July 1, 1941. J. E. KEISTER 2,247,779

HIGH FREQUENCY APPARATUS

Filed June 1, 1940

Fig. 1.

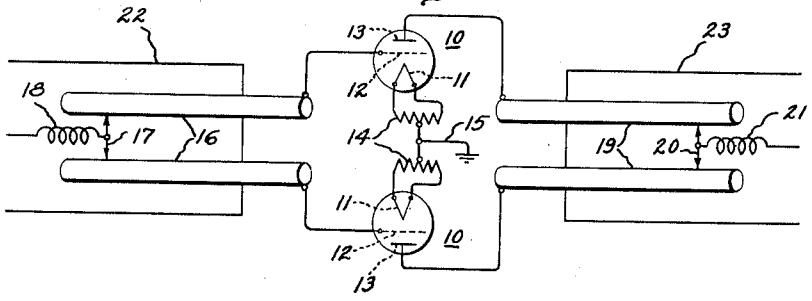


Fig. 3.

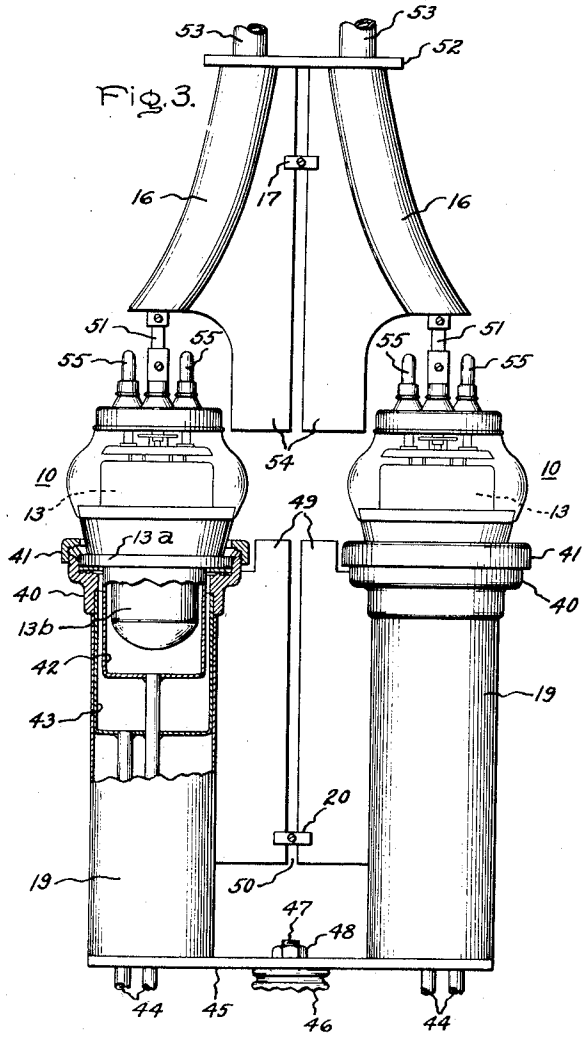
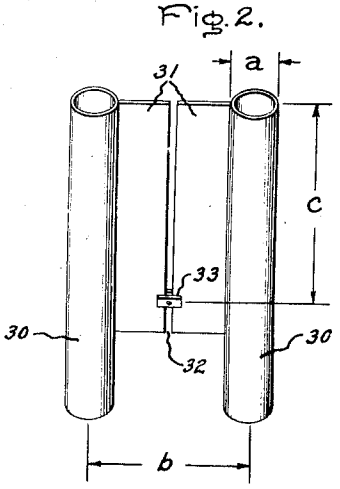


Fig. 2.



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HIGH FREQUENCY APPARATUS

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Application June 1, 1940, Serial No. 338,367

10 Claims. (Cl. 179—171)

My invention relates to high frequency apparatus. More specifically, it relates to a tuned circuit structure for an ultra high frequency amplifier.

In thermionic amplifiers, particularly high power push-pull amplifiers operating at ultra high frequencies of the order of 30 megacycles and upwards, such as are employed in television transmitters, resonant transmission lines are advantageously employed as tuned circuit elements. It is an object of my invention to provide an improved resonant line structure for a high power amplifier of this type.

It is another object of my invention to provide an improved transmission line structure which may advantageously constitute an integral part of an ultra high frequency power amplifier structure and perform a plurality of functions therein.

Another object of my invention is to provide a transmission line structure comprising spaced apart conductors with means to decrease the surge impedance of the line.

A further object of my invention is to provide the transmission line tank circuit structure of a high power amplifier with means to facilitate accurate adjustment of the length of the line.

Still another object of my invention is to provide an ultra high frequency tank circuit structure comprising a short-circuited resonant line with means to decrease the surge impedance of the line and to reduce the physical size of the shorting member.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing, in which Fig. 1 is a circuit diagram of a high power push-pull amplifier for ultra high frequency operation in which my improved structure may advantageously be employed; Fig. 2 is a perspective view of an elementary transmission line structure illustrating certain principles embodied in my invention, and Fig. 3 is a side elevation, partially in section, of one embodiment of my invention.

Referring now to Fig. 1, a push-pull amplifier comprising a pair of thermionic devices 10 is illustrated. These may be high power triodes, for example, each having a cathode 11, a grid 12, and an anode 13. The cathodes 11, illustrated as of the filamentary type, are connected to potentiometers or filament transformer secondaries 14 to which a suitable source of filament potential, not shown, may be applied in a conventional manner. The usual balanced connection between cathodes and ground is made by the conductor 15.

Both the input and output circuits of the devices 10 in Fig. 1 are illustrated as tank circuits comprising resonant transmission lines. Of course, only one of the circuits may be tuned if desired. As shown, the input tank circuit connected to the grids 12 comprises a pair of transmission line conductors 16 in parallel spaced relation. The length of the line can be adjusted by means of the movable shorting member 17. The common grid return connection is made through an impedance 18 and a source of suitable grid bias potential, not shown, to ground. The anode tank circuit also comprises a similar pair of transmission line conductors 19 and adjustable shorting member 20. The common anode return connection is made through impedance 21 and a suitable source of anode potential, not shown, to ground. Input and output circuits 22 and 23 are illustrated as looped conductors inductively coupled to the transmission lines 16 and 19 respectively. Of course, any other types of coupling means known to the art may be employed.

A detailed explanation of the adjustment and operation of the above-described amplifier circuit is deemed unnecessary. The proper adjustment of the respective transmission lines, in order to tune them to resonance at the operating frequency, depends upon the electrical line characteristics and the impedances of the devices 10 and associated connections, as is well known. In accordance with my invention, now to be described in detail, a transmission line structure is provided particularly suited both to the electrical and mechanical requirements of such an amplifier.

The relationship between transmission line structure and its electrical characteristics will next be considered briefly. Referring now to Fig. 2, a pair of parallel tubular conductors 30 is illustrated which might comprise the transmission line conductors of one of the tank circuits of Fig. 1, for example. It is well known in transmission line theory that the surge impedance of such a line is a function both of the diameters a of the conductors employed and the distance between their centers b. If their diameters a are increased, other factors remaining constant, the surge impedance of the line is decreased; while if the distance between their centers b

is increased, other factors remaining constant, the surge impedance is increased.

Considering for a moment the two conductors **30** alone, if the line is properly excited by a high frequency potential applied, for example, to the upper ends of the conductors **30** and if a short-circuiting members is connected directly between the conductors at a lower point, standing electrical waves will appear on the line. The proper line length at which it exhibits the characteristics of a parallel resonant tank circuit depends upon the surge impedance of the line and the impedance of the load to which it is connected, as mentioned previously. For example, when the line is coupled to a capacitive load it is also known that the physical length of the line may be increased if its surge impedance is decreased.

In a practical amplifier structure embodying such a line the values of the diameters *a* and of the spacing *b* are determined by other structural considerations, as will be shown presently. In accordance with my invention means are provided for decreasing the surge impedance of the line without changing these dimensions. This is accomplished by means of a pair of opposed plates **31** positioned between the conductors **30** and extending inwardly toward each other. These plates are of high electrical conductivity as, for example, copper. The outer edge of each plate conductively engages one of the conductors **30**. The inner opposed edges define a relatively narrow gap **32** which is of substantially less width than the spacing *b* between the conductors. An adjustable short circuiting member **33** is provided for determining the electrical length of the line, which is approximately the physical distance *c* in Fig. 2.

The position of the short-circuiting member **33** is adjusted until the transmission line is resonant at the operating frequency. As is well known, the effect of the member **33** is to cause standing waves of voltage and current to appear upon the line. The distribution of voltage and current depends upon the characteristics of the load coupled to the line and upon the distance from the member **33** to the point at which the driving voltage is applied, i. e., the upper ends of the conductors **30** in Fig. 2, under the assumed conditions. The line is adjusted to resonance when the member **33** occupies a position at which the current flowing therethrough is a maximum. This also corresponds to a point of minimum voltage on the standing voltage wave. In other words, the member **33** is positioned substantially at an antinode of the current wave and at a node of the voltage wave. If the line is long enough there may be several such points, but for reasons apparent to those skilled in the art the member **33** is preferably placed at the first current antinode occurring as the member is moved downwardly from the upper ends of conductors **30**.

By means of the structure just described the surge impedance of the line is greatly reduced, as will be apparent to those skilled in the art. The conductive plates **31** restrict the magnetic flux surrounding the conductors **30**, so that most of the flux passing between the conductors must pass through the relatively narrow gap **32**. This results in a consequent decrease in the line inductance and, therefore, a corresponding decrease in the surge impedance. Looking at it in another way, it decreases the effective spacing between the conductors and increases the effective diameters thereof.

A practical embodiment of my invention, as illustrated in Fig. 3, will now be described. The essential structure of a high power push-pull amplifier suitable for operation at ultra high frequencies is illustrated. This structure may be employed in a circuit such as is shown in Fig. 1, wherein corresponding elements have been given corresponding reference numerals. The amplifier comprises a pair of thermionic devices **10** each of which is supported by a transmission line conductor **19** forming an element of the anode tank circuit. The conductors **19** comprise hollow cylinders of sufficient diameter to surround the bases of the devices **10**. Any suitable means may be employed for mounting the devices **10** on the conductors **19** so as to form a unitary structure therewith. As illustrated, the anode **13** of each of the devices **10** extends downwardly exteriorly thereof, forming a supporting base. The upper end of each conductor **19** is provided with a flared mounting ring **40** on which is seated a flange **13***a* formed on the exterior portion of the anode **13** of the device **10**. A suitable clamping ring **41** in threaded engagement with the ring **40** holds the device **19** securely in position. A reentrant downwardly extending portion **13***b* of the anode **13** is surrounded by suitable cooling jackets **42** and **43** which direct the flow of a coolant, such as water, over the external surface of the anode to remove heat therefrom in the conventional manner. The coolant is supplied through conduits **44** extending upwardly within the conductors **19** to the water jackets **42** and **43** in the usual manner. The conductors **19** may of course themselves form one wall of the fluid cooling jackets if desired. The whole assembly is supported by a metal plate **45** on an insulator **46** to which the plate is secured by means of a stud **47** and a nut **48**.

In the structure just described it will be observed that the diameter of the transmission line conductors **19** is determined by the structure of the devices **10** and the cooling system associated therewith. The spacing between the conductors **19** is also determined by structural requirements. Thus, the spacing between the devices **10** must be sufficient to provide adequate cooling thereof and protection for the enclosing glass envelopes. The spacing must also be great enough to provide sufficient insulation therebetween in view of the high potentials existing between the anodes and other portions of the structure. Therefore, since the conductors **19** are necessarily spaced an appreciable distance apart, their surge impedance is of appreciable value. If an adjustable shorting member is connected directly between them to adjust the length of the transmission line, it has been found at ultra high frequencies that the line must be very short. In fact, it has been found at ultra high frequencies that it may be necessary to place such a shorting member between the flared rings **40**. This is obviously impractical, both from the standpoint of making effective conductive connection between the conductors and in adjusting the electrical length thereof. A very slight movement of the shorting member on a line of such limited length results in a considerable variation of the electrical characteristics thereof. Further, the shorting member itself must be of considerable length and at ultra high frequencies its inductance may be appreciable. This has the effect of further shorten-

ing the required length of line and aggravates the difficulties.

In accordance with my invention these difficulties are obviated by employing the plates **49** which are of material having high electrical conductivity, such as copper, between the conductors **19**. These correspond to the plates **31** in the transmission line illustrated in Fig. 2 and previously described. They constitute opposed radial flanges or fins extending axially along the conductors **19** and defining a relatively narrow gap **50** therebetween. One edge of each plate conforms generally to the shape of a conductor **19** and flared ring **40** and is maintained in good electrical contact therewith as by welding or soldering; or the plate **49** may of course form an integral part of the conductor **19**. The upper end of each plate **49** is also extended upward adjacent the clamping ring **41** so as to extend substantially the full effective length of the transmission line. The conductors **19** and plates **49** are made somewhat longer than necessary so that the line length may be adjusted by moving the shorting member **20**. The member **20**, which is adjustably positioned to bridge the gap **50**, is relatively small and of low inductance and provides good electrical contact between the two portions of the line. In accordance with the principles previously discussed in connection with Fig. 2, the required length of the transmission line has now been materially increased since its surge impedance has been reduced, and adjustments of the shorting member **20** may be made with much greater convenience and precision.

Since the shorting member **20** and all portions of the amplifier structure below this point are at ground radio frequency potential, the common anode connection may be made to any point on this portion of the structure, preferably at the stud **47**.

The grid tank structure for the device **10** in Fig. 3 is similar to the anode circuit structure just described. The pair of transmission line conductors **16** is illustrated as diverging downwardly toward the grid connections **51** from an upper supporting plate **52**. The conductors **16** are illustrated as of hollow tubular construction and act as conduits for conveying cooling air from the pipes **53** to the upper terminal structure of the devices **10** in order to increase further the effective heat dissipation during operation. The plates **54** associated with the conductors **16** correspond in all respects to plates **49** associated with the conductors **19**. They conform to the contour of the conductors **16**, making intimate conductive connection therewith, and may also extend downwardly over the upper terminal structure of the devices **10** so as to extend substantially the entire effective length of the transmission line, which includes the grid connections **51**. The conductors **16** and plates **54** are made somewhat longer than necessary so that the length of the line may be adjusted by means of the movable shorting member **17**. The common grid connection may be made to the shorting member **17** or to any part of the structure thereabove. If the supporting plate **52** is of conductive material, the grid connection may preferably be made thereto.

The circuit connections to the terminals **55** of the filamentary cathodes of the devices **10** have been omitted from Fig. 3 to simplify the drawing as they form no part of my invention. They may be connected to any suitable source of filament current as shown in Fig. 1.

In the illustrated embodiments of my invention the plates **31**, **49** and **54** have been illustrated as extending substantially the entire length of the line. Of course, it will be appreciated that, in some circumstances, it may be desirable to have them terminate short of one or both ends of the line. Their effectiveness is thereby somewhat reduced, but their function obviously remains the same. Thus in some cases, the short-circuiting members **33**, **20** or **17** may bridge the main transmission line conductor elements **30**, **19** or **16** directly and the plates **31**, **49** or **54** may be shorter than the required distance between the short-circuiting member and the end of the line to which the exciting voltage is applied.

It will be seen that I have provided an improved transmission line structure combining desirable mechanical features with highly efficient electrical characteristics, and which is eminently suited to form an integral part of an amplifier structure.

While I have shown particular embodiments of my invention, it will of course be understood that I do not wish to be limited thereto since modifications may be made, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination with an ultra high frequency amplifier comprising a pair of thermionic devices disposed in spaced relation and each having anode and grid terminals, a pair of resonant transmission line conductors connected to a like pair of said terminals and adapted and arranged to form a tuned tank circuit therewith, a pair of plates of high electrical conductivity positioned between said conductors, one edge of each plate being in conductive engagement with one of said conductors and opposing edges of said plates being in close proximity to each other and defining a relatively narrow gap therebetween, and a conductive member adjustably bridging said transmission line for adjusting the electrical length of said line substantially to resonance at the operating frequency of said amplifier.

2. In combination with an ultra high frequency amplifier structure comprising a pair of thermionic devices disposed in parallel spaced relation and each having an external anode, a resonant line tank circuit extending between said anodes, said circuit comprising a pair of hollow tubular transmission line conductors, one end of each of said conductors surrounding and conductively engaging one of said anodes, a pair of opposed metallic fins supported by the respective conductors, said fins extending axially substantially the length of said line and defining a gap therebetween of substantially less width than the spacing between said conductors, and a conductive member adjustably bridging said gap.

3. In combination, in a push-pull amplifier for amplifying currents of a high frequency, the structure comprising a pair of similar thermionic amplifying devices disposed and arranged in parallel spaced relationship and having a pair of corresponding terminals, a transmission line having a pair of conductors terminating in conductive connections at said terminals and comprising elements of a resonant circuit therebetween adapted to have standing waves of current of said high frequency developed thereon, low resistance means positioned between said conductors and electrically associated therewith for materially decreasing the surge impedance of said

line, said means being in conductive engagement with said line along a substantial portion of its length and defining a gap between said conductors of less width than the spacing therebetween, and means to short-circuit said line substantially at an antinode of said standing current waves.

4. A high frequency push-pull power amplifier structure comprising, in combination, a pair of electron discharge devices disposed and arranged in parallel spaced relation and each having an external anode base structure, a resonant line tank circuit between said anodes comprising a parallel pair of hollow, cylindrical, transmission line conductors, one end of each conductor conductively engaging the base structure of one of said devices, low resistance means positioned between said conductors and electrically associated therewith for materially decreasing the surge impedance of said line, said means being in conductive engagement with said line along a substantial portion of its length and defining a gap between said conductors of less width than the spacing therebetween, and a conductive member adjustably short-circuiting said line for adjusting the electrical length thereof substantially to resonance at the operating frequency of said amplifier.

5. The combination, in a high power push-pull amplifier structure adapted for operation at ultra high frequencies, of a pair of hollow, cylindrical, transmission line conductors disposed and arranged in parallel spaced relationship, a pair of thermionic devices each having a metallic base forming one electrode terminal thereof, said conductors engaging and supporting the bases of the respective devices and comprising elements of a resonant tank circuit therebetween, means to decrease the surge impedance of said line comprising a pair of opposed metal plates mounted adjacent each other between said conductors with one edge of each plate conductively engaging a respective conductor, opposing edges of said plates being in close proximity to each other and defining a gap of substantially less width than the spacing between said conductors, and an adjustable conductive member bridging said plates for adjusting the electrical length of said transmission line.

6. In combination, a push-pull power amplifier adapted for operation at ultra high frequencies, the structure comprising a pair of tubular conductors mounted vertically in parallel spaced relationship and comprising elements of a short-circuited resonant transmission line, a pair of power amplifier tubes each having a metal base structure forming an anode terminal connection therefor, the upper ends of said conductors receiving and supporting said base structures, a pair of opposed, radial, metal flanges supported by the respective conductors, said flanges extending vertically substantially the length of said line and defining a gap therebetween of substantially less width than the spacing between said conductors and a metal member bridging said plates at the short-circuited end of said line.

7. A short-circuited resonant line structure for high frequency operation comprising a pair of spaced apart transmission line conductors adapted to have standing electrical waves of current and voltage developed thereon, low resistance means positioned between said conductors and electrically associated therewith for materially decreasing the surge impedance of said line, said means being in conductive engagement with said line along a substantial portion of its length and defining a gap between said conductors of less width than the spacing therebetween, and short-circuiting means for determining the length of said line.

8. A resonant transmission line structure comprising a pair of spaced conductors, a pair of conductive plates mounted adjacent each other between said conductors with one edge of each plate conductively engaging a respective conductor, opposing edges of said plates being in close proximity to each other and defining a gap of substantially less width than the spacing between said conductors, and an adjustable conductive member bridging said transmission line for adjusting the electrical length of said line.

9. An open wire resonant transmission line for ultra high frequency operation comprising a pair of spaced apart transmission line conductors, means to decrease the surge impedance of the line comprising a pair of opposed flanges of high electrical conductivity respectively supported by said lines and extending inwardly toward each other, said flanges being separated to define a gap, and a shorting member conductively bridging said line.

10. A short-circuited resonant transmission line structure adapted to be energized to have standing current waves of a high frequency developed thereon comprising, in combination, a pair of spaced transmission line conductors, opposed metallic members conductively engaging the respective conductors and extending substantially the entire length of said line, said members defining a gap therebetween of substantially less width than the spacing between said conductors, and a metallic short-circuiting member bridging said gap substantially at an antinode of said high frequency standing current waves.

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