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INPUT LOADING CHARACTERISTICS OF CLASS B AMPLIFIERS

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Fig. 1.

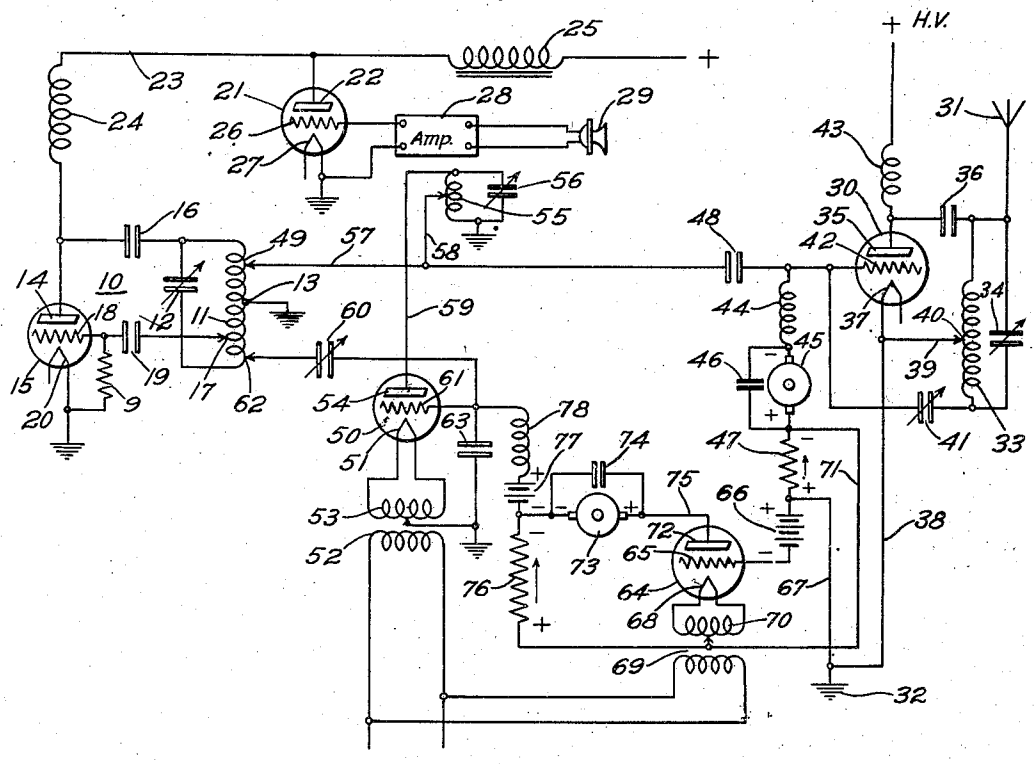
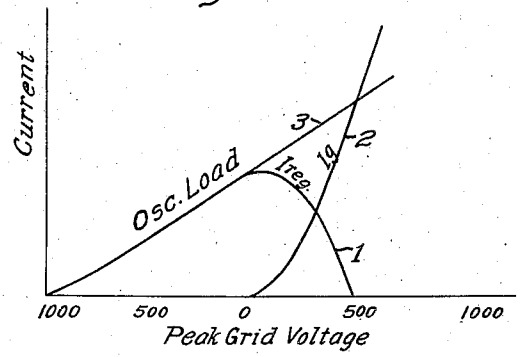


Fig. 2.



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INPUT LOADING CHARACTERISTICS OF CLASS B AMPLIFIERS

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This invention relates to radio transmitters and particularly to transmitters which employ class "B" amplification.

A class "B" amplifier is defined as one which operates so that the power output is proportional to the square of excitation voltage. This is accomplished by operating the amplifier with a negative grid bias such that the plate current is almost zero with no excitation. An excitation grid voltage is applied such that essentially half sine-waves of plate current are produced on the least negative half-cycle of the grid voltage. The grid usually swings positive on excitation peaks and thereby introduces harmonics into the output waves, as will be explained later, which must be filtered from the output by suitable means.

Since the grid of the class "B" amplifier tube draws current when the excitation voltage is such that the grid swings positive but not at other times, it is obvious that in the usual transmitters employing class "B" amplification, there is a varying load on the oscillator. Or looking at the operation of the circuit from a different viewpoint, the impedance of the apparatus connected to the oscillator output decreases as soon as the power amplifier grid swings positive.

Because of the varying load on the oscillator, the wave shape of the oscillator output is distorted, the distortion taking the form of a flattened wave top during the period that the amplifier grid is drawing current. Since the peak of the wave is flattened only when the grid draws current and not at other times it is obvious that the wave peaks impressed on the power amplifier grid are not proportional to the modulating voltage. It is equally obvious that this results in distortion of the transmitted signal.

The flattened wave form of the higher voltage peaks of the oscillator output may be looked upon as being caused by poor voltage regulation of the oscillator, this voltage regulation referring to voltage regulation within the radio frequency cycle itself rather than to voltage regulation of the R. M. S. value. The poor regulation referred to is caused, primarily, by the fact that when the amplifier tube draws grid current, this current is supplied by the condenser in the oscillator tank circuit. This discharge of the tank circuit condenser lowers the condenser voltage, and therefore flattens the peaks of the output wave of the oscillator.

In the present transmitters employing class "B" amplification, the distortion caused by the varying load on the oscillator is kept small by keeping the value of the exciting voltage low enough to avoid swinging the power amplifier grid too far positive.

By keeping the exciting voltage at a comparatively low amplitude the flattening of the oscillator wave is held to a permissible value.

An object of our invention is to provide means for preventing or reducing signal distortion in a transmitter of the above-mentioned type caused by the grid of a power amplifier swinging positive.

Another object of our invention is to provide means for flattening the wave peaks of the oscillator in a transmitter of the above-mentioned type at all values of the modulating voltage.

Still another object of our invention is to provide a circuit of the above-mentioned type in which the output of the power amplifier tube may be increased without causing a prohibitive increase in the signal distortion.

In practicing our invention, we connect the plate impedance of a regulator tube across the output circuit of the oscillator. With the regulator tube so connected, its plate impedance is also in parallel with the input impedance of the power amplifier. Means are provided for increasing the plate impedance of the regulator tube as soon as the grid of the power amplifier swings positive.

The above-mentioned means includes a resistor connected in the grid biasing circuit of the power amplifier so that the voltage drop across the resistor is proportional to the power amplifier grid current. This voltage drop so controls the plate impedance of the regulator tube that as the power amplifier grid current increases, the impedance of the regulator tube increases and the load on the oscillator is gradually transferred from the regulator tube to the grid circuit of the power amplifier.

Other features and advantages of our invention will appear from the following description taken in connection with the accompanying drawing, in which,

Figure 1 is a schematic diagram of a radio transmitter embodying our invention, and

Fig. 2 is a view showing several curves which aid in understanding the invention.

Referring to Fig. 1 the circuit comprises an oscillator 10 of the well known Hartley type having a tuned circuit consisting of an inductance coil 11 and a variable condenser 12. The inductance coil 11 is grounded at approximately its midpoint 13. The upper end of the coil 11 is connected to the plate 14 of the oscillator tube 15 through a coupling condenser 16. A point 17 on the inductance coil 11 on the opposite side of the

grounded point 13 is connected to the grid 18 through a coupling condenser 19. The grid 18 is connected to the filament 20 through a grid leak resistor 9, the filament 20 being grounded.

The output of the oscillator 10 is amplitude modulated in this case by means of the well known Heising circuit. This circuit comprises a modulator tube 21 which has its plate 22 connected to the plate 14 of the oscillator tube 15 through a conductor 23 and a radio frequency choke coil 24. Plate potential is supplied to the plates of the modulator and oscillator tubes through an audio frequency choke coil 25 as is well understood in the art.

The grid 26 and the grounded filament 27 of the modulator tube are connected to the output circuit of an audio frequency amplifier 28. A microphone 29 is connected to the amplifier input circuit.

The power amplifier 30 for amplifying the modulated output of the oscillator 10 is of the class "B" type. The output of the amplifier 30 is fed to a radiating system comprising an antenna 31 and a ground 32 by means of a tank circuit which comprises an inductance coil 33 and a variable condenser 34. The plate 35 of the amplifier tube 30 is connected to the upper end of the tank circuit 33, 34 through a coupling condenser 36. The antenna 31 is connected to the same end of the tank circuit 33, 34. The filament 37 is grounded through a conductor 38 and connected through a conductor 39 to an intermediate point 40 on the inductance coil 33. The amplifier 30 is neutralized by means of a neutralizing condenser 41 connected between the grid 42 and the lower end of the tank circuit 33, 34. Plate potential is supplied to the amplifier 30 through a radio frequency choke coil 43.

The grid biasing circuit of the amplifier 30 includes a radio frequency choke coil 44, a biasing generator 45 shunted by a by-pass condenser 46, and a resistor 47 connected in series. These three units are connected between the filament 37 and the grid 42 to maintain the grid 42 biased at the desired average negative potential.

The power amplifier is coupled to the output circuit of the oscillator 10 through a coupling condenser 48 which is connected between the grid 42 of the tube 30 and a point 49 on the coil 11 of the oscillator tuned circuit. The other coupling connection is through the ground.

In accordance with our invention a low impedance vacuum tube 50 is connected across the oscillator output so that it draws current from the oscillator 10 until biased to cut-off.

The filament 51 of the regulator tube 50 is heated by alternating current supplied through the transformer 52. The midpoint of the transformer secondary 53 is grounded.

The plate 54 is connected to the output circuit of the oscillator 10 through an auto-transformer comprising an inductance coil 55. The coil 55 is tuned to the same frequency as the oscillator 10 by means of a variable condenser 56.

The primary circuit of the auto-transformer may be traced from the point 49 on the oscillator tuned circuit through the conductors 57 and 58, the lower half of the coil 55, through ground to the grounded midpoint 13 of the oscillator coil 11.

The secondary circuit may be traced from the plate 54 of the regulator tube 50 through the conductor 59, the inductance coil 55, through ground to the grounded filament 51 of the regulator tube 50. Thus, it will be seen that the plate voltage of the regulator tube 50 is supplied by the modulated output of the oscillator 10 and that this oscillator voltage is stepped-up by the auto-transformer in order to have greater control over the plate current of the regulator tube.

Since radio frequency voltages are impressed upon the plate 54 of the regulator tube 50, it was found necessary to neutralize the tube 50 by connecting a neutralizing condenser 60 between the grid 61 of the regulator tube 50 and a point 62 on the coil 11 of the oscillator tuned circuit, this point and the point 49 to which the plate 54 of the regulator tube is connected being on opposite sides of the grounded point 13.

A by-pass condenser 63 is connected from the grid 61 to ground to keep radio frequency currents out of the regulator tube biasing circuit which will now be described.

The biasing of the grid 61 of the regulator tube 50 is controlled by the output current of a three-electrode vacuum tube 64 connected to act as a direct-current amplifier.

The grid 65 of the tube 64 is connected through a biasing battery 66 to the lower end of the regulating resistor 47 and to ground through a conductor 67. The biasing battery 66 is poled to give the grid 65 a negative bias and its voltage is sufficient to cause the tube 64 to operate nearly at the cut-off point until the grid 42 of the power amplifier 30 swings positive.

The filament 68 is heated through a transformer 69. The secondary 70 of this transformer has its mid-point connected to the upper end of the regulating resistor 47 through a conductor 71.

Positive potential is supplied to the plate 72 of the tube 64 by means of a generator 73 shunted by a by-pass condenser 74, the generator having its positive terminal connected to the plate 72 through a conductor 75. The negative terminal of the generator 73 is connected to the midpoint of the secondary 70 of the filament transformer 69 through a resistor 76.

The upper end of the plate resistor 76 is coupled to the grid 61 of the regulator tube 50 through a battery 77 and radio frequency choke coil 78. The battery 77 is connected in opposition to the voltage drop in the resistor 76 in order to make the grid 61 of the regulator tube slightly positive since there is always some current flowing through the resistor 76.

While a direct-current amplifier has been shown, the output of the tube 64 may be connected to the input of the regulator tube 50 by any suitable audio-frequency coupling such as an audio-frequency transformer.

The operation of the circuit can best be understood by referring to the curves shown in Fig. 2. It will be noted that until the peak grid voltage reaches such a value that the power amplifier grid becomes positive the entire load on the oscillator represented by curve 3 is caused by the regulator tube 50. Up to this point, the plate current of the regulator tube represented by curve 1 has been almost directly proportional to the peak grid voltage. It may be noted here that the peak voltage on the grid 42 equals the exciting or oscillator output voltage plus the grid biasing voltage.

As soon as the power amplifier grid 42 swings positive, the current flow through the grid bias circuit increases and causes a drop in the regulating resistor 47 such that the grid 65 of the amplifier tube 64 becomes more positive. This increases the current flowing through the output resistor 76 and the voltage drop in the resistor 76 is in such a direction as to make the grid 61

of the regulator tube more negative. Consequently, the impedance of the regulator tube **50** is increased and the adjustment of the circuit is such that in spite of the increasing voltage on the plate **54** the plate current decreases as indicated by the curve **1**.

From the above description, it will be apparent that as the grid current of the power amplifier tube increases, the plate current of tube **50** decreases, the circuit being so adjusted that the sum of these two currents increases approximately in direct proportion to the value of the exciting voltage. This is illustrated in Fig. 2 which shows that the sum of the curves **1** and **2**, equals a straight line curve **3**, which represents the total load on the oscillator. As a result, the output of the oscillator tank circuit, which is normally sinusoidal in wave form, has the peaks of the wave so flattened at all amplitudes that the amplitude of the peaks is proportional to the modulating voltage.

In one embodiment of our invention, the amplifier was a 100 kw. AW220 tube, the regulator and oscillator tubes were 20 kw. UV848 tubes, and the tube 64 was a 50 watt tube. The regulating resistor **47** had a value of 50 ohms.

Various modifications may be made in our invention without departing from the spirit and scope thereof, and we desire, therefore, that only such limitations shall be placed thereon as are imposed by the prior art and are set forth in the appended claims.

We claim as our invention:

1. A radio transmitter comprising an oscillator, an amplifier having its input coupled to the output of said oscillator, means for modulating the output of said oscillator, said amplifier being so biased that grid current flows during a portion of said modulation, and means for automatically loading said oscillator when no current is flowing in said grid circuit.

2. A radio transmitter comprising an oscillator, means for modulating the output of said oscillator, an amplifier having its input coupled to the output circuit of said oscillator, said amplifier being so biased that grid current flows during a portion of said modulation, voltage regulator means for automatically loading said oscillator so long as the grid current of said amplifier is below a predetermined value.

3. A radio transmitter comprising an oscillator, means for modulating the output of said oscillator, an amplifier having its input coupled to the output circuit of said oscillator, said amplifier being so biased that grid current flows during a portion of said modulation, and means for automatically maintaining the load on said oscillator substantially constant.

4. A radio transmitter comprising an oscillator, means for modulating the output of said oscillator, an amplifier having its input coupled to the output circuit of said oscillator, said amplifier being so biased that grid current flows during a portion of said modulation, a vacuum tube including a control electrode and having its plate circuit connected in parallel with the output circuit of said oscillator, and means for making said control electrode more negative as the grid current of said amplifier increases.

5. A radio transmitter comprising an oscillator, means for modulating the output of said oscillator, an amplifier having its input circuit connected to the output circuit of said oscillator, said input circuit including a control electrode which is so biased that it becomes positive during a portion of said modulation whereby grid current flows, a regulator tube including a control electrode and having its plate impedance connected in parallel with said oscillator output circuit, and means for varying the potential on the control grid of said regulator tube in response to the flow of said grid current.

6. A radio transmitter comprising an oscillator, means for modulating the output of said oscillator, an amplifier having its input circuit connected to the output circuit of said oscillator, said input circuit including a control electrode which is so biased that it becomes positive during a portion of said modulation whereby grid current flows, a regulator tube including a control electrode and having its plate impedance connected in parallel with said oscillator output circuit, and means for making the control grid of said regulator tube more negative in response to an increase in said grid current.

7. A radio transmitter comprising an oscillator, means for modulating the output of said oscillator, an amplifier having its input circuit connected to the output circuit of said oscillator, said input circuit including a control electrode which is so biased that it becomes positive during a portion of said modulation whereby grid current flows, a regulator tube including a control electrode and having its plate impedance connected in parallel with said oscillator output circuit, a resistor in the grid biasing circuit of said amplifier, a control amplifier tube having its input connected across said resistor, and means for so connecting the output circuit of said control amplifier to the control grid of said regulator tube that an increase in potential drop across said resistor makes the regulator tube control more negative grid.

8. In combination, a source of high frequency energy, means for modulating said energy, an amplifier having its input coupled to the output circuit of said source and having its control electrode so biased that it swings positive during said modulation, and regulator means connected to the output circuit of said source for maintaining the load on said source substantially constant irrespective of current flow in said grid circuit.

9. In combination, a source of high frequency energy, means for modulating said energy, an amplifier comprising a control electrode, said amplifier having its input coupled to the output circuit of said source and having its control electrode so biased that it swings positive during said modulation, and regulator means connected to the output circuit of said source for assuming an increasing load as the instantaneous voltage in said output circuit increases until said control electrode becomes positive a predetermined amount and for then assuming a decreasing load as said instantaneous voltage further increases.

10. In combination, a source of high frequency energy, means for modulating said energy, an amplifier having its input coupled to the output circuit of said source, the input impedance of said amplifier varying with the instantaneous voltage in said output circuit, an impedance device in parallel with said input impedance and means for increasing the impedance of said impedance device in response to a decrease in said input impedance.

11. In combination, a source of high frequency energy, means for varying the amplitude of said energy in accordance with a modulating voltage, an amplifier having its input coupled to the output circuit of said source, said amplifier hav-

ing an input impedance which decreases after said modulating voltage exceeds a predetermined instantaneous value, an impedance device in parallel with said input impedance, and means for increasing the impedance of said impedance device in response to a decrease in said input impedance.

12. In combination, a source of high frequency energy, means for varying the amplitude of said energy in accordance with a modulating voltage, an amplifier having its input coupled to the output circuit of said source, said amplifier having an input impedance which decreases after said modulating voltage exceeds a predetermined value, a vacuum tube having its plate impedance connected in parallel with said input impedance through a tuned circuit, said vacuum tube having a control electrode, and means including an amplifier for making said control electrode more negative in response to a decrease in said input impedance.

13. In combination, an oscillator including a tuned circuit and a vacuum tube having a filament connected to a point on said tuned circuit, said tube having a plate and a grid connected to points on said tuned circuit on opposite sides, respectively, of said first point, means for modulating the output of said oscillator in accordance with a modulating voltage, an amplifier having its input coupled to the output circuit of said oscillator, said amplifier having an input impedance which varies with variations in said modulating voltage, a vacuum tube having its plate impedance connected in parallel with said input impedance, the plate of said vacuum tube being connected to said tuned circuit on one side of said point, said vacuum tube having a control electrode connected through a neutralizing condenser to said tuned circuit on the opposite side of said point, and means for making said control electrode more negative in response to a decrease in said input impedance.

14. In combination, a source of high frequency energy, means for varying the amplitude of said energy in accordance with a modulating voltage, an amplifier having a cathode and a control electrode, a radio frequency choke coil, a biasing voltage source and an impedance unit connected in series between said cathode and said control electrode, means for coupling said source and said amplifier comprising a coupling condenser connected between the output circuit of said source and a point intermediate said control electrode and said choke coil, an impedance device connected across the output circuit of said source, and means for increasing the value of said impedance in response to an increase in current flow in said impedance unit.

15. A radio transmitter comprising an oscillator having a tuned output circuit, means for amplitude modulating the output of said oscillator, an amplifier having its input circuit connected to said tuned output circuit, said input circuit including a grid which is so biased that it becomes positive during the peaks of said modulation whereby grid current flows and flattens the wave of the voltage supplied by said tuned output circuit, and means for automatically flattening said wave while said grid is not drawing current.

16. A radio transmitter comprising an oscillator having a tuned output circuit, means for amplitude modulating the output of said oscillator, an amplifier having its input circuit connected to said tuned output circuit, said input circuit including a grid which is so biased that it becomes positive during the peaks of said modulation whereby grid current flows and flattens the wave of the voltage supplied by said tuned output circuit, and means for flattening said wave at all amplitudes of said modulation, the degree of flattening being proportional to the amplitude of said modulation.

17. The method of straightening the characteristic of an electron discharge device having input electrodes and an input circuit connected thereacross which includes uniformly loading the input circuit of the device up to a point where curvature of the device characteristic occurs, and, decreasing the loading beyond that point whereby input voltages build up faster on the input electrodes of the device relative to their building up speed during the time of uniform loading.

18. In apparatus for the amplification of undulatory electrical currents, an electron discharge device amplifier, input and output circuits therefor, an electron discharge device load coupled to the input circuit of the amplifier, and means for polarizing electrodes of the electron discharge device of the load so that cut-off occurs during the time when, with increasing value of input to the amplifier, the ratio of output to input of the electron discharge device amplifier is not a constant.

19. In combination, an electron discharge device amplifier having an input circuit and an output circuit, said amplifier having a characteristic curve comprising a substantially linear portion followed by a curved portion, a load electron discharge device coupled to the input circuit of said amplifier electron discharge device, and means for polarizing said load electron discharge device so that for excitation energy applied to said input circuit which causes said amplifier to normally operate upon the curved portion of its characteristic curve, said load electron discharge device is rapidly reduced in conductivity whereby the output characteristic of said amplifier is substantially linear over said normally curved portion of its characteristic.

20. A radio transmitter comprising an oscillator having an output circuit, means for amplitude modulating the output of said oscillator, an amplifier having its input circuit connected to said output circuit, said input circuit including a grid which is so biased that it becomes positive during the peaks of said modulation whereby grid current flows and flattens the wave of the voltage supplied by said output circuit, and means for automatically flattening said wave while said grid is not drawing current.

21. A radio transmitter comprising an oscillator having an output circuit, means for amplitude modulating the output of said oscillator, an amplifier having its input circuit connected to said output circuit, said input circuit including a grid which is so biased that it becomes positive during the peaks of said modulation whereby grid current flows and flattens the wave of the voltage supplied by said output circuit, and means for flattening said wave at all amplitudes of said modulation, the degree of flattening being proportional to the amplitude of said modulation.

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