331-98

X1149
X1170
X1389

X333
83

V.H.F Oscillator which utilizes a single coax. type oscillator circuit with the grid connected to the cathode by a condenser. Ind. arrangement end.

Re

Feb. 3, 1953

L. E. BARTON

LIGHTHOUSE TUBE OSCILLATOR

Filed Jan. 8, 1945

2,627,577

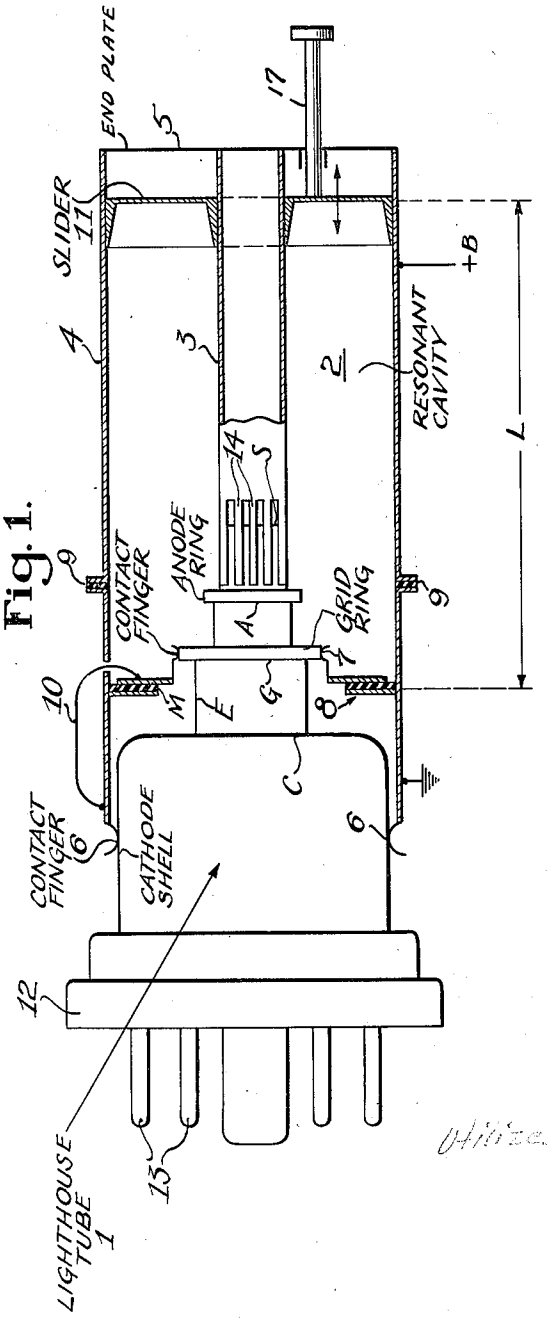


Fig. 1.

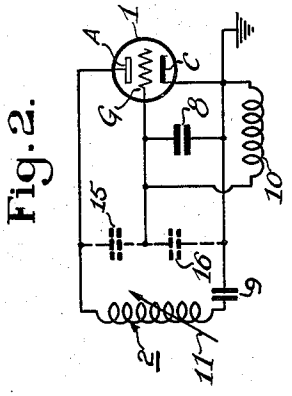


Fig. 2.

Utilizes a single tuned circuit

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LIGHTHOUSE TUBE OSCILLATOR

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Application January 8, 1945, Serial No. 571,920

4 Claims. (Cl. 250—36)

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This invention relates to very high frequency oscillation generators utilizing electron discharge devices having appreciable electron transit time effects. The invention is particularly concerned with a vacuum tube oscillator which generates oscillations above 500 megacycles, wherein the electron stream in the tube lags the grid voltage to an appreciable extent.

In conventional oscillation generators producing oscillations of relatively low radio frequencies, the associated circuit supplies radio frequency voltages to the grid and plate electrodes which are 180° out-of-phase with respect to each other, a condition necessary for oscillation. At these low radio frequencies, the transit time of the electrons in the vacuum tubes is negligible and practically zero. However, when it is desired to generate frequencies above 500 megacycles, it has been found that the transit time is no longer negligible and becomes appreciable. This is particularly the case when "lighthouse" tubes are employed to generate oscillations. The "lighthouse" tube is a disc-seal electronic vacuum tube in which the grid and anode connections protrude through the glass envelope in the form of parallel metallic rings spaced from one another along the length of the tube. The cathode is coupled to an outer metallic shell for the radio frequency current. One such "lighthouse" tube mentioned herein by way of example only, is the General Electric type 446 triode. A description and illustration of this type of tube is given in the Science News letter for August 19, 1944, page 115.

It has been found that the electron stream within the lighthouse tube may lag the radio frequency grid voltage by as much as 180°, particularly at frequencies higher than 500 megacycles. It will thus be seen that the normal phase relation of 180° between the grid and plate radio frequency voltages, as supplied by the external tuned circuits of conventional low frequency oscillators, is no longer conducive to efficient oscillations, and in some instances the oscillator will not oscillate at all under these conditions. Where the transit time of the electrons within the vacuum tube is 180° at some frequencies, it is then necessary for the radio frequency voltages supplied to the grid and plate electrodes of the tube by the external circuits to be in phase in order to produce oscillations.

It is known to be able to compensate for the transit time phenomenon in "lighthouse" vacuum tubes by employing two tuned resonator circuits; to wit, a plate-grid resonator and a grid-cathode

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resonator with suitable coupling between the two resonators. The disclosure in Turner copending application Serial No. 428,665, filed January 29, 1942, and now Patent No. 2,408,355, is an example of this known practice. The relative adjustments of these two tuned resonator circuits having suitable coupling between the two, permits a phase to compensate for the electron transit time within the tube, and enables the external tuned circuit to supply radio frequency grid and plate voltages of any phase relation to these electrodes. This correction of the phase relation between the radio frequency grid and plate voltages depends in part at least upon the type of coupling between the two tuned circuits and also upon the tuning of the tuned circuits. In many instances, a feed back loop between the two tuned circuits has been found to be satisfactory to cause the production of oscillations.

A disadvantage in the use of two tuned circuits in high frequency oscillators having appreciable electron transit time effects resides in the difficulty of aligning the two tuned circuits to obtain the proper phase relation for oscillation, and also in the difficulty of maintaining this proper phase relation with change in tuning over a desired frequency band. Another disadvantage is that these tuned circuits require realignment when vacuum tubes are changed due to the fact that no two tubes are exactly alike in their interelectrode capacitances.

The present invention overcomes the above mentioned alignment difficulties in oscillators having appreciable transit time effects, and simplifies the tuning and construction of the system by providing a single tuned circuit for use in an oscillator system at frequencies above 500 megacycles.

An object of the invention is to provide a simplified oscillator system for use at ultra high frequencies above 500 megacycles in which a vacuum tube is employed having an appreciable transit time.

Another object is to provide an oscillator capable of generating oscillations of frequencies above 500 megacycles by means of a single resonant cavity type of tuned circuit.

A further object is to provide in an ultra high frequency oscillator system utilizing a "lighthouse" tube having appreciable transit time effects at the operating frequency, a simplified construction requiring the use of only a single metallic resonant circuit.

In one specific aspect, the invention is an oscillator tube of the "lighthouse" type having a

transit time which provides a phase shift of substantially 180° at the center of the frequency band to be generated and at a desired plate voltage. The tube is selected to have the proper electrode spacing to produce the 180° phase shift within the tube for the electron stream at the operating frequency. A single cavity resonator is coupled across the tube electrodes and cooperates with the interelectrode capacities to constitute a single tuned circuit supplying the grid and plate electrodes with radio frequency cophasal voltages. A condenser of suitable value is placed between the grid and cathode to assure the proper feed back voltage.

A feature of the invention lies in the mechanical construction of the resonator assemblage which provides fast heat dissipating properties, thus decreasing the plate temperature during operation to a considerable extent compared to known types of oscillator construction.

Although the invention is herein described in connection with a "lighthouse" tube, it should be distinctly understood that any type of tube can be employed in the practice of the invention so long as it has an appreciable electron transit time producing a phase shift of approximately 180° more or less, as set forth more in detail hereinafter.

Other objects and features will appear from the following description which is given in conjunction with a drawing wherein:

Fig. 1 illustrates a view partly schematic and partly mechanical, of the oscillator of the invention utilizing a "lighthouse" tube; and

Fig. 2 shows the equivalent electrical circuit of Fig. 1.

The oscillator system of Fig. 1 comprises a lighthouse tube 1 having grid and anode metallic rings or discs G and A, respectively, protruding through the glass envelope portions E. The cathode (not shown) is located within the lower glass envelope portion E and it is capacitively coupled to the outer metallic shell C for a radio frequency current path to the shell. Metallic rings G and A are in the shape of discs which are respectively connected to the grid and anode electrodes within the tube. The anode is also supplied with a metallic outer stub S which is connected to, or a part of the anode ring A and protrudes from one end of the lighthouse tube. The other end of the lighthouse tube is provided with a suitable insulation base 12 and metallic prongs 13 for cooperation with a tube socket, not shown. Tubes of this character are known in the art and manufactured by the Radio Corporation of America and the General Electric Company. One such tube mentioned by way of illustration is the GL-446 triode.

The tube 1 is connected to a metallic resonant cavity 2 having an inner conductor 3 and an outer conductor 4 connected at one end by a metallic end plate 5. The inner conductor 3 is hollow and is provided at the end removed from the end plate 5 with a plurality of slots 14 for enabling resilient contact to be made with the anode stub S of the tube 1. It will be seen that the anode stub fits snugly within the end of the hollow conductor 3 having the slots S and makes direct electrical contact with this inner conductor. The resonant cavity 2 is provided at the end opposite the end plate 5 with a multiplicity of contact fingers 6 for making good electrical contact with the outer cathode shell C of the lighthouse tube. The outer conductor 4 of the resonant cavity is also provided with a multiplicity of contact fingers 7 for coupling to the grid ring G. The contact fingers 7 are insulated, from a direct current standpoint, from the outer conductor 4 by means of mica ring M, and constitute part of a radio frequency by-pass condenser 8 with the outer conductor 4. In the actual construction of the resonator, the contact fingers 6 and 7 for the cathode shell and the grid ring respectively are annular in shape and each of these annular arrangements comprises a multiplicity of resilient metallic fingers for assuring good electrical contact with the elements which they engage. The outer conductor 4 of the resonant cavity is divided in two by means of an annular insulating ring forming a blocking condenser 9. This blocking condenser is in effect a by-pass condenser for the radio frequency energy but serves to block the passage of direct current from the anode (plate electrode) polarizing supply+B to the grid or ground. It should be noted that the resonant cavity 2 is grounded at that portion directly connected to the cathode shell C. The cavity 2 is also provided with a metallic short circuiting slider 11 which is adapted to move in two directions shown by arrows along the length of the resonant cavity upon operation of actuating member 17. The slider 11 is a metallic short circuiting member which directly connects the outer surface of the inner conductor 3 with the inner surface of the outer conductor 4 and serves to tune the cavity resonator to a desired frequency of operation. The approximate effective length of the cavity resonator is indicated by the dimension L.

A connection 10 from the grounded portion of the resonant cavity 2 to the contact finger 7 serves as a grid return choke and may be placed within the cavity. This choke is actually in the form of a wire about one inch long and provides the necessary inductance to act as a choke coil at the very high frequencies at which the oscillator functions. The condenser 8, it should be noted, is connected across the grid and cathode and provides a capacity in shunt to the grid cathode interelectrode capacity.

The operation of the oscillator of Fig. 1 may be better understood by reference to Fig. 2, which shows, generally, the equivalent electrical circuit. The same reference characters have been used in both Figs. 1 and 2 to designate the same or equivalent parts.

Referring to Fig. 2, the capacities 15 and 16 shown in dotted lines represent the plate-grid and grid-cathode interelectrode capacities of the tube 1. The condenser 8 is an external capacity in shunt to the grid cathode interelectrode capacity 16, and the value of condenser 8 is selected to provide the proper radio frequency excitation voltage on the grid. An inspection of the circuit of Fig. 2 will show that, in effect, the interelectrode capacities 15 and 16 comprise a voltage divider. The value of condenser 8 determines the radio frequency voltage ratio between the plate-cathode and the grid-cathode electrodes. The thickness of the mica ring M of the condenser 8 and its area is so chosen that there is provided a proper feed back. Tuning is effected by varying the slider 11, thus changing the inductance of the resonant cavity 2. Further inspection of Fig. 2 will show that the oscillator is generally like the well known Colpitts type, except that the grid-cathode radio frequency voltage is in phase (cophasal) with the plate-cathode radio frequency voltage instead of 180° out-of-phase.

Due to the fact that the system of Fig. 1 is designed to operate at frequencies above 500 megacycles, the lighthouse tube has an appreciable transit time at these frequencies due to the interelectrode spacing. The tube 1 is selected so as to produce a theoretical transit time phase shift of approximately 180° at the desired plate voltage and at the center of the band of frequencies to which the oscillator system can be tuned. In practice, oscillations will occur in the system of Figs. 1 and 2 over a phase shift angle due to transmit time in the tube of about 120° to 240°, although theoretically the phase shift angle of the tube 1 may be anywhere between 90° and 270°. The reason that oscillations will occur in the system even when the phase shift angle in the vacuum tube 1 (due to transit time) is only 120° or 240°, or anywhere between these values when cophasal radio frequency grid and plate voltages are supplied by the external circuit 2, is because there is an effective or resultant componant in the system which will produce the desired 180° phase relation necessary to cause oscillation.

It should be noted that there is a fixed phase relation between the plate-cathode and the grid-cathode due to transit time at given plate and grid voltages, and that there is no means provided for shifting this phase relation in the oscillator tube. The phase shift angle due to transit time in the tube can, however, be changed by changing to a vacuum tube having different electrode spacing, or by using a different value of plate voltage, or both. In the practice of the present invention, the radio frequency voltages supplied to the grid and the plate electrodes are in phase (cophasal) relative to each other, or 180° out-of-phase with respect to the radio frequency voltages supplied to the conventional low frequency oscillator.

The ratio of the grid and plate radio frequency voltages supplied to the tube for proper oscillation depends upon the mu (amplification constant) of the tube, and is usually selected for maximum oscillations (about three to four times minimum requirements). If the mu of the tube 1 is forty, for example, then the theoretical minimum feed back would be one-fortieth, and four times one-fortieth is equal to one-tenth plate voltage E_p. This means that the radio frequency voltage supplied to the grid should be about one-tenth the plate radio frequency voltage or $E_g = \frac{1}{10} E_p$. The value of the condenser 8 supplied across the grid and cathode determines the proper voltage ratio.

A feature of the invention lies in the fast heat transfer qualities of the center rod 3 to the wall of the resonant cavity 2. This is because the plate A is conductively as well as electrically connected to the inner conductor or center rod 3 which has appreciable cross-sectional area. Rod 3 is soldered to the thin copper end plate 5 and this end plate in turn is soldered to the outer conductor 4. The end plate 5 is made thin in order that the inner edges may be soldered to the adjoining parts for good heat conductivity and still permit flexibility at the plate end of rod 3 to allow for tube tolerances. The center rod 3 and end plate 5 of the cavity resonator are made of copper or other material having good heat conducting properties. The outer conductor 4 may be a material such as brass having less heat conductivity because of the larger area. The heat transfer to the air from the surface 4 is mostly by convection unless the outside surface is painted. In one experimental embodiment tried out in practice, the temperature of the plate electrode of the tube 1 decreased 60° centigrade compared to the other systems where an isolating condenser was employed at the location between the plate of the tube and the cavity resonator, for approximately three watts vacuum tube plate dissipation. The vacuum tube plate temperature, by an arrangement like Fig. 1, was only 20° centigrade hotter than the outer conductor 4 as compared to an 80° centigrade difference in temperature with an arrangement in which the isolating condenser was directly adjacent the plate ring A for a given plate dissipation.

In an experimental embodiment of the invention tried out in practice with a GL-446 tube, the oscillator functioned satisfactorily to produce oscillations over a range of about 2140 megacycles (14 centimeters) to about 1250 megacycles (24 centimeters) for a plate voltage of about 250 volts, and this range can be extended to a somewhat lower frequency with relatively feeble oscillations with a lower plate voltage of about 70 volts, and to a somewhat higher frequency also with relatively feeble oscillations with a higher plate voltage of about 300 volts. Other experiments made with a Radiotron A-2222 vacuum tube having a greater grid-cathode spacing and consequently a greater electron transit time than that provided by the GL-446 tube, show that satisfactory oscillations could be obtained for a frequency band of 900 megacycles to 1400 megacycles with zero bias on the grid and approximately 80 to 150 volts for the plate.

What is claimed is:

1. An ultra high frequency oscillator generating oscillations above 500 megacycles, comprising a lighthouse tube having a cathode metallic shell, a grid ring, and a plate ring spaced from and parallel to said grid ring, a concentric line resonator having an inner conductor and an outer conductor connected together at one end by an end plate, said inner conductor having a hollow terminal fitting at its other end for direct connection to the plate of said tube, said outer conductor being longer than said inner conductor and provided with contact fingers at its end remote from said end plate for coupling to said cathode metallic shell, insulation separating said outer conductor into two portions arranged end-to-end, said insulation forming part of a blocking condenser for the plate electrode polarizing potential and a by-pass condenser for the radio frequency voltage, and a capacitive connection from said grid ring to that portion of said outer conductor which is located between said insulation and said cathode metallic shell.

2. An oscillator in accordance with claim 1, characterized in this that said capacitive connection has such value of capacitance that in combination with the grid-cathode interelectrode capacitance there is obtained a total value of grid-cathode capacitance having such ratio to the plate-grid interelectrode capacity that the radio frequency voltage supplied to said grid is approximately one-tenth the radio frequency voltage supplied to the plate of said tube.

3. An ultra high frequency oscillator generating oscillations above 500 magacycles comprising a vacuum tube having cathode, grid and plate electrodes so spaced within an evacuated envelope so that there is an electron transit time within the tube producing between electrodes thereof a phase shift substantially between 120° and 240° at the frequency of oscillation, a concentric line resonator having an inner conductor and an

outer conductor connected together at one end by an end plate, said inner conductor having a hollow terminal fitting at its other end for direct connection to the plate of said tube, said outer conductor being longer than said inner conductor and provided with contact fingers at its end remote from said end plate for coupling to said cathode, insulation separating said outer conductor into two portions arranged end-to-end, said insulation forming part of a blocking condenser for the plate electrode polarizing potential and a by-pass condenser for the radio frequency voltage, and a capacitive connection from said grid to that portion of said outer conductor which is located between said insulation and said cathode metallic shell.

4. An ultra high frequency oscillator generating oscillations above 500 megacycles comprising a vacuum tube having cathode, grid and plate electrodes so spaced within an evacuated envelope that there is an electron transit time within the tube producing between electrodes thereof a phase shift substantially between 120° and 240° at the frequency of oscillation, a concentric line resonator having an inner conductor and an outer conductor connected together at one end by an end plate, said inner conductor having a hollow terminal fitting at its other end for direct connection to the plate of said tube, said outer conductor being longer than said inner conductor and provided with contact fingers at its end remote from said end plate for coupling to said cathode, insulation separating said outer conductor into two portions arranged end-to-end, said insulation forming part of a blocking condenser for the plate electrode polarizing potential and a by-pass condenser for the radio frequency voltage, a tuning slider connecting the outer surface of the inner conductor and the inner surface of the outer conductor of said resonator and movable over a portion of the length of said inner conductor, said inner conductor, end plate and outer conductor being made of material of good heat conducting properties, and a capacitive connection from said grid to that portion of said outer conductor which is located between said insulation and said cathode metallic shell.

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