Feb. 10, 1942. J. F. RAMSAY 2,272,851

ELECTRICAL OSCILLATION GENERATOR

Filed Feb. 15, 1939

Fig. 1

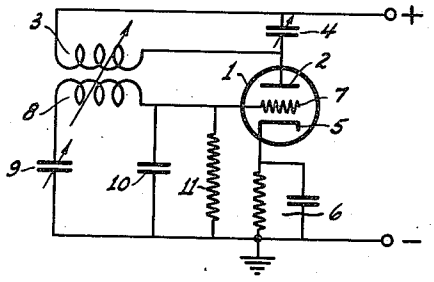


Fig. 2

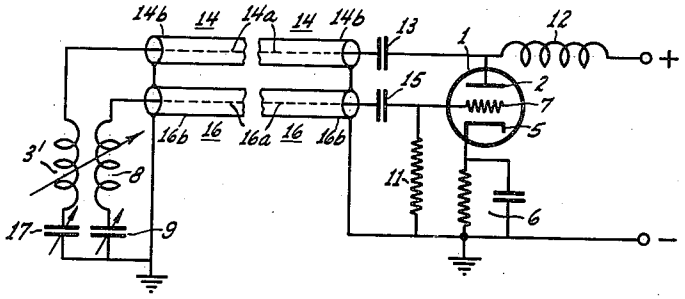


Fig. 3

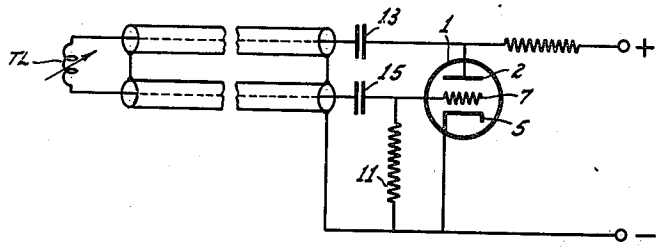


Fig. 4

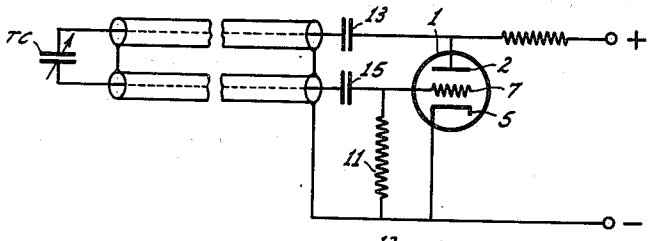
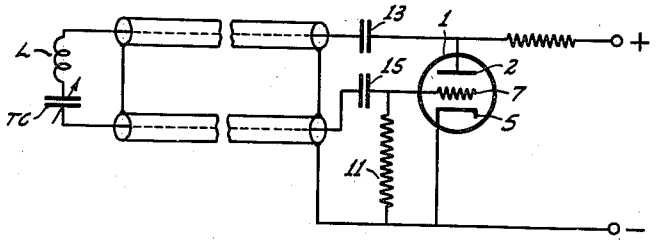


Fig. 5



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ELECTRICAL OSCILLATION GENERATOR

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In Great Britain February 17, 1938

7 Claims. (Cl. 250—36)

This invention relates to electrical oscillation generators.

One object of the invention is to provide an improved and simple electrical oscillation generator which can cover a wide frequency range with standard components.

Another object of the invention is to provide improved highly efficient remotely tunable oscillation generators of wide tuning ranges and satisfactory output voltages which are easy to design and which, despite the use of co-axial or other high frequency cables for remote tuning, are flexible as to the frequency coverage obtainable.

According to one feature of this invention an electron discharge device oscillator of the kind having a frequency determining variably tunable resonant circuit in or associated with the grid circuit is characterised in that said resonant circuit comprises a fixed condenser in parallel with a series combination of inductance and tuning capacity so that the grid of the oscillator valve is in effect capacitatively "tapped down" on the tuned circuit. By virtue of the fact that the tuning condenser is in series with the said coil in the grid circuit and there is no connection to their junction point, it is possible to obtain a very high maximum/minimum capacity ratio as the stray capacity is made up of the minimum capacity of the variable condenser and the stray distributed coil capacity. By using a good quality variable condenser and a coil of the sectionalised winding type so as to reduce the distributed capacity, very extended tuning ranges can be obtained.

According to another feature of this invention a remotely tunable electron discharge device oscillator comprises an electron discharge device having at least a cathode, a control grid and an anode, and an oscillation maintaining frequency determining feed back circuit between the anode and control grid, said circuit consisting of a length of high frequency cable having a reactance or reactances inserted at its mid-point, said reactance or reactances being series connected between the inner conductors of each half of the cable, the outer conductors of the two halves being electrically continuous and the two halves of the cable being laid parallel and running concurrently between the discharge device, at one end of the two halves, and the remote tuning point at which the inserted reactance or reactances is or are located.

If the inserted reactance were of zero value, i. e. if the run of cable from anode to grid were unbroken, the device would oscillate at substantially the "half-wave" frequency of the cable as given by

$$f_{\frac{\lambda}{2}}=\frac{492}{l} \text{ megacycles}$$

where

$$f_{\frac{\lambda}{2}}$$

is the "half-wave" frequency and l the length of the cable in feet. This formula assumes the cable to be "ideal"; in practice the "half-wave" frequency is a little lower than that given by the above formula. The insertion of positive reactance in the run of the cable lowers the frequency of oscillation below the "half-wave" frequency; the insertion of negative reactance causes the frequency of oscillation to lie between the "half-wave" frequency and twice the said frequency.

The invention is not limited to the use of a feed-back cable between anode and grid of the same valve for obviously it is possible to provide a plurality of valves (say two) in cascade and connect the feed back cable between the anode of the last valve and the control grid of the first. The phase of the voltage fed back must, of course, be such as to support oscillation generation.

The invention is illustrated in the accompanying drawing.

Referring to Figure 1 which shows diagrammatically one embodiment of the first feature of this invention a triode 1 has its anode 2 connected to the positive terminal of a source (not shown) of anode potential through an anode coil 3 tuned by a small condenser 4. The cathode 5 of the triode is connected to earth and to the negative terminal of the anode source through the usual capacity shunted bias resistance combination 6. The control grid 7 is connected to earth through a fixed grid coil 8 in series with a variable tuning condenser 9. Shunted across the series combination of grid coil and tuning condenser is a fixed condenser 10 in parallel with a grid leak 11. The anode coil 3 is inductively back-coupled as indicated by the arrow to the grid coil 8 for oscillation generation. With this oscillator the frequency is determined substantially by the frequency of the grid circuit as made up of the grid coil 8 tuned by the fixed and variable condensers 10, 9, in series. The fixed condenser 10 should not be too small, otherwise the range covered will be reduced but, on the other hand, it should not be too large, otherwise there may be difficulty in maintaining oscil-

lations since the larger the fixed condenser the smaller its reactance and the smaller the voltage tapped off to the grid. It is preferable to resonate the anode coil 3 towards the higher frequency end of the tuning range to be covered, for as the resistance of the grid coil 8 increases with frequency, the circuit tends to stop oscillating and resonating the anode coil in this way counteracts this effect. Although the anode coil 3 is shown as tuned by a small condenser 4 the tuning capacity for this coil may, in some cases, be constituted by the self-capacity of the coil itself.

As shown in Figure 2 the circuit of Figure 1 can, with comparatively slight modification, be adopted for remote control. For such modification, the fixed condenser is replaced by a length of suitable cable—for example high frequency concentric cable—and a second length of cable is used to couple the anode to the anode coil. More specifically, referring to Figure 2, the remotely tuned oscillator therein shown comprises a triode 1 whose anode 2 is connected through a choke 12 to the positive terminal of a source (not shown) of anode potential, and is capacity coupled through a condenser 13 to the inner conductor 14*a* at one end of a length 14 of high frequency concentric cable. The grid 7 of the triode is connected either directly or as shown through a condenser 15 to the inner conductor 16*a* at the corresponding end of a similar length 16 of high frequency cable. The outer conductors 14*b*, 16*b* of the two cables are earthed; the grid 7 is connected to earth (at the valve) through a grid leak 11 and the cathode 5 is connected to earth (again at the valve) through a capacity shunted resistance combination 6. The two cables lead to a remote point where tuning is to be effected. At this remote point the inner conductor 16*a* of the grid cable 16 is connected to earth through a fixed inductance 8 and a tuning capacity 9 in series and the inner conductor of the anode cable is connected to earth either directly through an anode coil or (as shown) through an anode coil 3′ in series with a condenser 17. The anode coil is inductively coupled to the inductance in the grid circuit at the remote point.

If the cable 16 is capacitative for all frequencies in the tuning range to be covered the design of an oscillator as shown in Figure 2 is, in principle, the same as that of an oscillator as shown in Figure 1. It will be noted that the oscillator of Figure 2 incorporates the added feature that the anode circuit is a parallel fed split-capacity circuit. The condenser 17 is not essential for the anode coil 3′ may be so chosen as to resonate with the capacity of the cable at a desired frequency—preferably near the higher frequency end of the tuning range. The simplest case in which the cable 16 is capacitative is at relatively low frequencies, i. e. at frequencies somewhat remote from that at which the cable is a quarter wave length long. If, therefore, the oscillator is required to act as the local oscillator of a superheterodyne receiver for remote tuning of said receiver (an important practical application) the highest oscillator frequency required should be well below that at which the cable 16 is a quarter wave length long. In practice this requirement is readily satisfied if a fairly low intermediate frequency—e. g. 110 kc. or 450 kc.—is adopted and the receiver is not required to tune over the short wave bands. Thus, to take a practical example, a superheterodyne receiver with an intermediate frequency of 450 kc. would require a local oscillator tunable from 600 kc. to 1950 kc. for a signal range of 150 kc. to 1500 kc. In such a case a co-axial cable 30 feet long could be very satisfactorily used at 16 for such a cable would be a quarter wave length long at about 6 megacycles. In fact the cable length could be increased to 60 feet without difficulties arising.

A remotely controllable arrangement such as that shown in Figure 2 presents the advantages (1) that, by reason of the use of a separate anode cable 14, the regeneration is applied at and is controllable at the remote point so that separate interchangeable anode coils 3′ can be employed, one for each of the medium and long wave ranges to be covered and a fairly even output voltage thus obtained and (2) the advantage of extended tuning range already explained with reference to Figure 1 is also obtained to a large extent with the remote control type of arrangement. The latter advantage facilitates "ganging," e. g. (in a superheterodyne receiver) ganging remote controlled oscillator tuning with remote controlled signal circuit tuning. By employing remote tuning condensers with specially shaped vanes, or remote tuning condensers driven through specially shaped cams, a very high degree of accuracy of ganging can obviously be obtained, but, even without resorting to these expedients (which are often undesirable on account of cost) reasonably good ganging can be effected if the medium wave range is divided up into two or three sub-ranges and separate coils used for each sub-range.

It is not necessary to employ variable condensers for remote tuning for by dispensing with such variable condensers and employing instead remote variable inductances—in particular a single remote variable inductance for terminating the grid cable (16 in Figure 2) and a fixed anode inductance (for a given range) for terminating the anode cable (14 in Figure 2)—the frequency of resonance will be substantially determined by the cable capacity in conjunction with the value of the remote inductance in the grid circuit.

In cases where the oscillator has to be remotely tuned over relatively high radio frequencies, the cables will be inductive at some frequencies, purely resistive at others, and capacitative at still others, so that the method of design cannot be based on the simple inductance-capacity principles of the prototype "split-capacity" oscillator. In British Patent 493,862, dated October 17, 1938, there is described, inter alia, a tuned grid type of back-coupled oscillator wherein a co-axial cable, connected at one end to the grid coil is terminated at the other by a series circuit comprised of inductance and capacity. By virtue of the cyclic reactance properties of the cable, the system consisting of the cable and the remote series inductance-capacity circuit can present (at the grid) tunable capacitative reactance over distinct ranges of frequency associated with the discontinuities in the reactance of the cable. At any given frequency in these ranges the reactance of the cable-series circuit system may be made equal in magnitude to and opposite to the reactance of the grid coil, thus providing resonance. For a given set of circuit parameters a plurality of resonant frequencies is possible each being associated with a possible range of tuning. These possible ranges of tuning are, in the above identified British patent termed the "first mode," the "second mode," the "third mode" . . . and so on. Oscillation on a given mode may be obtained by resonating the anode

circuit at or near one end of a particular mode. Accordingly by employing a remotely tunable anode line such as the line 14 of Figure 2 it is possible, in carrying out this invention as applied to a high radio frequency oscillator such that the reactance of the grid cable changes sign over the tuning range, to effect what may be termed "mode jumping" by control at the remote end. In such a case the grid circuit would be designed in the manner described in the above mentioned British patent and a similar remotely tunable arrangement employed for the anode. The provision of interchangeable remote anode coils of different values obviously facilitates "mode jumping." In an embodiment of this nature, of course, a blocking condenser to prevent D. C. energisation of the anode cable is necessary.

A somewhat simpler arrangement can be made by dispensing with anode and grid coils at the valve end. A co-axial cable terminated in a series inductance capacity circuit will present an impedance maximum at a given frequency just as a quarter wave line terminated in a low resistance presents a high resistance at the quarter wave frequency. Thus the grid may be made to "see" a high impedance much as though it were presented with a resonant circuit. Terminated lines can accordingly be used instead of resonant tuned circuits at grid and anode. The resulting circuit then becomes simply that of a remotely tuned "split capacity" oscillator as first described herein with reference to Figure 2 except that it is no longer a "split-capacity" but a "resonant line" oscillator, both anode and grid lines being "tuned" and the terminating impedances being coupled together. The circuit as a circuit is almost exactly the same whether the oscillator oscillates as "split capacity" oscillator (length of line less than ¼ wave length) or as a "higher mode" oscillator (length of line greater than ¼ wave length), the method of operation depending on the choice of remote circuit parameters.

Thus the "split-capacity" method of operation is suited to the local oscillator of a low intermediate frequency superheterodyne receiver where short wave reception is not required, whereas "resonant line" operation is suited to the case where the intermediate frequency is high and/or short wave reception is required.

In the case where the anode circuit is tuned by a cable terminated in a series inductance-capacity circuit, a plurality of modes of tuning exists, both as respects grid and anode cable circuits. The higher modes of oscillation are likely to exist together since corresponding to each resonant frequency on each of the modes there is, at the high frequency end of each mode, an anode cable resonance, thus predisposing the grid modes to oscillate simultaneously. This tendency can be overcome by a suitable choice of remote coils and suitable adjustment of the mutual coupling at the remote point. There are found in practice to be two predisposing causes for the occurrence of simultaneous modes of oscillation; first too tight coupling between grid and anode coils and second, the existence of high impedances in the terminating circuits. Thus by adjustment of remote coupling and a suitable choice of remote inductance-capacity values it is possible to localise the oscillation on a given desired mode, optimum values being found for each mode.

Should it be desired to secure continuous oscillation over a relatively large frequency range, e. g. the short wave band of 6—18 megacycles, it is necessary to intercalate high frequency modes between modes realisable with the given cables by altering the cable length physically or artificially.

Figure 3 shows an embodiment of the second feature of the invention. As will be apparent from a comparison of Figures 2 and 3 and the similarities between them, the second feature of the invention, is a development of the first, the development consisting in providing a series connection from anode to grid via the cable without using any shunt connected circuits between cable "inner" and earth at the remote point. In Figure 3 the tuning reactance is a variable inductance TL connected between the "inners" of the two cable lengths. The tuning range obtained by variation of the inductance TL extends from quite a low frequency (if TL is large) to the "half-wave" frequency of the whole run of cable (go and return) when TL is zero. In Figure 3 if

$$f_{\frac{\lambda}{2}}$$

is the "half-wave" frequency for the whole run of cable—

$$f_{\frac{\lambda}{2}} < \frac{492}{l}$$

in megacycles, where l is the length in feet—the tuning range is (theoretically)

$$0 \text{ to } f_{\frac{\lambda}{2}}$$

Figure 4 shows a modification of Figure 3 in which a tuning condenser TC replaces the tuning inductance TL of Figure 3. The tuning range obtained by varying TC is from the "half-wave" frequency (when TC is very large) to twice this frequency, approximately (when TC is very small). Actually the circuit will not oscillate at twice the "half-wave" frequency since, for this, TC would have to be zero and there would be no feed back. If F_λ is twice the "half-wave" frequency—i. e. the "full-wave" frequency—the tuning range for Figure 4 is (theoretically)

$$f_{\frac{\lambda}{2}}$$

to F_λ. In practice the range does not quite reach the limits

$$f_{\frac{\lambda}{2}}$$

or F_λ at either end.

Figure 5 shows a further modification differing from Figure 4 in that a series loading coil L is provided. The theoretical tuning range with this arrangement is from 0 to F_λ. In practice a range from a little above 0 to F_λ is obtainable.

Oscillators as shown in Figures 3, 4 and 5 have two main advantages in connection with remote controlled superheterodynes namely: (1) a very long control line can be used—for medium and long wave reception a control distance (receiver to control point) of 200 feet is practicable and (2) in the case of short wave reception a control distance can be standardised thus with a control distance of 20 feet (suitable for "arm-chair" control) reception to as low a wave length as 19 metres is possible.

In practical embodiments of the invention it is sometimes desirable to reduce the feed back by "tapping down" the anode cable at the valve end or, alternatively, by "tapping down" the grid cable at the valve end.

On analogy with the circuits described in said British patent, higher order modes of oscillation are possible and can be excited or suppressed, as required, by suitable means known per se.

In all the illustrated embodiments feed back is taken from the output of a valve to the input of the same valve. Clearly this is not essential and several valves in cascade could be used with feed back taken from the output of one valve to the input of a preceding valve provided that the obvious precautions as to phase shift in the feed back line are taken to ensure feed back in the correct phase for oscillation maintenance.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed I declare that what I claim is:

1. In an oscillation generator circuit, an electron discharge device having an anode, a cathode and a grid electrode, a frequency determining tunable resonant circuit comprising a series combination of inductance and tuning capacity connected between the grid electrode and the cathode of said device and a fixed capacity in parallel with said series combination of inductance and tuning capacity, said grid electrode being in effect capacitatively tapped down on the resonant circuit whereby said grid electrode receives substantially less voltage than the total developed across the inductance.

2. An arrangement as disclosed in claim 1 characterized by that the series combination of inductance and tuning capacity is located at a point remote from the discharge device and is connected thereto by means of a transmission line which forms said capacity.

3. In a remotely tunable oscillator circuit, an electron discharge device having a grid circuit and an anode circuit, a frequency determining variably tunable resonant circuit in said grid circuit including a coil, an anode coil connected in said anode circuit by means of a length of high frequency cable leading to a remote point, tuning means in series with said first named coil, the series combination being connected in the grid circuit by means of a second length of high frequency cable leading to said remote point, said first named coil being coupled to said anode coil for oscillation generation, and a grid leak connected between the grid and cathode of said valve.

4. In an oscillation generator circuit adapted to produce oscillations in any desired one of a plurality of modes of vibration, an electronic tube provided with an anode, a cathode and a grid electrode, aperiodic feed circuits for energizing said electrodes, a pair of conductors extending one from the grid and the other from the anode of said tube for a distance which is greater than a quarter wave length of the highest desired operating frequency, variable reactance means connecting the remote ends of said conductors for controlling the frequency of oscillations solely from said remote point.

5. In a remotely tunable oscillation generator circuit, an electron discharge device having at least a cathode, a control grid and an anode, an oscillation maintaining frequency determining feedback circuit between the anode and control grid, said circuit including a high frequency transmission line connected between the anode and control grid of said discharge device and having series connected reactance inserted at its midpoint, said reactance being remotely situated with respect to said electron discharge device, and constituting remote tuning means.

6. In an oscillator generator circuit adapted to produce oscillations in any desired one of a plurality of modes of vibration, an electronic tube having an anode, a cathode and a grid electrode, aperiodic feed circuits for energizing said electrodes, a pair of conductors extending from said tube to a remote point, one of the conductors extending from the grid electrode to the remote point and the other conductor from the anode to the remote point, means connecting the remote ends of said conductors, for controlling the frequency of oscillations solely from said remote point, said last named means including a variable inductance device.

7. In an oscillator generator circuit adapted to produce oscillations in any desired one of a plurality of modes of vibration, an electronic tube having an anode, a cathode and a grid electrode, aperiodic feed circuits for energizing said electrodes, a pair of conductors extending from said tube to a remote point, one of the conductors extending from the grid electrode to the remote point and the other conductor from the anode to the remote point, means connecting the remote ends of said conductors for controlling the frequency of oscillations solely from said remote point, said last named means including a variable condenser.

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