May 25, 1937. H. S. POLIN 2,081,711

HIGH FREQUENCY APPARATUS

Filed Feb. 15, 1933 2 Sheets-Sheet 1

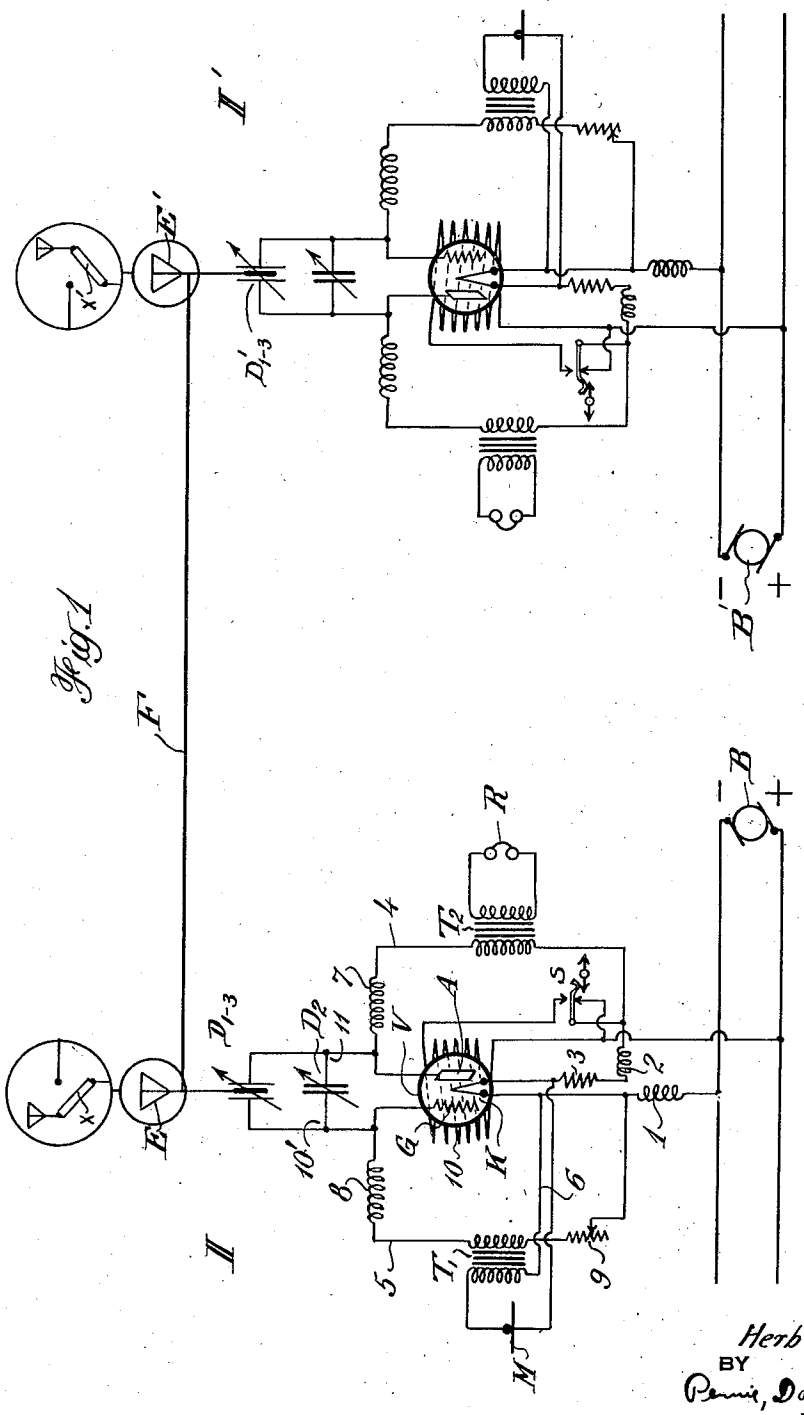


Fig. 1

INVENTOR
Herbert S. Polin
BY
Pennie, Davis, Marvin & Edmonds
ATTORNEYS

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Fig. 2,

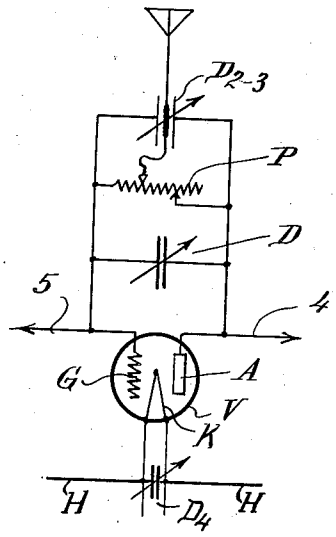


Fig. 3,

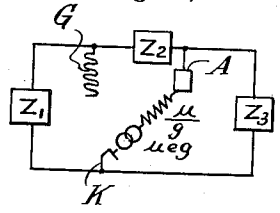


Fig. 4,

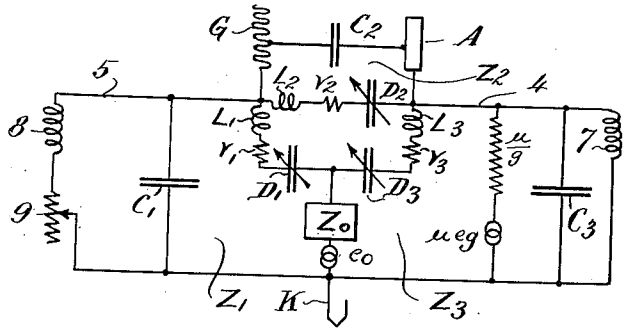


Fig. 5,

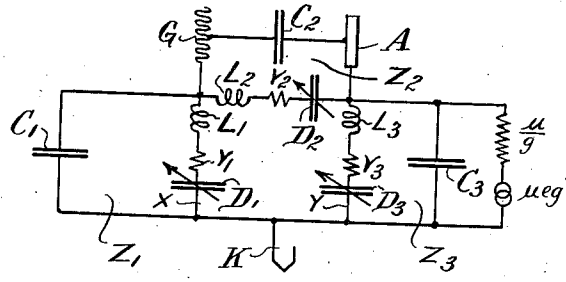


Fig. 6,

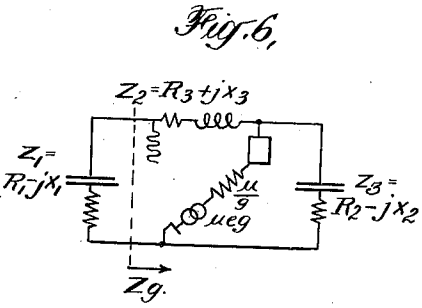


Fig. 7,

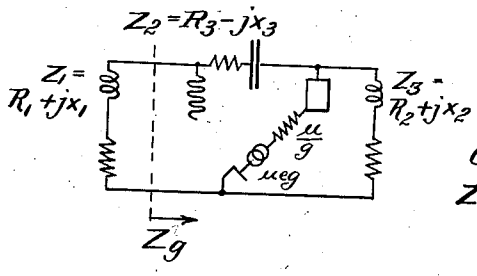
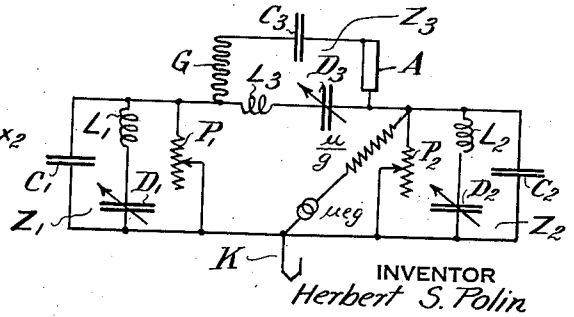


Fig. 8,



INVENTOR
Herbert S. Polin
BY
Dennis, Davis, Mecum & Edmonds
ATTORNEYS

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UNITED STATES PATENT OFFICE

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HIGH FREQUENCY APPARATUS

Herbert Spencer Polin, Port Washington, N. Y., assignor to Polin, Inc., New York, N. Y., a corporation of Delaware

Application February 15, 1933, Serial No. 656,783

7 Claims. (Cl. 250—17)

This invention relates to electronic apparatus for the production and detection of extremely short electro-magnetic waves; and to signaling systems embodying such apparatus.

The invention provides a short wave oscillation generator which is continuously adjustable throughout a relatively wide frequency range and in such fashion as to satisfy at each frequency the conditions requisite to the efficient production of sustained oscillations.

By virtue of the novel principles of frequency adjustment employed in the system of the present invention, the ultimate frequency of sustained oscillation is not, as in certain of the known short wave oscillation generators, limited by the interelectrode tube capacities, but rather is determined by the maximum mutual conductance of the tube in relation to the energy dissipating characteristics of the system.

It results from the principles of high frequency electric wave generation disclosed herein that the operation may, from time to time, be duplicated, either with the same or different apparatus, constructed of standard parts and manufactured under usual tolerances as to permissible variations in electrical constants of the apparatus utilized.

Employed in a system of two-way intercommunication, a plurality of stations in accordance with this invention are caused, each to radiate continuously at a common, extremely high, carrier frequency from a novel system of wave radiation so associated with the oscillator that the combined carrier frequency energies received at a local station from all of the other stations may be applied regeneratively to the local oscillator thereby greatly increasing its amplitude of oscillation to the end of further amplifying modulated carrier waves transmitted or received thereat. This regeneratively applied energy serves the further useful purpose of maintaining the oscillators at the several stations in exact syntony of oscillation at the common carrier frequency.

In the drawings:

Fig. 1 shows diagrammatically a pair of high frequency units, each incorporating an oscillation generator and detector in accordance with the present invention, together with the requisite signal transmitting, receiving and modulating elements for effecting two-way intercommunication between units.

Figs. 2–8 inclusive, are schematic showings which, in conjunction with the accompanying text, are explanatory of the novel features disclosed herein.

Referring to System II shown at the left in Fig. 1, the circuit employs a vacuum tube V having an anode A, a cathode K, and a control grid G. Tube V is energized from a direct current source B the negative terminal of which is connected through a high frequency blocking element 1 to one side of the cathode K. The positive terminal of source B is connected through contacts of a switch S to the other side of the cathode through blocking element 2 and resistance 3; and also over conductor 4 to the anode A. The potential drop across resistance 3 applies the necessary positive operating potential to the anode A of the tube. Grid G is connected over conductor 5 to the negative side of the cathode. A signal modulating device M, such as a microphone transmitter, energized over conductors 6 by the potential drop across the cathode K, is coupled through transformer T_1 to grid conductor 5, for purposes of modulating the high frequency carrier in accordance with signaling currents. Similarly, a signal indicating element R, such as a pair of headphones, is coupled to the anode conductor 4 through a transformer T_2, for indicating the rectified components of a modulated carrier wave.

High frequency blocking elements 7 and 8 are interposed in the anode conductor 4 and the grid conductor 5 respectively, for restricting the high frequency currents within their proper paths.

Connected by short leads directly between grid G and anode A, is an extremely small variable condenser D_2. For purposes of withdrawing oscillatory energy from or impressing oscillatory energy upon the system, there is provided a triplate condenser D_{1-3} having an intermediate stator plate connected to a wave radiator or antenna E, and external plates connected respectively, by short leads, to the grid G and anode A. The plates of condensers D_2 and D_{1-3}, other than the intermediate stator plate, are preferably annular, with the plate separations adjustable by screw-threaded means.

Interposed in the grid conductor 5 is a resistance 9, preferably variable, which, together with condensers D_2, D_{1-3}, and the interelectrode tube capacities, constitutes a grid condenser—leak resistance combination for suitably adjusting the bias on grid G to provide efficient oscillation generation and detection.

Operation of a switch S includes in the anode circuit of tube V, a magnetron coil 10 surrounding the tube, thereby optionally, to supplement the oscillatory action of the system.

The system of Fig. 1 may be modified as shown

in Fig. 2, by the addition of a high resistance P, of the order of a fraction of a megohm or greater, connected between anode and grid electrodes of tube V, as indicated. Also the intermediate stator plate of condenser D_{1-3} may be variably tapped to this resistance forming thereby a potentiometer connection. This potentiometer arrangement has been observed, in some instances, to assist in the oscillatory action of the system as well as to facilitate frequency adjustments thereof.

The system of Fig. 1 may be further modified as shown in Fig. 2 by the addition of a variable condenser D_4, of the same construction as condenser D_1, connected directly by the pair of conductors extending to the filament K. Also wave radiators H—H may be associated with the respective filament terminals as shown. This addition has, upon suitable adjustment of condenser D_4 been observed greatly to increase the amplitude of oscillation.

The system of Fig. 1 will, upon proper adjustments of the circuit elements indicated as variable, generate sustained oscillations of extremely high frequency. Operation thereafter to transmit and receive signals is apparent from the drawings. On transmitting the amplitude of high frequency oscillations produced by tube V, is varied in correspondence with modulating potentials applied to grid G due to activation of device M. Detection of modulated waves impinging upon antenna E, is effected through curvature of the tube characteristic, the modulating components being indicated by device R.

The system 1′ at the right in Fig. 1, is identical with the system 1, and in conjunction therewith, provides an arrangement for effecting two-way intercommunication between stations at a common carrier frequency to which both stations are adjusted by means of the variable condensers D referred to. This intercommunication may be accomplished by wireless waves, in which event the tri-plate condensers are provided, by operation of switches X and X′, with wave radiators E; or, for wire transmission of signals, the antennas E may be replaced by a conductor F.

At the oscillation frequency the circuit of Fig. 1 reduces to the basic "potentiometer" type of oscillation generator of Fig. 3, where Z_1, Z_2 and Z_3 are the resulting impedances between the tube electrodes, including the effects of the inherent interelectrode capacities; while u and g are the magnification factor and mutual conductance of the tube. e_g symbolizes the grid voltage resulting from the flow of oscillatory current in impedance Z_1. Figs. 4 and 5 indicate the manner in which the Fig. 3 circuit is evolved from those of Fig. 1.

In Figs. 4 and 5, C_1, C_2 and C_3 are the indicated interelectrode tube capacities. D_1, D_2 and D_3 are the capacities between the respective plates of condensers D_{1-3} and D_2. The capacities D of Fig. 4 are connected between the grid and anode electrodes through inductance and resistance elements L and r to symbolize the electrical constants of the associated connecting leads 10′ and 11, Fig. 1.

The signal modulating and indicating elements M, R, T_1 and T_2 of Fig. 1 are omitted from Fig. 4, as playing no part in the generation of high frequency oscillations, and further as interposing at the oscillation frequency, negligible impedances in conductors 4 and 5. In Fig. 1 the intermediate plate of the tri-plate condenser D_{1-3} is effectively connected to the cathode K through the impedance-to-ground of wave radiator E or of the conductor F extending to system 1′, as indicated by Z_0, Fig. 4. Voltage e_0 in series with Z_0, Fig. 4, designates the component of the wave radiated from station 1′ transmitted to station 1, Fig. 1, when both stations are radiating at the common carrier frequency.

At the oscillation frequency connections 4 and 5, due to the isolating action of blocking elements 7 and 8, serve merely to apply the necessary direct operating potentials to the grid and anode electrodes, but otherwise play no part in the production of high frequency oscillation. With this understanding these connections are omitted in the simplified showing, Fig. 5. Considering the action of but one station in isolation, the voltage e_0, Figure 4, is zero. Also, since at the oscillation frequency the impedance Z_0 is quite small in relation to the requisite impedances Z_1, Z_2 and Z_3, it may be assumed zero for purposes of analysis. Accordingly in Fig. 5, the cathode K is shown directly connected to the point between capacities D_1 and D_3.

The Fig. 5 circuit is seen to be equivalent to that of Fig. 3. Each interelectrode impedance Z, Fig. 3, comprises in Fig. 5, an interelectrode tube capacity C having connected in parallel therewith a small inductance L in series with a small resistance r and an adjustable condenser D.

Referring to Fig. 3, the condition for oscillation is expressed by the following equation:

$$(1) \qquad \frac{g}{u}\cdot(Z_1+Z_2+uZ_2)-(Z_1+Z_2+Z_3)=0$$

Inasmuch as the vector impedances Z, Equation 1, in general comprise real and imaginary components, the sums of each of which must separately add up to zero, Equation 1 is equivalent to a system of two equations determining the frequency f and the value of mutual conductance g at which oscillations can be maintained. It is obvious from the problem that the values for f and g derived from the fundamental equation must be real, positive quantities if oscillations are to be sustained.

Accordingly there are implicit in Equation (1) a number of limitations upon physical apparatus which must be met to assure efficient production of oscillations having a desired frequency. For example, the mutual conductance g derived from Equation (1) must not exceed the maximum mutual conductance g_m of the tube. Equation (1) requires at the oscillation frequency an impedance Z_2 between grid and anode which contains a reactance component of opposite sign to reactance components of impedances Z_1 and Z_3 which must simultaneously exist between grid and cathode and between anode and cathode, respectively. The two possible impedance combinations satisfying this limitation are shown in Figs. 6 and 7. Needless to say that at the oscillation frequency the vector impedances Z_1, Z_2 and Z_3 are subject to very definite restrictions as to magnitude and phase angle, in conformity with the limitation of Equation (1) that the real and imaginary components must separately add up to zero.

It is apparent from these and like considerations that an arbitrary change in the oscillation frequency in general necessitates readjustment of the several impedances Z_1, Z_2 and Z_3. There is this drawback, however, that as the frequency at which it is desired to produce oscillations is steadily increased, it becomes increasingly difficult physically to establish the mentioned im-

pedances at the requisite values in accordance with Equation (1).

As illustrative of the difficulties in this respect, attention is directed to the fact that the impedances Z must always include in parallel relation to any circuit elements connected between tube electrodes, the interelectrode tube capacities, which latter tend to approach short-circuit magnitude and to dominate the resulting impedances Z as the oscillation frequency increases, tending thereby greatly to limit the ultimate oscillation frequency considerably below that achievable purely on the basis of the maximum mutual conductance g_m in relation to the energy dissipating characteristics of the system. Also there exist in general definite physical limitations to the resulting impedances of such auxiliary circuit elements as may be associated with the tube electrode in an attempt to maintain the impedances Z at the requisite values. Restrictions falling in this category are typified by the limiting inductance of the shortest lead that can be connected between tube electrodes.

Such short wave oscillation generators as have heretofore come to my attention fail not only to incorporate means for individually adjusting the several impedances Z_1, Z_2 and Z_3, of the basic circuit Fig. 3, to assure efficient oscillation production at an arbitrarily selected frequency, but fail more signally to incorporate means for maintaining these impedances at the optimum and in many cases at even the requisite values for sustaining oscillations at extremely short wave lengths.

In contrast to these deficiencies of known short-wave oscillation generators, with the system of the present invention the independently adjustable plates of condensers D_{1-3} and D_2 controlling the capacities D_1, D_2 and D_3, Fig. 5, provide independent adjustments for the interelectrode impedances Z. Moreover, by virtue of the unique manner in which these adjustable capacities D are associated with the tube electrodes through the small series inductances L, the impedances Z may be individually established at the requisite values for oscillation down to extremely short wavelengths.

The explanation of this is that each condenser D by virtue of its series connection with an inductance L, alters the inductance effectively connected between a pair of tube electrodes in accordance with the expression:

$$(a) \qquad L' = L - \frac{1}{4\pi^2 f^2 D}$$

Thus merely by varying the capacity D, the effective inductance L' may be made as small as desired at an arbitrarily selected frequency f; or may even be made negative, i. e. capacitive. The effective inductances L' connected in parallel relation to the associated interelectrode tube capacities C, constitute tuned circuits the resonance frequencies and hence the impedance of which may, at an arbitrarily selected frequency, be established at the requisite magnitudes and reactance signs for sustaining oscillation.

It will be observed that the adjustable capacities D are in each instance arranged in series relation in the closed circuits L—C—D with the associated interelectrode tube capacities C. Capacities D will thus in general, due to their small magnitude which may be of the order of the interelectrode tube capacities, have a controlling influence upon the oscillation frequency. Accordingly with the system of the present invention the conditions for and frequency of oscillation are not greatly affected by variations in tube capacities resulting from manufacturing tolerances, and in any event such variations may be compensated by slight readjustment of the capacities D.

The resistances r are small and their influence upon the oscillation frequency negligible so long as the resonant frequencies of Z_1, Z_2 and Z_3, adjusted in the manner explained, depart appreciably from the oscillation frequency. This is in accordance with the well understood principle that the resistance component of a tuned circuit ordinarily becomes appreciable only in the vicinity of resonance.

If the potentiometer P, Fig. 2, is included, the circuit of Fig. 5 becomes that of Fig. 8, wherein P_1 and P_2 are the portions of P situated between the grid and the tapping point, and between the tapping point and the anode, respectively. The potentiometer is thus seen to influence the impedances Z_1 and Z_2, and is of assistance in micrometric adjustments of the oscillation frequency, as for example in tuning stations 1 and 1', Fig. 1, to a common carrier frequency. The potentiometer P may in addition partake of the nature of a crystallographic control.

Referring to the diagrammatic showing of Fig. 4, if one or more distant stations are radiating in synchronism with the station shown, the carrier frequency energy from these distant stations which is picked up by the local antenna, will, as stated, produce a voltage e_0 in series with the antenna to ground impedance Z_0. This voltage e_1 of carrier frequency may be applied regeneratively to the grid-cathode circuit of the tube through capacity D_1, serving thereby greatly to intensify the resulting amplitude of oscillation. In this way a portion of the carrier frequency energy emanating from each station becomes available at every other station to amplify the modulated signals transmitted or received at that station.

Application of the received carrier energy to the local oscillator in the manner shown in Fig. 4 serves the additional useful function of maintaining all oscillators in exact syntony. This results from the familiar phenomenon that thermionic oscillation generators which react upon one another will tend to "pull into step" at a common frequency of oscillation, provided they are adjusted to oscillate independently at frequencies which are sufficiently close to one another.

If, referring to Fig. 4, the antenna-to-ground impedance Z_0 is appreciable, it may, for purposes of analysis, be replaced by a pair of suitably chosen impedances connected respectively at points X and Y, Fig. 5. This modification, it will be observed, does not alter the novel principles of operation of the present invention, since condensers D_1 and D_3 still control the effective inductances L_1' and L_3' of the connections identified therewith.

I claim:

1. Short electric wave generating apparatus comprising an electronic tube having an anode, a grid and a two-terminal filament, connections from said filament terminals respectively to said grid and anode, a connection between grid and anode, capacity serially interposed in said anode-to-grid connection, a condenser connected between said filament terminals, and open-ended radiating conductors comprising a poise and a

counterpoise directly connected respectively to the plates of said condenser.

2. Short electric wave generating apparatus comprising an electronic tube having an anode, a grid and a two-terminal filament, connections from said filament terminals respectively to said grid and anode, a connection between grid and anode, capacity, including a tri-plate condenser having a wave radiator connected to the intermediate plate thereof, serially interposed in said anode-to-grid connection, a resistance bridged between grid and anode, a condenser connected between said filament terminals, and radiating conductors extending from the respective plates thereof.

3. A short wave oscillation generator comprising: an electronic tube having anode, cathode and grid electrodes, connections containing no lumped inductance extending external to said tube between each pair of said electrodes, each of said connections containing a condenser in series, the capacities of said condensers being so related to the distributed inductances inherent in said connections and to the interelectrode capacities of said tube as to adapt said tube to the production of oscillations at a short wavelength, and means for energizing said tube including a pair of energizing connections extending from said cathode to said grid and anode respectively, said energizing connections functioning substantially as high frequency choke impedances at the oscillation frequency.

4. A short wave oscillation generator comprising: an electronic tube having anode, cathode and grid electrodes, connections containing no lumped inductance extending external to said tube between each pair of said electrodes, each of said connections containing a condenser in series, the capacities of said condensers being so related to the distributed inductances inherent in said connections and to the interelectrode capacities of said tube as to adapt said tube to the production of oscillations at a short wave-length, at least one of said condensers being adjustable for varying said wavelength, and means for energizing said tube including a pair of energizing connections extending from said cathode to said grid and anode respectively, said energizing connections functioning substantially as high frequency choke impedances at the oscillation frequency.

5. A short wave oscillation generator comprising: an electronic tube having anode, cathode and grid electrodes, connections containing no lumped inductance extending external to said tube between each pair of said electrodes, each of said connections containing an adjustable condenser in series, the capacities of said condensers being so adjusted in relation to the distributed inductances inherent in said connections and to the interelectrode capacities of said tube as to adapt said tube to the production of oscillations at a selected short wavelength, and means for energizing said tube including a pair of energizing connections extending from said cathode to said grid and anode respectively, said energizing connections functioning substantially as high frequency choking impedances at the oscillation frequency.

6. A short wave oscillation generator comprising: an electronic tube having anode, cathode and grid electrodes, a connection containing no lumped inductance extending external to said tube between said grid and anode, said connection containing a condenser in series, a pair of connections extending external to said tube from said grid and anode respectively through a common impedance to said cathode, each of said connections containing a condenser in series, the capacities of said condensers being so related to the electrical constants of said connections, said impedance and the interelectrode capacities of said tube as to adapt said tube to the production of oscillations at a short wavelength, and means for energizing said tube including a pair of energizing connections extending from said cathode to said grid and anode respectively, said energizing connections functioning substantially as high frequency choking impedances at the oscillation frequency.

7. A short wave oscillation generator comprising: an electronic tube having anode, cathode and grid electrodes, a connection containing no lumped inductance extending external to said tube between said grid and anode, said connection containing a condenser in series, a pair of connections extending external to said tube from said grid and anode respectively through a common impedance to said cathode, each of said connections containing a condenser in series, the capacities of said condensers being so related to the electrical constants of said connections, said impedances and the interelectrode capacities of said tube as to adapt said tube to the production of oscillations at a short wavelength, the condenser included in said anode-to-grid connection being adjustable for varying said wavelength, and means for energizing said tube including a pair of energizing connections extending from said cathode to said grid and anode respectively, said energizing connections functioning substantially as high frequency choking impedances at the oscillation frequency.

HERBERT SPENCER POLIN.