March 8, 1949. C. J. STARNER 2,463,724

ELECTRON DISCHARGE CIRCUIT HAVING FOLDED ANODE INDUCTORS

Filed Feb. 20, 1945 2 Sheets-Sheet 1

Fig. 1.

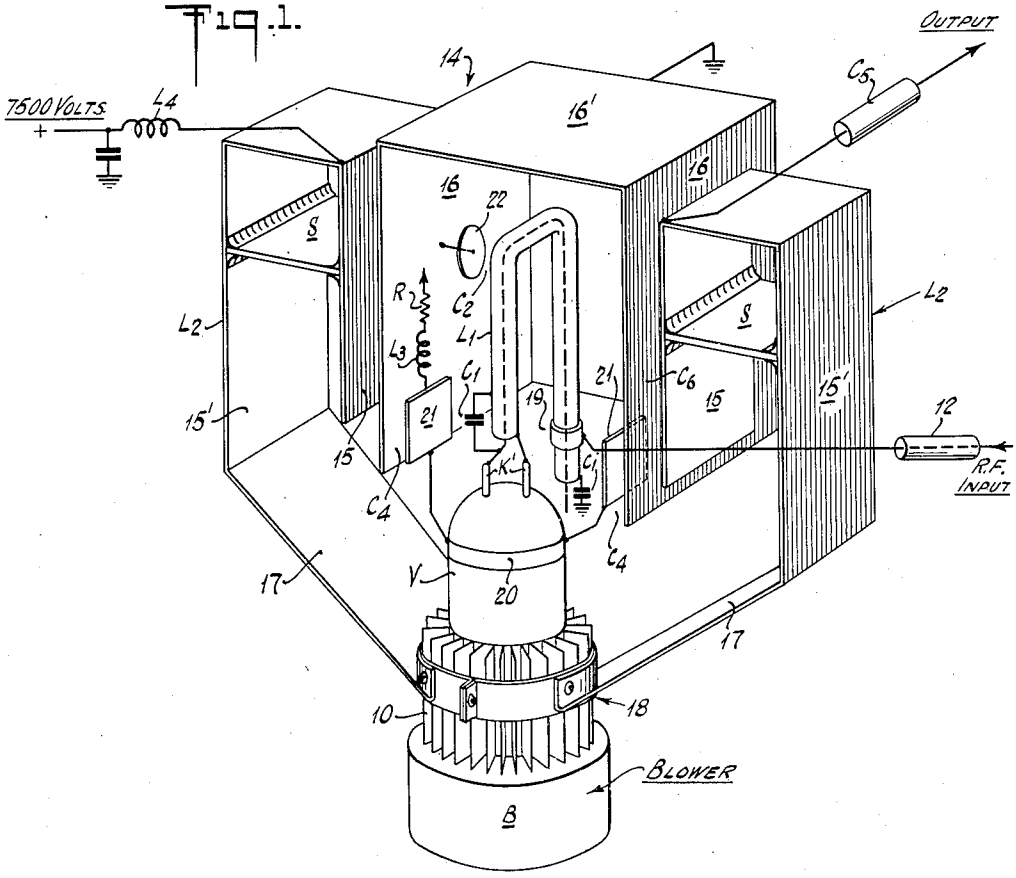
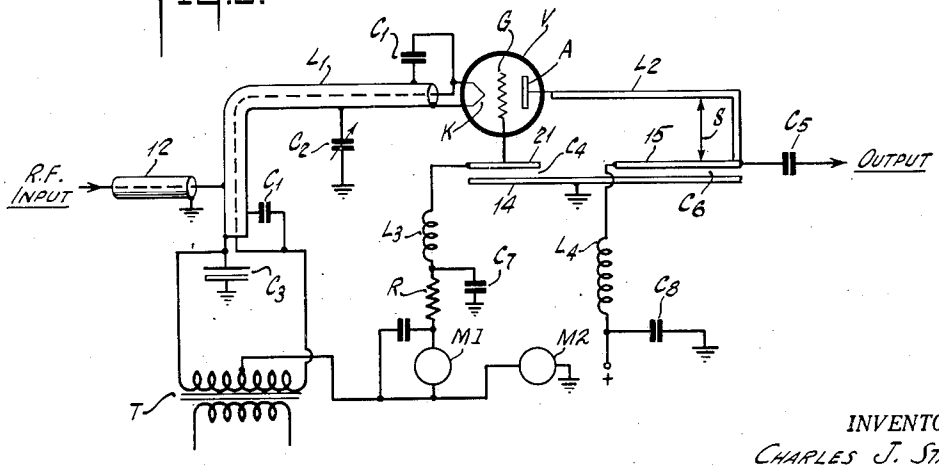


Fig. 2.



INVENTOR.
CHARLES J. STARNER.

BY

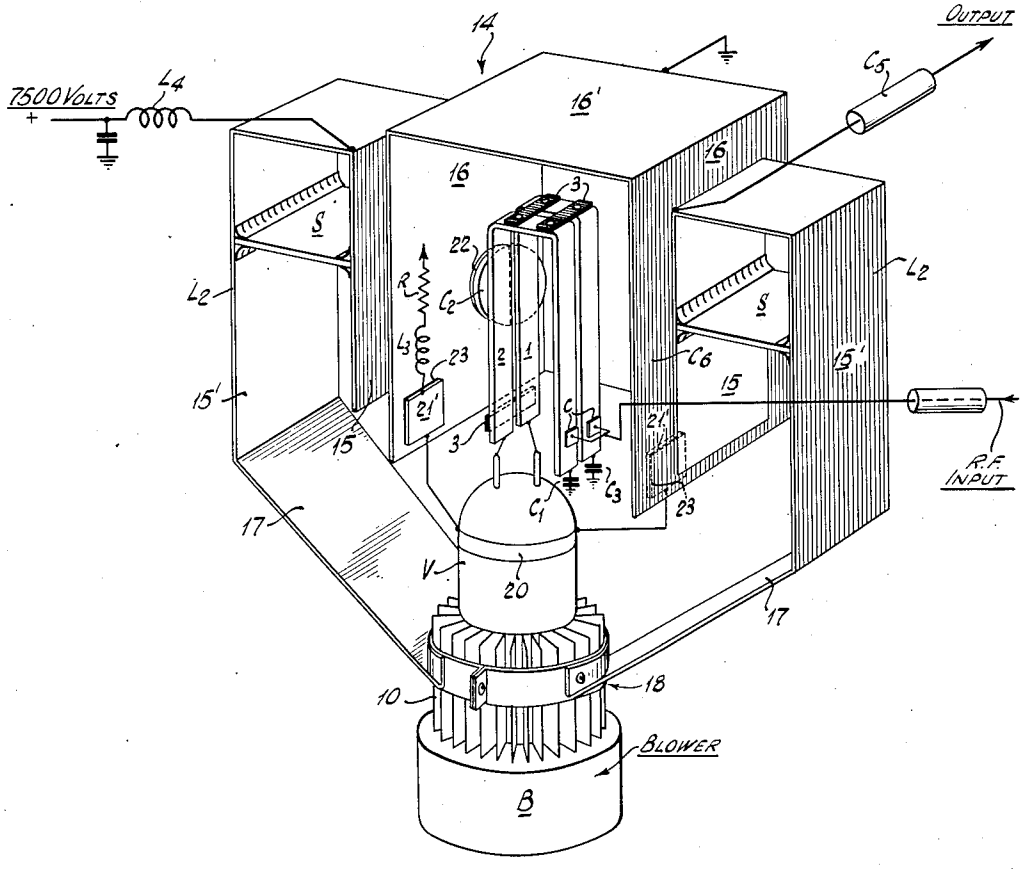
ATTORNEY.

March 8, 1949. C. J. STARNER 2,463,724

ELECTRON DISCHARGE CIRCUIT HAVING FOLDED ANODE INDUCTORS

Filed Feb. 20, 1945 2 Sheets-Sheet 2

Fig. 2.



INVENTOR
CHARLES J. STARNER.
BY H. G. Brown
ATTORNEY

Patented Mar. 8, 1949

2,463,724

UNITED STATES PATENT OFFICE

2,463,724

ELECTRON DISCHARGE CIRCUIT HAVING FOLDED ANODE INDUCTORS

Charles J. Starner, Haddonfield, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application February 20, 1945, Serial No. 578,899

6 Claims. (Cl. 179—171)

1

This invention relates to transmitter circuits, and particularly to a novel mechanical construction for a high power radio transmitter station.

An object of the present invention is to provide a high power electron discharge device electrical circuit in the form of a mechanical construction which is simple to build and permits easy removal of the associated electron discharge device.

Another object is to provide a simplified radio transmitter construction wherein the load current is a very small part of the circulating current (KVA) and which enables symmetrical tuning of the anode circuit of the electron discharge device stage.

A more specific object is to provide an improved mechanical circuit arrangement for a grounded grid type of vacuum tube amplifier stage useful in a frequency modulation transmitter operating in the range of 42 to 56 megacycles, and wherein the vacuum tube stage is capable of providing an output of the order of 15 kilowatts with reduced anode circuit losses compared to prior constructions.

A more detailed description of the invention follows in conjunction with a drawing, wherein:

Fig. 1 illustrates my improved mechanical construction for a single vacuum tube stage in a high power transmitter;

Fig. 2 schematically illustrates the equivalent circuit arrangement of Fig. 1; and

Fig. 3 is a slight modification of the system of Fig. 1.

In order to aid in an understanding of the mechanical construction of Fig. 1 of the invention, reference will first be made to Fig. 2 showing the equivalent circuit diagram. The same parts in both figures are designated by the same reference characters. Both figures show a single vacuum tube amplifier stage adapted for use in a frequency modulation transmitter operating in the frequency range of 42 to 56 megacycles. This stage comprises an electron discharge device V having within an evacuated glass envelope a cathode K, a grid G and an anode A. Vacuum tube V is designed to provide a power output of the order of 15 kilowatts and has an anode equipped with a plurality of externally located metallic fins 10 (note Fig. 1) for efficiently radiating heat. These fins are air-cooled by means of a vertical flow of air from a blower B, as shown in Fig. 1.

2

Radio frequency excitation at the transmitter output frequency is fed into the inductor L_1 through a coaxial transmission line 12 from a lower power stage. L_1 can be considered as an open single wire transmission line, the return path being the ground plane of the cabinet which houses the equipment. The characteristic impedance of this line is kept essentially uniform throughout its length by maintaining uniform spacing between the line and the cabinet walls. It will be noted that one end of the line L_1 terminates at the cathode K and the other end terminates at ground for radio frequency currents through the direct current blocking capacitor C_3. Physically, L_1 consists of a hollow copper conductor which also serves as one conductor for single phase alternating current cathode heating power, 60 cycles for example, which is supplied through transformer T. The other conductor for cathode heating is an insulated cable inside the hollow conductor. Capacitors C_1 are by-pass capacitors which serve to keep the insulated cathode heating cable at the same radio frequency potential as the outside hollow conductor.

The frequency determining elements of the complete radio frequency input circuit consist of the distributed constants of the transmission line L_1, the grid-to-cathode capacity of the triode V and the variable capacitor C_2. The electrical length of L_1, considering the grid-to-cathode capacity and the C_2 capacity, is three-quarter wavelength. Capacitor C_2 is variable so that maximum excitation can be obtained by varying C_2 until the D. C. grid current (indicated by ammeter M1) is maximum. The radio frequency feed tap near the ground end of L_1 is set at a point that will result in an approximate impedance match of the transmission line from the previous stage.

The grid of V is connected to capacitor C_4 which serves essentially as a ground for radio frequency voltages but blocks the direct current bias voltage. This connection gives rise to the term "grounded grid amplifier." This capacitor comprises a metallic plate 21 which is spaced from a ground surface 14. For reasons which will be explained later, the grid of V is not exactly at ground potential for radio frequency but is very nearly so. The grid of V is also connected to a conventional grid leak circuit consisting of radio

frequency choke L_3, by-pass capacitor C_7, grid-leak resistor R, and indicating instrument M1 which connects to the center tap of the cathode heating transformer.

The anode of V receives high voltage direct current through choke L_4 and inductor L_2. The anode tuned circuit consists mainly of inductor L_2, capacitor C_6, the anode-to-grid capacity of V_1 and the stray anode-to-ground capacity. The inductor L_2 is variable by means of a motor (not shown) driving a sliding contact S between L_2 and C_6, as a result of which the anode circuit is tuned. Capacitor C_6 comprises a metallic plate 15 which is spaced from the ground surface 14. The capacity of C_6 is such that it serves not only to block the direct current voltage but also as a source of radio frequency voltage for feeding power to the second stage. Capacitors C_3, C_4 and C_6 all have a common ground plane so that radio frequency ground currents are confined to the shortest possible path.

It will be noted that the grid of V acts as a shield for radio frequency voltages between input and output circuits in much the same manner as the shield or screen grid of a tetrode so as to prevent interelectrode capacity feedback from the anode circuit to the input circuit. Putting it in other words, it is desired that there be only electronic transfer of energy from the input to the output circuit, and no feedback of energy in the reverse direction from the anode circuit to the input circuit through the tube. However, there still remains a small internal capacity between the anode and cathode of V and this may be neutralized to obtain proper operation of the amplifier. This may be accomplished by inserting a small amount of inductance in the connection between the grid of V and the capacitor C_4. This inductance is not shown schematically in the diagram and it is not apparent from a casual inspection of the physical set up that this inductance is present. The inductance required in the range from 42 to 54 megacycles is quite small and is made up entirely of the internal lead inductance from the grid terminal to the center of the actual grid of V plus the external connection from the grid terminal of V_1 to the capacitor C_4. The internal inductance is, of course, not variable, and the external connection may be a short fixed length of four inch wide copper strap connector. Therefore, neither of these inductances would normally be shown schematically as circuit elements.

Fig. 1 shows a highly desirable mechanical construction for accommodating vacuum tube amplifier V. The ground surface 14 of Fig. 1 is shown as comprising a U-shaped metallic surface having two vertical plates 16, 16 joined at the top by a horizontal metallic plate 16'. The anode inductor L_2 is shown as comprising two symmetrically located U-shaped metallic surfaces each of which includes an outer vertical plate 15' and an inner shorter vertical plate 15 joined at the top by a horizontal plate, as shown. The inner plates 15 of each of the two anode surfaces are located adjacent to but spaced from the plates 16 of the ground surface 14 and constitute therewith condensers C_6. Both parts of the inductor L_2 are tunable or adjustable by means of the horizontal sliders S which short-circuit portions of the plates 15' and 15. These sliders make contacts with the plates 15 and 15' by means of spring fingers and may be moved over the lengths of the plates 15 and 15' by means of a motor (not shown). The lower ends of the

plates 15', 15' of the inductor L_2 are connected by flat metallic straps 17 to a circular metallic band 18 upon which the anode fins 10 rest. It will thus be seen that there is provided symmetrical anode tuning for the vacuum stage, and that current in the anode circuit divides evenly on both sides of the circuit, thus causing a substantially even current distribution around the anode. Further, by dividing the inductor L_2 into two symmetrical parts, the inductance of the anode circuit is divided by one-half and thus raises the frequency limits. Another advantage of using two symmetrical elements of large surface area for the inductor L_2 is that the losses in the anode oscillatory circuit is reduced because of an increased conducting surface area and better current distribution to tube anode relative to an oscillatory circuit having only one metallic surface.

The inductor L_1 is in the form of a coaxial line and is connected at one end to the cathode terminals K_1 of the vacuum tube V. The radio frequency input circuit is connected to the outer conductor of L_1 by means of a strap 19 which can be moved over the outer conductor of L_1 for matching the impedance of the input circuit to the cathode inductor.

The grid of the tube is connected to a metallic strap 20 from whose opposite sides connections extend to flat metallic plates 21 located near to but spaced from the ground plates 16, 16. These two plates 21, 21 together with the plates 16, 16 constitute the condenser C_4 of Fig. 1. It will thus be seen that the grid is grounded from a radio frequency standpoint in symmetrical manner. If desired, the plates 21, 21 forming the grid blocking capacitor may be replaced by smaller plates separated from the ground surface 15 by means of mica as a dielectric instead of air. In this way, I can obtain a lower reactance (higher capacity) than that obtainable from the air capacity. One advantage of the mica dielectric is that no adjustment in capacity is needed over a certain range of frequencies used. The grid can in this last modification still be considered as slightly above ground potential for radio frequencies. The variable capacitor C_2 of Fig. 2 is shown in Fig. 1 as comprising a round disc 22 spaced from but movable with respect to the outer conductor of the cathode inductor L_1.

Among the advantages of the mechanical construction of Fig. 1 are: The arrangement is simple to build and enables the vacuum tube V to be easily removed from the bottom; the symmetrical anode tuning circuit enables a reduction in the anode circuit inductance by one-half, provides a substantially uniformly distributed current distribution around the anode, reduces losses in the anode circuit by better current distribution to the tube anode and by providing less current density due to the wide metallic surface of the inductor L_2; and because the load or output current is a very small part of the high circulating current, there is no disadvantage in taking output current from only one side of the symmetrical anode circuit.

With one embodiment of Fig. 1 of the invention tried out in practice, the elements of the ground surface 14 were thirty-six inches wide with a twelve inch separation between vertical plates 16, 16. The vertical plates 15', 15' of the inductor L_2 were approximately six inches wide, while the smaller vertical plates 15, 15 of the inductor L_2 comprising condenser plates were twenty-eight inches wide. The condenser C_5 was a lumped

sulphur type of capacity. The anode potential supplied to the inductor L_2 through the choke coil L_4 was approximately +7500 volts direct current. Each side of the symmetrical anode circuit carried approximately fifty amperes of radio frequency energy. The power output of the tube was approximately fifteen kilowatts.

Fig. 3 illustrates a mechanical construction substantially identical with Fig. 1, except for the following differences: The plates 21' which serve the same purpose as plates 21 in Fig. 1 are smaller in size and are spaced from the grounded surfaces 16 by means of mica spacers 23, instead of air, thus providing lower reactance (higher capacity); and a different mechanical arrangement is used for the cathode inductance L_1. The flexible filament conductors at the tube are connected to two spaced copper bus conductors or bars 1 and 2 which are in the form of a U and of the same dimension as the original tubular type of Fig. 1. These bus conductors are held rigidly in place by Mycalex insulator strips 3. Capacitor C_2 is located in the same position on the line as in Fig. 1, except that now the capacitor is split with one-half fastened to one bus 1 and the other half to the other bus 2, with the ground plate 22 common to both. Power is fed into line L_1 at an impedance matching point, but through a split capacitor C. Tuning is accomplished by raising the capacity of C_2, thus tuning both bus bars 1 and 2 at the same time and keeping the voltage distribution the same on both buses. The two parallel buses 1 and 2, therefore, act, as far as the radio frequency is concerned, as one line, with the cabinet acting as a ground plane, while at the same time these conductors 1 and 2 carry filament heating current. Elimination of one condenser C_1 at the tube terminals also tends to give a smoother line electrically.

Although the invention has been described in connection with a single ended vacuum tube stage, it should be understood that the principles of the invention are applicable to a push-pull or parallel type of amplifier stage.

What is claimed is:

1. In combination, an electron discharge device having an anode electrode, a pair of folded anode inductors symmetrically located on opposite sides of said device, said inductors each comprising a pair of parallel plates of appreciable surface area which extend away from one end of said device and are joined together at the end remote from the device, said inductors being parallel but spaced from each other, coextensive in length, and similarly arranged, and a metallic ground surface located between said inductors and capacitively coupled to one plate of one inductor and a corresponding plate of the other inductor.

2. In combination, an electron discharge device having an anode electrode, a pair of folded anode inductors symmetrically located on opposite sides and extending away from one end of said device in a direction parallel to the longitudinal axis of said device, said inductors each comprising a pair of flat parallel plates of appreciable surface area which are joined together at the end remote from said device and whose planes are parallel to said longitudinal axis, one plate of each pair being longer but narrower than the other plate of the same pair, the longer plate of each pair being further away from the longitudinal axis than the narrow plate of the same pair, and a U-shaped ground surface composed of flat metallic plates located between said inductors and having its legs located adjacent but spaced from the short plates of said inductors so as to form capacitors therewith.

3. In combination, an electron discharge device having an anode electrode and a grid electrode, a pair of folded anode inductors symmetrically located on opposite sides and extending away from one end of said device in a direction parallel to the longitudinal axis of said device, said inductors each comprising a pair of flat parallel plates of appreciable surface area which are joined together at the end remote from said device and whose planes are parallel to said longitudinal axis, one plate of each pair being longer but narrower than the other plate of the same pair, the longer plate of each pair being further away from the longitudinal axis than the narrow plate of the same pair, and a U-shaped ground surface composed of flat metallic plates located between said inductors and having its legs located adjacent but spaced from the short plates of said inductors so as to form capacitors therewith, and relatively smaller plates located between the legs of said U-shaped ground surface and forming capacitors therewith of low impedance to the operating frequency of said device, said last capacitors serving to ground said grid electrode for radio frequency energy.

4. In combination, an electron discharge device having an anode electrode, a grid electrode and a cathode, a pair of folded anode inductors symmetrically located on opposite sides and extending away from one end of said device in a direction parallel to the longitudinal axis of said device, said inductors each comprising a pair of flat parallel plates of appreciable surface area which are joined together at the end remote from said device and whose planes are parallel to said longitudinal axis, one plate of each pair being longer but narrower than the other plate of the same pair, the longer plate of each pair being further away from the longitudinal axis than the narrow plate of the same pair, and a U-shaped ground surface composed of flat metallic plates located between said inductors and having its legs located adjacent but spaced from the short plates of said inductors so as to form capacitors therewith, relatively smaller plates symmetrically located between and spaced adjacent to the different legs of said U-shaped ground surface to form therewith capacitors of low impedance to the operating frequency for said grid electrode, a coaxial line located substantially along the longitudinal axis of said device and forming an inductor for the cathode of said device, a plate arranged adjacent to but movable with respect to said coaxial line, a connection from said plate to said ground surface, whereby said last plate forms a capacitor for tuning said coaxial line inductor.

5. An electron discharge device amplifier stage for a radio transmitter operating in a frequency range of the order of 42 to 56 megacycles, comprising a vacuum tube having an anode, a grid and a cathode, anode radiator fins at one end of said tube, cathode terminals at the other end of said device, a pair of similar and similarly arranged folded anode inductors symmetrically located on opposite sides of said device and extending away from the cathode terminal end of said device, each of said inductors comprising a pair of parallel metallic plates which are joined together at the end remote from said device, the planes of said plates being parallel to the longitudinal axis of said device, a metallic ground surface located between said inductors and closely

spaced from the inner plates of both said inductors so as to form therewith a pair of electrical capacitors, other plates located adjacent said ground surface to form therewith capacitors of low impedance to the operating frequency, connections from said last plates to said grid, and means coupled to said cathode terminals and located on the same side of said device as said terminals for tuning said cathode.

6. In combination, an electron discharge device having an anode electrode, a metallic band connected to said anode electrode, a pair of folded back anode inductors symmetrically located on opposite sides of and connected to said band, said inductors each comprising a pair of parallel plates of appreciable surface area, the parallel plates of each inductor extending away from said band and being joined together at the end remote from the band, and an adjustable tuning slider

coupled between the parallel plates of each inductor.

CHARLES J. STARNER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,143,540	Buschbeck	Jan. 10, 1939
2,246,188	Roder	June 17, 1941
2,342,896	Salzberg	Feb. 29, 1944
2,370,423	Roberts	Feb. 27, 1945

FOREIGN PATENTS

Number	Country	Date
516,890	Great Britain	Jan. 15, 1940