

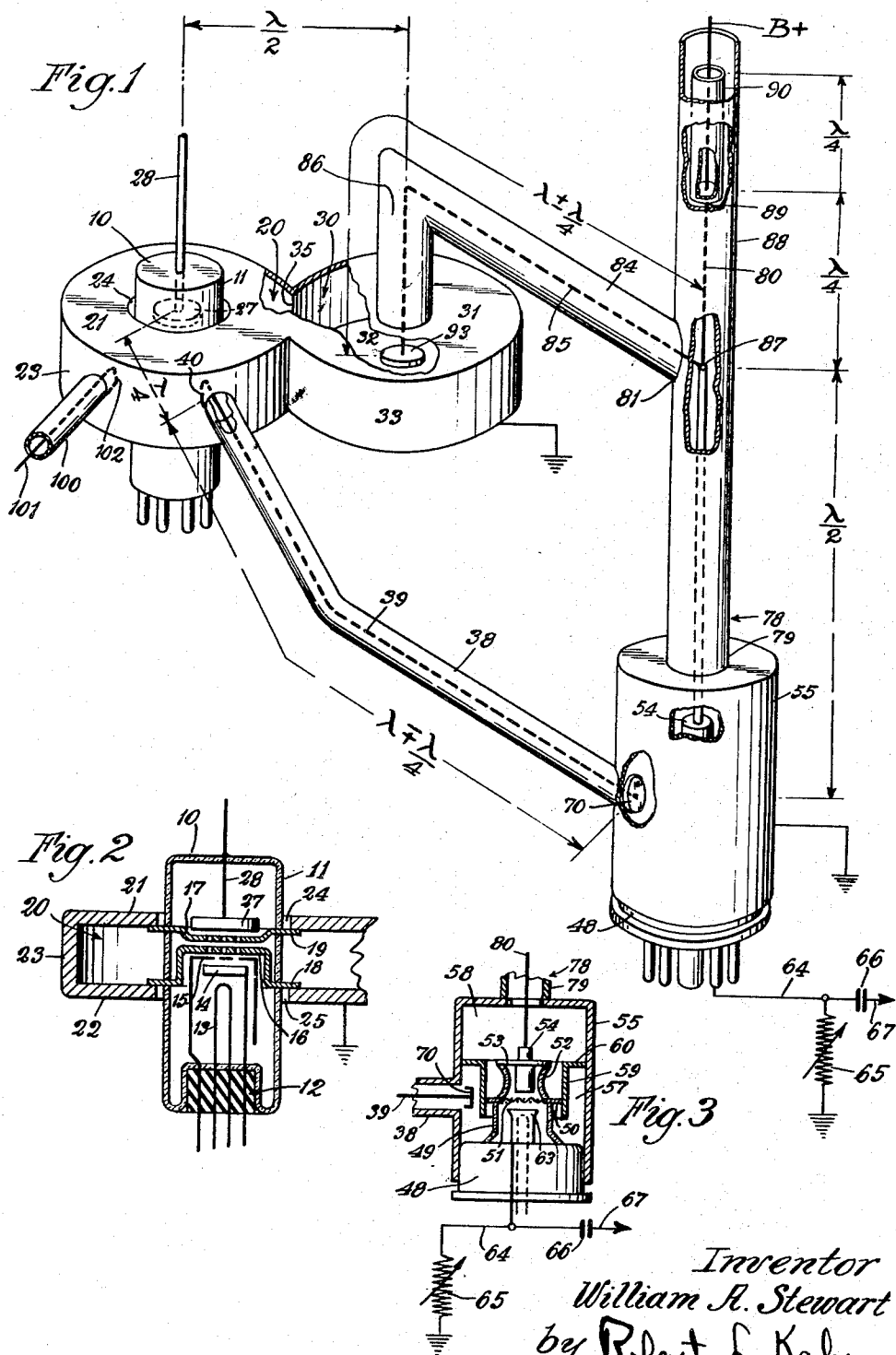
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VARIABLE FREQUENCY CAVITY RESONATOR OSCILLATOR

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VARIABLE FREQUENCY CAVITY
RESONATOR OSCILLATOR

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This invention relates to an electrical apparatus and particularly to an ultra high frequency oscillator whose frequency output may be varied over a limited range without substantial change in power.

In systems operating at ultra-high frequency, it is customary to use cavity resonators with velocity modulated electron discharge devices for generating oscillations. Cavity resonators as a rule have fairly high Q's and, as a result, have a resonant frequency response which is comparatively sharp. In order to associate pre-fabricated elements or components of a communication system operating at ultra-high frequency, it is necessary that each of the components be tuned to the frequency desired. Because of production inaccuracies, it is impossible to manufacture an oscillator whose resonant frequency is the critical value desired. As a rule, temperature variations in addition to geometrical variations will modify the resonant frequency. Because of the comparative sharpness of response and the frequency range of such devices, a small percentage variation in frequency results in a substantial numerical frequency deviation and may make frequency alignment difficult.

It has hitherto been the practice to vary the dimensions of cavities in order to control the resonant frequency. The variation of volume is inconvenient and difficult, particularly since excellent electrical contact between sliding surfaces must be maintained in order to retain the desired electrical characteristics. It is also possible to vary the resonant frequency of cavities by variation of impressed potential upon the oscillator. This is an undesirable method since it affects power output, as well as mode of oscillation within the cavity, and may result in a widely different frequency being established. In addition, cavities oscillating at higher modes may be unstable.

I have determined that it is possible to vary the frequency of a sharply-tuned cavity type oscillator by coupling in a variable impedance, the coupling and impedance being of such character that the frequency output of the oscillator is varied over a small range without substantial impairment of the power output. In coupled circuits, it is possible to provide a sharply-tuned circuit and couple the same to another circuit whose resonant frequency is the same or slightly different from the resonant frequency of the first circuit. By means of control of the coupling and the character of the added circuit, it is possible to reflect into the sharply-tuned circuit a

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sufficient variation of reactance so that the resonant frequency is changed.

With cavities resonating at ultra-high frequencies, the conventional reactances are no longer effective. In such case, the character of reactance may be recognized merely by its effect on the relative phase between voltage and current. Because of the comparatively sharp resonance of a cavity, it is of course difficult to vary the frequency too greatly from its resonant value. However, I have determined that a frequency variation of the order of about 2% on either side of the resonant frequency is possible and that such a range is amply sufficient to provide for alignment purposes.

The invention herein generally provides for two transmission lines coupled to a sharply resonant cavity, the transmission lines differing in effective length from each other by an odd number of half wavelengths. An amplifier is provided at the termination of the lines.

The gain of the amplifier provides an effective means for controlling the coupling between the transmission lines. Hence, a control of amplifier gain effectively controls the frequency of the entire system.

Referring now to the drawings, Figure 1 is a perspective view with certain parts broken away of a system embodying this invention. Figure 2 is a sectional elevation of an oscillator tube used for exciting a cavity. Figure 3 is a sectional elevation of the amplifier tube shown in Figure 1.

A velocity modulated type of vacuum tube 10 has evacuated glass envelope 11 with press 12 into which are sealed a plurality of wires. Thus cathode heater 13 energizes cathode 14, both being mounted on wires sealed in press 12. As is well known in the art, the tube of which this is an example, customarily requires cathodes having high electron emission. Since such cathodes are well known in the art, their construction and treatment need not be described in detail. As is evident from the drawing, cathode 14 has its electron emitting surface substantially perpendicular to the axis of tube 10. In proximity to cathode 14 is grid structure 15 also supported from a wire sealed in press 12. Grid structure 15 is spaced axially of the tube from cathode 14 and is adapted to have impressed thereon a suitable positive potential.

Beyond grid 15 in the electron path are a pair of spaced grid wall members 16 and 17. Grid member 16 has downwardly and outwardly extending flange 18 which passes through envelope 11, the glass being sealed on opposite sides there-

of. Similarly, grid member 17 has flange 19 which passes through envelope wall 11, the two flanges forming metal rings around envelope 11 and extending from inside of envelope 11 to the outside thereof. The various grid members are formed of metal. Thus grid 15 may be formed of molybdenum, tungsten, or even iron. Grid members 16 and 17 are preferably of such a material as to provide good electrical conductivity on their opposing inner surfaces. To complete the structure, a cavity generally designated as 20 and having the general shape of a flattened toroid is provided. Cavity 20 has generally circular upper and lower walls 21 and 22 respectively joined by curved side wall 23. Inner edges 24 and 25 of walls 21 and 22 are soldered or otherwise joined to flanges 19 and 18. Thus in effect cavity 20 is built around vacuum tube 10. Cavity 20 is formed of a metal like copper and may have its inner surface silver-plated to reduce skin resistance.

The resonant frequency of cavity 20 is determined by the physical dimensions thereof including the distance between opposing grid members 16 and 17. The distance between grid 15 and adjacent grid member 16 is also quite important. The spacing and dimensioning of these elements are matters well known in the art and need not be detailed here.

Beyond grid member 17 is reflector 27 carried by wire 28 passing through the upper end of envelope 11. The spacing between the reflector and adjacent grid member 17 is also important in determining the operation of the device. An electron discharge device such as described herein operates upon a velocity modulation principle and induces oscillations in cavity 20. By spacing the elements a proper distance apart and by operating with proper voltages, continuous oscillations in 20 may be maintained at a frequency normally determined by the dimensions of cavity 20 and separation of grids 16 and 17.

In accordance with this invention, however, it is preferred to couple second cavity 30 to cavity 20. Thus cavity 30 may have generally circular top and bottom walls 31 and 32 respectively joined by curved side wall 33. Cavities 20 and 30 are joined together by having a common peripheral portion along curved outer walls 23 and 33 respectively. This common portion indicated by numeral 35 is so proportioned as to provide a passageway joining the cavities, this passageway being oriented and dimensioned to provide a predetermined amount of coupling. Cavity 30, like cavity 20, is formed of metal having excellent electrical conductivity on the inner surface thereof and providing a resonant cavity having a high Q. The natural frequency of cavity 30 is preferably the same as that of cavity 20 within the limits of normal production. The physical dimensions of cavities 20 and 30 will not be the same because of the effect of the space between grids 16 and 17 on cavity 20. In practice, cavity 20 will have physically smaller dimensions, such as a smaller diameter, to equalize its resonant frequency to cavity 30.

Coupled to cavity 20 is transmission line 38 which may be either a wave guide or, as shown here, a coaxial line. Transmission line 38 has the outer conductor passing into side wall 23 of cavity 20. Inner conductor 39 of this transmission line terminates in loop 40 going to outer conductor 38, loop 40 being so dimensioned and disposed as to pick up the magnetic fields within cavity 20. As shown, loop 40 is oriented substantially in line

between opposing walls 21 and 22 of cavity 20. In the event that less coupling is required, the plane of this loop may be turned away from this orientation. Inner conductor 39 may be supported with respect to outer conductor 38 in any manner well known in the cable art. Thus for example, beads, a solid dielectric, or even metal supporting stubs may be provided. The length of transmission line 38 corresponds to an odd number of quarter wave lengths as measured within the transmission line, as referred to the natural frequency of cavity 20.

Transmission line 38 is coupled at its remote end to an amplifier tube. As shown, the amplifier tube is of the type known in the trade as a Lighthouse tube. It is understood of course that any other type of tube suitable for this purpose may be used.

This type of tube comprises metal base 48 to which is sealed glass envelope 49 substantially of the shape shown. Glass envelope 49 is secured to externally extending rim 50 of perforated or woven grid structure 51. Right above grid rim 50, there is provided glass envelope 52 of somewhat smaller dimensions than envelope 49. Glass envelope 52 carries at its upper end rim washer 53 through which passes anode 54. It is understood of course that the various portions inside of the glass envelopes are properly evacuated and sealed in accordance with well-known practice.

The entire tube is covered by metal shell 55, which is fastened to shell 48. Outer cavity member 55 forms part of the walls of two resonant cavities 57 and 58 respectively. Cavity 57 is separated from cavity 58 by cylinder 59 carried by rim 50 and extending upwardly toward the top of the tube. Cylinder 59 itself carries flange 60 which extends to the inner wall of shell 55 and thus serves to partition the entire space within shell 55 into the two cavities.

Disposed within envelope 49 and below grid 51 is cathode 63 whose electron emitting surface faces grid 51. Cathode 63 in general has the same electron emitting properties as cathode 15 of oscillator tube 10, namely, high electron emissivity. This cathode may be energized by a heater of the usual construction. Cathode 63 may have its potential with respect to ground varied by having cathode lead 64 connected to variable resistance 65. A modulating potential upon cathode 63 may be impressed through blocking condenser 66 by lead 67. By varying the effective potential between the cathode and remaining electrodes in the amplifier, the gain of the tube may be varied within limits.

Input coupling to the tube may be provided by terminating inner conductor 39 of transmission line 38 in hat or disc 70 within cavity 57. The shape and dimensions of hat 70 are so chosen as to provide proper coupling.

To provide an output feed, coaxial line 78 is connected to the amplifier. Coaxial line 78 has outer conductor 79 joined to shell 55, a suitable aperture in the shell top being provided. Inner conductor 80 extends into shell 55 to anode 54. Inner conductor 80 at its extreme upper end is connected to a suitable source of B plus potential so that a metallic connection to anode 54 is necessary. In addition thereto, this conductor serves as a pick-up within chamber 58 to feed ultra-high radio frequency energy from this chamber into coaxial line 78.

Coaxial line 78 extends up to point 81 where a T is formed. Point 81 is so chosen that between 75 this point and hat 70, there is an odd number of

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half wave lengths. As is well known, the phase shift in an amplifier is a function of the operating voltage as well as geometry of the tube. In certain types of tube such as the Klystron, the phase shift may amount to a number of complete wave lengths.

From T 81, side branch 84 of the coaxial system extends, this having central conductor 85. This line may have the last portion thereof formed as stub 86 extending toward cavity 30. Central conductor 85 is joined to central conductor 80 at point 87. The length of line 84 plus stub 86 is an odd number of quarter wave lengths but must differ from line 38 by an odd number of half wave lengths. Thus the two lines together should add up to an integral number of complete wave lengths. In more concise form, line 38 may be an integral number of wave lengths minus or plus one quarter wave length and line 84 and stub 85 may be an integral number of wave lengths plus or minus one quarter wave length. It is understood that for purposes of calculation zero may be considered an integral number.

Beyond point 87, central conductor 80 extends as shown while outer conductor 79 is extended beyond T 81 to form coaxial section 88. At point 89, a quarter wave length or any odd number of quarters from junction 87, away from the amplifier, central conductor 80 has a choking sleeve 90 around it. This sleeve may be about a quarter wave length long and, in accordance with well-known practice, serves to choke off radio frequency energy.

Coaxial stub 86 has the outer conductor connected to cavity 30, it being joined at a suitable aperture thereto in a manner similar to the junction between outer conductor 79 and amplifier shell 55. Inner conductor 90 is terminated in hat or disc 93 disposed within cavity 30 and adapted to serve as an electrostatic coupling means between the line and the cavity.

The phase difference between the centers of cavities 30 and 20 is one-half a wave length or 180 degrees. In order for the system to operate, it is essential that all the phase shifts around the system add up to an integral number of wave lengths plus or minus one quarter. In other words, the phase at disc 93 at any instant due to the transmission through the lines and amplifier will be either 90 degrees or 270 degrees out of phase with the voltage at the center of cavity 20.

From the preceding, it may be understood that the purpose of the invention is to reinject into the oscillator system a voltage which appears either capacitive or inductive depending upon the direction of phase shift. This voltage, therefore, tends to place respectively either a capacity or an inductance in shunt with the oscillator system, thereby changing the effective frequency. The amount of the shift in effective frequency is, of course, dependent upon the amplification in the system and tube, and the amount of phase shift introduced by changes in said amplification. It should be possible, therefore, dependent upon whether the reinjected voltage leads or lags in phase, to make the inherent phase shift due to changes in the voltage on the amplifier tube actually add to the effectiveness of the system.

Thus as an example, line 38 may be three-quarters of a wave length long. The shift between disc 70 and junction 87 will be one-half a wave length plus any integral number of half wave lengths which may occur within certain types of amplifiers. The entire length of line from junction 87 to disc 93 may be one and one-

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quarter wave lengths plus or minus any integral number of wave lengths. From loop 40 to disc 93, the total phase shift will be an odd number of half wave lengths. It should be noted that loop 40 is 90 degrees away from center of cavity 20. The half wave length shift between the two cavities will thus bring all the phase shifts to an integral number of full wave lengths plus or minus 90 degrees.

There will be a certain amount of phase shift other than the usual 180 degrees, if a triode is used, this being generally inherent in an amplifying tube operating in the frequency range where cavity resonators are employed. This inherent shift must be corrected so that the above-mentioned condition holds. Otherwise, there will be a resistive component introduced which will tend to reduce the efficiency of the oscillator.

For this reason, a practical system would utilize "line stretchers" so that the phase relationships can be easily attained. Further, the reinjection point (disc 93) would be made adjustable, as would loop 40, so that the coupling of the amplifying system to the oscillator could be controlled. The amplifier should have a fairly low Q and may be neutralized by employing feedback of the correct phase relationship between the grid and plate tank circuits. These circuits should be tuned to the center frequency of the system. It may be noted that variations of the voltages of tubes operated in the frequency ranges where cavity oscillators are operated may be accompanied by phase shifts within the tube itself. Attention, therefore, must be given to these shifts in the design of the system; such shifts could be made to add to the effectiveness of the system.

The odd quarter wave length of each of the transmission line paths is effective in providing a transformer action for matching purposes. Thus as between cavity 20 and cavity 57 in the amplifier, an impedance transformation is necessary due to the nature of the line terminations. In cavity 20, line 38 has a magnetic pick-up loop while, in cavity 57, line 38 has electrostatic coupling disc 70.

In the line between the amplifier output and cavity 30, the same impedance transformation effect is present. Furthermore, by having each of the lines an odd number of quarter wave lengths, the sharpness of resonance of the lines is reduced. Assuming a sinusoidal distribution of potential and current along the lines, it is clear that such a length of line takes advantage of the comparatively broad peaks in a sine wave. Thus the effective electrical length of each of the lines may be varied through a small angle with little difficulty. The controllable variable in the system is the amplifier and by controlling the amplification, the amount of out-of-phase voltage at the reinjection point, disc 93, may be changed, thus changing the effective resonance of cavity 30, and hence cavity 20.

The actual coupling points in cavities 20 and 30 are the centers thereof and between these points there exists a phase difference of a half wave length. Loop 40 has a quarter wave phase difference from its cavity center while disc 93 has a similar phase displacement from the center of cavity 30. In the case of disc 93, the phase difference may be either positive or negative, or in terms of angle may be 90 or 270 degrees. Thus, between loop 40 and disc 93, there may be a phase difference of 180 degrees or any multiple thereof. With regard to disc 70, the phase dif-

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ference between disc 70 and the control grid of the amplifier is 180 degrees.

It is understood, of course, that the cavities are suitably grounded as shown in the drawing.

What is claimed is:

1. A variable ultra high frequency oscillating system comprising an element having one sharply resonant frequency peak, means for maintaining continuous oscillations in said element, a pair of transmission lines, means for coupling said lines to said element at points having a phase difference equivalent to an integral number of half wave lengths, said transmission lines each having an odd number of quarter wavelengths and differing in length by an odd number of half wave lengths, and an amplifier coupled to said two lines, said amplifier having an input and output connected respectively to said lines.

2. The system of claim 1 wherein means are provided for varying the amplification of said amplifier whereby the effective frequency of said system is varied.

3. A variable ultra high frequency oscillating system comprising a cavity sharply resonant to one frequency, means for maintaining continuous oscillations in said cavity, a pair of transmission lines, means for coupling said lines to said cavity at points having a phase difference equal to an integral number of half wave lengths, each line having an odd number of quarter wave lengths and both differing in length by an odd number of half wave lengths, and an amplifier coupled to said two lines, said amplifier having an input and output connected respectively to said lines.

4. The system of claim 3 wherein means are provided for varying the amplification of said amplifier.

5. The system of claim 3 wherein said transmission lines are of the coaxial type.

6. A variable ultra high frequency oscillating system comprising a pair of similar sharply resonant cavities, means for coupling said cavities together, means for maintaining continuous oscillations in one cavity, a transmission line for each cavity, means for coupling said transmission line to the corresponding cavity, the coupling points having a phase difference equal to an integral number of half wave lengths with each coupling means providing an additional quarter wave length phase difference, said lines having each an odd number of quarter wave lengths and differing in length by an odd number of half wave lengths, and an amplifier coupled to said two transmission lines, said amplifier having an input and output connected respectively to said lines.

7. The system of claim 6 wherein said lines are of the coaxial type.

8. The system of claim 6 wherein means are provided for varying the amplification of said amplifier.

9. A variable ultra high frequency oscillating system comprising a pair of generally cylindrical resonant cavities coupled together to form a composite cavity having a general figure 8 shape,

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a transmission line coupled to each component cavity at points in said cavity having a phase difference of an integral number of half wave lengths with the coupled ends of said lines having a phase difference of a quarter wave length between the line end and the coupling point, said transmission lines each having an odd number of quarter wave lengths and differing in length by an odd number of half wave lengths, and an amplifier coupled to said two lines, said amplifier having an input and output connected respectively to said two lines.

10. The system of claim 9 wherein means are provided for varying the amplification through said amplifier.

11. The system of claim 9 wherein the transmission line to the amplifier input has a capacitive coupling and wherein the transmission line from the output of said amplifier has a capacitive coupling to its resonant cavity.

12. A variable ultra high frequency oscillating system comprising a sharply resonant cavity resonant to one frequency, a second similar cavity, means for coupling said two cavities together so that oscillations in one will induce oscillations in the other, means cooperating with said first cavity for maintaining continuous oscillations therein, a first transmission line going from said first cavity, a second transmission line going from said second cavity, means for coupling said two lines to said cavities at points having a phase difference of an integral number of half wave lengths with the line ends having a phase difference of a quarter wave length with respect to the coupling point, said two transmission lines each having an odd number of quarter wave lengths and differing in length by an odd number of half wave lengths, and an amplifier coupled to said lines, said amplifier having an input to which said first line goes and an output from which said second line goes.

13. The system of claim 12 wherein said lines are of the coaxial type and wherein capacitive couplings are provided at the amplifier end of the first line and the cavity end of the second line.

14. The system of claim 12 wherein means are provided for varying the amplification through said amplifier.

15. The system of claim 12 wherein said amplifier comprises a velocity modulated electron discharge device.

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