March 9, 1937. P. O. FARNHAM 2,072,945

AMPLIFIER CIRCUIT

Filed March 19, 1931 5 Sheets-Sheet 1

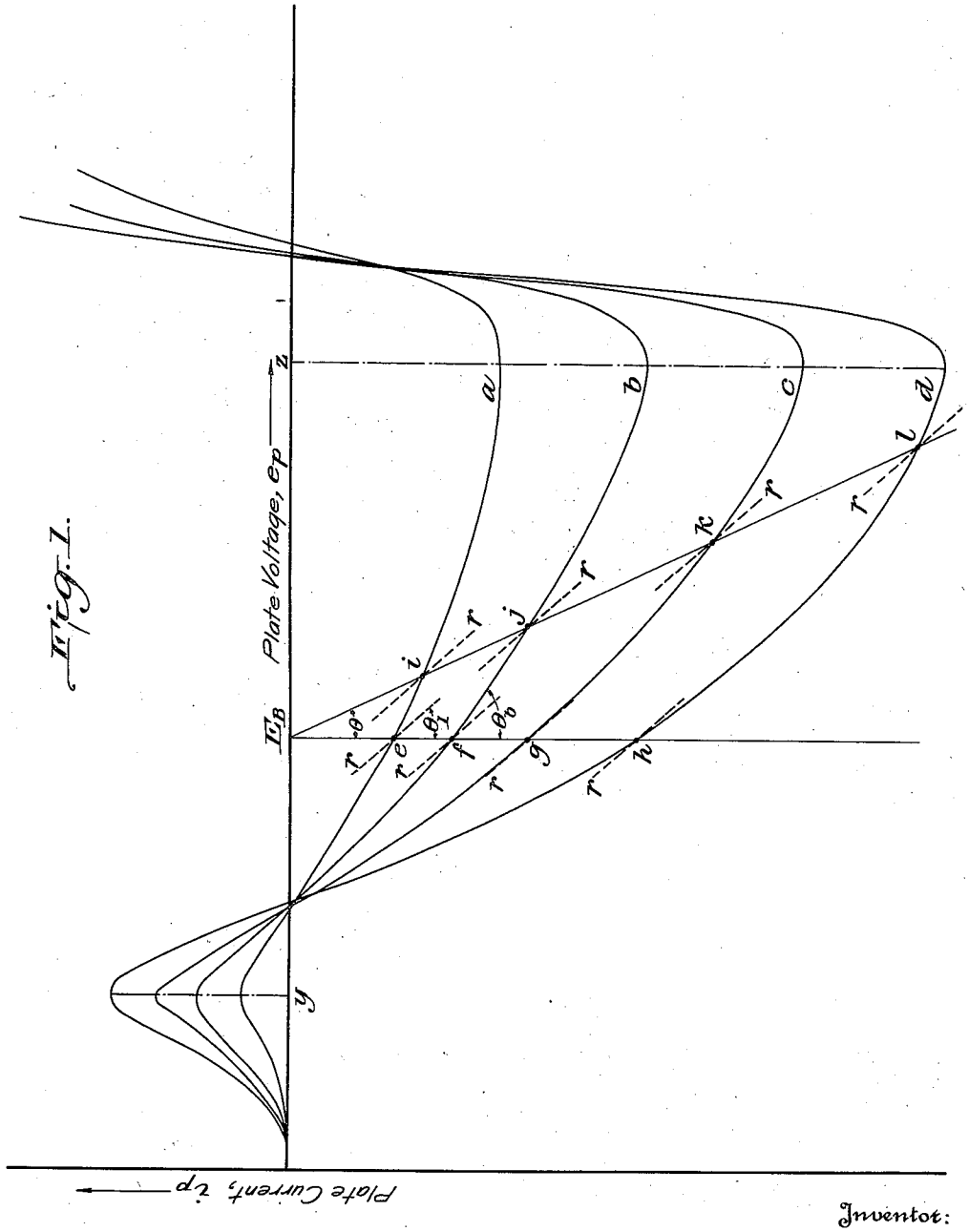


Fig. 1.

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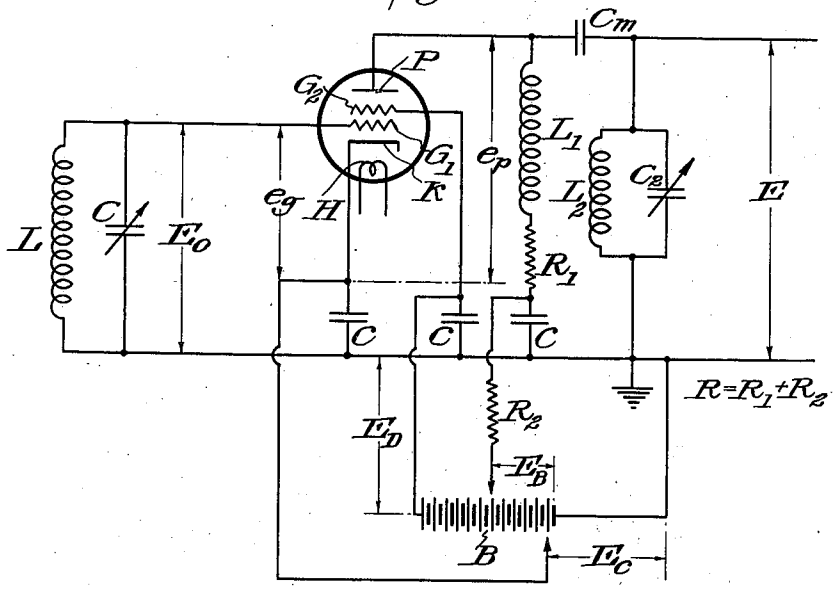
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AMPLIFIER CIRCUIT

Filed March 19, 1931 5 Sheets-Sheet 2

Fig. 2.



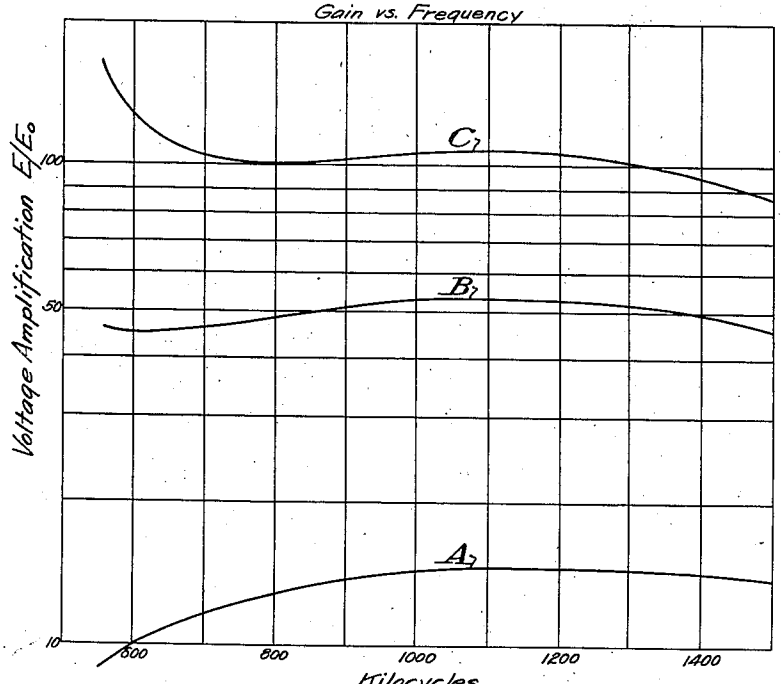


Fig. 3.

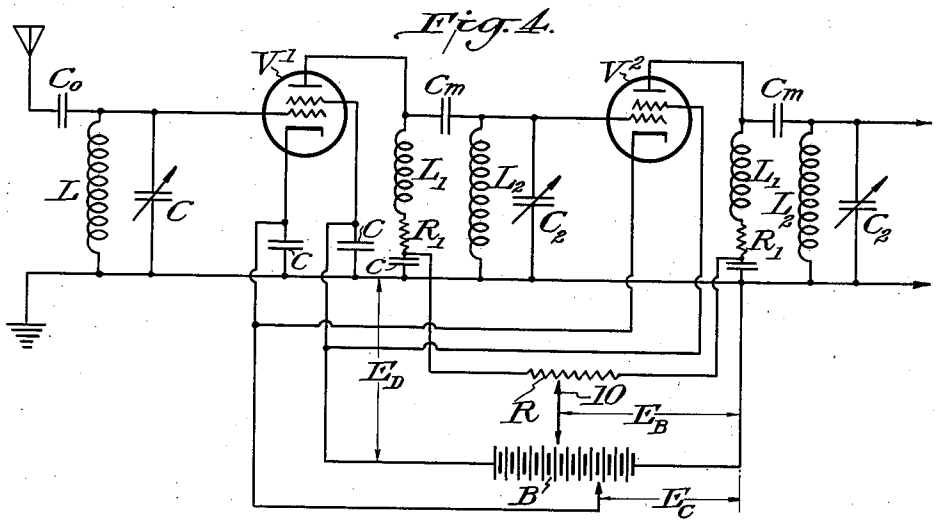
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AMPLIFIER CIRCUIT

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Fig. 4.



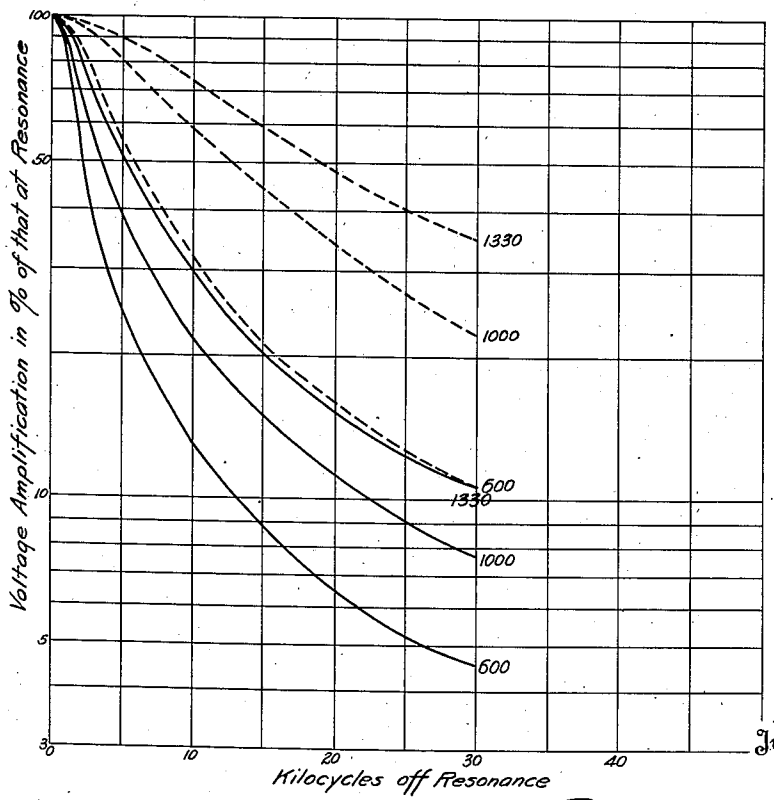


Fig. 5.

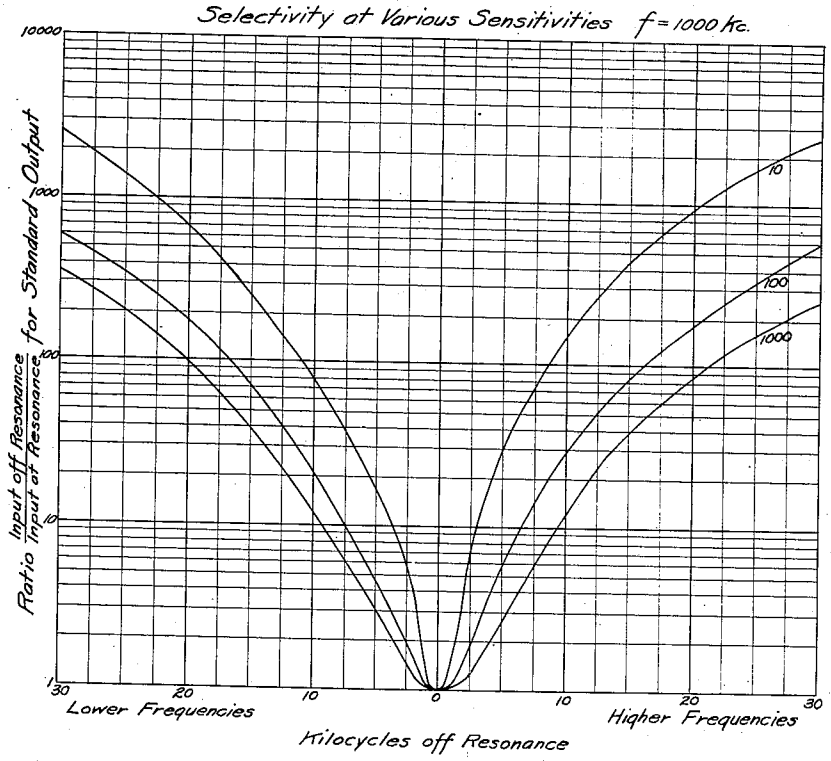
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AMPLIFIER CIRCUIT

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Fig. 6.



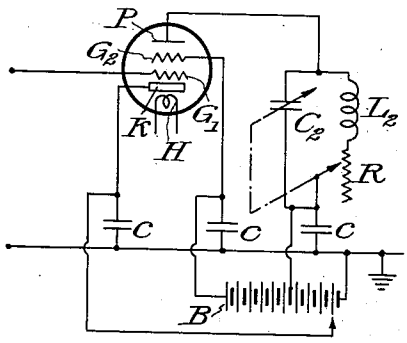


Fig. 7.

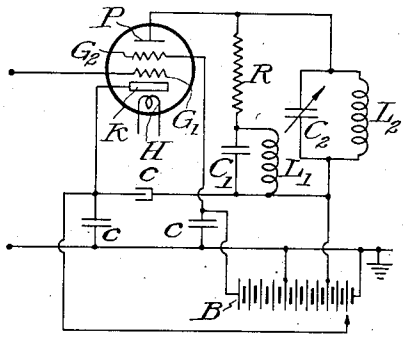


Fig. 8.

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AMPLIFIER CIRCUIT

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Fig. 9.

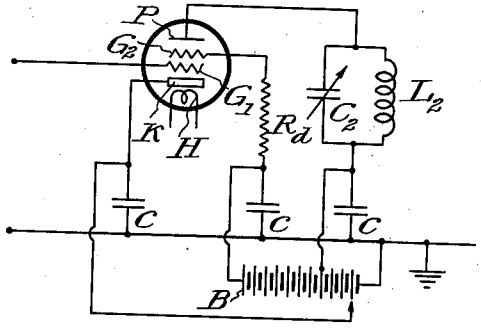


Fig. 10.

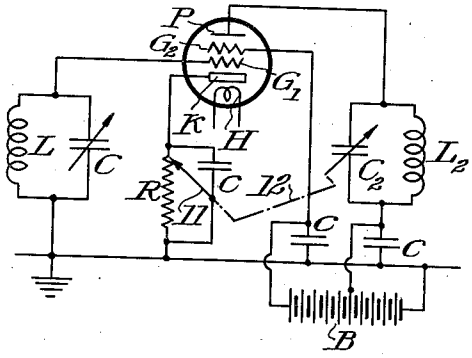
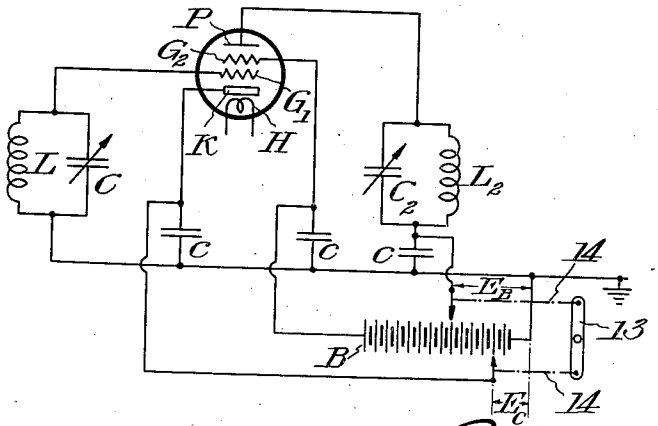


Fig. 11.



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Patented Mar. 9, 1937 2,072,945

UNITED STATES PATENT OFFICE

2,072,945

AMPLIFIER CIRCUIT

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Application March 19, 1931, Serial No. 523,859

30 Claims. (Cl. 179—171)

This invention relates to amplifier circuits and particularly to methods of and circuit arrangements for rendering the dynatron suitable for use in tuned high frequency amplifiers.

The more usual design requirements for a tuned amplifier are freedom from oscillation and freedom from marked variation in gain as the amplifier is tuned over a range of frequencies. For some uses, for example in the case of radio receivers where two or more tuned stages may be cascaded, the requirements are comparatively rigid, as the stability, sensitivity and selectivity of the receiver must be maintained under all operating adjustments to which the receiver may be subjected by an unskilled operator.

Since the conditions which give rise to oscillations, and which cause variations in gain and/or selectivity with changing adjustments of the operating controls in the case of the dynatron are quite different from those which produce disturbing effects in the case of the usual or positive resistance tubes, the known methods of securing stability and satisfactory sensitivity and selectivity characteristics are not applicable to the dynatron. Furthermore, it is well known that a dynatron will act as a satisfactory oscillator when a tuned impedance, of appropriate design, is included in the plate circuit of the dynatron. This accepted use of the dynatron as a generator of oscillations, as well as the peculiar problems encountered in attempting to operate the dynatron in a tuned amplifier have, so far as I am aware, restricted the use of the dynatron amplifier to circuits having a non-reactive plate load, i. e., a plate load consisting of a positive resistance having a magnitude appreciably less than the negative plate resistance of the dynatron.

Objects of the invention are to provide methods of and circuit arrangements for employing the dynatron in amplifier stages of the type having a resonant output circuit. Further objects are to provide methods of and circuit arrangements for employing dynatrons in tuned high frequency amplifiers. Further objects are to provide methods of and circuit arrangements for preventing self-oscillation and for maintaining satisfactory operating characteristics throughout the entire range of operating adjustments of a dynatron amplifier having a tuned output circuit. More specifically, objects of the invention are to provide, in a dynatron amplifier having a tuned output circuit, methods of and circuit elements for automatically maintaining an approximately constant ratio between the magnitude of the plate resistance and the plate load, and/or for automatically preventing that ratio from reaching or exceeding unity.

These and other objects of the invention will be apparent from the following specification, when taken with the accompanying drawings, in which

Fig. 1 is a curve sheet illustrating, for different control grid potentials, the relation between plate current and plate voltage in a dynatron of the tetrode or screen grid type,

Fig. 2 is a circuit diagram of a single stage dynatron amplifier, tunable over a range of frequencies,

Fig. 3 is a curve sheet illustrating the relation between stage gain and frequency, for different control grid bias voltages, in an amplifier such as shown in Fig. 2,

Fig. 4 is a circuit diagram of cascaded dynatron amplifier stages embodying the invention,

Fig. 5 is a curve sheet illustrating the selectivity, for the same gain, obtained with a dynatron amplifier embodying the invention, and with a known amplifier of the positive plate resistance type,

Fig. 6 is a curve sheet illustrating the selectivity of a dynatron amplifier stage for various amplification ratios and at one value of circuit tuning, and

Figs. 7 to 11 inclusive are circuit diagrams illustrating other embodiments of the invention.

The several curves *a*—*d* of Fig. 1 are typical curves showing the relationship existing between plate current and plate voltage in a dynatron of the tetrode type for different values of control grid bias E_c, the characteristic curve *a*, corresponding to a large negative bias, while curve *d*, corresponds to a relatively low negative bias. Assuming that a steady plate supply voltage E_B is selected near the middle of the limits *y*, *z*, of plate voltage within which the plate-cathode resistance of the tube is negative, and that a tuned plate-cathode impedance having a fixed value R_B at resonance is included in the circuit, some of the characteristic properties of a dynatron will be determined from an analysis of the curves of Fig. 1. For the plate supply voltage E_B, the values of plate current for different control grid bias voltages are given by the points of intersection *e*, *f*, *g*, and *h*, respectively, of the ordinate through point E_B, and the several characteristic curves which correspond to bias voltages *a*, *b*, *c* and *d*.

Further, the value of the negative plate resistance at a given bias voltage is represented by the slope of the curve at the point of inter-

section. For example, the plate resistance r_p of the tube for a bias voltage corresponding to curve b and plate voltage E_B is equal to

$$\tan \theta_b \text{ or } \frac{de}{di}$$

at the intersection point f.

Similarly, the magnitude of the external plate load or R_B may be indicated graphically, at each operating point, by drawing through the same the short broken lines r which have a slope equal to $\tan \theta_1$. As the load impedance is assumed to be constant, all of these lines r have the same slope or make the same angle θ_1 with the E_B ordinate.

It can be shown that the voltage amplification for a dynatron amplifier is expressed by the equation:

$$\frac{e_p}{e_g} = \mu_p \frac{\frac{R_B}{r_p}}{1-\frac{R_B}{r_p}} \quad (1)$$

where e_g is the alternating voltage between control grid and cathode, e_p is the alternating voltage between plate and cathode, and

$$\mu_p = \left|\frac{\Delta e_p}{\Delta e_g}\right| \quad (2)$$

for constant plate current with no load between plate and cathode.

Since the load impedance is positive and the plate resistance is negative under all conditions now under consideration, it is evident that the load impedance R_B is always greater than the negative quantity r_p. For convenience of discussion, however, the algebraic sign of these quantities may be neglected in the following explanation by comparing the magnitudes or numerical values of these impedances.

When the plate load is less than the plate resistance, $R_B < r_p$, the tube and associated circuits will operate satisfactorily as an amplifier. Reverting to Fig. 1, it will be seen that this condition obtains at operating points e and f. When the external impedance and plate resistance are equal, $R_B = r_p$, the amplification as given by equation (1) becomes infinite since the term

$$1-\frac{R_B}{r_p}$$

reduces to zero, and oscillation of the system is impending. This condition obtains at operating point g, since the slope of curve c at this point is equal to the slope of the line r through that point. When the load is of greater magnitude than the plate resistance, the system will oscillate. This condition obtains at point h on curve d, i. e., at negative grid bias voltages less than that corresponding to curve c.

It is therefore apparent that a dynatron amplifier having a tuned plate load impedance will oscillate at any frequency for which the plate load is a pure resistance, R_B, that is greater than the plate resistance r_p. This oscillating condition may be reached either by adjusting the control grid bias towards less negative values or by increasing the plate load.

An amplifier system adapted to the selective amplification of signals over a band of frequencies should retain certain features of performance throughout its entire range of adjustment. The amplifier should not oscillate at any adjustment of the amplification control, nor should it oscillate at any frequency to which the system may be tuned.

In accordance with the present invention, the tendency to oscillate as an electrode voltage is adjusted to increase the amplification is overcome by a simultaneous and automatic adjustment of another electrode voltage. One method of obtaining this action, when the amplification rate is controlled by varying the control grid bias, is by introducing into the plate circuit a resistance R of such value, $\tan \theta$, that the plate potential varies with grid bias to avoid conditions favorable for oscillation at any gain control adjustment of grid bias. Referring again to Fig. 1, a consideration of the operating characteristics of the dynatron will show that the operating points, for different grid bias potentials when a direct current resistance $R = \tan \theta$ is included in the plate circuit, may be determined graphically by drawing a line through point E_B and at an angle θ to the ordinate through that point. For control grid bias voltages corresponding to curves a to d, the points of intersection i to l, respectively, indicate the operating points, and it is to be noted that, within the region in which the plate-cathode resistance has a negative resistance, the insertion of a positive resistance in the plate circuit has the effect of impressing upon the plate a direct current voltage which is greater than the plate supply voltage E_B.

By appropriate by-passing of the resistance R for carrier frequencies, the alternating current impedance of the plate load is not affected by the introduction of resistance R and the graphical analysis of the problem of insuring stability of operation may be completed by drawing through points i, h, etc., the lines r to indicate the magnitude of the resistance of the resonant plate load E_B. An inspection of Fig. 1 will show that stable operation has been insured by the insertion of the plate resistance R since, for all values of gain control up to a control grid bias corresponding to curve d, the resonant plate load R_B is less than the plate impedance r_p. Applying the test for oscillation, it is seen that for each indicated operating point, the slope of the line r is less than the slope of the plate current characteristic at that point. By inspection, it will be observed that these slopes approach most closely at the operating point k, which indicates that maximum amplification obtains at a control grid bias indicated by curve c.

Reverting to the question of freedom from oscillation as the output circuit is tuned over a band of frequencies, it has long been recognized that the impedance, at resonance, of a tuned circuit varies with the frequency to which the circuit is tuned. If the plate load impedance R_B should vary widely with the tuning of the output circuit, these variations will be greatly exaggerated in the gain-frequency characteristic of the dynatron stage for a constant value of r_p (i. e. a constant control grid bias as represented by the curves of Fig. 1) as may be seen from an inspection of Equation (1), particularly when R_B and r_p approach equality. Unless due precautions are taken, the tuning of the output circuit may so alter the magnitude of the load impedance that oscillatory conditions are established. Optimum conditions so far as concerns stability of operation with tuning, may be obtained by maintaining a constant ratio between the magnitudes of the external plate load and the plate-cathode resistance. This condition may be realized, either completely or to an extent sufficient to prevent oscillation, by main-

taining the plate load substantially invariant with tuning for a fixed plate resistance, or by varying the plate resistance as a substantially linear function of a varying plate load. In accordance with the first method, the plate circuit includes a compensating or corrective network, in addition to the tuned output circuit, which maintains the load impedance, as viewed from the plate and cathode terminals, substantially independent of the tuning of the output circuit.

One satisfactory embodiment of the invention for securing operation which conforms to the requirements predicated upon Fig. 1 is illustrated diagrammatically in Fig. 2. As indicated by the above discussion, the vacuum tube is of the tetrode or screen grid type having an input circuit which may be a resonant circuit LC connected between control grid G_1 and an equipotential cathode K, which is heated to emitting temperature by a heater H. The source of current supply for impressing voltages on the several tube electrodes is indicated diagrammatically as a battery B, but it is obvious that any suitable source, such as the customary power supply devices, may be employed. As indicated, a negative bias E_c is applied to the control grid, and the screen grid G_2 is connected to a point on the current source at which the voltage E_D is greater than the supply source voltage E_B which determines the plate voltage.

The tuned output circuit L_2C_2 is not connected directly across the plate P and cathode K, but is coupled to the plate through a condenser C_m. The direct current potential from supply source B is impressed upon plate P through a shunt circuit which includes a choke L_1 and resistances R_1 and R_2 which have a total resistance equal to that of resistance $R=\tan\theta$ of the above discussion of Fig. 1. Condensers C are provided to bypass the plate resistance R_2, the screen grid and cathode leads for carrier frequencies.

Many factors such as the type of tube, the maximum gain desired and the frequency range, have a bearing upon the choice of the values of the several circuit elements, but, as illustrative of one practical arrangement, the following values are cited as suitable when a tube of the commercial UY 224 type is employed:

E_B =85 volts
E_c =from −10 to −14 volts
E_D =170 volts
R_1 =2500 ohms
R_2 =15,000 ohms
LC =tunable from 550 to 1500 kilocycles
L_1 =2.75 millihenries
C_m =about 15 micromicrofarads
L_2 =approximately 220 microhenries
C_2 =adjustable from 40 to 440 micromicrofarads
C =approximately 0.5 microfarad

The inductance L_1, resistance R_1 and associated condenser C form one path from plate to cathode, with a second path through the coupling condenser C_m and parallel tuned circuit L_2C_2. The resistance R_1 is necessary to prevent oscillation at a frequency determined substantially by the choke L_1 in shunt with C_m and the inherent plate-cathode capacity of the tube. It is also useful in holding down the value of the load impedance at the lower end of the frequency band. The combined resistances R_1 and R_2 act to increase the plate voltage, for a constant plate supply voltage E_B, as the control grid bias E_c is reduced to increase the stage gain. The curves A, B and C of Fig. 3 indicate the observed relation between gain and frequency for three different adjustments of the control grid bias E_c in the dynatron circuit shown in Fig. 2. Since the gain is approximately independent of frequency, it is apparent from a consideration of Equation (1), that the value R_B is substantially independent of frequency. The observed performance of this dynatron stage therefore demonstrates that the parallel circuit through which the direct current potential is applied to the plate acts as a compensating circuit which maintains the effective external load impedance substantially independent of the tuning of the resonant output circuit L_2C_2. This is decidedly in contrast with the conventional positive resistance amplifier circuits which would exhibit a variation of maximum stage gain of from about 40 at the low frequency end to about 70 at the high frequency end of the frequency range of from 550 to 1500 kilocycles.

Two or more stages of dynatron amplification may be readily cascaded in accordance with the present invention. One convenient circuit arrangement is illustrated in Fig. 4, in which the circuit elements of each stage may be, and except as here specified are preferably, substantially identical with the corresponding elements of Fig. 2. The tuned input circuit LC of the first dynatron V^1 is coupled through the condenser C_0 to the collecting structure which is diagrammatically shown as an antenna system. The general arrangement of the stage elements is as shown in Fig. 2 and the various elements are identified by the same reference characters. The novel feature peculiar to the cascading of two dynatron stages resides in the provision of a resistance R which is shunted across the low potential terminals of the resistances R_1 of the cascaded stages. An adjustable tap 10 on this resistance R is connected to the direct current supply source B to impress a direct current voltage upon the plates P of the cascaded tubes V^1 and V^2. The significance of this arrangement is that the total resistive impedance in the plate circuits of the respective dynatrons may be so adjusted that the tube characteristics are equalized to give maximum gain at the same value of the common control grid bias E_c.

In both of the described embodiments of the invention the frequency uniformity of gain is accompanied by a further operative improvement which is indicated by the selectivity curves of Figs. 5 and 6. This improvement in selectivity may be considered as resulting from a decrease in the net positive resistance of the tube and output circuit as a whole, and becomes greater as the load impedance approaches the magnitude of the plate resistance. Hence when the stage gain is increased by using less control grid bias E_c, and

$$\frac{R_B}{r_p}$$

approaches unity, the selectivity increases. This is a desirable condition and in marked contrast to the conventional positive resistance circuits since greater selectivity is required when weak signals are to be received. At the same time, this increase in selectivity tends to reduce the high audio frequency components of the noise output of the receiver and thus acts as an automatic audio transmission or tone control. Furthermore, the selectivity of a dynatron amplifier stage may be made, in accordance with this in-

vention, substantially more uniform over the tuning range than in the case of the positive resistance tube and tuned circuit.

The solid line curves 600, 1000 and 1330, of Fig. 5 indicate the selectivity of the dynatron circuit of Fig. 2 for signals of these three frequencies and for the same amplification. The dotted line curves identified by the same numbers indicate the selectivity of a typical radio frequency amplifier stage of the positive plate resistance type for the same amplification. It will be noted that the selectivity of the dynatron amplifier is superior to that of the positive resistance amplifier, and that there is less variation with frequency in the case of the dynatron.

The curves of Fig. 6 show the relation between amplification and selectivity at a single frequency of 1000 kilocycles. The lower curve, identified by reference numeral 1000, shows the selectivity for a stage input, E_0, of 1000 microvolts, the curves 100 and 10 being corresponding selectivity curves for input voltages of 100 and 10 microvolts, respectively, with the amplifier gain increased to maintain a constant output level. It will be noted that the selectivity increases rapidly as he stage gain is increased for decreasing signal strength.

Other circuit arrangements may be employed for maintaining the desired ratio between plate load impedance and plate resistance and some appropriate designs are shown in Figs. 7 to 11 inclusive. The circuit elements which are, or may be, substantially identical with those shown in Fig. 2 are identified by the same reference characters but will not be described in detail.

As shown in Fig. 7, the tuned output circuit is not a simple parallel tuned circuit, but includes an adjustable resistance R in series with the inductance L_2, the adjustable tap of the resistance being mechanically connected to the adjustable element of the tuning condenser C_2. The rate of variation of the effective value of R with tuning is so chosen that the impedance at resonance, R_B, remains approximately constant over the tuning range.

In the arrangement shown in Fig. 8 a corrective network comprising resistance R in series with a parallel L_1C_1 circuit is in shunt with the tuned output circuit L_2C_2. The general operation of the circuit is similar to that of Fig. 2, and, by appropriate choice of the values of the elements of the shunt circuit, the impedance of the composite output circuit, as viewed from the plate and cathode terminals, may be maintained substantially independent of frequency.

The circuit of Fig. 9 includes a resistance R_d between the screen grid G_2 and the current source B. The effect of resistance R_d is to alter the shape of the current-voltage curves as the control grid bias E_c is adjusted to control amplification, due to the automatic change in screen grid potential obtained by the voltage drop across R_d. By introducing sufficient resistance in the screen grid circuit, the screen grid voltage will be reduced at such a rate that the plate resistance r_p is greater than the plate load for all values of control grid bias.

The circuit illustrated in Fig. 10 provides for an automatic change in the magnitude of the plate resistance r_p with the changing value of the load impedance R_B as the circuit L_2C_2 is tuned over the band of frequencies. The control grid bias is determined by the cathode bias resistor R and the effective magnitude of this resistor is varied automatically with tuning by connecting the adjustable tap 11 of the resistor with the adjustable element of condenser C_2, as indicated by broken line 12. The resistance R may be varied wtih frequency at such rate that

$$\frac{R_B}{r_p}$$

remains substantially constant, thus ensuring substantially uniform gain at all frequencies, or the ratio may vary with frequency provided r_p is never less than R^B.

In the circuit arrangement illustrated in Fig. 11, the control grid bias E_c and plate voltage E_B are varied simultaneously to ensure that the plate load will not be greater than the plate resistance for any operating adjustment of the amplifier. As indicated diagrammatically by the lever 13 and broken lines 14, the cathode and plate circuit taps to the supply source B are mechanically connected to increase the plate supply voltage E_B as the bias voltage E_c is reduced to increase the stage gain. Referring again to Fig. 1, it will be apparent that plate supply voltage E_B may be increased at such rate as to effect operation at points *i*, *j*, *k* and *l*, as the control grid bias is successively decreased to values corresponding to curves *a* to *d*, respectively.

To those familiar with the design and operation of amplifier circuits, it will be apparent that the described methods for securing stability of operation, and/or a predetermined gain-frequency characteristic, may be carried out with other circuit arrangements. While a substantially uniform gain for all frequencies is usually desirable, it is obvious that the invention provides a method of securing other gain-frequency characteristics if such are desired for special uses.

In the following claims, the term "plate load impedance" refers to the impedance, at resonance, of the output network as viewed from the plate and cathode terminals of the tube; and the term "plate impedance" is used in its customary sense to identify the internal impedance, r_p, of the tube.

I claim:

1. In a dynatron amplifier, the combination with an electron tube and means for applying to the elements thereof potentials effective to give the same a negative plate resistance, of a tuned output circuit connected to the plate electrode of said tube, and means rendering the ratio of plate load impedance to plate resistance substantially independent of the frequency to which said output circuit may be tuned.

2. The invention as set forth in claim 1, wherein said means comprises circuit elements cooperating with said tuned output circuit to render the plate load impedance substantially independent of the frequency adjustment of said tuned output circuit.

3. The invention as set forth in claim 1, wherein said means comprises circuit elements constituting a path between plate and cathode in shunt with said tuned output circuit.

4. The invention as set forth in claim 1, wherein said means comprises a resistance constituting a series element between the cathode and a tube electrode upon which the direct current potential is more positive than that of the tube cathode.

5. An amplifier circuit comprising a tube and means applying to the electrodes thereof direct current potentials effective to give the plate impedance a negative characteristic, and an output

network for said tube, said output network including impedances providing two parallel paths between plate and cathode, one path comprising an inductance and resistance serially connected between the plate and the source of plate current supply, the second path comprising a tuned output circuit coupled to said plate through a capacity.

6. The invention as defined in claim 5, wherein a condenser is connected between a point in said resistance and ground to by-pass a portion of said resistance and the plate current supply for alternating currents of frequencies within the tuning range of said output circuit.

7. In a dynatron amplifier, the combination with an electron tube and means energizing said tube for dynatron operation, of a tuned output circuit whose impedance at resonance varies with the frequency to which said circuit is tuned, and means other than said tuned circuit for automatically varying the plate impedance of the tube as the output circuit is tuned over its frequency range.

8. In a dynatron amplifier, the combination with an electron tube and means energizing said tube for dynatron operation, of a tuned output circuit whose impedance at resonance varies with the frequency to which said circuit is tuned, means for automatically varying the plate impedance of the tube as the output circuit is tuned over its frequency range and at such rate that the ratio of plate load impedance to plate impedance remains approximately constant.

9. In a dynatron amplifier, the combination with an electron tube and means energizing said tube for dynatron operation, of a tuned output circuit whose impedance at resonance varies with the frequency to which said circuit is tuned, and means for automatically varying the direct current potential applied to one of the tube electrodes as the output circuit is tuned over its frequency range.

10. The invention as set forth in claim 9, wherein said means includes an adjustable circuit element for varying the control grid bias, and a mechanical connection between said adjustable circuit element and the variable element of said tuned circuit.

11. In an amplifier, a pair of cascaded stages comprising a pair of electron tubes energized to operate as dynatrons, a tuned output circuit for each tube, means for effecting a simultaneous adjustment of the gain of each stage, and adjustable means determining the relative rates at which the gain of the stages is affected by the action of said first means.

12. In an amplifier, a pair of cascaded stages comprising two electron tubes energized to operate as dynatrons, a tuned output circuit for each tube, and means associated with each stage for preventing oscillation thereof, said means including circuit elements adjustable to determine the relative gain of the individual stages.

13. A cascaded dynatron amplifier comprising a pair of electron tubes energized to operate as dynatrons, a tuned output circuit for each of said tubes, a connection from the plate of each tube to a source of plate current supply, said connections being in parallel with the tuned output circuit of the respective tubes and including inductance and resistance, means for adjusting the amplification of said tubes, and means for varying the resistance included in one of said connections, thereby to provide a second amplification control for the tube associated with said adjustable resistance.

14. A cascaded dynatron amplifier, comprising the combination with two tubes energized to operate as dynatrons, a tuned circuit coupling the two tubes, a tuned output circuit for the second tube, of means for preventing oscillation of either tube, said means comprising a circuit coupled between the plates of the said tubes and comprising an inductance connected to the plate of each tube and three resistances serially connected between the said inductances, an adjustable tap on the center resistance of said three resistances and connected to the source of plate current supply and capacities by-passing said center resistance for alternating currents of frequencies within the tuning range of said tuned circuits.

15. In combination, a dynatron amplifier tube network provided with a high frequency input circuit and a load circuit coupled to the amplifier anode, an adjustable circuit element connected to one of the electrode circuits of said amplifier, the ratio of load impedance to tube impedance varying with adjustment of said adjustable element, and means for maintaining said ratio substantially less than unity as said element is adjusted.

16. In combination, a dynatron amplifier tube network provided with a high frequency input circuit and a load circuit coupled to the amplifier anode, an adjustable circuit element connected to one of the electrode circuits of said amplifier, the ratio of load impedance to tube impedance varying with adjustment of said adjustable element, and means for maintaining said ratio substantially less than unity and substantially constant as said element is adjusted.

17. In combination, a dynatron amplifier tube network provided with a high frequency input circuit and a load circuit coupled to the amplifier anode, an adjustable circuit element connected to one of the electrode circuits of said amplifier, the ratio of load impedance to tube impedance varying with adjustment of said adjustable element, and adjustable means simultaneously operative with said adjustable element for maintaining said ratio substantially less than unity as said element is adjusted.

18. A method of controlling the gain of a dynatron amplifier which consists in varying in an increasingly negative potential direction the control grid bias thereof to reduce the amplifier gain, and simultaneously varying the potential on another electrode in an increasingly positive sense to maintain the internal plate resistance of the amplifier more nearly independent of the variation of said grid bias.

19. In combination with a screen grid tube provided with input and output circuits and means for applying potentials to the tube electrodes such that the tube and circuits provide a dynatron network, a volume control element connected to the control grid of the tube, and an additional element, responsive to adjustment of said control element, for varying the potential of an electrode other than said control grid.

20. In combination with a screen grid tube provided with input and output circuits and means for applying potentials to the tube electrodes such that the tube and circuits provide a dynatron network, a volume control element connected to the control grid of the tube, and an additional element, responsive to adjustment of said control element, for varying the potential of an elec-

trode other than said control grid in a direction to maintain the network free of any tendency to produce oscillations.

21. In a dynatron amplifier, the combination with an electron tube and means energizing said tube for dynatron operation of a tuned output circuit whose impedance at resonance varies with the frequency to which said circuit is tuned, and means in said output circuit for maintaining the total impedance of said output circuit substantially constant during tuning.

22. In a dynatron amplifier, the combination with an electron tube and means energizing said tube for dynatron operation of a tuned output circuit whose impedance at resonance varies with the frequency to which said circuit is tuned, and means in said output circuit for maintaining the total impedance of said output circuit substantially constant during tuning, said means comprising an aperiodic reactive network.

23. In a dynatron amplifier, the combination with an electron tube and means energizing said tube for dynatron operation of a tuned output circuit whose impedance at resonance varies with the frequency to which said circuit is tuned, and means in said output circuit for maintaining the total impedance of said output circuit substantially constant during tuning, said means comprising an aperiodic reactive network in series in said output circuit.

24. In a dynatron amplifier, the combination with an electron tube and means energizing said tube for dynatron operation of a tuned output circuit whose impedance at resonance varies with the frequency to which said circuit is tuned, and means in said output circuit for maintaining the total impedance of said output circuit substantially constant during tuning, said means comprising a network whose effective resistance varies with variation of tuning.

25. In a dynatron amplifier, the combination with an electron tube and means energizing said tube for dynatron operation of a tuned output circuit whose impedance at resonance varies with the frequency to which said circuit is tuned, and means in said output circuit for maintaining the total impedance of said output circuit substantially constant during tuning, said means comprising an aperiodic network whose effective resistance increases with decreasing frequency.

26. In a dynatron amplifier, the combination with an electron tube and means energizing said tube for dynatron operation of a tuned output circuit whose impedance at resonance varies with the frequency to which said circuit is tuned, and means in said output circuit for maintaining the total impedance of said output circuit substantially constant during tuning, said means comprising a network consisting of a resistor shunted by a capacity whose effective resistance increases with decreasing frequency whereby the total impedance of said output circuit is maintained substantially constant over the tuning range of said circuit.

27. In a dynatron amplifier, the combination with an electron discharge tube and means energizing said tube for dynatron operation, of a tuned output circuit whose impedance at resonance varies with the frequency to which said circuit is tuned, and an aperiodic reactive network having one end thereof connected to the anode of said tube and the other end thereof to the said tuned circuit for maintaining the effective impedance of said circuit substantially constant as the output circuit is tuned over its frequency range.

28. A method of controlling the gain of a screen grid amplifier which consists in varying the control grid bias thereof in an increasingly negative potential direction to reduce the amplifier gain, and simultaneously varying the potential on another electrode in an increasingly positive sense to maintain the internal plate resistance of the amplifier more nearly independent of the variation of said grid bias.

29. A method of controlling the gain of a screen grid amplifier which consists in varying the control grid bias thereof in an increasingly negative potential direction to reduce the amplifier gain, and simultaneously varying the potential on the plate electrode in an increasingly positive sense to maintain the internal plate resistance of the amplifier more nearly independent of the variation of said grid bias.

30. In combination with a signal frequency amplifier including a tube provided with at least a cathode, signal input grid, positive screen grid and positive plate, a tunable signal input circuit connected between the input grid and cathode, a tunable signal output circuit coupled to the plate and cathode of said tube, means for varying the potential difference between said input grid and cathode over a desired range of values to adjust the gain of the tube, and a network electrically associated with the plate circuit of said tube having its constants so chosen that the amplifier load impedance approaches the magnitude of the plate circuit resistance as the tube gain is increased whereby the selectivity of the signal amplifier is a maximum when the gain varying means is adjusted to secure maximum amplifier gain.

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