

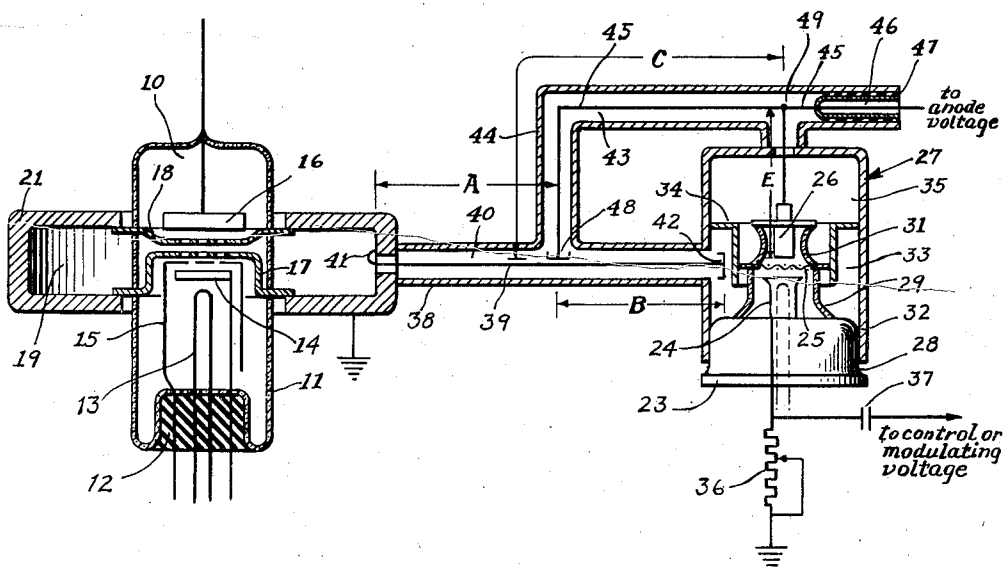
March 30, 1948.

W. A. STEWART

2,438,768

APPARATUS FOR VARYING THE FREQUENCY OF RESONANT CAVITIES

Filed April 28, 1944



INVENTOR.

William A. Stewart
by his Attorneys
Houston & Houston

UNITED STATES PATENT OFFICE

2,438,768

APPARATUS FOR VARYING THE FREQUENCY
OF RESONANT CAVITIES

William A. Stewart, Philadelphia, Pa., assignor,
by mesne assignments, to Philco Corporation,
Philadelphia, Pa., a corporation of Pennsylvania

Application April 28, 1944, Serial No. 533,183

9 Claims. (Cl. 179-171.5)

1

2

The present invention relates to arrangements for varying the frequency of resonant cavities such as used in ultra-high frequency radio circuits. The invention relates further to an apparatus and means for frequency modulating oscillators of the type whose frequency is fixed or controlled through the agency of an associated resonant cavity.

Resonant cavities are useful in ultra-high frequency techniques for a number of purposes. In one application of the resonant cavity to ultra-high frequency systems the cavity is used in conjunction with an oscillator tube to supply the essential circuit constants and thereby to determine the frequency of oscillation. In this application the cavity may be of a generally toroidal shape, and usually surrounds at least a portion of the vacuum tube. Such cavities are commonly used in conjunction with velocity modulated vacuum tubes and generally are of relatively small dimensions. In such ultra-high frequency circuit arrangement it is frequently desirable or necessary to vary the frequency of the cavity. In order to tune the cavity or, in other words, to shift the resonant frequency thereof, it has been common to insert various devices, such as tuning plugs or vanes, into the cavity through suitable openings therein. Such devices are generally rather difficult to construct and adjust and hence it has been found desirable to provide an alternative arrangement for changing the resonant frequency of the cavity without physical adjustment of the cavity structure itself, and without substantial physical displacement either of the magnetic field therein, or alteration of the length of the electrostatic lines of force therein.

In other ultra-high frequency circuit arrangements resonant cavities are utilized with velocity modulated vacuum tubes, and the frequency of the cavity is varied, or modulated, by providing means for introducing voltage variations into the supply voltages for the vacuum tube. Such arrangements have the disadvantage of causing concomitant power output variations. Therefore, it has also been found desirable to provide an improved method and apparatus for frequency modulating the ultra-high frequency energy associated with cavity oscillating circuits. Heretofore the possible range of such variation, or in other words the range of the modulation, has not been as great as desired and hence it is desirable to provide an arrangement whereby the modulation frequency band will cover a wide

range of, for example, several percent of the center frequency.

In accordance with the present invention the above mentioned desirable characteristics, and others which subsequently will become apparent, are accomplished by providing an apparatus by which the frequency of a cavity resonator may be varied by electrical means over a wide range of frequencies.

It is, therefore, an object of the present invention to provide an improved arrangement for varying the frequency of a resonant cavity.

It is another object of the present invention to provide an apparatus for electrically varying the frequency of a circuit element such as a resonant cavity.

It is still another object of the present invention to provide an improved apparatus for varying the frequency of ultra-high frequency radio circuit elements through a relatively wide range of frequencies.

Still another object of the present invention is to provide an improved arrangement for modulating ultra-high frequency energy over a range amounting to several percent of the central frequency.

Still another object of the present invention is to provide an arrangement for modulating the ultra-high frequency energy of an oscillator without appreciably changing the power output level.

Other and further objects of the present invention will subsequently become apparent by reference to the following description taken in connection with the accompanying drawing, wherein the figure schematically shows an apparatus for electrically varying the frequency of a ultra-high frequency tuned circuit such as a resonant cavity.

In order to illustrate the present invention, it may be assumed that it is desired to control the frequency of a resonant cavity associated with a velocity modulated vacuum tube. In the drawing there is shown a velocity modulated tube 10 which may be any one of a number of the generally used types of ultra-high frequency vacuum tubes. Such tube, for example, may comprise an evacuated glass envelope 11 having a reentrant stem or press 12 through which suitable lead-in conductors extend to the interior of the vacuum tube. The vacuum tube may be provided with a heater 13 arranged to heat a cathode 14 having a plane surface arranged parallel to the perforated plane surface of a grid structure 15. The grid structure 15 is spaced from the plane surface of a suitable anode 16 a sufficient distance to

allow for the perforated inner walls 17 and 18 which form part of a resonant cavity 19. The perforated wall structures 17 and 18 in a tube of the type illustrated are sealed to the inner walls of the glass envelope 11. The outer portion of the resonant cavity 19 may be formed of an annular ring-like structure 21 having walls of sufficient thickness to provide adequate mechanical strength, which in turn are connected by any suitable means (not specifically shown) to join with the inner wall structures 17 and 18.

In the past in order to vary the frequency of the resonant cavity 19 it has been common to insert, through suitable openings in the outer wall 21, plugs or vanes which either reduce the net volume of the cavity 19, displace the magnetic field therein, or change the length of the electrostatic lines of force. Such devices are frequently undesirable for mechanical reasons, at least, and are difficult to adjust accurately. It is desired to provide other means for accomplishing this frequency variation. Furthermore, where it was desired to frequency modulate the energy of the resonant cavity 19, this was accomplished by varying the voltages supplied to the electrodes within the envelope 11, which of course had the undesired effect of changing the power output of the system. In order to vary the frequency of the resonant cavity 19 for either of the purposes just mentioned, or for other purposes, there is provided, according to the present invention, the apparatus shown to the right of the vacuum tube 10 and the resonant cavity 19.

An ultra-high frequency amplifying apparatus comprising a suitable vacuum tube 23 having an indirectly heated cathode 24, a control grid 25 and an anode 26 is arranged for cooperation with a resonant cavity structure 27. The vacuum tube 23, which in the drawing has been shown as having a particular construction, is but one of a number of ultra-high frequency vacuum tubes which might be utilized as an ultra-high frequency radio amplifying device. The particular vacuum tube 23 illustrated is of the "lighthouse" type, and has a metal shell base 28 above which is positioned a glass envelope 29 which is secured to the externally extending rim of the perforated grid structure 25. Immediately above the grid ring of the grid 25 there is provided a glass envelope 31 of somewhat smaller dimensions which is secured at its lower rim to the grid ring, and at its upper rim to a washer-like structure secured to the anode 26. The metal shell 28 of the vacuum tube serves as a closure for the open end of an outer cavity member 32. The outer cavity member 32 in effect forms part of the walls of two chambers or resonant cavities. The one cavity 33 comprises that volume between the base shell 28 and an intermediate structure 34. The other cavity 35 comprises that volume between the upper portion of the cavity shell 32 and the intermediate structure 34. The intermediate structure 34 comprises an annular member arranged to contact the inner surface of the cylindrical outer shell member 32, and depending from this ring-like portion of the member 34 is a skirt or cylindrical section of such dimensions as to make contact with the grid flange or ring extending outwardly from the grid structure 25. The intermediate member 34 is preferably adjustable axially so that the circuit constants of the apparatus may be adjusted thereby to determine the frequency of operation. This structure acts as a radio-frequency amplifier of variable gain.

Suitable conductors interconnect the cathode

heater with the exterior of the vacuum tube 23 which generally is provided with suitable contact prongs (not shown). The cathode 24 is connected to an adjustable resistor 36, one end of which is connected to ground. The grid structure 25 has a D. C. ground return which includes the member 34, the cavity structure 27, the outer conductor 38 of line 40, and the grounded resonant cavity 21 of tube 10. The juncture of the resistor 36 with the conductor connected to the cathode 24 may be coupled through a capacitor 37 to a control or modulating voltage where it is desired to vary the frequency of the resonant cavity 19 at regular intervals or periodically. If slow frequency variations are desired the coupling capacitor may, of course, be omitted.

The lower cavity 33 is coupled to the resonant cavity 19 by means of a coaxial transmission line comprising an outer conductor 38 and an inner conductor 39. The end of the coaxial conductor 39 adjacent the resonant cavity 19 is provided with a loop 41 which preferably is arranged to be at a point of maximum magnetic field intensity in the cavity 19, and is so orientated as to have the desired degree of pick-up. Generally this desired degree of pick-up is such that the maximum effect is obtained. At the other end of the coaxial line the inner conductor 39 is capacitively coupled to the cavity 33 by a capacity hat 42 having its surface arranged adjacent the skirt portion of the intermediate member 34. At an intermediate point on the coaxial line 40 which comprises the outer conductor 38 and the inner conductor 39 another coaxial line section 43 is joined thereto. This intermediate point may be referred to as the reinjection coupling point. The coaxial line 43 comprises an outer conductor 44 and an inner conductor 45 which is connected to the anode 26 of the vacuum tube 23 and which extends to the source of anode voltage. In order to isolate the ultra-high frequency from the source of anode voltage, the inner conductor 45 is connected to a radio frequency filter or choke 46 which is supported by an insulating sleeve 47 within the outer conductor 44. The radio frequency filter 46, which is preferably a quarter-wavelength long, is positioned closely adjacent to the point where the coaxial line 43 makes connection with a suitable aperture adjacent the top of the outer shell structure 32.

The other end of the inner conductor 45 is provided with a capacity hat 48 positioned adjacent to the inner conductor 39 of the coaxial line 40. The junction of the coaxial line section 43 and the coaxial line 40, i. e. the reinjection coupling point, is preferably so positioned that the distance therefrom to the loop 41, which distance has been indicated as the dimension A in the drawing, is such that the reinjection coupling point is at or near a maximum voltage point on the line 40 with respect to the frequency involved. The distance from the reinjection point to the grid 25 of the vacuum tube 23, indicated by the dimension B, is such as to provide a maximum voltage point on the grid, or such as to properly energize the grid-to-cathode cavity 33. The length of the coaxial line 43, generally indicated by the dimension C, which extends from the reinjection point at the capacity hat 48 to the effective working surface of the anode 26, is such as to provide a maximum voltage point at the reinjection coupling point at or near the operating frequency. The length C furthermore is such as to prevent undue regeneration and undesired oscillation.

Referring now to the *modus operandi* of the system, it may be stated that the invention is based on the discovery that a resonant cavity may be tuned by coupling to said cavity a line which is resonant at a frequency differing somewhat from the natural resonant frequency of the cavity and by terminating said resonant line in a variable impedance. The effective resonant frequency of the cavity then becomes a function of the magnitude of the said terminating impedance. In the drawing the resonant line consists of that portion of the line 40 which extends from the coupling loop 41 to the reinjection coupling point. The length of this line, indicated in the drawing by the dimension A, should be of the order of an odd quarter-wavelength at a frequency differing somewhat, say by plus-or-minus 2 to 5%, from the natural resonant frequency of the cavity alone. The frequency to which the line section A is resonant will be referred to hereinafter as the "side-frequency."

According to the present invention, the frequency of the oscillations generated by the tube 10 may be varied by terminating the resonant length of line A in an impedance the magnitude of which may be varied at will to effect the desired frequency changes. The variable impedance may, if desired, be any conventional variable resistor suitable for use at ultra-high frequencies, but preferably such variable impedance comprises an electronically simulated impedance. To this end the structure to the right of the reinjection coupling point comprises means for electronically simulating a desired impedance across the end of the resonant line section A. Employing the dimensions hereinafter recited, such simulated impedance is largely resistive, its magnitude largely dependent upon the gain of the amplifier tube 23. With such a system both positive and negative resistances may be simulated. It is, however, not outside the scope of the present invention to employ other line dimensions whose effect will be to simulate reactive impedances, but such is not, at present, considered to be the preferred embodiment of the invention.

As was indicated above, the line section A is preferably an odd quarter of a wavelength long at the side-frequency. The line section B, extending from the reinjection point to the capacity hat 42, is preferably an even quarter-wavelength long at the side-frequency. The line section C, which extends from the reinjection point to the anode supply point 49, has a length, preferably, of an odd quarter-wavelength at the side frequency. The distance D (not shown in the drawing), which may be taken as the electrical distance from the capacity hat 42, through the grid electrode 25, and to the working surface of the anode 26, is preferably an even number of quarter-wavelengths, but at least four, at the side-frequency. This electrical length includes the usual phase reversal taking place between the grid and plate of the tube. This amounts, of course, to two quarter-wavelengths. The distance E, which extends from the anode working surface to the anode supply point 49, is preferably an odd quarter-wavelength. The dimensions C and E are not individually critical, but preferably the dimension C plus the dimension E is an even number of quarter-wavelengths at the side frequency.

If it is desired to vary the frequency of the resonant cavity 19 by manual means, the contact on the adjustable resistor 36 is manipulated. If, on the other hand, it is desired to periodically

control or to modulate the frequency of the energy in the cavity 19, a suitable source of modulating voltage is connected to the coupling capacitor 37. For example, it may be assumed that the coupling capacitor 37 is connected to a sine wave, square wave, or other recurrent pattern voltage generator which thereby will produce a periodically varying gain of the amplifying tube 23 which thereby produces a proportional change in the resonant frequency of the cavity 19. The total frequency shift of the resonant cavity 19 will be proportional to the peak voltage applied through capacitor 37 to the amplifying device 27. The frequency deviation thus produced may be relatively great, for example of the order of several percent of the entire frequency.

While for the purpose of illustrating and describing the present invention certain specific apparatus has been disclosed, it is to be understood that I do not wish to be limited thereto since obviously other equivalents might be utilized and various alterations in the circuit arrangement and in the instrumentalities employed might be made as may be commensurate with the scope of the invention defined in the appended claims.

I claim:

1. In an ultra-high frequency circuit, the combination comprising an ultra-high frequency oscillating circuit the frequency of which is to be varied, an ultra-high frequency amplifier including a vacuum tube having a plurality of cavities, a coaxial line interconnecting one of said cavities with said oscillating circuit, and a coaxial line interconnecting the other of said cavities with said first coaxial line so as to provide a reinjection coupling point at a voltage point on said first coaxial line.

2. In an ultra-high frequency circuit, the combination comprising an oscillating circuit the frequency of which is to be varied, an ultra-high frequency amplifier including a vacuum tube having a grid-to-cathode cavity and a grid-to-anode cavity, a coaxial line interconnecting said oscillating circuit with said grid-to-cathode cavity, and a second coaxial line interconnecting said grid-to-anode cavity with an intermediate point on said first coaxial line to provide a reinjection coupling point having a maximum voltage at or near the operating frequency.

3. In an ultra-high frequency circuit, the combination comprising an oscillating circuit the frequency of which is to be varied, an ultra-high frequency amplifier including a vacuum tube having a grid-to-cathode cavity and a grid-to-anode cavity, a coaxial line interconnecting said grid-to-cathode cavity with said oscillating circuit, and a second coaxial line interconnecting said grid-to-anode cavity with an intermediate point on said first coaxial line so as to provide a voltage point on the grid of the amplifying vacuum tube.

4. In an ultra-high frequency circuit, the combination comprising a resonant cavity the frequency of which is to be varied, an ultra-high frequency amplifier including a vacuum tube having a plurality of cavities, a coaxial line interconnecting one of said cavities with said first mentioned resonant cavity, and a coaxial line interconnecting the other of said latter cavities with an intermediate point on said first coaxial line, said latter coaxial line being capacitively coupled to said first coaxial line, said latter coaxial line being of such length as to minimize the possibility of regeneration and oscillation.

5. In an ultra-high frequency circuit, the com-

bination of a resonant cavity the frequency of which is to be varied, an ultra-high frequency amplifier including a plurality of cavities, a coaxial line interconnecting one of said cavities with said first mentioned cavity, said coaxial line being inductively coupled to said first mentioned cavity and capacitively coupled to said other cavity, and a second coaxial line interconnecting the other of said amplifier cavities with an intermediate point on said first mentioned coaxial line so as to provide a reinjection coupling point at a voltage point on said first coaxial line.

6. The combination comprising an oscillating circuit having a resonant cavity the frequency of which is to be varied, an ultra-high frequency amplifier including a vacuum tube and a grid-to-cathode cavity and a grid-to-anode cavity, a coaxial line connected by a loop to said oscillating circuit resonant cavity, capacitive coupling means connecting said coaxial line with said grid-to-cathode cavity, a second coaxial line connected between the anode of said vacuum tube and an intermediate point on said first coaxial line, said latter coaxial line having an inner conductor capacitively coupled to the inner conductor of said first coaxial line, and means for controlling the amplification of said amplifying vacuum tube.

7. In an ultra-high frequency circuit, the combination comprising an ultra-high frequency resonant cavity the frequency of which is to be varied, an energy pick-up means positioned within said cavity, an ultra-high frequency amplifier circuit, a coaxial transmission line interconnecting said pick-up means with said amplifier circuit, a second coaxial transmission line interconnecting said amplifier circuit with an intermediate point on said first coaxial line to re-inject amplified ultra-high frequency energy into said first line, and means for varying the gain of said amplifier circuit thereby to vary the operating frequency of said resonant cavity.

8. An ultra-high frequency apparatus adapted to control the operation of another circuit, comprising an amplifier tube having a resonant cavity structure, an adjustable common partition provided within said cavity structure to form two cavities, one cavity being arranged as a grid-to-cathode cavity and the other cavity being ar-

5. ranged as a grid-to-anode cavity, a transmission line capacitively coupled to said grid-to-cathode cavity, said transmission line being adapted to be connected to the circuit to be controlled, a second transmission line interconnecting said grid-to-anode cavity with a point on said first transmission line so as to re-inject amplified ultra-high frequency energy into said first line, and means for controlling the gain of said amplifier thereby to control the operating frequency of said controlled circuit.

9. In an ultra-high frequency circuit, the combination comprising a cavity type oscillating circuit the frequency of which is to be controlled, an ultra-high frequency amplifier including a vacuum tube having a grid-to-cathode cavity and a grid-to-anode cavity, a coaxial line interconnecting said grid-to-cathode cavity with said cavity type oscillating circuit, said coaxial line being inductively coupled thereto and being capacitively coupled to said grid-to-cathode cavity, a second coaxial line interconnecting said grid to anode cavity with an intermediate point on said first coaxial line so as to re-inject amplified ultra-high frequency energy therein, means for varying the gain of said amplifier thereby to control the operating frequency of said oscillating circuit, and means for applying a modulating voltage to said amplifying tube to vary the frequency of said oscillating circuit in accordance with said modulating voltage.

WILLIAM A. STEWART.

REFERENCES CITED

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

UNITED STATES PATENTS

	Number	Name	Date
40	2,200,986	Fraenckel	May 14, 1940
	2,213,103	Gluyas	Aug. 27, 1940
	2,213,104	Gluyas, Jr.	Aug. 27, 1940
	2,241,976	Blewett	May 13, 1941
	2,280,026	Brown	Apr. 14, 1942
45	2,280,824	Hansen	Apr. 28, 1942
	2,312,919	Litton	Mar. 2, 1943
	2,329,779	Nergaard	Sept. 21, 1943
	2,349,811	Crosby	May 30, 1944