

Sept. 14, 1937.

H. O. PETERSON
RADIO FREQUENCY AMPLIFIER

2,093,094

Filed Oct. 31, 1932

2 Sheets-Sheet 1

Fig. 1

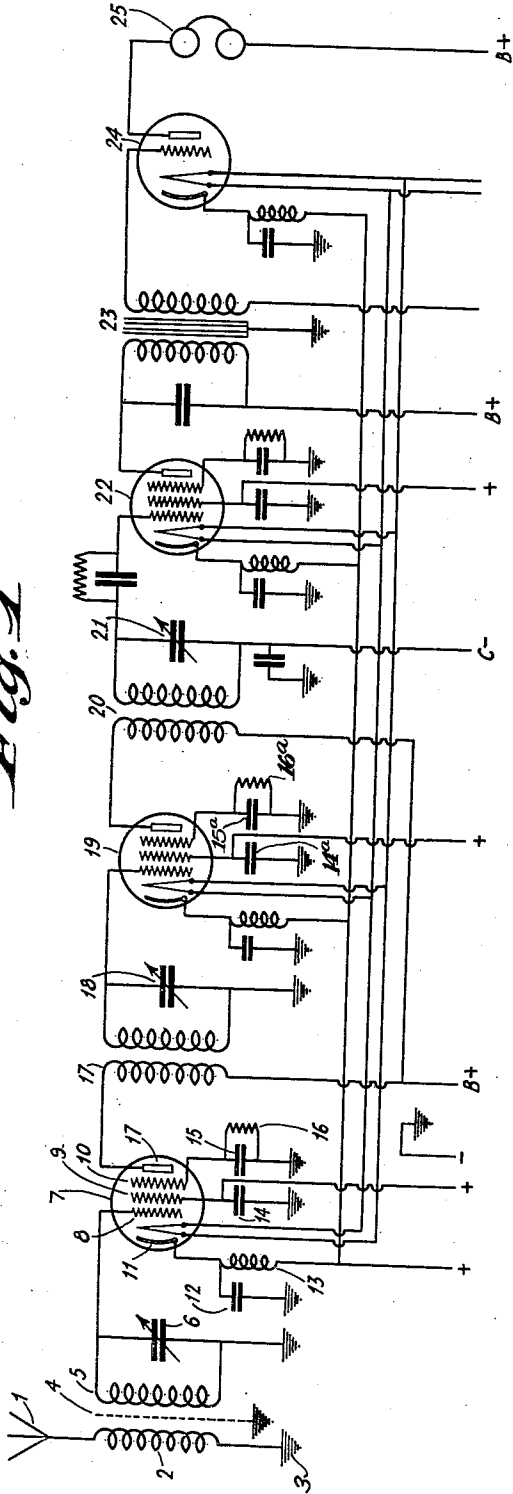


Fig. 2

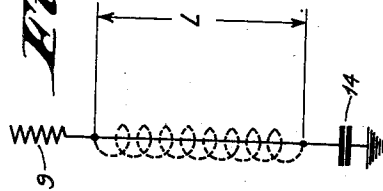
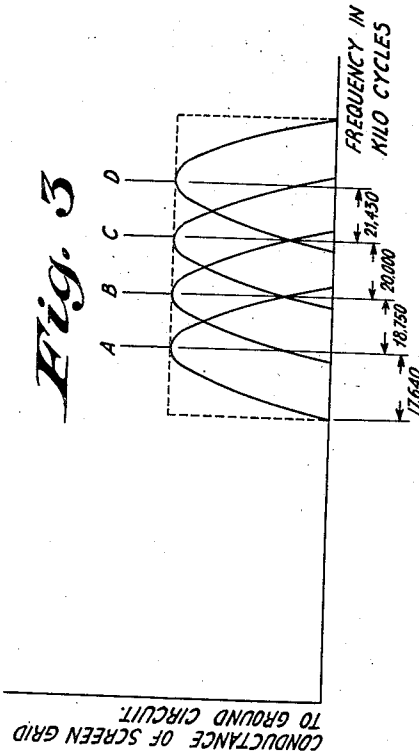


Fig. 3



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Fig. 4

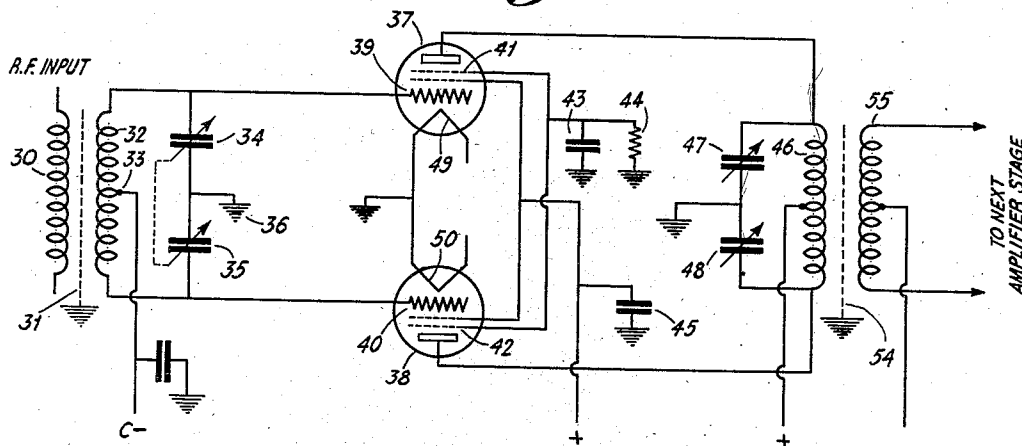


Fig. 5

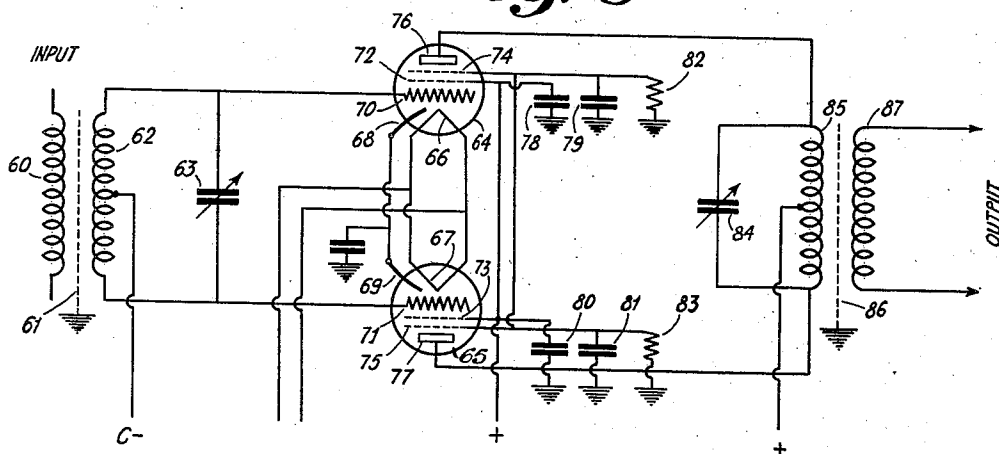
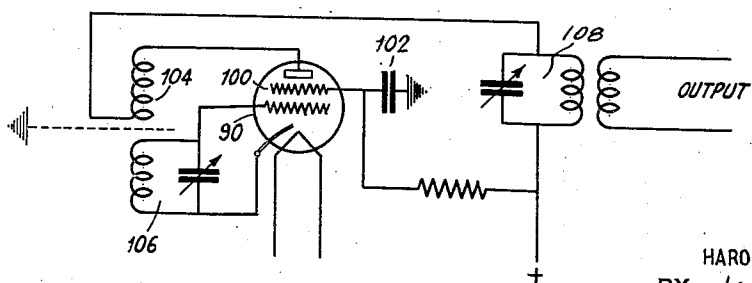


Fig. 6



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RADIO FREQUENCY AMPLIFIER

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Application October 31, 1932, Serial No. 640,384

16 Claims. (Cl. 179-171)

This invention relates to improvements in amplifier circuits, and more particularly to tube amplifiers which are operated at high radio frequencies.

It is an object of this invention to improve radio frequency amplifier circuits using tubes of the screen grid and pentode type, whereby they will operate more stably at very high frequencies.

Vacuum tubes of the screen grid type have for a number of years been used quite effectively for the amplification of very high radio frequencies. I have noted however, that such radio frequency amplifiers do not always operate with perfect stability at some of the high frequencies for which they have been designed. Since such amplifier units are generally very well shielded and all supply leads effectively filtered, it is believed that the instability observed is due to residual capacity coupling from plate to grid. The effective value of plate to grid capacity coupling becomes more and more effective as a means for producing regenerative oscillations as frequency is increasing, for the reason that the reactance of a given amount of capacity coupling decreases with increase of frequency. There is also another effect which tends to increase the effective value of plate to grid capacity in screen grid tubes. This other effect is due to the inherent inductance of the wire within the tube between the screen and the base. Measurements indicate that the inductance of the length of wire leading from the screen and the base in a typical tube of the screen grid type is approximately 0.1 microhenry. At very high frequencies the reactance of this amount of inductance becomes appreciable and it is found that the customary by-pass condenser no longer effectively ties the screen grid directly to ground for radio frequencies. The effect of this inductive reactance is to increase the plate to grid capacity thus causing instability.

To overcome the foregoing difficulty is the principal object of my present invention. To do so, I replace the ordinary large by-passing condenser with a smaller one of such a value as to series resonate with the inductance of the screen grid and/or suppressor grid leads whereby either or both of these grids are maintained at ground potential at the signal or other frequencies at which regeneration occurs, thereby preventing feed back through the inter-element capacity of the tube or tubes as the case may be.

That is to say, heretofore such grids as the screen grid of a tetrode or pentode tube were by-passed to ground by means of a large condenser. This condenser offered no appreciable

hindrance to radio frequency currents, and therefore at the lower radio frequencies, the screen grid was effectively maintained at ground radio frequency potential as a result of which there could be no inter-element or capacity feed back from the plate to control grid which might give rise to undesired parasitic oscillation generation. However, at higher frequencies, these ordinary by-passing condensers offer still less impedance to radio frequency currents, as a result of which the screen grid grounding circuit becomes one wherein the screen grid, due to the appreciable inductance of the screen grid lead, is maintained not at ground radio frequency potential, but at some appreciable radio frequency potential. Consequently, at high operating frequencies undesired regenerative action takes place, tending to make the amplifier oscillate at the frequency to which it is tuned.

As already indicated to some extent, this undesirable tendency to oscillate is eliminated by connecting the screen grid to ground through a condenser of such value as to resonate with the inductance of the screen grid lead at the frequency on which the tendency to oscillate is experienced. This series resonance effect will reduce the tendency to oscillate over a band of frequencies centering about the frequency to which the screen by-passing circuit is tuned. Now, if it is desired to stabilize an amplifier over a considerable band of frequencies several such series resonance circuits might be employed in the amplifier system, each tuned to a different frequency and these resonance frequencies distributed at discreet intervals throughout the frequency band over which it is necessary to provide these stabilizing means, depending of course upon having available several screens to which this application may be applied, as for instance, in a multi-staged RF amplifier. In the case of r. f. pentodes, such as the "Radiotron 57", series resonance may be applied to the suppressor circuit as well as to the screen, thus affording two different frequencies of series resonance per tube. In different radio frequency amplifier stages, similar tuned circuits operating at different frequencies may be set up, and, in the event that the series tuning effect of each grid is found too sharp, the series resonant curve characteristic of each grounding connection may be broadened, for example, by paralleling the grid lead tuning condenser with a resistance. If desired, this resistance may be placed in series with the condenser and/or a lumped inductance may be connected in parallel or in series with the condenser to still

further vary the frequency or frequency band at which the grids are maintained at ground potential through series resonance effects.

Referring now to the drawings which more specifically describe my invention,

Fig. 1 is a wiring diagram of a conventional short wave radio frequency receiver amplifier employing screen grid tubes;

Fig. 2 is a diagram of a grid grounding circuit;

Fig. 3 is a curve showing a desirable over-all characteristic which may be obtained by the use of my invention;

Fig. 4 is a wiring diagram of a push-pull radio frequency amplifier utilizing the features of my invention;

Fig. 5 is a wiring diagram of another modification of a push-pull radio frequency amplifier utilizing the features of my invention, and

Fig. 6 is a wiring diagram of an oscillator utilizing the features of my invention.

Referring to the conventional radio frequency amplifier receiver shown in Fig. 1, the antenna 1 energizes the input circuit 5, 6 through inductance 2 grounded at 3. A suitable shield 4 is interposed between the antenna primary inductance 2 and the secondary inductance 5. The input circuit is tuned by a variable condenser 6. The vacuum tube 7 of the first radio frequency stage is of the "Pentode" type having in addition to the customary control grid 8 a screen grid 9 which normally prevents feed back and, consequently, undesired parasitic oscillation generation. A suppressor grid 10 suppresses the secondary emission from the plate. The cathode 11 is by-passed to ground by a condenser 12 and is also provided with a radio frequency choke 13. The screen grid 9 is by-passed to ground by a condenser 14. The suppressor grid 10 is by-passed to ground by a condenser 15 and resistance 16 connected in parallel. To accomplish the results of my invention a proper predetermined selection of the correct values of capacity is necessary for the by-pass condensers 12, 14 and 15, as will be explained in further detail later.

Other parts of the receiver circuit are the RF transformer 17, tuning condenser 18, second radio frequency amplifier tube 19, radio frequency transformer 20, tuning condenser 21, detector tube 22, audio frequency transformer 23 and audio tube 24, which are connected to phones 25.

No further description of the receiver circuit is deemed necessary as its operation should be apparent to those skilled in the art.

Referring now to Fig. 2, the screen grid lead of length L has an appreciable inductance at very high frequencies. This effective inductance is indicated by the dotted inductance coil. To offset the resultant objectionable inductive reactance at very high frequencies I propose to tune this length of lead L by connecting the lead of the screen grid 9 to ground with a condenser 14 having a capacitive reactance equal and opposite to the inductive reactance of the lead L so that the lead and condenser will series resonate at the operating frequency. Since the addition of a variable condenser at this portion of the circuit would add complication to the tuning of the radio frequency amplifier, I propose to insert fixed predetermined values of capacity to each lead, to be resonant at a different frequency in the range over which trouble from instability has been experienced. For example, in a receiver

having a range of from 14 to 18 meters, by my invention I tune each of the screen grid leads with suitable condensers to a different frequency in the troublesome range which is, of course, included in the overall operating frequency range of the amplifier. Thus, condenser 14 is of such a capacity value as to resonate with the inductance of lead L at a wave length of 14 meters or a frequency of 21,430 kilocycles. Correspondingly, the value of condenser 15 is chosen so as to series resonate with its grid lead at 15 meters or a frequency of 20,000 kilocycles. Condenser 14a is chosen in value to series resonate with its grid lead at 16 meters or 18,750 kilocycles. Condenser 15a tunes its grid lead to 17 meters, or 17,640 kilocycles. Similarly, the other grid condensers are chosen to resonate at different frequencies at which parasitics tend to occur. For the entire receiver a form of band stabilizing characteristic such as shown by the curve in Fig. 3 is obtained, the over-all stabilizing characteristic being indicated by the dotted lines. Frequencies of this band are effectively grounded so that regeneration cannot occur. It will be noted from the curve that each of the condensers 14a, 15a, 14 and 15 cause grid lead tunings such as indicated by the overlapping curves A, B, C and D. However, it is not necessary that each characteristic curve overlap as one may tune all grid grounding circuits alike and get a suitable width or band pass by a suitable choice of constants, as, for example, by paralleling each condenser with a resistance.

Thus, resistances 16 and 16a have been placed in parallel with the suppressor grid series tuning condensers. To further vary the band pass, lumped inductances may be used.

Fig. 4 shows a push-pull radio frequency amplifier stage having a primary input coil 30, electrostatic shield 31, secondary coil 32 which is connected at its center 33 to -C, the secondary coil being tuned by variable uncontrolled condensers 34 and 35 which are connected to ground at 36. The tubes 37 and 38 have control grids 39 and 40 connected in phase opposition to the secondary coil 32. The suppressor screen 41 and 42 of both tubes are connected to ground through a tuning condenser 43 paralleled by resistance 44. Likewise, the screen grids of both tubes are connected to ground by a tuning condenser 45. The plate of tubes 37 and 38 are connected to the primary coil 46 of the next stage which is also tuned by a pair of variable condensers 47 and 48. The tubes also have cathodes 49 and 50 grounded as indicated. A shield 54 is interposed between the primary coil 46 and secondary coil 55. The condenser 43 tunes the suppressor grid structure to series resonate at a frequency about which stabilization is desired. Similarly, condenser 45 tunes the screen grid leads to the same or to another frequency.

The modification shown in Fig. 5 is also a push-pull radio frequency amplifier stage, but differs from that of Fig. 4 in that each screen grid and suppressor grid has an individual grid lead tuning condenser which are adjusted to the same, widely different, or adjacent or overlapping frequency bands at which parasitics tend to occur.

Referring to Fig. 5, the circuit comprises primary input coil 60, shield 61 and secondary 62, which is connected at its center to -C. The entire secondary is tuned by a variable condenser 63. Tubes 64 and 65 are of the triple grid type, having, if desired, separate heater filaments 66

and 67 with heated cathodes 68 and 69. Tubes 64 and 65 also have control grids 70 and 71, screen grids 72 and 73, suppressor grids 74 and 75, and plates 76 and 77. The individual by-pass condensers 78, 79, 80 and 81 are of predetermined capacity in order to tune to series resonance the respective grid leads. The use of separate condensers, of course, presents the advantage of individual adjustment of each tube. The resistances 82 and 83 of Fig. 5 maintain the suppressor grids at a suitable unidirectional potential in respect to the cathode, as well as broadening the series tuned circuit formed of grid lead and condenser. Other parts of the circuit are the tuning condenser 84, primary coil 85, shield 86 and secondary output coil 87.

While Fig. 1 shows a complete circuit of a conventional radio frequency amplifier, it is to be understood that other forms of circuits may be employed with the grids of their respective stages tuned to the operating or parasitic range of frequencies as described above. It is also to be understood that the circuits may be located in shielded compartments and the power supply leads thoroughly filtered against potential variations. Also, the individual by-pass condensers of the push-pull arrangements may be selected purposely to tune each grid lead to the different band pass frequencies so as to accomplish the overlapping effect as shown by the curve in Fig. 3.

It is to be clearly understood that my invention is not limited to circuits used in radio receivers, but may be applied equally as well to higher powered circuits such as radio transmitters. In that event, the input coil 30 of Figure 4 would indicate a source of radio frequency energy to be transmitted, and the final output coil 46 of the stage represented in Figure 4 would feed energy to a succeeding transmitter stage or antenna.

Similar remarks are applicable to Figure 5. Also, my present invention may be applied to frequency multiplier stages of a transmitting system in which case Figures 4 and 5 by suitable choice of grid bias applied through the minus C lead and by suitable tuning of the output circuits to harmonic frequencies may be made to act as frequency multipliers. More specifically, by impressing a high negative bias upon the grids 39, 40 of Figure 4 through the minus C lead and coil 32 such that only positive peaks of applied input potential from primary coil 30 cause plate current to flow, then odd harmonics may be obtained in the output circuit consisting of coils 46 and condensers 47 and 48 by suitably tuning them to the harmonic frequency. For even harmonics the plates of tubes 37, 38 would be connected in parallel and then feed in such parallel relation to a suitable parallel tuned circuit having a variable condenser and inductance coil connected in parallel.

To prevent parasitic oscillation generation in a system such as shown in Figure 4 when used as a frequency multiplier the screen grids would be grounded as illustrated through condenser 45 of such a value as to tune the screen grid inductance structure so as to series resonate at some parasitic frequency. To broaden the series tuning effect, the condenser 45 may, of course, be paralleled with a suitable resistance, and the parallel combination may be further paralleled by a suitable inductance coil or connected in series with an inductance coil to give the desired operating characteristic.

However, it is preferable, as shown in Figure 5,

when the arrangement is used for higher powered amplification or harmonic frequency production, to use separate grounding condensers for each grid lead structure of each tube in order to provide for separate adjustments. By tuning each grid lead, that is to say, the grid leads to the suppressor grids and screen grids, to a different band of frequencies as indicated by curves a, b, c, and d of Figure 3, an over-all characteristic for the push-pull arrangement shown in Figure 5 will be obtained as shown by the dotted lines in Figure 3. This dotted line indicates the range over which effectively no regenerative action will take place and secondly indicates the range over which exceedingly stable operation occurs. It is preferable for operation purposes, that the mean frequency transmitted by the push-pull system of tubes shown in Figure 5 lies intermediate curves b and c of Figure 3, although it is to be clearly understood that the various condensers may be so chosen so that all of the curves of Figure 3 coalesce into a single curve. Or, the various condensers may be so chosen, together, with, of course, resistances and lumped inductors to produce efficient grounded grids at various widely separated frequencies or bands of frequencies.

It is to be further clearly understood that each grid lead structure may be connected in parallel to ground through several condensers, each of which tunes the same grid to a different frequency. In this manner, due to series resonance at these different frequencies, the various grids may be maintained at ground potential over a band of frequencies or at particular separated isolated frequencies.

Also, my present invention may be applied to oscillators, for example, to prevent feed-back through the tube system, screen and/or suppressor grids may be used, grounded in accordance with my present invention. Controllable feed-back may then be had by the use of variable tickler coils or by means of variable condensers. A typical inductive feed-back circuit is shown in Figure 6. The screen grid tube 90 is provided with a screen grid 100 grounded in accordance with my invention by a series tuning condenser 102. Feed-back is accomplished by tickler coil 104 coupled to grid circuit 106. Output energy may be taken from tuned plate tank circuit 108. Employing a typical tube such as the Radiotron 224 or 236, I have found that the screen grid lead has an inductance of approximately 0.1 microhenry at a parasitic feed-back frequency of 20,000 kilocycles. The reactance of 0.1 microhenry is approximately 12.6 ohms. Therefore, to series resonate this reactance there will be required a capacity of 635 micro-microfarads for the tuning condenser 102.

It is to be understood that the invention is not limited to embodiments and features specifically shown and described herein, but that such embodiments and features are subject to changes and modifications without any departure from the spirit of the invention.

I claim:

1. A high frequency circuit comprising an electron discharge device having within an hermetically sealed container an anode, a cathode, a control grid adjacent said cathode and another electrode intermediate said control electrode and anode, said other electrode having a lead having appreciable inductive reactance of approximately 0.1 microhenry at an operating frequency of 20,000 kilocycles and predetermined values of ca-

capacitive means in the order of 635 micro-microfarads connecting said lead to ground for maintaining said other electrode through series resonance effects at ground potential for the operating frequency.

2. A high frequency circuit comprising an electron discharge device having within an hermetically sealed container an anode, a cathode, a control grid adjacent said cathode, a second grid adjacent said control grid, a third grid intermediate said second grid and said anode, said second and third grids having leads having appreciable inductive reactance of approximately 0.1 microhenry at the operating frequency of 20,000 kilocycles, and predetermined values of capacitive circuits in the order of 635 micro-microfarads connecting said leads to ground for maintaining said second and third grids through series resonance effects at ground potential for said operating frequencies.

3. A high frequency circuit comprising an electron discharge device having within an hermetically sealed container an anode, a cathode, a control grid adjacent said cathode, and another electrode intermediate said control electrode and cathode, said other electrode having a lead having appreciable inductive reactance of approximately 0.1 microhenry at a parasitic frequency of 20,000 kilocycles, and a condenser having a predetermined value of capacity in the order of 635 micro-microfarads shunted by a resistance for connecting said lead to ground for maintaining said other electrode through series resonance effects at ground potential.

4. A high frequency circuit comprising an electron discharge device having within an hermetically sealed container an anode, a cathode, a control grid adjacent said cathode, a second grid adjacent said control grid, a third grid intermediate said second grid and said anode, said second and third grids having leads having appreciable inductive reactance of approximately 0.1 microhenry at parasitic frequencies of 20,000 kilocycles, and a condenser having a predetermined value of capacity of the order of 635 microfarads shunted by a resistance for connecting each of said leads to ground for maintaining said second and third grids through series resonance effects at ground potential.

5. A high frequency circuit comprising a pair of electron discharge devices, each having within an hermetically sealed container an anode, a cathode, a control grid adjacent each cathode, and a screen grid intermediate said control grid and anode, a lead for said screen grid having appreciable inductance through a range of operating frequencies of said device, means for connecting said control grids in phase opposition, a high frequency circuit connected to said anodes, and a condenser connected to each of said screen grids and ground, said condensers being of such a value as to series resonate with the inductance of the screen grid leads whereby said screen grids are maintained at ground radio frequency potential at certain parasitic frequencies.

6. A high frequency circuit comprising a pair of electron discharge devices each having within an hermetically sealed container an anode, a cathode, a control grid adjacent each cathode and a screen grid intermediate said control grid and anode, a lead for said screen grid having appreciable inductance through a range of operating frequencies of said device, a suppressor grid intermediate said screen grid and said anode, means for connecting said control grids in phase

opposition, a high frequency circuit connected to said anodes, and a condenser connected to each of said screen grids and ground, said condenser being of such a value as to series resonate with the inductance of the screen grid leads whereby said screen grids are maintained at ground radio frequency potential at certain parasitic frequencies.

7. A high frequency circuit comprising a pair of electron discharge devices each having within an hermetically sealed container an anode, a cathode, a control grid adjacent each cathode and a screen grid intermediate said control grid and anode, a lead for said screen grid having appreciable inductance through a range of operating frequencies of said device, means for connecting said control grids in phase opposition, a high frequency circuit connected to said anodes, and a condenser connected to each of said screen grids and ground, resistances shunting said condensers, said condensers and said resistances being of such a value as to series resonate with the inductance of the screen grid leads whereby said screen grids are maintained at ground radio frequency potential at certain parasitic frequencies.

8. High frequency apparatus comprising a plurality of high frequency stages each including an electron discharge device having within an evacuated container an anode, a cathode, a control grid, and a screen grid, each of said screen grids having a lead having appreciable inductive reactance at a frequency for which it is undesired that regeneration take place, and, a condenser connected in series with each of said screen grid leads each of said condensers being of such a value as to series resonate with each screen grid lead at said frequencies whereby said screen grids are maintained effectively at ground radio frequency potential thereby preventing the undesired regenerative action.

9. High frequency apparatus comprising a plurality of high frequency stages each including an electron discharge device having within an evacuated container an anode, a cathode, a control grid and a screen grid, each of said screen grids having a lead having appreciable inductive reactance at a frequency for which it is undesired that regeneration take place, and, a condenser connected in series with each of said screen grid leads each of said condensers being of such a value as to series resonate with the screen grid leads of each of said stages to different frequencies whereby said screen grids are maintained effectively at ground radio frequency potential thereby preventing the undesired regenerative action over a band of frequencies.

10. High frequency apparatus comprising a plurality of high frequency stages each including an electron discharge device having within an evacuated container an anode, a cathode, a control grid and a screen grid, each of said screen grids having a lead having appreciable inductive reactance at a frequency for which it is undesired that regeneration take place, and, a condenser connected in series with each of said screen grid leads, a resistance shunting said condensers, each of said condensers and said resistances being of such a value as to series resonate with the screen grid leads of each of said frequency stages to different frequencies whereby said screen grids are maintained effectively at ground radio frequency potential thereby preventing the undesired regenerative action.

11. High frequency apparatus comprising a plurality of high frequency stages each including

an electron discharge device having within an evacuated container an anode, a cathode, a control grid and a screen grid, each of said screen grids having a lead having appreciable inductive reactance at a frequency for which it is undesired that regeneration take place, and, a condenser connected in series with each of said screen grid leads, a resistance shunting said condensers, each of said condensers and said resistances being of such a value as to series resonate at different overlapping frequency bands with the screen grid leads of each of said stages to different frequencies whereby said screen grids are maintained effectively at ground radio frequency potential thereby preventing the undesired regenerative action.

12. High frequency apparatus comprising a plurality of high frequency stages each including an electron discharge device having within an evacuated container an anode, a cathode, a control grid and a screen grid, each of said screen grids having a lead having appreciable inductive reactance at a frequency for which it is undesired that regeneration take place, and, a condenser connected in series with each of said screen grid leads, a lumped inductance shunting said condensers each of said condensers and said lumped inductance being of such a value as to series resonate at different overlapping frequency bands with the screen grid leads of each of said frequency stages to different frequencies whereby said screen grids are maintained effectively at ground radio frequency potential thereby preventing the undesired regenerative action.

13. A high frequency circuit comprising a pair of electron discharge devices each having within an hermetically sealed container an anode, a cathode, a control grid adjacent each cathode and a screen grid intermediate said control grid and anode, a lead for said grid having appreciable inductance through a range of operating frequencies of said device, a suppressor grid intermediate said screen grid and said anode, means for connecting said control grids and said suppressor grids in phase opposition respectively, a high frequency circuit connected to said anodes and a condenser connected to said suppressor grids to tune the grids of different stages to different frequencies whereby said suppressor grids are maintained at ground radio frequency potential at certain parasitic frequencies.

14. A high frequency circuit comprising a pair of electron discharge devices each having within an hermetically sealed container an anode, a cathode, a control grid adjacent each cathode and a screen grid intermediate said control grid

and anode, a lead for said grid having appreciable inductance through a range of operating frequencies of said device, a suppressor grid intermediate said screen grid and said anode, means for connecting said control grids and said suppressor grids in phase opposition respectively, a high frequency circuit connected to said anodes, a condenser and a resistance shunting said condenser connected to said suppressor grids, each of said condensers and said resistances being of such a value as to series resonate with the suppressor grid leads whereby said suppressor grids are maintained at ground radio frequency potential at certain parasitic frequencies.

15. A high frequency circuit comprising a pair of electron discharge devices each having within an hermetically sealed container an anode, a cathode, a control grid adjacent each cathode and a screen grid intermediate said control grid and anode, a lead for said grid having appreciable inductance through a range of operating frequencies of said device, a suppressor grid intermediate said screen grid and said anode, means for connecting said control grids and said suppressor grids in phase opposition respectively, a high frequency circuit connected to said anodes, a condenser and a resistance shunting said condenser connected to said suppressor grids, each of said condensers and said resistances being of such a value as to series resonate at different overlapping frequency bands with the suppressor grid leads whereby said suppressor grids are maintained at ground radio frequency potential at certain parasitic frequencies.

16. A high frequency circuit comprising a pair of electron discharge devices each having within an hermetically sealed container an anode, a cathode, a control grid adjacent each cathode and a screen grid intermediate said control grid and anode, a lead for said grid having appreciable inductance through a range of operating frequencies of said device, a suppressor grid intermediate said screen grid and said anode, means for connecting said control grids and said suppressor grids in phase opposition respectively, a high frequency circuit connected to said anodes, a condenser and a lumped inductance shunting said condenser connected to said suppressor grids, each of said condensers and said lumped inductance being of such a value as to series resonate at different overlapping frequency bands with the suppressor grid leads whereby said suppressor grids are maintained at ground radio frequency potential at certain parasitic frequencies.

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