Dec. 14, 1937. N. E. LINDENBLAD 2,102,426

FREQUENCY CONTROL

Original Filed April 5, 1932

Fig. 2

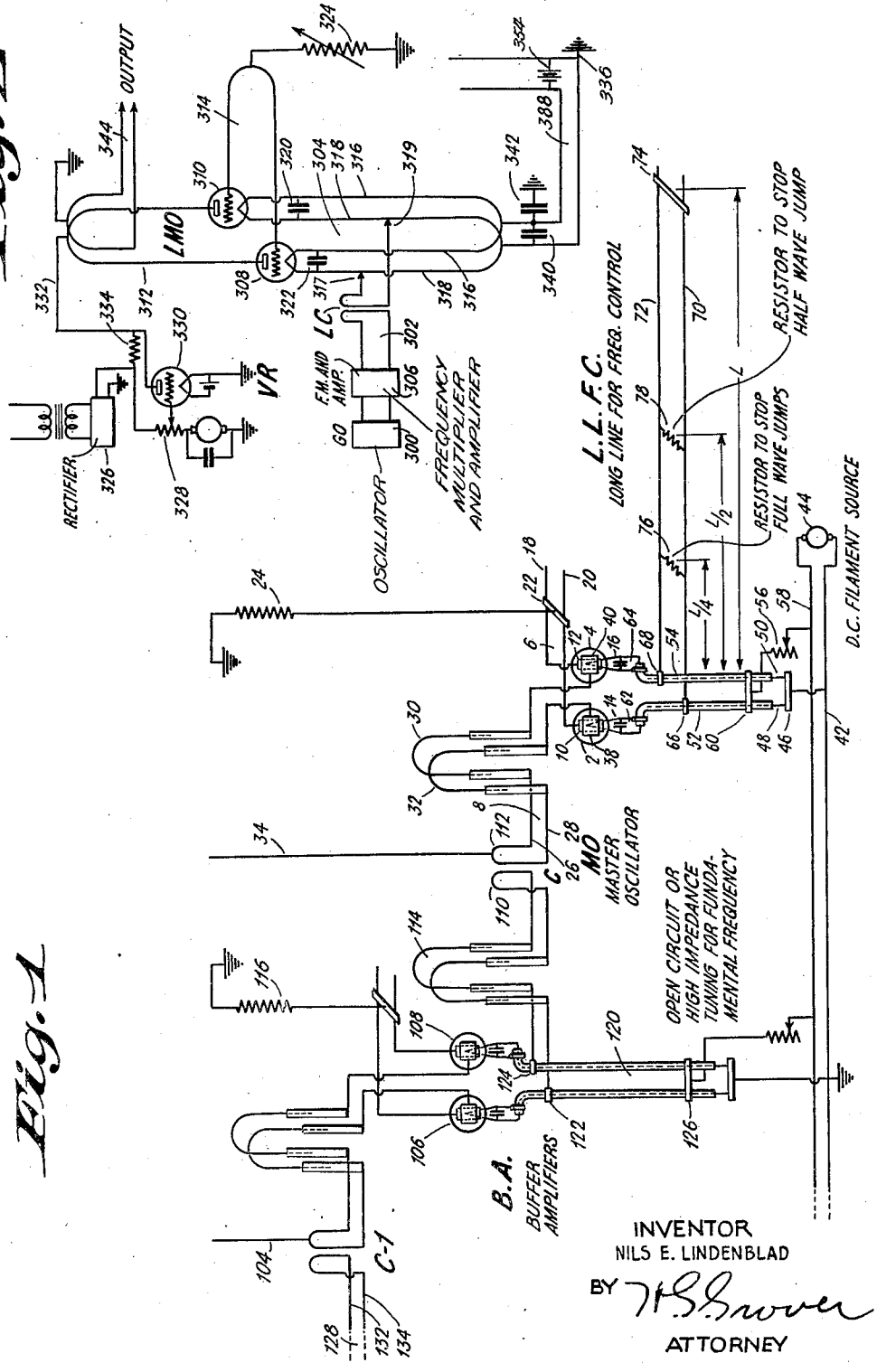


Fig. 1

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FREQUENCY CONTROL

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Original application April 5, 1932, Serial No. 603,310, now Patent No. 2,052,576, dated September 1, 1936. Divided and this application November 23, 1933, Serial No. 699,372. Renewed March 8, 1937

17 Claims. (Cl. 250—36)

My present application is a division of my copending application Serial Number 603,310, filed April 5, 1932, Patent No. 2,052,576 granted Sept. 1, 1936, and relates to the production and frequency stabilization of short waves.

A specific object of my present invention is to provide an improved line controlled oscillation generator and in particular an improved line controlled pushpull oscillation generator, the line being of the type described by Clarence W. Hansell in his United States Patent No. 1,945,546, granted February 6, 1934.

Pushpull oscillation generators of the regenerative vacuum tube type have been used for the generation of rather high frequency waves. However, the ordinary pushpull system as now known will prove impractical and in fact, inoperative in the ultra short wave length field approaching the high frequencies, with which I am now dealing. This failure is due to the large inter-element capacity of the electrode elements of the tubes which prevents the building up of the necessary high frequency controlling voltages for oscillation production. However, as pushpull arranged oscillators present many advantages due to their electrical and mechanical symmetry, it is an object of my present invention to improve their construction and operation whereby they may be utilized to produce oscillations at desired very high frequencies which in turn are frequency multiplied, according to another feature of my invention, to be more fully referred to and described hereinafter, to ultra short waves at high power and of frequencies of the order of magnitude of 450,000,000 cycles per second.

To make the oscillator operable for my purposes I tune not only the control grid and plate circuits, by means of circuits having substantially uniformly distributed inductance and capacity, but I also tune the cathode energizing circuits.

In this manner the impedance formed by the various tube electrodes and their associated circuits are more easily compromised to give high alternating potential variations at more nearly correct inter-electrode phase, resulting in such an optimum relationship between these factors, which produces a maximum of output and dependability of performance.

In view of the large control which the tuned cathode or filament circuit of my improved oscillator has upon the frequency of oscillations generated, I prefer to couple the long resonant transmission line for frequency control to the tuned filament circuit. The line acts, as described in the patent referred to, in one sense as a phase shifter, waves traveling down the line being fed back a time later proportional to the number of waves contained in the line. Hence, with a shift in frequency there is a shift in phase between the incoming and reflected wave proportional to the number of wave lengths on the line, and this shift in phase is in such a direction as to pull the frequency of oscillations generated back into step with the frequency for which the line is the correct number of half wave lengths long. Or, more simply, the line action may be described as that of a flywheel which does not permit anything connected thereto to run ahead or lag behind.

Although these resonant lines are made of the correct length for a desired operating frequency, yet, I have found that the frequency control, when using a long line for that purpose, tends to shift or jump to frequencies corresponding to the addition or subtraction of one or possibly more half waves to the length of the line. This is especially so if the line is very long, as it is preferably made, relative to the wave length used. Since it does not require a very large frequency jump to cause this frequency "jumping" phenomenon, a further object of my present invention is to improve the frequency stabilizing effect of such long line frequency control systems and to prevent these undesirable frequency "jump-overs". To eliminate this frequency shift condition I have found that the most simple expedient is to place impedances across voltage nodal points on the long transmission line, the impedances preferably being of a value equal to the surge impedance of the line. To prevent a shift of an odd number of half wave lengths either above or below a desired operating wave length, it is only necessary to locate a resistance or other impedance such as a condenser or small coil across the line at the voltage nodal point approximately at the middle thereof. Consequently, for an odd multiple shift, this point would then be located at a voltage maximum point putting such a heavy resistive load on the circuit as to prevent it from oscillating. Consequently, the circuit does not so to speak, choose this mode of operation.

If it is desired to prevent even multiple half wave length jumps, an additional resistance or impedance should be located at another voltage nodal point at the correct operating frequency, approximately one-quarter wave length away from either end of the line.

It should be clear, however, that the positioning of these impedances are not limited to the posi-

tions specifically mentioned, but may be placed, for example, all along voltage nodal points on the long line frequency controlling means. Also, it is not necessary that the impedances be made equal to the surge impedance of the line, but may vary in value and may be either inductors, condensers, resistors, or any combination thereof taken any number at a time.

As an alternative method of controlling the frequency of my primary oscillation generator, I may adjust the voltages and constants of the master oscillator circuit such that it is just on the verge of oscillating, although the master oscillator may be used as an ordinary amplifier and not adjusted near its oscillating value. Then, by using a low powered oscillator such as a crystal controlled oscillator, or a higher powered oscillator such as a long line frequency controlled oscillator of a desired wave length, whose outputs preferably are frequency multiplied either in known fashion or preferably by the frequency multiplication means to be described hereinafter, the primary oscillator is brought into oscillation and is frequency stabilized by the applied output of the frequency controlling or frequency multiplied oscillations from one of the sources mentioned. In this manner, after the frequency multiplied energy is brought to the same frequency as that which it is desired to produce in the power oscillator and applied thereto the primary or master oscillation generator is set into operation by the "guiding" or frequency multiplied oscillations. A lesser frequency controlling action, may be obtained by allowing the primary oscillator to oscillate while feeding controlling oscillations thereto. The latter of which, in that case, pull or lock the master oscillator into step with the constant frequency "guiding" oscillations which as indicated may be the frequency multiplied output of, say, a crystal controlled oscillator. However, as indicated, it is preferable that the primary oscillator be just on the verge of oscillating and be set into oscillation by the supplied low power constant frequency oscillations.

Further description is given by the aid of the accompanying drawing wherein

Figure 1 illustrates in wiring diagram form my improved line controlled oscillation generator; and

Figure 2 illustrates another circuit arrangement for establishing frequency control and stabilization by means of a tuned cathode circuit.

Referring to the master oscillator system of Figure 1, it will be seen that it comprises a pair of electron discharge devices **2**, **4**, having a tuned grid or control electrode circuit **6** and a tuned anode or plate circuit **8**. The tuned grid circuit **6** for the grid electrodes or electrodes **10**, **12** adjacent the cathodes **14**, **16** of electron discharge devices **2**, **4**, comprises a pair of parallel conductors **18**, **20** having substantially uniformly distributed inductance and capacity and arranged relatively close together so that radiation therefrom will be practically nil. The tuned circuit **6** is terminated by short circuiting strip or conductor **22** grounded through a resistor **24** which may be made variable if desired. Due to grid rectification, by a suitable choice of value for resistor **24**, the control electrodes **10**, **12** may be maintained at a suitable operating potential, but it is to be clearly understood that these grids may be polarized by substituting for resistance **24** a suitable source of unidirectional electromotive force such as a battery and potentiometer.

The tuned anode circuit **8** is formed like the tuned grid circuit. That is, the tuned circuit **8** is formed of a pair of relatively closely spaced conductors **26**, **28**, having substantially uniformly distributed capacity and inductance. While the grid circuit **6** has been shown tunable by movement of slide **22** along conductors **18**, **20**, the anode circuit is shown tunable by means of conductive trombone slide arrangements **30**, **32**. The sliding members and the stationary members of the trombone arrangements are arranged so as to be in electrical conductive relationship with respect to each other so that the potential supplied through conductor **34**, which, by the action of the voltage regulator is constant despite variations in voltage from the plate voltage rectifier **36**, may reach the plates or anodes **38**, **40** of the electron discharge devices **2**, **4**.

The cathode heating circuit may be traced from the grounded conductor **42**, connected to to the D. C. filament source **44**, through short circuiting or conducting strip **46**, through conductors **48**, **50** insulatingly supported within conducting tubes **52**, **54** through the outer legs of the filaments **14**, **16** and back through the inner legs of the filaments over the conducting tubes **52**, **54** through current varying or voltage controlling resistor **56**, to the other conductor **58** of the D. C. filament bus. The return to the conductor **58** is accomplished through the conducting or short circuiting strap **60**, which is made movable along tubes **52**, **54** so as to enable tuning of the filament or cathode energizing or heating circuit which is an important feature in my improved master oscillator.

Because of the close contiguity of the conductors **48**, **52**, they act as a single conductor for the high frequencies involved. However, to insure such action throughout the entire length of the filament or cathode heating circuit, by-passing condensers **62**, **64** are provided for the conductor systems **48**, **52** and **50**, **54** respectively.

It is to be noted also, that variable connections **66**, **68** are provided for the long line for frequency control comprising preferably a pair of closely spaced linear conductors **70**, **72** short circuited at their far ends by short circuiting conductive strap **74** movable along the conductors **70**, **72**.

In order to have the master oscillator operate at the exceedingly high frequencies contemplated, to provide basic master oscillations of fundamental frequency, it is essential that the cathode energizing circuit be tuned as described. Otherwise, due to the low capacitive reactance between the elements within the tube on one hand, and too great electronic time lag on the other hand, sufficiently optimum controiling potentials will not be set up on either the anodes or control grids, and this of course would not provide variation in the electron streams within the tubes at these high frequencies and therefore the desired high frequency output would not be produced. However, by tuning the various circuits as described, and by making the cathode ends of the tuned filament circuit of correct impedance, by adjustment of slider **60**, it will be found that the circuit will go into oscillation and produce an appreciable high output at frequencies heretofore difficult to attain with the ordinary pushpull circuits.

It should be obvious, therefore, that the cathodes have a substantial control on the frequency of oscillations generated and accordingly, I have connected the long line frequency control system comprising the conductors **70**, **72** to the tuned cathode energizing circuit. The line when short

circuited by strap 74 is tapped to the tubes or hollow cylinders 52, 54, which, because of their large diameter and relatively low reactance, carry at the high frequencies dealt with, most of the high frequency energy, the inner conductors serving in general to form a path for the unidirectional or low frequency heating current. Incidentally, it may be pointed out that throughout my improved system, to enhance frequency stability, unidirectional heating currents are employed; although alternating heating currents utilizing heater type of tubes may be utilized with some sacrifice in frequency stability.

The action of the "long" resonant line, so termed because it is many wave lengths long relative to the operating or controlled wave length, is more fully described in the United States patent of Clarence W. Hansell, No. 1,945,546, supra. Briefly, frequency stabilizing action of the line may be ascribed to the fact that waves travel down the line and return by reflection to the input end of the line. Now, should there be a shift in frequency such that a half wave length ingoing wave is not contained in the line a whole number of times, then it is reflected back from the far end of the line to the input end of the line with a phase shift augmented or multiplied by the number of half waves contained in the line. This phase shift, it will be found, is in such a direction as to pull the oscillator back into step in frequency with the frequency for which the line was made a corresponding whole number of half wave lengths long and, because of the augmented phase shift produced by the choice of long length for the line, the oscillator is rapidly pulled back to a correct operating frequency. This rapid return adjustment is still further increased by virtue of the fact that the line or frequency stabilizing or controlling means, is coupled to the tuned cathode circuit, which, as already pointed out, is very effective in controlling the generation of oscillations by the pushpull arranged electron discharge devices 2, 4. In addition, coupling to the filament circuit is preferred as it is more stable.

The line may be left open circuited, in which case strap 74 would be omitted and the line cut to the correct length. However it is preferred to terminate the line, for structural reasons, by a short circuiting strap so that the terminated end is at a voltage nodal point.

In practice the line has shown itself to be a simple and effective frequency controlling means. However, there is a tendency for frequency shifts corresponding to the addition or subtraction of possibly one or more half waves. This should be evident inasmuch as the line would be exactly divisible by such correspondingly spaced frequencies about the desired frequency of operation.

To prevent such frequency jump-over or shift, I connect across voltage nodal points on the long line conductors 70, 72, resistors 76, 78, which, in Fig. 1 have been illustrated as being placed one-quarter and one-half the length of the line respectively, away from the voltage maximum end or lefthand end of the line. It will be found that the resistor, which may be made equal in value to the surge impedance of the line, placed approximately at the center thereof, will prevent odd multiple half wave jumps in frequency. Similarly, a resistor placed one-quarter away from either end of the line will prevent jumps in frequency corresponding to even multiples of a half wave length of the desired operating frequency. Should it be desired to prevent even ones alone, the resistance at the mid-point is no longer necessary and may be removed, and, should it be desired to prevent odd half wave jumps alone, the resistor at the quarter ends may be disconnected. Moreover, if desired, these resistors, or other impedances, for example, condensers or inductors, or combinations thereof, may be placed across the line at any number of voltage nodal points thereon. It is to be noted however, that by special choice of impedances it may not be necessary to locate these impedances at the nodal points.

The action of these resistors or impedances to prevent the frequency jumps or shifts may be explained by stating that at frequencies other than the desired frequency, standing waves cannot be set up upon the line because of the heavy resistive loads presented by the resistors. In other words, due to the heavy load on the circuit, at undesired frequencies, the building up of voltage maximum points is prevented.

The action of the impedances at the nodal points can also be explained as follows:

The shorter a "long line" is the broader is the detuning necessary for jumping a certain multiple of half waves. On the other hand, a short line has, for the same reason, less fine control of the frequency. The scheme involved, therefore, combines the virtues of a long and a short line.

From what has gone on before, it is clear that the placing of these resistors on the line is not limited to the points specifically referred to, but resistors may be placed across voltage nodal points all along the entire length of the long line used for frequency control.

It is, of course, obvious that the line may be connected to the master oscillator in a more conventional way, for instance to the grid circuit or to any other portion of the circuit which may be found expedient. The reason for particularly pointing out the connection to the cathode circuit is that it has proved especially convenient and stable.

As already pointed out, constant frequency energy of the order of frequencies heretofore very difficult to obtain with ordinary regeneratively coupled electron discharge devices, is fed through the coupling arrangement C to the buffer amplifier B. A. The inductive coupling C is formed by the single loops 110, 112 adjacent each other, and made relatively movable so as to enable variation in coupling, the loop 110 being included in the tuned transmission line 114 similar in construction to the tuned anode circuit of the master oscillator tubes. The loop 112 is part of the tuned anode circuit 8 of the master oscillator tubes 2, 4.

In general, the mechanical and electrical construction of the buffer amplifier and its associated circuits are similar to the circuits of the master oscillator. The energy fed through the coupling C and impressed upon the tuned filament or cathode circuit 120 of the buffer amplifier tubes 106, 108 is reproduced and fed in amplified form through coupling C—1 and transmission line 128 formed of conductors 132, 134 to any suitable output circuit such as a magnetic frequency multiplier described more fully in my parent patent.

By virtue of the trombone slides in the transmission line 114, coupling the master oscillator through coupling C to the tuned filament circuit of the buffer amplifier, the line 114 is made of such a length that it is tuned to the fundamental

frequency and that its output ends 122, 124 are suitably matched by the impedance of the filament circuit. The tuning of the filament circuit by adjustment of short circuiting strap or conductor 126 should be such that the cathode ends of the circuit are of optimum phase and voltage to produce optimum performance of tubes 106 and 108.

Although the buffer amplifier may be set into oscillation by the application of the control potentials from the master oscillator, the buffer amplifier is, by virtue of its tuning, and also by virtue of the application of the frequency controlling currents or potentials from the master oscillator, guided, forced or locked into step for the production of amplified oscillations, corresponding identically in frequency with those oscillations generated by the master oscillator. This principle is used in the system which will be described in connection with Figure 2, for controlling the frequency of a master oscillator rather than by use of long line frequency controlling means illustrated in Figure 1.

It is to be noted that the buffer amplifier, if the grid circuit is given a tuning equivalent to grounded grids, is extremely stable. Moreover, although the feedback for such tuning is degenerative, the efficiency is not cut to the extent, compared with conventional, balanced or regenerative circuits, that it would be at longer waves. The virtue of the arrangement is that it often solves the problem of circuit stability at very high frequencies. When perfect grounded grid effect is desired, the slider on the grid tuning leads is placed a multiple (first multiple preferably) of a half wave from the grids proper. This then gives the same effect as if the grids were directly shorted together. Due to the dimensions of the glass envelope of a tube, a sufficiently direct short at these very high frequencies cannot be accomplished, thus it is preferred to use the procedure explained above. It is clear that in actual practice conditions such as described are often compromised with other circumstances to give a balanced optimum of performance.

In Figure 2, a primary master oscillating or "guiding" oscillator 300 is provided. This oscillator is of the constant frequency type, for example, of the crystal controlled variety or of the long line frequency controlled type. The output of the guiding oscillator GO is fed to a frequency multiplier and/or amplifier FM in whose output circuit 302 there appears the desired fundamental frequency energy. By inductive coupling LC the energy of fundamental frequency from output circuit 302 is fed to the tuned cathode energizing circuit 304 of the local master oscillator LMO. Preferably, this oscillator LMO is so adjusted that it just fails to oscillate without the application of energy from a frequency multiplier and amplifier FM or 306. However, upon the application of the energy from the frequency multiplier, the local master oscillator LMO goes into oscillation at a relatively high output and it is frequency guided and controlled or locked into step with the constant frequency oscillations from the frequency multiplier and amplifier 306.

Another way of controlling the frequency of the oscillations of the oscillator LMO would be to allow it to oscillate at nearly the fundamental frequency and then couple the relatively constant frequency oscillations from source 306 thereto. The oscillations generated by the oscillator LMO will be locked or guided into step with the oscillations supplied by the harmonics of the guiding oscillator, but, of course, the control will be to a lesser degree than in the case previously referred to wherein the master oscillator LMO is adjusted to be on the verge of oscillating rather than actually independently oscillating. Here, as in connection with Figure 1, it is to be noted that the frequency controlling oscillations whether from the line or from a chain of frequency multipliers and amplifiers are preferably applied to the tuned filament or cathode circuits of the pushpull tube arrangement.

To go into greater detail concerning the structural features of the arrangement shown in Figure 2, the electron discharge device oscillators or high vacuum tubes 308, 310 are provided with a tunable anode circuit 312, a tunable control grid circuit 314 and a tunable cathode energizing circuit 304. The tuning means, as in connection with Figure 1, may take the form of trombone slides within the various circuits, or may be short circuiting straps to which D. C. connections are made, but for the sake of simplicity they have been omitted. The cathode energizing conductors 316, 318 may be, as illustrated, simple linear conductors adjustable in length and arranged so that the portions leading to each filament are relatively close together as to prevent radiation therefrom. Or, the tubular system shown in Figure 1 may be utilized. The conductors 316, 318 are short circuited for high frequency currents at their filament ends by by-passing condensers 320, 322 so that with respect to radio frequency currents, the portions of the conductors 316, 318 leading to each filament act in parallel, it being remembered, however, that the pairs of conductors, namely, considering the pair leading to the filament to tube 308 and the pair leading to tube 310, act in series for the high frequency currents.

Preferably, the coupling LC is tapped on to the filament tuned circuit at points 317, 319 of such impedance that there will be a minimum of reaction upon the guiding oscillator with a change in load upon the local master oscillator LMO.

If desired, however, the coupling may be made at a high or low voltage point or high impedance point on the cathode energizing circuit. The grid tuning circuit 314 is grounded at a voltage nodal point through resistor 324, which, through grid rectification, furnishes suitable D. C. control bias upon the grids.

The anodes of the tube LMO are supplied with direct current potential through a voltage regulator VR which maintains constant voltage upon the anodes of tubes 308, 310 despite fluctuations in the output of the rectifier 326.

In connection with the voltage regulator VR, variations in voltage across resistance 328 causing variations in current flow through vacuum tube 330, as a result of which varying voltage drops occur across resistor 334 of such a magnitude as to compensate for voltage variations in the output circuit of rectifier 326, maintain constant voltage in conductor 332 and hence upon the anodes of the oscillator tubes 308, 310. Filament heating energy is supplied by battery 354.

One end of the filament energizing source is grounded at 336, and, through the conductors 338 feed the tuned cathode circuit of the local master oscillator LMO through voltage nodal points on the tuned circuit 304, the fixation of this point may be further secured as is desirable, by the action of by-passing condenser 340 and

342. Output energy may be taken inductively through the transmission line leads 344 grounded at a voltage nodal point as indicated.

Although I have shown the filament tuning conductors to be the means for conveying heating currents to the filaments of the various tubes, heating currents may be supplied through chokes to the filaments, the tuning conductors in that case carrying only high frequency currents and if desired blocked off from the heating currents by means of large blocking condensers.

It is to be distinctly understood that by the term "ground", used in the specification and appended claims, is meant any point or surface of zero or relatively fixed radio frequency potential.

Having thus described my invention, what I claim is:

1. A high frequency oscillation generator comprising a pair of push-pull connected electron discharge devices each having an anode, a cathode and a control electrode, a high frequency circuit connecting said anodes together, a high frequency circuit connecting said control electrodes together, and a high frequency circuit connecting said cathodes together, whereby said anodes are at opposite instantaneous polarity with respect to each other and said grids are at opposite instantaneous polarity with respect to each other, a frequency stabilizing circuit consisting of a pair of conductors having uniformly distributed inductance and capacity connected between said cathodes, and means for producing standing waves on said frequency stabilizing circuit.

2. High frequency apparatus comprising an electron discharge device having an anode, a cathode and a control electrode, a slider connected between said cathode and ground for tuning said cathode, and frequency controlling means coupled to said cathode tuned circuit for controlling the frequency at which said device operates.

3. Apparatus as defined in claim 2 wherein said frequency controlling means is in the form of a long transmission line, long relative to the operating wave length, said transmission line being closely coupled to said cathode tuned circuit, and means for producing standing waves thereon of a desired operating wave length.

4. High frequency apparatus comprising an electron discharge device having an anode, a cathode, and a control electrode, adjustable means connected in said anode circuit for tuning said anode circuit, means connected between said cathode and ground for tuning said cathode circuit, and additional adjustable means connected between said control electrode and ground for tuning said control electrode circuit, and frequency controlling means coupled to said cathode tuned circuit for controlling the device to function at a desired frequency.

5. Apparatus as claimed in claim 4 wherein said frequency controlling means comprises a long resonant transmission line, long relative to the operating wave length, and, means connected across voltage nodal points on said frequency controlling transmission line for enhancing the frequency stabilizing effect thereof.

6. In combination, an electron discharge device having coupled thereto a circuit in which high frequency undulatory electrical currents flow, and means coupled thereto for frequency stabilizing the frequency of oscillations in said circuit comprising a long resonant transmission line, a resistance connected across said line at a voltage nodal point thereof, and means for varying the length of said line.

7. An oscillation generator comprising a pair of devices each having an anode, a cathode and a grid, a tunable circuit connected between said anodes and tuned to the frequency of oscillation, a tunable circuit connected between said grids, a tunable circuit connected between said cathodes, and frequency controlling apparatus coupled between said cathodes for stabilizing the oscillation generator at the operating frequency.

8. A constant frequency oscillation generator comprising a pair of devices each having an anode, a cathode and a grid, a tunable circuit connected between said anodes and tuned to the frequency of oscillation, a tunable circuit connected between said grids, a high frequency circuit connected between said cathodes whereby said cathodes fluctuate out of phase in potential, and a frequency controlling circuit connected between said cathodes for stabilizing the oscillation generation at the operating frequency.

9. In combination, an electron discharge device having coupled thereto a circuit in which high frequency undulatory electrical currents flow, and means coupled thereto for frequency stabilizing the frequency of oscillations in said circuit, comprising a long resonant transmission line, a plurality of resistances connected across said line at voltage nodal points thereof and spaced away from each other, and means for varying the length of said line.

10. A high frequency oscillation generator comprising a pair of push-pull connected electron discharge devices each having an anode, cathode and a control electrode, an adjustable linear tuning circuit connected between said anodes, an adjustable linear tuning circuit connected between said grids for tuning said grids, whereby said grids are at opposite instantaneous polarity with respect to each other and said anodes are also at opposite instantaneous polarity with respect to each other, and a frequency stabilizing circuit consisting of a pair of conductors having uniformly distributed inductance and capacity connected to said cathodes for controlling said generator to produce oscillations of a desired frequency.

11. In combination, a pair of push-pull connected electron discharge devices each having an anode, a cathode having two terminals, and a grid, a tunable circuit connected between said grids, a tunable circuit connected between said anodes, whereby said grids are at opposite instantaneous polarity with respect to each other and said anodes are also at opposite instantaneous polarity with respect to each other, and a third tunable circuit connected between the two terminals of one cathode and the two terminals of the other cathode, said last tunable circuit functioning to enable said cathodes to fluctuate out of phase in potential, and means for producing oscillatory energy of a desired frequency in said last tunable circuit.

12. An oscillation generator for producing highly stabilized oscillations of a desired frequency comprising an electron discharge device having anode, cathode and control electrodes, means connected between each electrode and ground for individually tuning each of said electrodes of said generator to a condition most favorable to the generation of oscillations of the desired frequency, and means stabilizing the generator to produce oscillations of the desired frequency by means of standing waves, said last mentioned means being connected to said means tuning said cathode electrode.

13. An electron discharge device for high frequency energy comprising anode, cathode, and control electrodes, adjustable means for tuning each of said electrodes, and frequency controlling means coupled to said cathode for stabilizing the frequency at which said device operates.

14. High frequency apparatus comprising an electron discharge device having an anode, a cathode and a control electrode, means connected between said cathode and ground for tuning said cathode, and frequency controlling means coupled to said cathode tuned circuit for controlling the frequency at which said device operates.

15. A constant frequency oscillation generator comprising a pair of devices each having an anode, a cathode and a grid, a tunable circuit connected between said anodes and tuned to the frequency of oscillation, a circuit connected between said grids, a high frequency circuit connected between said cathodes whereby said cathodes fluctuate out of phase in potential, and a frequency controlling circuit connected between said cathodes for stabilizing the generation of oscillations at the operating frequency.

16. A constant frequency oscillation generator comprising a pair of devices each having an anode, a cathode and a grid, a tuned circuit connected between said anodes and tuned to the frequency of oscillation, a circuit connected between said grids, a high frequency circuit connected between said cathodes whereby said cathodes fluctuate out of phase in potential, and a frequency controlling circuit connected to points of opposite instantaneous polarity on said high frequency circuit for stabilizing the generation of oscillations at the operating frequency.

17. A constant frequency oscillation generator comprising a pair of electric discharge devices coupled together in push-pull relation, each of said devices having an anode, a cathode and a grid, a tuned circuit connected between said anodes and tuned to the frequency of oscillation, a circuit connected between said grids, a high frequency circuit connected between said cathodes whereby said cathodes fluctuate out of phase in potential, and a frequency controlling circuit connected between said cathodes for stabilizing the generation of oscillations at the operating frequency.

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