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STATIC LIMITING DEVICE

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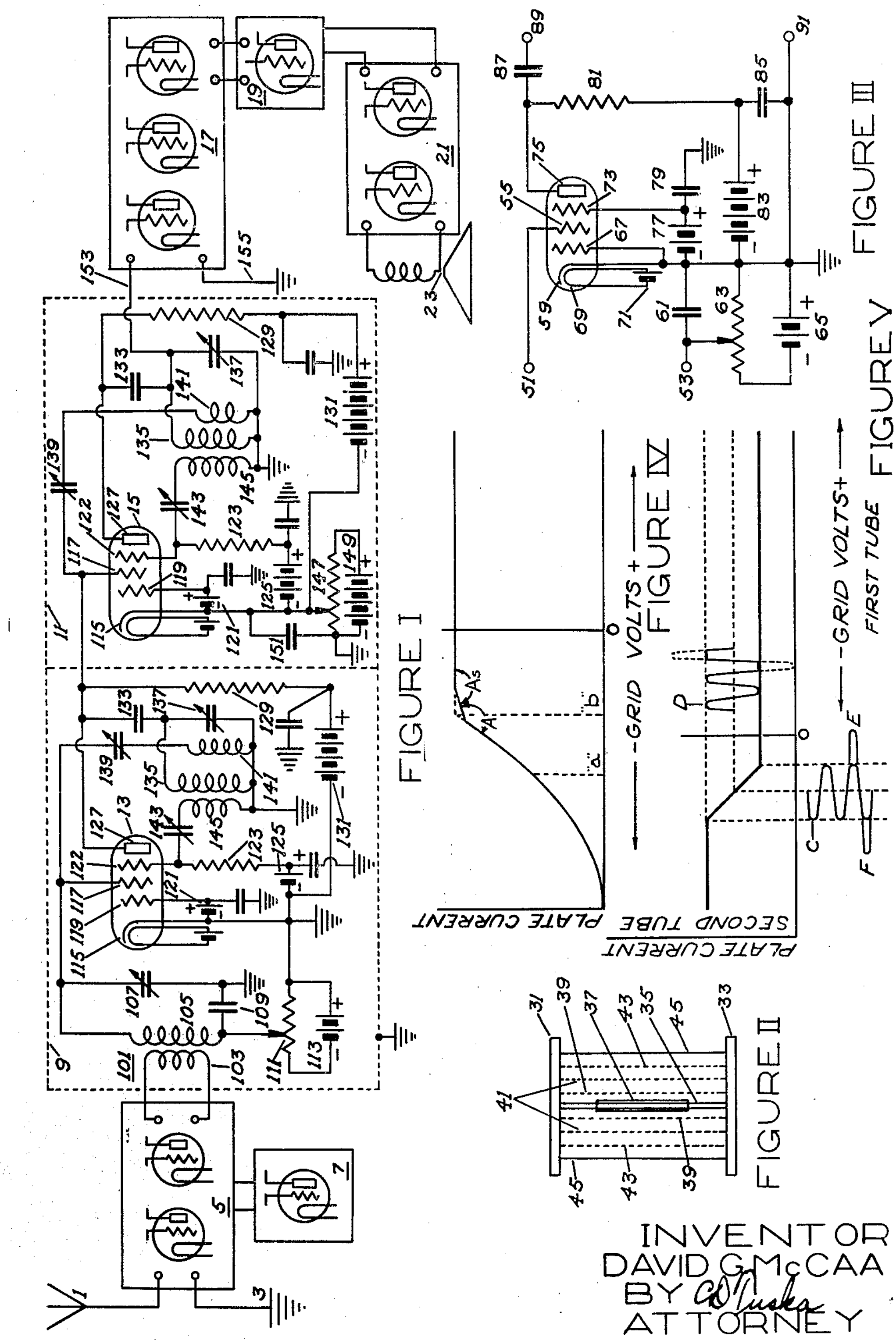

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STATIC LIMITING DEVICE

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10 Claims. (Cl. 250—20)

My invention relates broadly to static limiting devices for radio receiving systems. More specifically my invention relates to a pair of thermionic tubes arranged to sharply limit their output currents to predetermined values irrespective of the input voltage. The present invention is an improvement over my copending application Serial No. 6,015 filed February 11th, 1935, entitled Radio circuits for static limitation.

Although numerous current limiter devices have been proposed for the reduction of the effects of atmospheric static on radio receivers, most of these devices have handicaps which have prevented their general adaptation to radio telegraphic, radio telephonic and television reception. For example, the prior art limiters may distort, lower selectivity, require excessive operating voltages, employ complicated apparatus, or may be difficult to adjust. These difficulties are not present in the system disclosed in the above entitled copending application. The system disclosed therein is entirely suitable for receivers of moderate sensitivity.

However, I have discovered by the use of a receiver of great sensitivity connected to the output of the static gate of the above mentioned system, certain improvements. The present embodiment of my invention may be applied to receivers of widely different degrees of sensitivity with a greatly improved signal to static response ratio.

One of the objects of my invention is to limit the effects of static impulses on a radio receiving system. Another object is to apply a static limiting gate to the input of an extremely sensitive receiver. A further object is to neutralize the interelectrode capacities of a thermionic tube embodied in a static gate. A still further object is to neutralize the effects of space charges about the screen grid of a thermionic tube employed in a static limiter. Additional objects will be apparent from the accompanying specification, drawing, and appended claims.

My invention may be best understood by a reference to the accompanying drawing in which Figure I is a schematic diagram of one embodiment of my invention,

Figure II is a schematic representation of a preferred form of thermionic tube employed in the static gate,

Figure III is a circuit diagram which is included for purposes of explanation,

Figure IV is a graph showing the grid voltage, plate current characteristic of a thermionic tube circuit embodied in Figure III, and

Figure V is a graph showing the operating characteristic of the static gate of Figure I.

In Figure I, an antenna 1 and a ground 3 are connected to the input of a preselector, radio frequency amplifier, and first detector which are represented by the reference numeral 5. A local oscillator 7 is coupled to the first detector. Since these elements, per se, are not part of my invention, and are well known to those skilled in the art, the details are omitted. It is sufficient to point out that these elements form the preliminary stages of a superheterodyne receiving system.

The incoming signal and static representing currents beat in the first detector with the currents from the local oscillator to form currents of intermediate frequency. Within a pair of shields 9, 11 are located a pair of thermionic tubes 13, 15 which form a gate. Through this gate intermediate frequency signal representing currents are passed to an intermediate frequency amplifier 17. The intermediate frequency amplifier is coupled to a second detector 19 which may be connected to a suitable audio frequency amplifier 21. The audio amplifier output is connected to an indicating instrument 23, which may be a loudspeaker, cathode ray tube or the like. The intermediate frequency amplifier, second detector, audio amplifier, and signal indicator complete the superheterodyne receiving system. These elements, per se, are not my invention and, being well known to those skilled in the art, require no detailed description.

Having described the system as a whole, I shall now describe the details of the static gate, and the thermionic tubes employed therein. In Figure II, I have shown the electrode arrangement of a preferred form of thermionic tube. The envelope and mounting arrangements are not shown. Within an evacuated envelope and suitably mounted are a pair of insulated members 31, 33. A unipotential cathode 35 is supported between the centers of the insulated members 31, 33. The central portion 37 of the cathode is made electron emissive. Surrounding the cathode, and concentrically spaced therefrom and from each other, are a first grid 39, a control grid 41, a screen grid 43, and an anode 45. The several grids are helical windings of uniformly spaced turns of suitable wire. The helically wound grids extend from one insulated member to the other.

I have found a uniform arrangement of elements including a unipotential cathode, whose active surface length is shorter than the grid and anode lengths and concentrically arranged therein is the preferred arrangement. This arrangement lends itself to the sharply defined angular cut-off which I shall presently describe. The heater for the cathode is located within the cathode in the conventional manner. Although I prefer the above described form of tube, it should be understood that my invention is not limited in this respect as other types of thermionic tubes may be employed.

For purposes of explanation, Figure III shows the tube of Figure II connected in a circuit. In this circuit a pair of input terminals **51**, **53** are connected respectively to the control grid **55** of a tube **57** and to the cathode **59** through a by-pass condenser **61**. The lower input terminal **53** is also connected to the slider of a potentiometer **63**. A biasing battery **65** is connected across the potentiometer. The positive terminal of the battery is connected to cathode and ground. A space charge grid **67** is connected to cathode **59**. A heater **69** is energized by a battery **71** or other suitable current source. A screen grid **73** located between control grid and anode **75** is biased positively by a battery **77**. The battery may be by-passed by a capacitor **79**.

The anode **75** is connected through a resistor **81** of relatively high value to the positive terminal of a battery **83**. The negative terminal of the battery is grounded. The battery may be by-passed by a capacitor **85**. The anode is connected through a coupling capacitor **87** to an output terminal **89**. The other output terminal **91** is grounded. The screen biasing battery may be combined with the anode battery.

The operation of this circuit is not unlike a resistance coupled amplifier with one important exception. The anode resistor is chosen with an ohmic resistance of the order of one quarter to one megohm. The potential of the anode battery is of the order of 22½ volts. The screen grid potential may be from 12 to 22½ volts. With a control grid bias of 1½ to 3 volts, the anode current is very low. The plate current through the anode resistor plotted against the griad bias is represented in Figure IV.

The curve of Figure IV is taken with conventional meters and shows the following characteristic: The plate current is cut off by a sufficient negative bias on the control grid. The plate current gradually rises as the negative bias is reduced. As the grid is made less negative and beginning at "*a*" the plate current increases as a linear function with decreasing grid biases. The plate current appears to rise until it reaches the dash line portion of the curve. At the point "*b*" an abrupt angular change takes place. Beginning at "*b*" the grid may be made less negative and, in fact, very positive without change in plate current.

If the curve of Figure IV is taken with a highly sensitive direct current amplifier on the output or with dynamic operating characteristics, as, for example, a very sensitive radio frequency amplifier coupled to the output of the tube circuit, the characteristic is that of the solid line portion. In the solid line curve two angular changes are observed: The first is represented as an abrupt angular change A. The second is a less abrupt but nevertheless angular change A_s. The effect of these double angles is to diminish the utility of the limiting effect of the tube and circuit of Figure III.

The double angular changes A and A_s will either distort desired signals, permit a certain amount of undesired signals to pass, or both effects may be present. This double angle effect prevents sharp, clean cut-off action. I have found a small interelectrode capacity coupling between control grid and anode will account for some undesired signal currents which pass around the gate instead of through it. After exactly neutralizing, static currents still appear which are not properly limited by the cut-off or limiting action of the tube or gate as I prefer to call it.

Although I do not wish to be restricted to any particular theory of operation, certain observations lead me to believe that a space charge effect exists around the screen grid electrode which effects the anode current. Even if no potential is applied to the anode, some of the electrons flowing to the screen grid will pass through its meshes and form a space charge effect. The presence of this screen grid space charge has a deleterious effect on the dynamic operating characteristics of the tube because control grid voltages vary the screen grid current and the space charge effect varies with the screen grid current.

Whatever may be the explanation, I have found that the screen grid space charge effect may be neutralized by using means to stabilize the screen grid current or preferably by the method I am about to describe. After neutralizing the interelectrode capacity, and the screen grid space charge effect, I have been able to employ two tubes in cascade connection which have sharply defined maximum and minimum output current characteristics. This characteristic is represented in Figure V. The signal representing voltages C just pass through the gate and are faithfully represented as plate current changes D. Static representing voltages E, and F, exceed the gate width or opening and are sharply cut off.

Having described the improvements of the present invention over the prior art and the theory of operation, I shall now describe the preferred circuits and adjustments required to accomplish the desired results.

Referring to Figure I, the first tube **13** of the gate is located within a shield **9**. Within this same shield is suitably arranged an intermediate frequency transformer **101** whose primary **103** is connected to the output of the first detector. The secondary **105** is shunted by serially connected capacitors comprising a tuning capacitor **107** and a by-pass capacitor **109** of low reactance. The junction of the tuning and by-pass capacitors is grounded. The lower terminal of the secondary is connected to the slider of a biasing potentiometer **111**. A biasing battery **113** is connected across the potentiometer. The positive terminal of the biasing battery is connected to the cathode **115** of tube **13** and to ground. To avoid repetition it may be here stated that all batteries may be by-passed by suitable capacitors. The upper terminal of the secondary **105** is connected to the control grid **117** of tube **13**.

The space charge grid **119** instead of being connected directly to cathode **115** is biased positively to insure a steady uniform flow of electrons from the heated cathode. The bias battery is represented as **121**. The screen grid **122** is connected through a resistor **123** of relatively low value of the order of 1000 ohms to the positive terminal of a battery **125**. The negative terminal of this battery is connected to the cathode **115** which is grounded.

The anode or plate electrode **127** is connected through a resistor **129** of relatively high ohmic value to the positive terminal of battery 131. The negative terminal of this battery is connected to the cathode 115. I have found that the anode resistor 129 may have an appreciably capacity reactance. Such reactance may have an undesirable effect on the dynamic characteristic curve of the tube and circuit. This effect is eliminated by shunting the resistor 129 with a resonant circuit. The shunting circuit comprises a blocking capacitor 133 of very low reactance which is serially connected to a grounded inductor 135. The inductor 135 is shunted by a tuning capacitor 137. The resonant circuit 135, 137 is grounded. The blocking capacitor prevents the grounded resonant circuit from short circuiting the anode battery through the plate circuit resistor.

The resonant circuit 135, 137 also serves a second purpose; namely, neutralization of the control grid anode capacity and screen grid space charge effect. The former capacity is neutralized by connecting a small capacitor 139 from the control grid 117 to an inductor 141 which is coupled to the inductor 135 of the resonant circuit. The latter effect is neutralized by connecting a small capacitor 143 to the junction of the screen grid and the resistor 123, and to a second inductor 145 mutually coupled to the inductor 135 of the resonant circuit.

The second tube 15 of the cascade gate network is located within a shield 11. The circuit elements of the second tube which are similar to the first tube, described immediately above, are given similar reference numbers. Insofar as the second tube and circuit is similar to the first tube and circuit the description will be omitted. The distinguishing points are that the control grid of the second tube 15 is connected to the anode 127 of the first tube. The cathode of the second tube is connected to the slider of a potentiometer 147. The potentiometer has connected across it a biasing battery 149 whose negative terminal is grounded. The slider is connected to ground by a by-pass capacitor 151. The output terminals of the second tube are the ungrounded terminal 153 of the resonant circuit and ground 155. These terminals are connected to the intermediate frequency amplifier 17.

The method of adjusting the neutralizing elements will now be described. A strong signal is tuned in. The first gate tube 113 is biased to cut off. If the signal is still detected in the output device 23, it is because of the interelectrode capacities of tube 13. The neutralizing capacitor 139 is varied until the strongest signals produce no indication in the output device. After the first tube is neutralized, its control grid bias is restored to a normal operative setting. The control grid bias of the second tube 15 is adjusted to cut-off. The absence of neutralization is recognized by signals in the output. The neutralizing capacitor 139 of the second tube 15 is adjusted for zero output. When this adjustment has been made, the bias of the second gate tube is restored to normal.

If the biases of the two tubes have been adjusted to a value, which will just admit through the gate a desired signal, it may be expected that undesired signal impulses of greater strength would be limited. There is marked limitation but I have found that it is not as complete as the theory predicts. The reason for this incomplete limitation is found in the screen grid space charge effect. This effect may be neutralized by adjusting the screen grid neutralizing capacitors 143 of the first and second gate tubes.

In making this neutralizing adjustment both gate tubes are operated normally to just admit a desired signal. If no natural static is present, any severe local effect, such as a spark coil, will provide sufficient undesired signals. The neutralizing capacitors 143 are both adjusted until the noise or disturbing signals are minimized. The optimum condition is relatively easily determined. Once the adjustment is made no readjustment or retuning is required.

The gate width or signal admittance is adjusted by regulating the control grid biases of the gate tubes. If the gate is made too small, the modulation peaks will be cut off. If the gate is too large, disturbing static effects will be admitted. As pointed out above, neutralization of capacity or neutralization of screen grid space charge effect is not sufficient to accomplish the most effective limitation of static. Both effects must be eliminated for optimum results. I do not limit the neutralization to the species shown, as grid, plate, or reverse feedback will serve. Likewise any suitable form of filtered rectified alternating current may be substituted for the batteries shown in the accompanying drawing. Since other obvious modifications within the scope of my invention will occur to those skilled in the art, it should be understood that I am not limited to the precise arrangements shown.

I claim:

1. A static limiting device comprising a pair of thermionic tubes, each having control grid, cathode, screen grid, and anode electrodes; the first of said tubes having an input circuit including its control grid and cathode, and an output circuit including its anode and cathode; a resistance included in said output circuit; the second of said pair of tubes having an input circuit including its control grid and cathode and said resistance, and an output circuit including its anode and cathode and a second resistance; means for establishing a grid voltage-plate current statistic characteristic in each of said tubes in which the characteristic graph is represented by an abrupt angular change between a sloping portion and a horizontal portion, said abrupt change being effected by less than one tenth volt change of grid potential; and means for neutralizing the effect of varying screen grid currents in each of said tubes.

2. A static limiting device comprising a pair of thermionic tubes, each having concentric control grid, unipotential cathode, screen grid, and anode electrodes; the first of said tubes having an input circuit including its control grid and cathode, and an output circuit including its anode and cathode; a resistance included in said output circuit; the second of said pair of tubes having an input circuit including its control grid and cathode and said resistance, and an output circuit including its anode and cathode and a second resistance; means for establishing in each of said tubes a static grid voltage-plate current characteristic which is represented by a sloping portion and a horizontal portion which form an abrupt angle which is effected by a grid potential change of substantially less than one tenth volt; and means for neutralizing the effect of varying screen grid currents in each of said tubes.

3. A static limiting device comprising a pair of thermionic tubes, each having control grid, cathode, screen grid, and anode electrodes; the first of said tubes having an input circuit including its control grid and cathode, and an output circuit

including its anode and cathode; a resistance included in said output circuit; the second of said pair of tubes having an input circuit including its control grid and cathode and said resistance, and an output circuit including its anode and cathode and a second resistance; means for biasing the electrodes of each of said tubes so that said tubes have a static operating characteristic in which the input voltages of the first of said tubes plotted against the output currents of the second of said tubes is represented by a constant current portion, a variable current portion, and a second constant current portion of different value than said first portion, the intersection of said portions being represented by input potential changes of less than one tenth volt; means for neutralizing the effect of varying screen grid currents in each of said tubes; and means for neutralizing capacity coupling between the input and output circuits of each of said tubes.

4. A static limiting device comprising a pair of thermionic tubes, each having concentric control grid, unipotential cathode, screen grid, and anode electrodes; the first of said tubes having an input circuit including its control grid and cathode, and an output circuit including its anode and cathode; a resistance included in said output circuit; the second of said pair of tubes having an input circuit including its control grid and cathode and said resistance, and an output circuit including its anode and cathode and a second resistance; means for biasing the electrodes of each of said tubes so that said tubes have a static operating characteristic in which the input voltages of the first of said tubes plotted against the output currents of the second of said tubes is represented by a constant current portion, a variable current portion, and a second constant current portion of different value than said first portion, the intersection of said portions being represented by input potential changes of less than one tenth volt; means for neutralizing the effect of varying screen grid currents in each of said tubes; and means for neutralizing the capacity coupling between the input and output circuits of each of said tubes.

5. In a device of the character of claim 1 a space charge grid located between cathode and control grid in each of said tubes and biased to insure uniform emission from said cathodes.

6. In a device of the character of claim 2 a space charge grid located between cathode and control grid in each of said tubes and biased to insure uniform electron emission from said cathodes.

7. A static limiting device comprising a pair of screen grid thermionic tubes, each of said tubes having an input circuit and an output circuit including an anode, resistor, and cathode, means connecting the output of one of said tubes to the input of the other, resonant circuits effectively connected to each of the output circuits of said tubes, and means for neutralizing the effect of varying space charges about the screen grids of said tubes comprising capacitors connected to each of said screen grids and to inductors coupled to said resonant circuits.

8. In a device of the character described a pair of thermionic screen grid tubes further characterized by having output circuits whose currents are substantially constant over widely varying positive input voltages, means coupling the output of one of said tubes to the input of the other, a resonant circuit in the output circuit of each of said tubes, inductors coupled to said resonant circuits and capacitors connected to said inductors and to the screen grid and input electrodes of said tubes so that the capacity coupling between input and output circuits and the screen grid space charge effects are neutralized in each of said tubes.

9. In a device of the character of claim 8, a space charge grid in each of said tubes biased to insure steady uniform electron emission.

10. A static limiting device comprising a first and second thermionic screen grid tube, each having control grid, cathode, screen grid, and anode electrodes; resistors connected to said anodes and to a source of current; means for biasing said electrodes so that a grid voltage-plate current static characteristic is established in each of said tubes in which the characteristic graph is represented by an abrupt angular change between a sloping line portion and a horizontal line portion, said abrupt change being effected by less than one tenth volt change of grid potential; a connection effectively including the resistor in one of said anode circuits and the control grid and cathode of the other; means for neutralizing the effect of varying screen grid currents on said maximum constant currents; and means for eliminating the capacity coupling between control grid and anode electrodes in each of said tubes.

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