Feb. 3, 1942.

L. J. WOLF

2,271,519

NEUTRALIZING SYSTEM

Filed Jan. 2, 1940

FIG. 1.

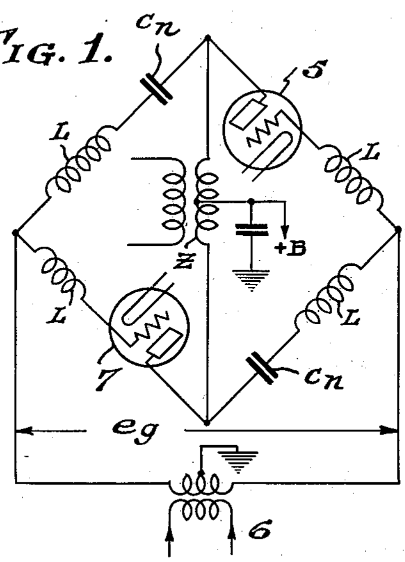


FIG. 2.

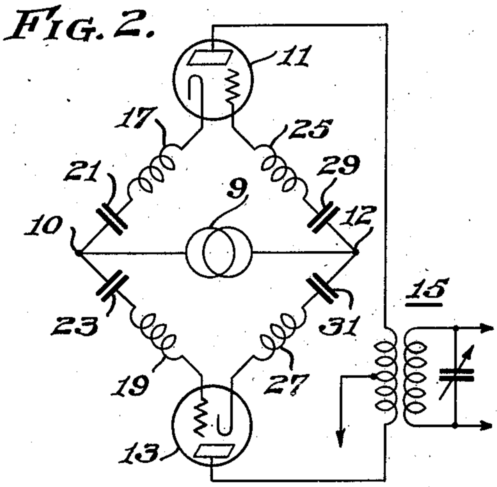


FIG. 3.

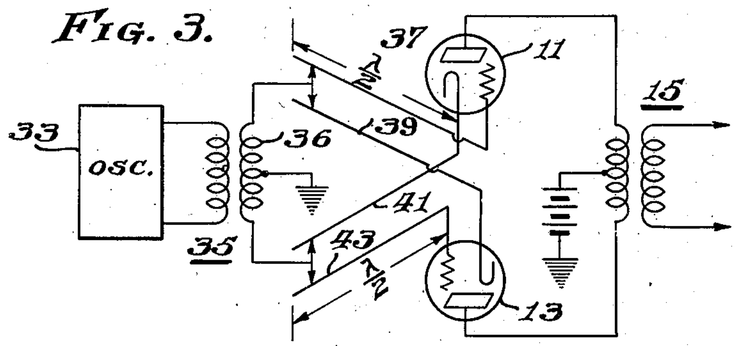
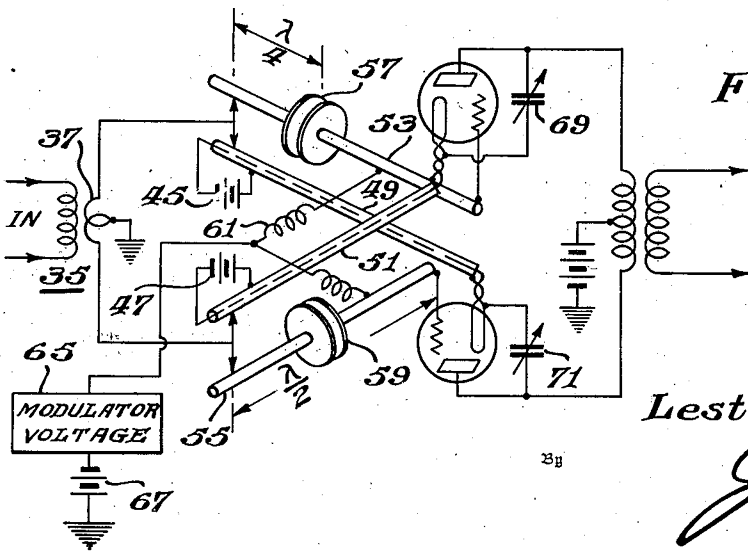


FIG. 4.



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NEUTRALIZING SYSTEM

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3 Claims. (Cl. 179—171.5)

This invention relates to amplifying systems, and more particularly to a neutralized radio frequency amplifier having improved characteristics.

It is well known that radio frequency amplifiers which are to be used in conjunction with a modulated signal create considerable distortion if the bandpass characteristics of the amplifier do not permit the full side band to be transmitted without attenuation. Amplifiers which are to be used in the transmission or reception of television signals must be able to pass a particularly wide band of frequencies. It is also known that radio frequency amplifiers employing three-element thermionic tubes must be neutralized in order to prevent self-oscillation.

Conventional neutralizing circuits have a tendency to decrease the bandpass characteristics of the amplifier. It is, therefore, the primary object of this invention to provide a neutralizing system for a high frequency amplifier which does not appreciably affect its bandpass characteristics. Other objects of this invention include the provision of an improved wide band amplifier, the provision of a neutralizing system which does not increase the frequency discrimination of a radio frequency amplifier, and the provision of a neutralized push-pull amplifier which may be modulated at signal frequency.

This invention will be better understood from the following description when considered in connection with the accompanying drawing in which Figure 1 is a schematic diagram of a conventional bridge neutralizing system; Figure 2 is a schematic diagram of an embodiment of this invention; Figure 3 is a schematic diagram of an alternate embodiment of this invention; and Figure 4 is the diagram of a modulated amplifier in accordance with this invention.

Referring to the conventional bridge neutralizing system which is schematically illustrated in Fig. 1, it will be seen that the voltage e_g across the input transformer 6 is applied in phase opposition to the two grid electrodes, while the output circuit impedance Z is connected between the anode electrodes of the push-pull tubes 5 and 7. The two neutralizing condensers C_n are connected between the anode electrode of each tube and the grid electrode of the other tube. The inductors L represent the inductances of the connecting leads. From this diagram, it will be seen that the neutralizing capacities C_n are effectively connected in shunt with the plate circuit impedance Z, since the midpoints of impedance Z and the input transformer secondary are both grounded.

The bandpass characteristic of a resonant circuit is conventionally measured in terms of the ratio of the inductive reactance to the resistance, known as the "Q" of the circuit. In a shunt resonant circuit, such as that commonly utilized in the output of an amplifier, the "Q" is proportional to the selectivity. In practice, the "Q" is increased by increasing the circuit capacity and decreasing the inductive reactance, because the resistance of a coil increases more rapidly than its reactance. It follows, therefore, that any capacity which is added to the output circuit, in order to provide neutralization for example, tends to increase the "Q" of the circuit and to increase the attenuation of frequencies on either side of the frequency of resonance.

In accordance with this invention, neutralization is accomplished entirely within the grid and cathode circuits, and no additional capacity is added to the output circuit. Consequently, the bandpass characteristics of the amplifier are improved, thus permitting a greater output to be realized within a given range of frequencies, or for the same output an increased range of frequencies may be amplified.

Referring now to Fig. 2, generator 9 represents a source of high frequency voltage which is to be amplified. This voltage may be obtained from an oscillator or from another amplifier, and preferably is balanced with respect to ground. One terminal 10 of the source 9 is connected to the cathode of the first amplifier tube 11 and also to the grid of the second amplifier tube 13, through series resonant circuits which include inductors 17, 19 and capacitors 21, 23. The other terminal 12 of the source 9 is similarly connected to the grid of the first amplifier tube 11 and to the cathode of the second amplifier tube 13 through series resonant circuits which include inductors 25, 27 and capacitors 29, 31. The anode electrodes of the two tubes are connected to the terminals of an output transformer 15. In order to simplify the drawing, means for applying fixed biasing potentials to the various electrodes in this circuit have not been illustrated. It is to be understood, however, that the various electrodes are conventionally biased in the well-known manner.

The four inductors 17, 19, 25 and 27 may be merely the inductance of the leads connecting the various electrodes, or separate inductors may be inserted in series with the leads, depending on the inductance of the leads at the operating frequency. In amplifiers designed for ultra high frequency operation, it has been found that the lead inductance itself is sufficient. The four inductors are tuned to series resonance by the four capacitors 21, 23, 29 and 31. Consequently, the electrical length of the connection from each electrode to the respective terminal of the source 9 is a half wave length, and the electrical length of the connection from the cathode of one tube to the grid of the other tube is a full wave length. It will be realized, therefore, that, at the operating frequency, the cathode of each tube is always at the same potential as the grid of the other tube. It is to be understood that the electrical lengh of the various connections may be multiples of a half wave length without changing the voltage relation noted above.

It is known that the impedance of a series resonant circuit is extremely low. Consequently, the input voltage from the source 9 is applied in phase opposition between the grid and cathode electrodes of the two amplifier tubes 11 and 13. The grid and cathode potentials oscillate about an average reference potential, which may be the potential of ground, and it will be recognized that, when the grid of tube 11 is positive with respect to its cathode, the grid of tube 13 will be negative with respect to its cathode. The two tubes, therefore, become alternately conductive during each half cycle of the applied radio frequency voltage. An output voltage is developed in the anode circuit in the usual manner.

The manner in which neutralization is effected will become apparent upon a further consideration of Fig. 2. The test of neutralization is that the voltage in the output circuit must not be induced in the input circuit through the interelectrode capacities, and that the input voltage must not be induced in the output circuit through the interelectrode capacities. Assuming that the capacity existing within each of the amplifier tubes between the anode and the cathode is equal to the capacity between the anode and the grid, it will be seen that equal currents will flow from anode to anode through the two branches of the input circuit. Since the impedance of the connections in the input circuit are all equal, no voltage appears across the source 9, and consequently there can be no feedback from the output to the input. Otherwise considered, a voltage induced on the cathode of tube 11 by reason of a potential appearing on its anode is balanced out by an exactly equal and opposite voltage induced on the grid of tube 13 by its anode.

The assumption that the anode-cathode capacity is equal to the anode-grid capacity is not fully met in all tubes. However, in certain tubes now available, these capacities have been found to be substantially identical. If, in any given instance, measurements indicate that the anode-cathode capacity is not equal to the anode-grid capacity, the condition of equality may readily be achieved by providing a small shunt capacitor between the appropriate tube electrodes. This capacitor will be very much smaller than that utilized in the conventional cross-neutralization system and, consequently, does not represent a serious load on the anode circuit. For example, where a neutralizing capacitor of 8 to 10 micromicrofarads is required in the conventional cross-neutralization system illustrated in Fig. 1, the correcting capacitor necessary to balance the tube capacities in accordance with this invention will be of the order of 2 to 3 micromicrofarads.

A modification of this invention which utilizes parallel line resonators in place of the series resonant circuits described above is illustrated in Fig. 3. In this instance, the source of input voltage is an oscillator 33 which is coupled to the neutralized amplifier through a transformer 35 having a balanced low impedance secondary winding 36. One terminal of the secondary winding 36 is connected to the midpoint, or point of symmetry, of a folded full wave line comprising two parallel half wave conductors 37 and 39. The open end of conductor 37 is connected to the grid of the first tube 11, while the open end of the conductor 39 is connected to the cathode of the second tube 13. The other terminal of the secondary 36 is similarly connected to the midpoint of a folded full wave line comprising inductors 41 and 43, the open ends of which are connected respectively to the cathode of tube 11 and the grid of tube 13. An output transformer 15 is connected between the anode electrodes, as before.

The operation of the device illustrated in Fig. 3 is similar to that of the previously described arrangement, and need not be described again.

A practical arrangement in which provision is made for modulating the amplifier is illustrated in Fig. 4 to which reference is now made. The cathode conductors 49, 51 of the resonant lines are hollow tubes within which one or more insulated leads are arranged for energizing the heater or cathode of the amplifier tubes. Alternatively, the cathode heater leads may be twisted around or made parallel to the line conductors. In the illustrated example, the cathodes are energized by batteries 45 and 47 which are located at the ends of the resonant lines. However, the resonant lines may be extended a quarter wave beyond the point at which the input voltage is applied, and the filament leads brought out at the ground potential point which would then be provided, or brought back to the grounded midpoint of the input transformer secondary winding. The grid conductors 53 and 55 are divided into two sections by means of capacitors 57 and 59 located at the points of maximum voltage which are approximately a quarter wave length from the closed end of the lines. These capacitors may take any convenient form, and their purpose is to isolate the grid electrodes for low frequency voltages so that suitable biasing and modulating potentials may be applied without appreciably attenuating the applied radio frequency input voltage. The two grid electrodes are connected through a pair of radio frequency choke coils 61, 63 to one terminal of a source of modulation voltage 65. The other terminal of the modulation source is grounded through a grid biasing battery 67. The radio frequency input is applied to the closed ends of the resonant lines, as before, and the output is taken between the two anode electrodes. Capacitors 69 and 71 are the small compensating capacitors described above for equalizing the anode-cathode capacity of the tubes.

I have thus described a neutralized amplifier for use in connection with modulated high frequency voltages which appreciably reduces the sideband attenuation caused by the conventional neutralizing capacitors. A system for modulating such a neutralized high frequency amplifier has also been described.

I claim as my invention:

1. In a radio frequency amplifier a pair of thermionic tubes having cathode, grid and anode electrodes; a source of radio frequency voltage

having two output terminals; connections comprising low impedance paths for radio frequency currents from one of said terminals to the grid of one of said tubes and to the cathode of the other of said tubes; a capacitor in said connections for effectively isolating the grid of one of said tubes from the cathode of the other of said tubes for modulation frequency currents, other connections from the other of said terminals to the cathode of said one tube and to the grid of said other tube, a capacitor in said other connections for effectively isolating the cathode of said one tube from the grid of said other tube for modulation frequency currents, the electrical length of said connections being equivalent to a half wave length at said radio frequency; a source of modulating voltage; means for applying said modulating voltage in like phase to an electrode in each of said tubes for varying the potential difference between each of said grids and its adjacent cathode in accordance with said modulating voltage; and an output circuit connected between said anode electrodes.

2. A modulated neutralized radio frequency amplifier comprising a pair of thermionic tubes having cathode, grid and anode electrodes; a source of radio frequency voltage having two output terminals; connections comprising a low impedance path for radio frequency currents from one of said terminals to the grid of one of said tubes and to the cathode of the other of said tubes; connections comprising a low impedance path for radio frequency currents from the other of said terminals to the cathode of said one tube and to the grid of said other tube, a capacitor in each of said connections for effectively isolating the grid of each tube from the cathode of the other tube for modulation frequency currents; a source of modulating voltage; means for applying said modulating voltage to said electrodes so that the potential differences between said grids and their adjacent cathodes are varied in accordance with said modulating voltage; and an output circuit connected between said anode electrodes.

3. In a radio frequency amplifier a pair of thermionic tubes having cathode, grid and anode electrodes; input means for connection to a source of radio frequency voltage; connections from said input means for applying said voltage in a given phase between ground and the grid of one of said tubes and the cathode of the other of said tubes; connections from said input means for applying said voltage in the opposite phase between ground and the cathode of said one tube and the grid of said other tube; a capacitor in said connections for effectively isolating the grid of each tube from the cathode of the other for modulating voltages; a source of modulating voltage; means for applying said modulating voltage to said electrodes so that said modulating voltages varies the effective grid-cathode voltage of each of said tubes in like manner; and an output circuit connected between said anode electrodes.

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