits without the use of moving mechanical elements.

Various types of switching systems for microwave energy have been used heretofore which employ moving mechanical elements for selecting the desired one of a plurality of load circuits for connection to a microwave generator. Such movable mechanical elements introduce erratic operation and transmission losses due to variations in contact potential and by inherent discontinuities in circuit conformation. The instant invention contemplates the use of a system of cavity resonators or resonant coaxial lines wherein the different load circuits are selectively coupled to predetermined different resonant modes of said resonators or lines, and wherein different ones of the modes are excited by varying the frequency of the microwave generator.

In a typical embodiment of the invention, a microwave generator of the reflex velocity modulation type is coupled into a cavity resonator having a plurality of resonant modes which are excited by different microwave frequencies. Coupling apertures, or coupling loops extending into the cavity resonator, couple different load waveguides or lines to the resonator only when it is excited at a predetermined one of the resonant modes. Thus, one of the load lines is coupled to the resonator for one predetermined operating frequency and another of the load lines is coupled to the resonator for a different operating frequency. Switching is accomplished by varying the operating potentials applied to the velocity modulation reflex generator whereby the combined generator and cavity resonator is caused to oscillate at either one of the desired operating frequencies.

Systems of this type may be employed as "left-right" switching radar systems such as are employed for directing gun fire, aeronautical navigation or for various types of "homing" directional radio devices. A novel coupling circuit and double dipole directional antenna system also is disclosed for utilizing the invention for directional transmission purposes.

Among the objects of the invention are to provide an improved method of and means for switching microwave energy. Another object is to provide an improved method of and means for switching a microwave generator between a plurality of microwave load circuits without the

use of movable mechanical elements. A further object is to provide an improved microwave transmission system comprising an adjustable frequency microwave generator coupled to a resonant device having a plurality of resonant modes, and a plurality of load circuits selectively coupled to different ones of the resonant modes. An additional object is to provide an improved microwave switching device comprising an adjustable frequency microwave generator coupled to a cavity resonator having a plurality of resonant modes, and a plurality of waveguides connected to different load devices and coupled into said resonator to abstract microwave energy therefrom in response to excitation of different ones of said resonant modes.

A further object is to provide an improved microwave transmission system including a microwave generator coupled into a bi-resonant cavity resonator, a plurality of load circuits also coupled into said resonator and responsive to excitation of different ones of said resonant modes, and means for varying the frequency of said generator for selectively exciting different ones of said modes. Another object is to provide an improved directional microwave transmission system including an adjustable frequency microwave generator coupled to a resonant device having a plurality of resonant modes excited at different frequencies, and a pair of waveguide transmission systems terminated in directional antenna elements and coupled to said resonant circuit in different ones of said modes whereby said antennas are separately excited by predetermined variation of the frequency of said generator. A further object is to provide a directional antenna and coupling system therefor including a common reflector for said selectively excited microwave antennas.

The invention will be further described by reference to the accompanying drawings of which Figure 1 is a cross-sectional, partially plan view of a first embodiment of the invention; Figure 2 is a cross-sectional, partially plan view of a modification of said first embodiment of the invention; Figure 3 is a graph indicative of the multi-resonant operating characteristics of the invention; Figure 4 is a cross-sectional, plan view of a second embodiment of the invention; Figure 5 is a cross-sectional, partially plan view of said first embodiment of the invention in combination with a directional microwave antenna system for providing microwave radiation with two principal lobes; and Figure 6 illustrates in greater detail the structural features of said directional

3

antenna and coupling system. Similar reference characters are applied to similar elements throughout the drawings.

Referring to Figure 1, a typical microwave generator 1 of the reflex velocity modulation type includes a cathode heater element 3 for energizing an indirectly heated thermionic cathode 5, and an electron accelerator 7, for accelerating and directing the electron beam through an apertured axial portion 9 of a toroidal cavity resonator 11, and a reflector electrode 13 all disposed on a common axis within an evacuated envelope 15. The cathode may be grounded, the acceleration electrode may be biased at a fixed positive potential from a source not shown, and the reflector electrode 13 may have impressed thereon a suitable negative potential to reflect the electron beam back through the central portion 9 of the cavity resonator 11. By connecting a source of control signals 17 to the reflector electrode 13, the potential thereon may be varied in a manner providing an effective control of the microwave frequency which is generated. The operation of such generators is well known in the art.

A microwave-permeable, gas-tight window 19 in the side of the cavity resonator 11 of the microwave generator 1 opens into a second cavity resonator 21 which is proportioned to resonate in the modes indicated by the solid and dash line arrows 23 and 25, respectively, indicating the magnetic field. By varying the potential applied to the reflector electrode 13 in response to control signals from the source 17, the output frequency generated by the reflex oscillator will depend upon the resonant characteristics of the combined system including the tube cavity resonator 11 and the second cavity resonator 21. Thus, the generated frequency will depend upon the mode of excitation of the second cavity resonator 21, and the control signal source or control voltage applied to the reflector electrode 13 will cause the combined system to generate oscillations which may shift from one predetermined frequency to a second predetermined frequency as different modes of the second cavity resonator are excited.

A first waveguide 27, which may be connected to a first load, not shown, is coupled into the second cavity resonator 21 by means of a coupling aperture 29 in a manner whereby microwave energy is abstracted from the cavity resonator and applied to the load only when the resonator is excited in the mode indicated by the solid line arrows 23. When the system is resonating in this mode, the resultant coupling through a second coupling aperture 31 to a second waveguide 33 connected to a second load, not shown, is effectively zero, since the second aperture 31 is located at a null point between the magnetic fields of the resonant mode 23. However, if the second cavity resonator 21 is excited in the mode indicated by the dash line 25, effective microwave coupling is provided through the second aperture 31 and second waveguide 33 to the second load instead of through the first aperture 29 and the first waveguide 22 to the first load.

It should be understood that the coupling aperture 19 between the cavity resonator 11 and 21 should be quite large in order to provide close coupling therebetween. The reflex generator 1 has been illustrated in elevation as compared to the plan view of the cavity resonator 21 and waveguides 27 and 23, in order to illustrate more completely the structural details of such a system.

4

It should be understood, however, in Figs. 1, 2 and 5, that the portion of the structure to the left of the axis 35 should be rotated 90° with respect to the structure illustrated to the right of said axis.

The system shown in Figure 2 is a modification of that described heretofore by reference to Figure 1 wherein the structure is modified only in a manner whereby "two-cell" and "three-cell" resonant modes indicated by the dash lines 25 and 23, respectively, are excited within the cavity resonator 21. This arrangement permits switching between two operating frequencies which are much more closely related than is possible with the "two-cell" resonator shown in Fig. 1.

The first coupling aperture 29 couples the first load through the first waveguide 27 to the cavity resonator 21 only when it is excited in the mode 25 shown in dash lines. Also the second coupling aperture 31 couples the second load through the second waveguide 33 to the cavity resonator 21 only when it is excited in the mode shown by the solid lines 23. This type of modal excitation of the cavity resonator provides practically complete cut-off of energy through one of the waveguides when the other abstracts energy for its associated load, since the modes are so positioned that the resultant magnetic coupling is maximum through one aperture and practically negligible through the other, no matter which mode is excited.

The graph of Figure 3 indicates the power output which may be derived from the cavity resonator 21 and applied to the first and second loads, respectively, as the frequency is varied between the values f_1 and f_2 by varying the reflector control voltage V_R between the values V_1 and V_2 . The additional power peaks 37, 39, 41 and 43 indicate other less efficient pairs of modes which may be utilized if desired.

Figure 4 shows a second embodiment of the invention wherein a conventional magnetron generator 51 of the variable frequency type is coupled through a coaxial transmission line 53 to a resonator 55 having perpendicularly disposed resonant modes indicated by the solid and dash line arrows 57, 59, respectively. A system utilizing such a resonator may be operated for switching between two closely related frequencies determined by the relative lengths of the transverse axes 61 and 63 of the resonator.

A first load, not shown, is coupled to the resonator through a first load transmission line 65 which is terminated in a coupling loop 67 disposed upon the horizontal transverse resonator axis 63. This load is coupled to the generator only when the resonator 55 is excited in the mode indicated by the dash line arrows 59. Similarly a second load is coupled to the resonator through a second coaxial load line 69 terminated in a second coupling loop 71 disposed on the vertical transverse resonator axis 61, whereby energy is coupled to the second load only when the resonator 65 is excited in the mode indicated by the solid line arrows 67. Substantially perfect cancellation of energy transfer is provided for each load circuit when the other load circuit is abstracting energy from the resonator. It should be understood that all three coupling loops extending into the resonator 55 would, in practice, be rotated 90° in order to couple effectively to the resonator. The schematic illustration thereof in Fig. 4 has been employed to clarify and simplify the structural relations between elements.

5

Referring to Figures 5 and 6, any of the systems described heretofore may be employed to actuate a selectively directional antenna system for providing angularly disposed radiation lobes 75 and 77 in response to selective excitation of dipoles 79 and 81 which are, respectively, disposed at points within the curvature of and eccentric to the axis of a parabolic wave reflector 83. The lengths of the waveguides 27 and 33 coupling the dipoles to the cavity resonator 21 may be so proportioned that an effectively infinite impedance is presented to the undesired frequency when energy of said frequency is propagated through the other of said waveguides. Such proportioning of the waveguides is highly desirable since otherwise they might parasitically absorb considerable energy from the undesired resonant mode in the resonator 21.

Figure 6 illustrates in greater detail a satisfactory arrangement of the bi-directional double dipole antenna system forming a portion of the system of Fig. 5, the operation of which has been described heretofore.

Thus, the invention described comprises an improved method of and means for switching a microwave generator between a plurality of load circuits without the use of moving mechanical elements, wherein a cavity resonator or other resonant device may be selectively excited in two different resonant modes by shifting the generator frequency, and wherein different load circuits are selectively and substantially exclusively coupled to said resonator in only one of its modes of excitation. The system further has been described in combination with a bi-directional antenna system of the type employed in directional navigation systems and the like.

I claim as my invention:

1. An ultra-high frequency energy switching system for selectively connecting a source of energy to different load elements, said system including a cavity resonator coupled to said source and having at least two different longitudinal resonant modes, means for coupling one of said load elements to said resonator to extract energy in one of said modes, means for coupling another of said load elements to said resonator to extract energy in another of said modes, and means for varying the frequency of said energy source to excite said resonator selectively in different ones of said modes.

2. An ultra-high frequency energy switching system for selectively connecting a source of energy to different load elements, said system including a cavity resonator coupled to said source and having at least two different parallel resonant modes, means for coupling one of said load elements to said resonator to extract energy in one of said modes, means for coupling another of said load elements to said resonator to extract energy in another of said modes, and means for varying the frequency of said energy source to excite said resonator selectively in different ones of said modes.

3. An ultra-high frequency energy switching system for selectively connecting a source of energy to different load elements, said system including a cavity resonator coupled to said source and having a plurality of coupling apertures and at least two different parallel resonant modes, a first waveguide opening into said resonator through one of said apertures for coupling one of said load elements to said resonator to extract energy in one of said modes, a second waveguide

6

opening into said resonator through another of said apertures for coupling another of said load elements to said resonator to extract energy in another of said modes, and means for varying the frequency of said energy source to excite said resonator selectively in different ones of said modes.

4. An ultra-high frequency energy switching system for selectively connecting a source of energy to different load elements, said system including a cavity resonator having a plurality of coupling apertures and at least two different parallel resonant modes, means for coupling said source to said resonator through one of said apertures, a first waveguide opening into said resonator through one of said apertures for coupling one of said load elements to said resonator to extract energy in one of said modes, a second waveguide opening into said resonator through another of said apertures for coupling another of said load elements to said resonator to extract energy in another of said modes, and means for varying the frequency of said energy source to excite said resonator selectively in different ones of said modes.

5. An ultra-high frequency energy switching system for selectively connecting a source of energy to different load elements, said system including a first cavity resonator having a plurality of coupling apertures and at least two different parallel resonant modes, said source including a second cavity resonator opening into said first resonator, a first waveguide opening into said first resonator through one of said apertures for coupling one of said load elements to said resonator to extract energy in one of said modes, a second waveguide opening into said first resonator through another of said apertures for coupling another of said load elements to said resonator to extract energy in another of said modes, and means for varying the frequency of said energy source to excite said first resonator selectively in different ones of said modes.

6. An ultra-high frequency energy switching system for selectively connecting a source of energy to different load elements, said system including a cavity resonator having a plurality of coupling apertures and at least two different parallel resonant modes, said source comprising a reflex microwave oscillator having a frequency controlling electron reflecting electrode and a second cavity resonator opening into said first resonator, a first waveguide opening into said first resonator through one of said apertures for coupling one of said load elements to said resonator to extract energy in one of said modes, a second waveguide opening into said first resonator through another of said apertures for coupling another of said load elements to said resonator to extract energy in another of said modes, a source of potential for said electrode and means for varying said potential for varying the frequency of said energy source to excite said resonator selectively in different ones of said modes.

7. An ultra-high frequency energy switching system for selectively connecting a source of energy to different antenna elements, said system including a cavity resonator having a plurality of coupling apertures and at least two different parallel resonant modes, means for coupling said source to said resonator through one of said apertures, a first waveguide opening into said resonator through one of said apertures for coupling one of said antenna elements to said resonator to extract energy in one of said modes, a

7

second waveguide opening into said resonator through another of said apertures for coupling another of said antenna elements to said resonator to extract energy in another of said modes, and means for varying the frequency of said energy source to excite said resonator selectively in different ones of said modes.

8. A system according to claim 7 including a parabolic wave reflector having said antenna elements positioned eccentrically with respect to its axis, the relative lengths of said waveguides being proportioned to minimize parasitic wave propagation therein in response to wave transmission through the other of said waveguides, whereby excitation of said resonator in different ones of its resonant modes provides selective variation of the direction of wave propagation from said reflector.

ROBERT L. SPROULL.

8

REFERENCES CITED

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

UNITED STATES PATENTS

	Number	Name	Date
	2,054,816	Hollmann	Sept. 22, 1936
	2,067,156	Lux	Jan. 5, 1937
	2,337,184	Carter	Dec. 21, 1943
5	2,380,981	McElhannon	Aug. 7, 1945
	2,408,425	Jenks et al.	Oct. 1, 1946
10	2,409,227	Shockley	Oct. 15, 1946
	2,421,725	Stewart	June 3, 1947
	2,425,328	Jenks et al.	Aug. 12, 1947
15	2,444,152	Carter	June 29, 1948
	2,450,026	Tomlin	Sept. 28, 1948