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R. A. HEISING

2,142,313

ELECTRIC OSCILLATOR

Filed Sept. 2, 1936

FIG. 1

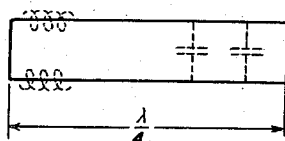


FIG. 2

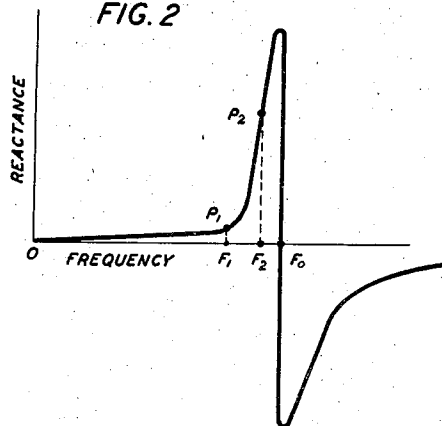


FIG. 3

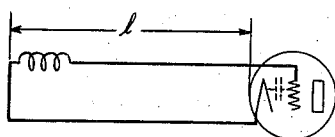


FIG. 4

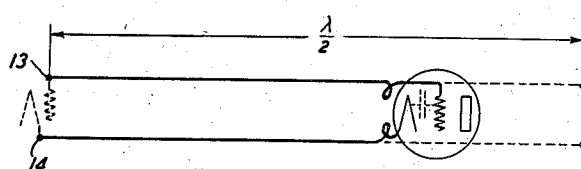


FIG. 5

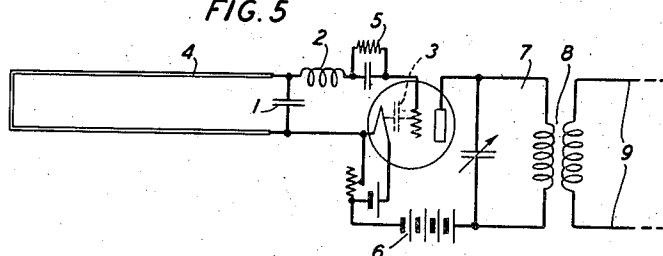
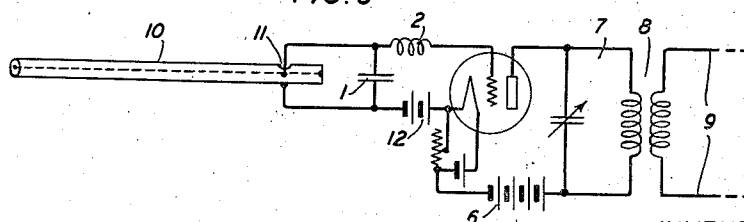


FIG. 6



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ELECTRIC OSCILLATOR

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6 Claims. (Cl. 250—36)

This invention relates to electric oscillators. Its principal object is to improve the frequency stability of oscillators operating at wave-lengths of a meter or less.

It has been possible to construct a relatively stable electric oscillator by using a Lecher circuit or concentric transmission line connected to the grid-cathode circuit of an electron discharge device as the tuning or frequency stabilizing element. It has been found that the frequency stability is increased with increased length of line so that a three-quarter wave-length line renders the circuit more stable than a quarter wave-length line. A five-fourths wave-length line gives still greater stability than a three-quarter wave-length line.

There is, however, considerable difficulty and expense involved in building long transmission lines. Moreover, these lines make the apparatus unduly large. It is therefore desirable if a transmission line be used as a stabilized tuning circuit of an oscillator, to make it as short as possible. However, with the shorter transmission line section the frequency is not sufficiently stable.

Another problem which is involved is that of suitably coupling the transmission line to the electron discharge tube. With the shortest possible connections there is still a length of lead wire between the electrode of the discharge device and the transmission line conductor to which it is connected. Moreover, the electron discharge device will allow current to flow from the grid to the cathode while oscillating thereby producing power loss. In addition to the lead wires and grid leak circuits which introduce loss and effective resistance in the associated circuits, there is a damping effect introduced by what is known as active grid loss. If, therefore, the transmission line is closely coupled to the electron discharge tube these various losses are reflected into the transmission line by the coupling so that they effectively introduce resistance into the transmission line itself thus greatly decreasing its selectivity. An important feature of the invention is the provision of means to so couple the transmission line to the electron discharge device as not to introduce into the transmission line substantial amounts of resistance.

The extent to which an electrical element such as an inductance coil or a capacity element tends to discriminate between currents of different frequencies is dependent primarily upon the magnitude of its reactance with respect to that of its resistance. If the selectivity factor of an in-

ductance coil, that is, the ratio of its reactance to its resistance be denoted by "Q" we may write

$$Q = \frac{\omega L}{R} \quad (1)$$

where ω is the angular velocity at the frequency under consideration, L is the inductance and R the series resistance. Similarly, for a condenser

$$Q = \frac{1}{\omega CR} \quad (2)$$

in the case of a tuned circuit which comprises equal component reactance of opposite sign or a net reactance which is substantially zero, we may take as a measure of the selectivity or "Q" of the circuit the ratio of the either reactance component to the effective series resistance of the circuit. In other words, either Equation 1 or Equation 2 may be applied to the case of a tuned circuit. In this specification and the appended claims, the expression "selectivity factor" and "Q" will be used interchangeably with this significance.

In accordance with the invention, an electric discharge device which may be of the well-known type having a cathode and an impedance control grid is provided with an input circuit comprising reactance elements which, together with the inherent grid-cathode capacity, tune the input circuit to the desired operating frequency in a certain desired manner. A frequency stabilizing circuit comprising a quarter wave-length high Q or low-loss line short-circuited at one end is associated with the vacuum tube oscillator by a loose coupling to the tuned input circuit. The coupling involves a step-down impedance transforming connection of such character that the resistances inherent in the electrode leads and grid leak and polarizing circuits and the virtual resistance represented by the active grid loss are greatly reduced insofar as they effectively enter into the selectivity of the quarter wave-length line. It results from this that the selective characteristic of the line remains very steep in its resonance region and the line is so little affected by the impedances of the tube circuit to which it is coupled, that its inherent inductance constitutes a very large part of the total inductance determining its natural resonance frequency. The oscillator consequently is stabilized at an operating frequency very close to the natural resonance of the line and therefore in a region in which its reactance characteristic is extremely steep, so that any tendency to change the oscillator frequency is opposed by a very large change

in the reactance of the line. It thus becomes possible to utilize the inherent high Q of a quarter wave-length line without impairment by the resistances of the associated tube circuits.

Other features and aspects of the invention will be apparent from a consideration of the detailed description and appended claims taken in connection with the annexed drawing in which:

Fig. 1 illustrates the approximate equivalence of a quarter wave-length line and a tuned circuit;

Fig. 2 portrays the reactance frequency characteristic of a quarter wave-length line short-circuited at one end;

Fig. 3 illustrates a transmission line directly connected to the input electrodes of the vacuum tube and co-acting therewith to constitute a quarter wave length line;

Fig. 4 is a diagram to assist in explaining the operation of a coupling circuit;

Fig. 5 shows schematically a circuit in which the quarter wave-length line of Fig. 3 is coupled to the vacuum tube by a tuned circuit; and

Fig. 6 illustrates diagrammatically the schematic of the preferred form of oscillator circuit including the impedance transforming connection according to the invention.

A quarter wave-length line with one end short-circuited as indicated in Fig. 1 may, for certain purposes, be viewed from its open end as the substantial equivalent of a tuned circuit having the inductance and capacity indicated by dotted line elements. In the region of the resonant point of the tuned circuit its performance characteristic is similar in general form to that of a quarter wave-length line. At frequencies remote from the resonance frequency the performances of the two circuits are different, but within the region in which the transmission line is to be used as a frequency stabilizer for an oscillator in accordance with the principles of this invention, the parallel resonant circuit and the short-circuited quarter wave-length transmission line may theoretically be regarded as equivalents. This is shown in Fig. 2 which is a graph of the reactance curve of either the short-circuited quarter wave-length transmission line or the parallel resonant tuned circuit from zero frequency up to a frequency beyond the resonance point.

Fig. 3 represents the equivalent circuit of a transmission line short-circuited at its remote end and connected to the electrodes of an electric discharge device to operate as a quarter wave-length line. Inasmuch as the capacity between the grid and cathode is equivalent to a considerable portion of the entire capacity involved, the resultant resonance frequency will not be that of F_0 the natural frequency of the quarter wave-length line, but will fall at F_1 , a considerable distance from the resonance frequency of the transmission line per se and at which it has a reactance measured by the ordinate of the reactance curve at frequency F_1 up to the point P_1 on the curve. It will be apparent that the rate of change of reactance at frequency F_1 with change in frequency which is measured by the slope of the curve at point P_1 is not large and this in spite of the fact that the selectivity factor or Q of the connected transmission line per se may be very high.

The ideal vacuum tube would among other things have a grid of extremely small capacity and grid-cathode leads of zero reactance and resistance. Under such conditions, attaching the transmission line as in Fig. 3 would enable operating at point P_2 on the steep part of the graph

of Fig. 2. The capacity of the grid and the inductance of the lead wires, however, have such low reactance to resistance ratios compared to the corresponding ratio of the transmission line that if included in the frequency determining stabilizing circuit, they will seriously reduce its selectivity.

In accordance with the present invention, there is provided a coupling circuit which will largely eliminate the deleterious effects of these inter-electrodes and lead circuit reactances. If a suitable transmission line is connected to the grid and the cathode of the vacuum tube as in Fig. 4 such that with the grid capacity and the lead inductances added it constitutes the equivalent of a half wave-length line, the grid and lead reactances will merge with those of the transmission line and a circuit connected to the remote terminals 13, 14 of the transmission line will be presented with the same impedance as if connected directly to the grid and cathode of the tube, but with the grid-cathode capacity and the lead reactance eliminated at the operating frequency. The stabilizing circuit may accordingly be connected to terminals 13 and 14 and will be in effect directly connected to a grid and cathode.

In case it is desired to use a more compact form of oscillator, the transmission line type of coupling may be replaced by a circuit involving lumped reactances as illustrated in Fig. 5. As shown in Fig. 5 an oscillator system involves a tuned circuit including the elements 1 and 2 connected up to serve as an equivalent of the half wave-length coupling transmission line and at the same time to avoid excessive physical magnitude. The element 1 has a capacity approximately equivalent to the grid-cathode capacity which is represented in dotted line at 3. A lumped inductance 2 is given such magnitude as to tune the circuit 1, 2, 3 to the operating frequency. A stabilizing transmission line 4 is connected to the terminals of the capacity element 1 which corresponds to the points 13, 14 of Fig. 4.

A grid leak resistance and stopping condenser combination of well-known type, as indicated at 5, serves to produce a suitable grid bias potential. The plate current circuit includes the plate current source 6 and a loop 7 tuned approximately to the operating frequency, and including the primary winding of a transformer 8 by which power is supplied to the load circuit 9. In this oscillator system, the frequency stabilizing transmission line 4 is so connected to the input electrodes of the vacuum tube that operation can occur at point P_2 or at any other desired part of the curve in Fig. 2 and at a frequency F_2 which is near to the natural frequency of the stabilizing line. This arrangement enables the stabilizing transmission line to develop a highly selective characteristic and to utilize its most effective operating range relatively unimpaired by grid-cathode reactances.

Power losses in the grid-cathode circuit still remain and appear as a resistance between terminals 13 and 14. The effective resistance which so appears is usually such as to impair the high selectivity or Q of the low loss transmission line when connected as in Fig. 5. It is therefore another object of this invention to so connect the stabilizing transmission line to the terminals 13, 14 that this resistance makes little change in the Q of the stabilizing lines and produces no noticeable effect upon its reactance.

It is, of course, desirable to use a stabilizing

circuit having a Q or selectivity factor as high as it is practicable to obtain. For this reason a short-circuited quarter wave-length coaxial line section as indicated at 10 in Fig. 6 may serve to great advantage. With such a high selectivity circuit it is undesirable to reduce its selectivity by couplings which introduce dissipative impedances between the terminals of the high selectivity circuit at its open end. According to a feature of this invention, coupling to the coaxial line section is effected by connecting one terminal of capacity element 1 to the outer conductor of section 10 and the other terminal to the inner conductor at a point a short distance from the short-circuited end, the connection to the inner conductor passing through an opening 11 in the outer conductor. This connection reduces the portion of the total reactance of the coaxial line which is presented across the terminals of capacity element 1. The reduction is, however, more than compensated for by the two counter-acting effects of increase in effective height and steepness of the reactance-frequency characteristic of the coaxial line in its resonance region and the further approach of the operating frequency F_2 toward the resonance frequency F_0 . The circuit of Fig. 6 is therefore extremely stable from a frequency standpoint and involves apparatus which is neither bulky nor expensive.

In order to bias the grid to the proper operating potential a C battery 12 may be provided, but it will be understood that the grid leak device 5 of Fig. 5 may be substituted if desired.

Although the features of the invention have been illustrated and described in particular circuit embodiments, it is to be understood that the invention is not to be limited thereto, but only by the scope of the appended claims.

What is claimed is:

1. In combination, an electron discharge device having a cathode, an anode and an impedance control element, a tuned output circuit connecting the anode and cathode, a tuned input circuit connecting the cathode and the impedance control element and a high selectivity circuit comprising a quarter wave-length line short-circuited at one end and having connections from its elements at a point near the short-circuited end to the tuned input circuit.

2. In combination, a quarter wave-length section of coaxial line short-circuited at one end, an electric discharge device having a cathode, an anode and an impedance control member, an output circuit connecting the anode and cathode, a tuned input circuit connecting the cathode and impedance control member, connections from two points on the input circuit to the inner and outer conductors, respectively, of the quarter wave-length section, the connection points of the quarter wave-length section lying intermediate its ends and closer to the short-circuited end than to the other end.

3. An oscillator comprising an electric discharge amplifier having input electrodes and output electrodes, a space current path connecting the output electrodes, a circuit tuned effectively to the desired oscillation frequency connecting the input electrodes, a coaxial line of quarter wave-length at the desired operating frequency having one end short-circuited, a lead from the

inner conductor of the coaxial line connected thereto at a point relatively close to the short-circuited end and passing out through an aperture in the surrounding conductor, a similarly located lead connected to the outer conductor, and means connecting the leads to the tuned circuit at electrically separated points to reduce the impedance introduced into the tuned circuit with respect to that presented by the leads at their terminals.

4. In combination, an electron discharge device having a cathode, an anode and an impedance control element, a tuned circuit connecting the impedance control element and the cathode, a frequency stabilizing circuit having a natural frequency substantially equal to the resonance frequency of the tuned circuit and having an extremely high ratio of reactance to effective resistance, electrical connections leading directly from two points in the frequency stabilizing circuit to two points in the tuned circuit, the reactance between the two points in the stabilizing circuit being relatively low compared with the entire reactance of the stabilizing circuit and the reactance between the two points in the tuned circuit being relatively low compared with the total reactance of the same kind in the tuned circuit whereby the tuned circuit and the stabilizing circuit are loosely coupled in order to diminish the impedance which is effectively introduced from the tuned circuit into the stabilizing circuit so as to achieve high selectivity in the stabilizing circuit, and an output circuit connected between the anode and cathode and uncoupled to the frequency stabilizing circuit except through the inherent coupling within the electron discharge device.

5. An oscillator comprising an electric discharge device having a cathode, an impedance control element and an anode, an input circuit path connected between the cathode and impedance control element, an output circuit connected between the cathode and anode, a frequency stabilizing circuit consisting of a coaxial line of effectively one-quarter wave-length at the operating frequency of the oscillations to be produced and short-circuited at one end, a capacity element connected in series in the input circuit path, and leads connecting its terminals, respectively, to the two conductors of the coaxial line so that the frequency stabilizing circuit is so loosely coupled to the input circuit that its inherent high ratio of reactance to resistance is not seriously impaired by impedance effectively introduced by the coupling to the input circuit.

6. An oscillator comprising an electric discharge device having a cathode, anode and impedance control element, an output circuit connecting the cathode and anode, a path connecting the cathode and impedance control element including in series a capacity element having a capacity approximately equal to that between the cathode and the impedance control element, and an inductance having a magnitude such that with these capacities it tunes the path to the operating frequency, and a frequency stabilizing transmission line of high selectivity connected to the terminals of the series capacity element.

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