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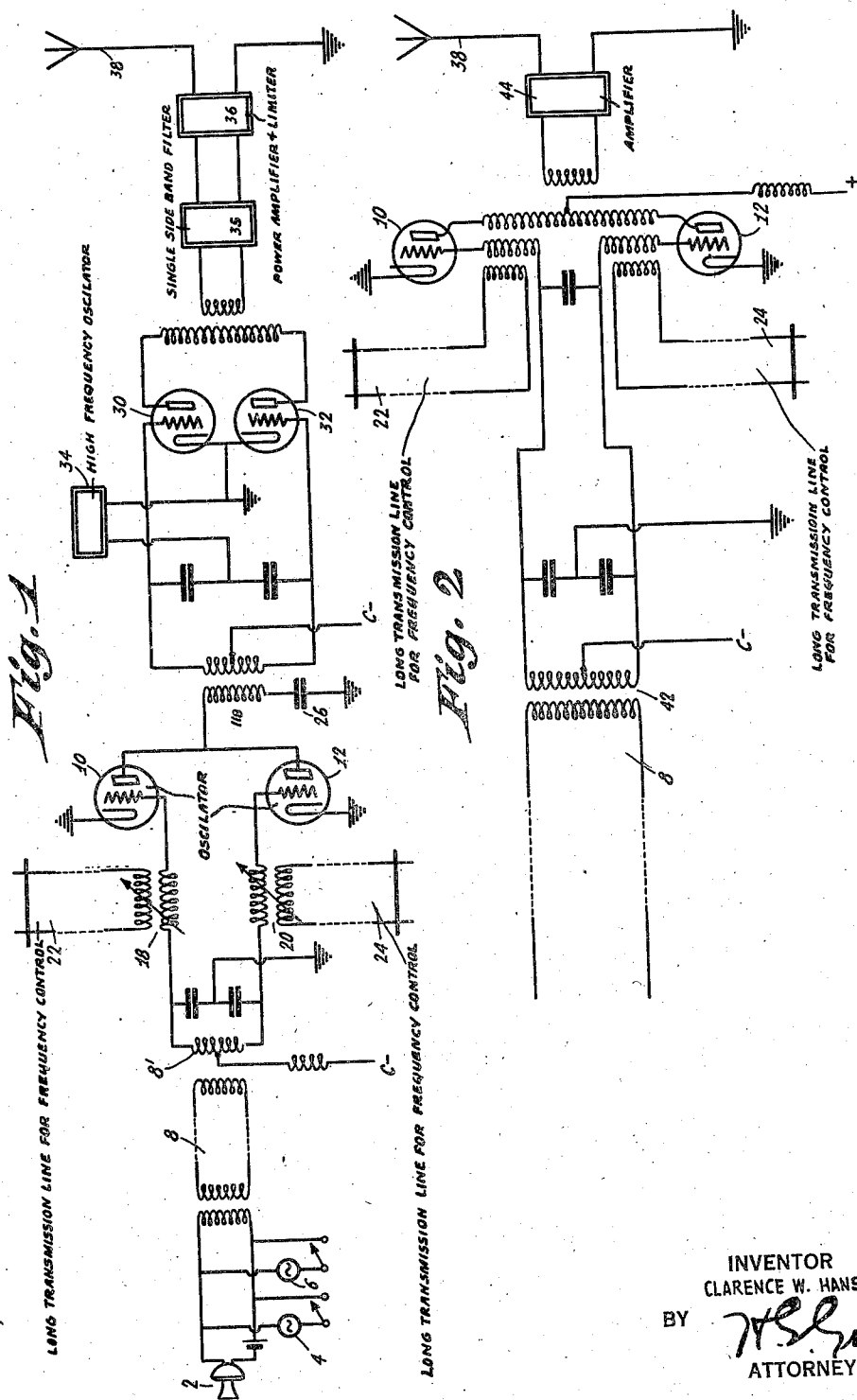
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2,027,975

FREQUENCY MODULATION

Filed June 25, 1930

3 Sheets-Sheet 1



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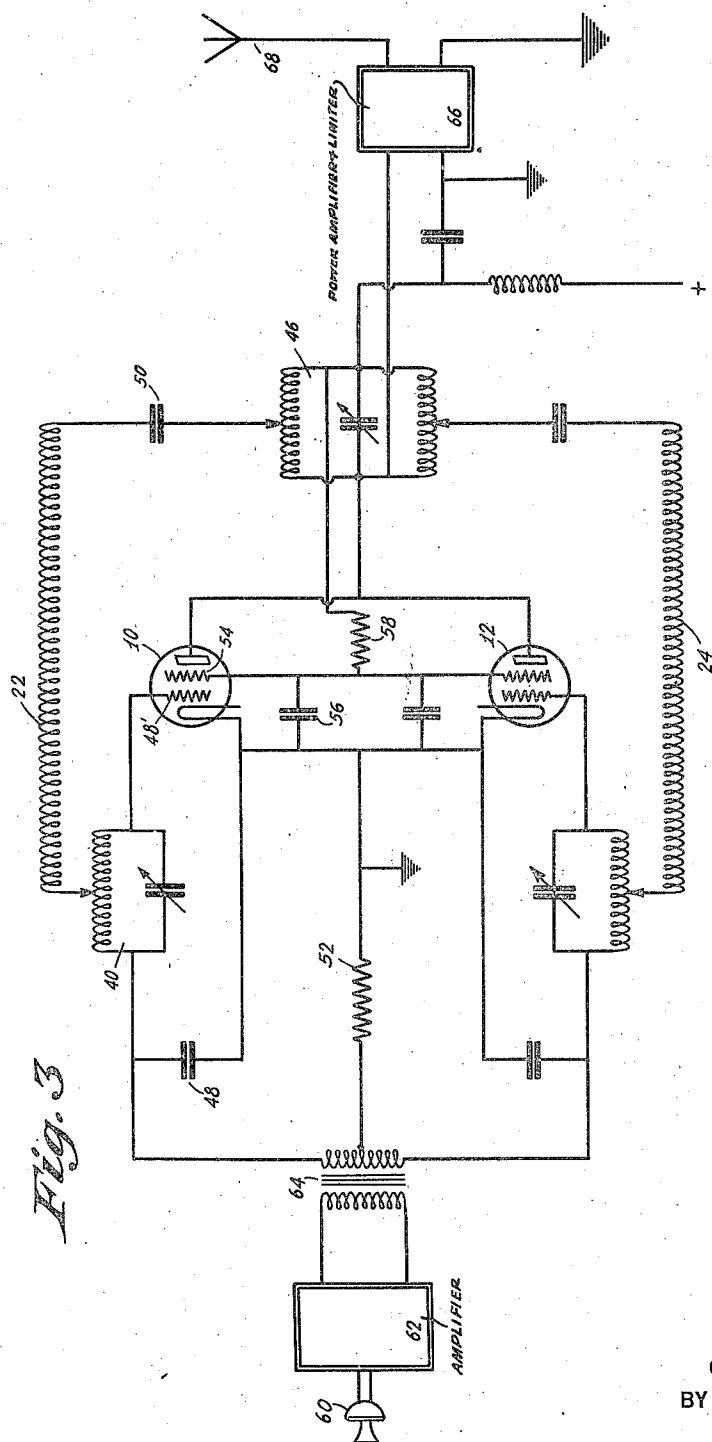
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3 Sheets-Sheet 2



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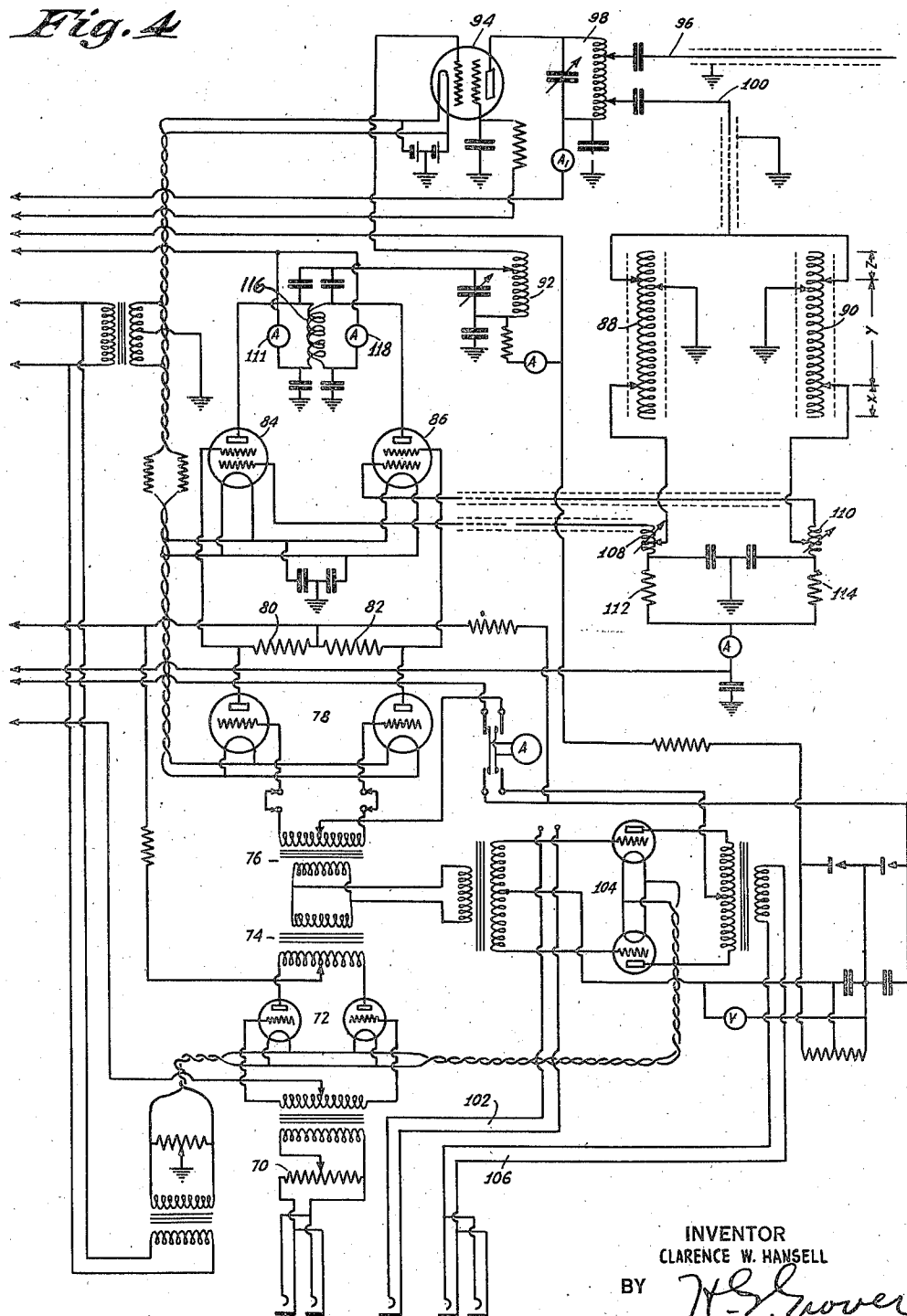
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Fig. 4



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FREQUENCY MODULATION

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Application June 25, 1930, Serial No. 462,614

23 Claims. (Cl. 179—171)

This invention relates to frequency modulation and has as its principal object, the provision of new and useful means for controlling, over a desired range, the frequency of generated oscillations.

A further object of this invention is to provide electron discharge device oscillators, having long line means for separately fixing their natural frequencies at or beyond the extreme frequencies of the desired range, coupled together so that they will produce, or, be forced to oscillate at, a common intermediate frequency, and means for varying the relative intensity of the energy supplied from each of the sources in order to vary the common frequency.

Long line frequency controlled oscillators are peculiarly adapted for this type of frequency modulation, for, they prevent undesired changes in frequency due to variations in load, biasing potentials circuit tuning and temperature. Moreover, they prevent frequency shift over large ranges, thereby precluding the possibility of shift or frequency drift of the frequency modulation system over a range greater than that allowed to the transmitter by the Government as would be the case with other types of oscillators; and, in fact, allow of signaling on a channel narrower than those allotted to one circuit in present day communication.

Still further objects of the present invention are to provide in radio signaling apparatus a transmitter having an electron discharge device having a plurality of grids to one of which is fed modulating energy, and to the other of which is fed energy to be modulated, and to provide cascaded high frequency stages in which the input and output circuits of each stage are shielded from each other and in which the stages are shielded from each other, whereby feed back is established solely through the means provided for that purpose.

Referring to the accompanying drawings, with the aid of which the invention is more fully described, Figures 1 and 2 illustrate frequency modulation transmitters, coupled according to the present invention, wherein periodic or resonant long lines are utilized for frequency control of the oscillators, and

Figures 3 and 4 are wiring diagrams of frequency modulation transmitters wherein, for frequency control, aperiodic long lines are used.

Referring to Figure 1, modulating energy in the form of speech energy from transmitter 2, and/or keyed alternating energy from sources 4 and 6 is fed over land line 8 and applied to

the input circuits of electron discharge device oscillators 10, 12 oppositely varying the bias placed upon the control electrodes thereof. By virtue of the interelectrode capacity of tubes 10, 12, or by the addition of external capacitors across the anodes and grids thereof, they are caused to be self oscillatory and by adjustment of the inductance 118 in the anode circuit and the inductances 18 and 20 in series with the control electrodes, the regeneration is adjusted and the natural frequencies of each of oscillators 10, 12 are caused to lie at opposite sides of a mean frequency and preferably beyond the extreme frequencies of a predetermined range. By virtue of the common plate inductance 118 the two vacuum tubes are caused to oscillate together on a single compromise frequency. If the oscillations are desired at a relatively low frequency it is preferable to use inductive feed back for the regeneration rather than the inter-element capacity of the tubes as illustrated.

In order to accurately fix the natural frequency of each oscillator 10, 12, resonant long lines 22, 24 for frequency control are coupled to the inductances 18, 20 included in the input circuits of the oscillators.

As described in my copending application, Serial Number 400,489, filed October 18, 1929, the long line is resonant, that is, it is left open-ended or short circuited so as to have standing waves formed or produced thereon. The length of line determines accurately the wave length of the standing waves formed, and they in turn pull the oscillator into step therewith. As the lines maintain constant oscillation frequency within narrow limits, they will prevent unwanted frequency drift of the system which may often occur if the oscillators are of the ordinary type.

The frequency, at which the system so far described oscillates normally without the application of input energy, will be determined by the circuits, and is some frequency between the frequencies at which tubes 10 and 12 would each oscillate at if the other were made to cease drawing anode current. However, the frequency of oscillations occurring in inductance coil 118 is dependent upon the relative bias of the control electrodes 10, 12 and will approach more nearly the frequency, at any given instant, of that tube whose control electrode is biased relatively more positive or, in other words, the frequency will be more nearly the natural frequency of the oscillator supplying most energy. In another sense, therefore, the input circuit including transformer 8' is a frequency determining

circuit. In the event that the bias on both tubes are alike, the frequency of energy appearing in coil 118 is that at which the two oscillators 10, 12 are forced to oscillate by virtue of their coupling through their common anode inductance.

The output of oscillators 10, 12 is fed, through the secondary of transformer 118 in phase opposition to the input electrodes of a carrier suppression modulator including electron discharge devices 30, 32. High frequency energy from oscillator 34, preferably of the type disclosed in my copending application Serial Number 400,489, filed October 18, 1929 or of the type disclosed by James L. Finch and James W. Conklin in their copending application Serial Number 363,660, filed May 16, 1929, is fed to the input electrodes of tubes 30, 32 in parallel. Output energy of the modulator is supplied if desired, to a filter 35 for eliminating one side band appearing in the output circuits of devices 30, 32, and, the output of filter 34 is fed to a power amplifier and limiter 36 and then transmitted, for example, by any suitable radiating antenna 38.

In Figure 2, modulating energy is fed from a source or land line 8 to the input circuit of two electron discharge devices 10, 12 having their anodes connected in pushpull or in phase opposition rather than cophasally as shown in Figure 1. As the oscillating circuit of Figure 2 is made up of the anode inductances, tube capacities and grid inductances it acts as a series tuned circuit and consequently there may be relatively little inductive feed back.

Each of the oscillators 10, 12 has its frequency controlled by means of resonant long lines 22, 24 fixing the natural frequency of oscillators 10, 12 at or beyond the extreme frequencies of a desired range. Because of the close coupling of the anode and control electrode circuits, the entire system is forced to oscillate at some common intermediate frequency. The common or floating frequency is varied according to the biasing potentials applied to the secondary of modulation transformer 42 connected to the control electrodes of tubes 10, 12 in phase opposition, the frequency approaching the natural frequency of that oscillator whose bias is altered positively so that the energy supplied by it appears in greater amount than that supplied by the other oscillator. If desired, frequency modulated energy from the oscillators 10, 12, is amplified by a suitable power amplifier 44 and then radiated over any suitable radiating antenna 38.

For a fuller discussion of the operation of the underlying principles of the frequency modulation oscillator tubes 10, 12, coupled together so as to be forced to oscillate at a common frequency, reference is made to my United States Patent Number 1,787,979, Serial Number 264,101 on Oscillation generation, filed March 23, 1928.

The long line used for frequency control need not be of the periodic or resonant type but may be, as shown in Figure 3, of aperiodic character, that is to say, of the type disclosed by James L. Finch and James W. Conklin in their copending application 363,660, filed May 16, 1929.

In Figure 3 aperiodic long line 22 which may be constructed in the form of a coil is coupled to the common tuned anode circuit 46 of screen grid tubes 10, 12 and to the tuned input circuit 40 of electron discharge device oscillator 10. The circuit 40 is grounded through a suitable condenser 48. The impedance of tuned circuit 40 should be so adjusted to the currents from line 22 that it equals the surge impedance of

line 22 thereby insuring aperiodic transfer of energy from output circuit 46 to the input circuit 40. Anode potential is kept from the control electrode 48' of vacuum tube 10 by a suitable blocking condenser 50. To suitably bias the control electrode 48' of vacuum tube 10, a grid leak resistance 52 is provided. Two grid leaks, one for each tube, may also be used. To prevent interelectrode feed back and to insure feed back over long line 22 which is made approximately an odd number of half wave lengths long taken at the frequency at which oscillator 10 is desired to oscillate naturally; namely, at or beyond an extreme frequency of a desired range, screen grid 54 is provided, grounded for radio frequency currents by condenser 56 and supplied with suitable biasing potential by the action of resistance 58. Provision is also made in building the equipment to provide for good electrical shielding between the anode circuit and the control grid circuits so that practically all the regeneration is from the energy carried back over the two long lines.

In addition, to further insure feed back solely through the long line feed back means provided, the stages should be shielded from each other.

Circuits and elements are connected to oscillator 12 in a fashion similar to that described in connection with oscillator 10. The length of line 24 of oscillator 12 is chosen however, to be an odd number of half wave lengths of a frequency at the other end of the range of desired frequencies relative to the natural frequency of oscillator 10.

Because of the common anode circuit 46, tuned to a frequency intermediate the oscillator frequencies, both oscillators 10, 12 are forced to oscillate at some common, intermediate frequency. Modulation energy from transmitter 60 amplified by a suitable amplifier 62 and applied to the control electrodes of electron discharge devices 10, 12 through transformer 64, causes the amount of energy supplied by each tube to vary, as a result of which the frequency of the energy appearing in tuned circuit 46 approaches the natural frequency of that tube supplying relatively more energy. Output energy is taken from tuned circuit 46 amplified and limited by power amplifier and limiter 66 and then transmitted or radiated by any suitable means such as antenna 68.

In Figure 4, I have shown an arrangement wherein feed back occurs from one of a plurality of cascaded tubes through aperiodic long lines to a preceding tube and wherein modulation voltages are applied to the screen grids of electron discharge devices rather than the control electrodes thereof. Modulation voltages appearing across resistance 70 are fed in pushpull fashion to an amplifier 72 and then applied pushpull fashion through transformers 74, 76 in phase opposition to the control electrodes of pushpull amplifier 78 having impedances 80, 82 in series with the anodes thereof. The resulting amplified modulation voltages appearing across impedances 80, 82 are applied to the screen grids of amplifiers 84, 86.

To the control electrodes of vacuum tubes 84, 86 are applied high frequency potentials, through aperiodic lines 88, 90, respectively, of the type disclosed in the Finch and Conklin application referred to. Modulated radio frequency output energy from electron discharge devices 84, 86 is fed to a tank circuit 92 and thence through the input electrodes of a power amplifier 94 of the screen grid type. Through

a suitable line 86, output energy from the tuned plate circuit 98 of tube 94 may be fed to an additional power amplifier before further transmission or radiation.

Feed back through lines 88, 90 occurs through connection 100 suitably shielded as shown. As the lines 88, 90 feed back energy from tube 94 which represents a second stage to tubes 84, 86 which represent a first stage, they should, for proper oscillation generation at the natural frequencies, be substantially an even number of half wave lengths long of the respective natural frequencies. Tank circuits 92 and 98 act as initial frequency determining circuits and force the system to oscillate at an intermediate frequency when no modulation biasing potentials are applied to the screen grids of tubes 84, 86, at which time the circuit including resistances 80, 82 becomes a frequency determining circuit.

Cathode energization and unidirectional biasing potentials for the various tubes are derived as indicated on the drawings. In order to test the voltage or current flowing in any part of the system test leads 102 are provided. A monitoring or "listening in" amplifier 104 of the push-pull variety, by means of test leads 106 allows of a check on the signal to be transmitted. In order to tune the grid circuits of tubes 84, 86 tuning inductances 108, 110 are provided; and, grid leaks 112, 114 maintain suitable biasing potentials on the control electrodes thereof. In order to determine separately the anode currents flowing in each of tubes 84, 86, the anode choke 116 is made in the form of a coil with two parallel wires in the winding having separately connected ammeters 118.

What I claim is:

1. An arrangement for generating frequency wobbled oscillations comprising two electron emission tube oscillation generators having their input and output circuits shielded from each other, long lines coupling said circuits together for fixing their natural frequencies to or beyond the extreme frequencies of the desired range of frequency wobble, means coupling the oscillation generators together to force them to oscillate at a common frequency, and means for simultaneously oppositely wobbling the bias of control electrodes of the tubes to oppositely vary the oscillation intensity in order to wobble the common frequency.

2. An arrangement for generating frequency wobbled oscillations comprising two screen grid electron emission tube oscillation generators having their input and output circuits shielded from each other, long lines coupling said circuits together and fixing their natural frequencies to or beyond the extreme frequencies of the desired range of frequency wobble, means coupling the oscillation generators together to force them to oscillate at a common frequency, and means for simultaneously oppositely wobbling the bias of the screen grids of the tubes to oppositely vary the oscillation intensity in order to wobble the common frequency.

3. An arrangement for generating oscillations and frequency modulating the generated oscillations in accordance with modulating energy comprising two electron emission tube oscillation generators having input and output circuits shielded from each other, long lines coupling said circuits together and for fixing their natural frequency to or beyond the extreme frequencies of the desired frequency range, means coupling the oscillation generators together to

cause them to oscillate at a common frequency, and means coupling the modulating energy to the control electrodes of tubes in phase opposition in order to oppositely vary their bias and consequently the oscillation intensity in order to similarly vary the common frequency.

4. An arrangement for generating oscillations and frequency modulating the generated oscillations in accordance with modulating energy comprising two screen grid electron emission tube oscillation generators having input and output circuits shielded from each other, long lines coupling said circuits together and for fixing their natural frequency to or beyond the extreme frequencies of the desired frequency range, means coupling the oscillation generators together to cause them to oscillate at a common frequency, and means coupling the modulating energy to the screen grids of the tubes in phase opposition in order to oppositely vary their bias and consequently the oscillation intensity in order to similarly vary the common frequency.

5. In radio signaling apparatus a transmitter comprising a pair of screen grid electron discharge devices, means for applying in phase opposition modulation energy to the screen grids of the devices, means for applying high frequency energy to be modulated to the other grids of said devices and, a tuned high frequency tank circuit connected in parallel to the anodes and cathodes of said devices.

6. In radio signaling apparatus a transmitter comprising a plurality of high frequency stages, each stage comprising an electron discharge device having a pair of grids, means for shielding the input and output circuit of each electron discharge device from each other, means for shielding the stages from each other, long line means for establishing high frequency feed back from one stage to another stage, and means for applying modulating energy to one of the grids of an electron discharge device in one of said stages.

7. In radio signaling apparatus, a transmitter comprising a pair of high frequency stages, one of said stages comprising a pair of screen grid electron discharge devices, the other stage including a screen grid electron discharge device, means for shielding the output and input circuits of said electron discharge devices from each other, means for shielding the stages from each other, means for establishing feed back from one stage to control electrodes of electron discharge devices forming another stage, and means for applying modulating energy to the screen grids of said last mentioned electron discharge devices.

8. In apparatus of the character described, a pair of electron discharge device oscillator tubes, means coupling the tubes together and feeding their output to an electron discharge device amplifier, a pair of long transmission lines coupling the output of said amplifier to the input circuits of said electron discharge device oscillator tubes each of said lines being of such a length as to cause each oscillator tube to operate at frequencies on opposite sides of a mean frequency when the other oscillator tube is rendered inoperative, and, means for modulating the output of said electron discharge device oscillator tubes.

9. In electrical apparatus a pair of electron discharge devices each having an anode a cathode and a control electrode, circuits intercon-

necting the control electrodes and cathodes and anodes and cathodes of said devices; the circuits for each of said devices having inductance and capacity of such value that normally said devices
 5 tend to operate on opposite sides of a mean frequency, a long transmission line a plurality of half wave lengths long at a frequency to one side of said mean frequency coupled to electrodes of one of said devices, said line tending
 10 to accurately fix the operating frequency of said device to said frequency at one side of said mean operating frequency, another long transmission line a plurality of half wave lengths long at a frequency lying to the other side of said
 15 mean frequency coupled to electrodes of said other electron discharge device, said last mentioned transmission line tending to cause said other device to operate accurately at said other frequency on said other side of said mean operating frequency, a plurality of said circuits
 20 being closely coupled together whereby said devices operate at said common mean frequency, and a circuit for oppositely varying the conductivity of said devices whereby the mean
 25 operating frequency of said devices shifts away from said mean frequency in accordance with the variation in conductivity of said devices.

10. Apparatus as claimed in claim 9; and an inductor in each of said circuits for each of
 30 said devices, the transmission line for each of said tubes being coupled to at least one of said inductors.

11. Apparatus as claimed in claim 9; and a common output circuit for said devices, said common output circuit having inductance and capacity
 35 and being tuned to the mean operating frequency of said devices, the long lines being connected from the common output circuit to the control electrode cathode circuits of said devices, and means for preventing the effects of
 40 interelectrode feed-back between the anodes and control electrodes of said devices.

12. Apparatus as claimed in claim 9, and a common output circuit for said devices, said
 45 common output circuit having inductance and capacity and being tuned to said mean frequency, each of said transmission lines being connected from said common output circuit to the control electrode cathode circuit of one of
 50 said devices, an impedance for terminating said lines, said impedance being connected between the output ends of said lines and the cathodes of said devices, said terminating impedances being equivalent in value to the characteristic
 55 surge impedances of said lines, and circuits connected to electrodes of said devices for preventing the effects of anode control-electrode feed-back through said devices.

13. In electric apparatus, a pair of electron
 60 discharge devices each having an anode a cathode and a control electrode, a circuit having inductance and capacity tuned to a mean operating frequency connected between said anodes and control electrodes, a circuit having inductance
 65 and capacity tuned to one side of said mean frequency connected between the control electrode and cathode of one of said devices, a circuit having inductance and capacity tuned to the other side of said mean frequency connected
 70 between the control electrode and cathode of said other device, transmission lines, a plurality of half wave lengths long at said frequencies on an opposite side of said mean frequency connected between said anode circuit
 75 and said control electrode cathode circuits, im-

pedances equal in value to the characteristic impedance of said transmission lines connected between the control electrode ends of said lines and said cathodes, circuits acting to prevent the effects of anode control electrode capacity of
 5 said devices, and, a circuit for varying oppositely the conductivity of said devices whereby the frequency of energy appearing in said common anode cathode circuit varies through said mean frequency.

14. In electrical apparatus, a source of modulating potentials, a pair of pushpull connected
 10 electron discharge devices each having a filament a plate and a grid, a resistor for connecting said plates in opposition, a circuit for applying said modulating potentials to said grids in
 15 opposition, a pair of vacuum tubes each having an anode a cathode a control electrode and a screen grid, connections applying the voltage variations across said resistors in relative phase
 20 opposition to said screen grids, a circuit having inductance and capacity connected between said anodes and said cathodes, an amplifier having within an hermetically sealed container an anode
 25 a cathode a control electrode and a screen grid, means coupling said circuit having inductance and capacity to the control electrode of said amplifier, means for grounding the screen
 30 grid of said amplifier for radio frequency potentials, a circuit tuned to a mean operating frequency and having inductance and capacity connected between the anode and cathode of said
 35 amplifier, a pair of transmission lines, a plurality of half wave lengths long respectively at at frequencies on opposite sides of said mean frequency, connected between said last mentioned
 40 circuit and the control electrodes of said pair of electron discharge devices for establishing feed back from said amplifier to said electron discharge devices, and, circuits terminating said
 45 transmission lines for rendering feed back there-over substantially aperiodic.

15. In a high frequency signaling system a pair of electron discharge devices each having
 50 an anode a cathode a screen grid and a control grid, a resistance circuit symmetrically connected between said screen grids, means for applying audio frequency potentials effectively in shunt to said symmetrical resistance circuit, means for subjecting said control grids to high
 55 frequency potentials, and, a tuned high frequency circuit connected between said anodes connected in parallel and said cathodes connected in parallel.

16. In a high frequency signaling system, a
 60 pair of electron discharge devices each having anode cathode and control grid electrodes, a tuned high frequency circuit connected between said anodes and cathodes, a vacuum tube amplifier having an input circuit and a tuned output
 65 circuit, means coupling the input electrodes of said vacuum tube amplifier to the tuned circuit connected between the anodes and cathodes of said electron discharge devices, and, a pair of transmission lines of different electrical length,
 70 each of said lines having uniformly distributed inductance and capacity connected between the tuned output circuit of said vacuum tube amplifier and control grids of said electron discharge devices for causing desired feed back sufficient
 75 to engender in the tuned output circuit of said vacuum tube amplifier high frequency electrical oscillations.

17. Apparatus as claimed in claim 16 in combination with means for varying the conductivity 75

of said electron discharge devices at a signaling rate, thereby modulating the oscillations in the tuned output circuit of said vacuum tube amplifier.

18. Apparatus as claimed in claim 16 wherein each of said devices is provided with a screen grid, wherein a resistance circuit is connected between said screen grids and wherein means are provided for causing variation in current flow through said resistance circuit at a signaling rate whereby the oscillations in said tuned amplifier circuit are modulated in accordance with signals to be transmitted.

19. In a high frequency signaling system a pair of electron discharge devices each having anode cathode control grid and screen grid electrodes, a high frequency circuit connected in parallel to said anode and cathode electrodes, a vacuum tube amplifier, means for coupling input electrodes of said vacuum tube amplifier to said high frequency circuit, a tuned high frequency circuit connected between the output electrodes of said vacuum tube amplifier, a pair of transmission lines each having uniformly distributed inductance and capacity coupling the output circuit of said amplifier to the control grids of said electron discharge devices whereby feed back occurs through said lines sufficient to cause continuous oscillatory electrical currents of high frequency to flow in said amplifier output circuit, and means for applying modulating potentials to the screen grid electrodes of said devices in order to modulate the oscillations in said tuned amplifier output circuit.

20. A system for producing oscillations comprising a pair of electron discharge devices each having anode cathode and control grid electrodes, a tuned high frequency circuit connected between the anode and cathode electrodes of said devices, a vacuum tube amplifier, means for coupling input electrodes of said vacuum tube amplifier to said tuned high frequency circuit, a tuned high frequency circuit connected between the output electrodes of said vacuum tube amplifier, and, a pair of transmission lines of different electrical length and having substantially uniformly distributed inductance and ca-

capacity coupling the tuned output circuit of said amplifier to the control grid and cathode electrodes of said electron discharge devices.

21. Apparatus as claimed in claim 18 wherein there is provided in addition an impedance connected between the output end of each line and the cathodes of said devices, the impedances being substantially equal in value to the surge impedance of the lines to which they are respectively connected.

22. Apparatus as claimed in claim 18 wherein means are provided for applying modulating potentials to electrodes of said devices in order to modulate the oscillations appearing in the tuned output circuit of said amplifier.

23. In a high frequency system, a pair of electron discharge devices each having anode cathode control grid and screen grid electrodes, a tuned high frequency circuit connected in parallel to the anode and cathode electrodes of said devices, a vacuum tube amplifier having input electrodes and output electrodes, means coupling said tuned electron discharge device circuit to the input electrodes of said vacuum tube amplifier, a tuned circuit connected between the output electrodes of said vacuum tube amplifier, a pair of transmission lines each having substantially uniformly distributed inductance and capacity connected between said tuned amplifier output circuit and the control grid electrodes of said electron discharge devices, impedances substantially equal to the surge impedances of the respective lines connected between the respective output ends of said lines and the cathodes of said devices for establishing feed back from the output circuit of said vacuum tube amplifier to the control grids of said devices whereby continuous oscillations are set up in said vacuum tube amplifier output circuit, a resistance circuit connected between the screen grid electrodes of said devices, and means for varying the current flow through said resistance circuit in a desired fashion in order to modulate in desired fashion the oscillations appearing in the tuned output circuit of said vacuum tube amplifier.

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