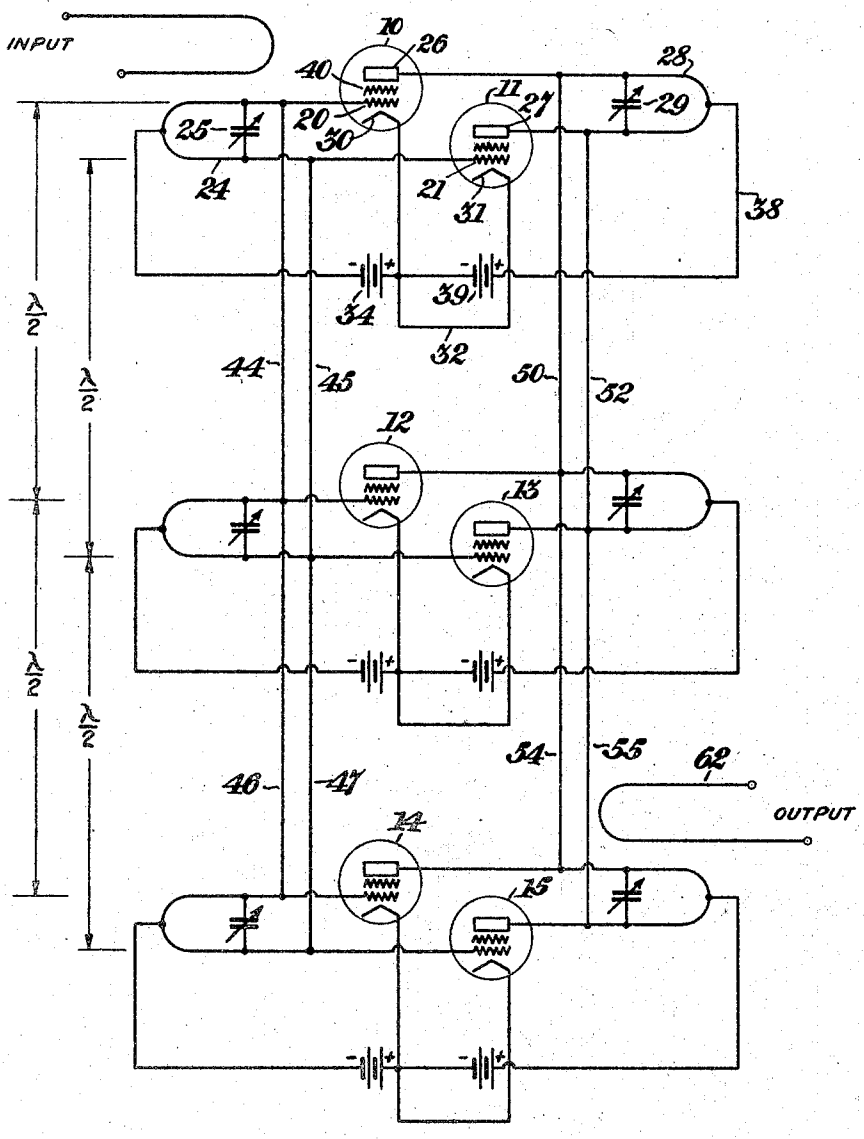
Feb. 1, 1944. C. B. WATTS JR 2,340,352

RADIO CIRCUIT

Filed May 18, 1942 2 Sheets-Sheet 1

Fig. 1.



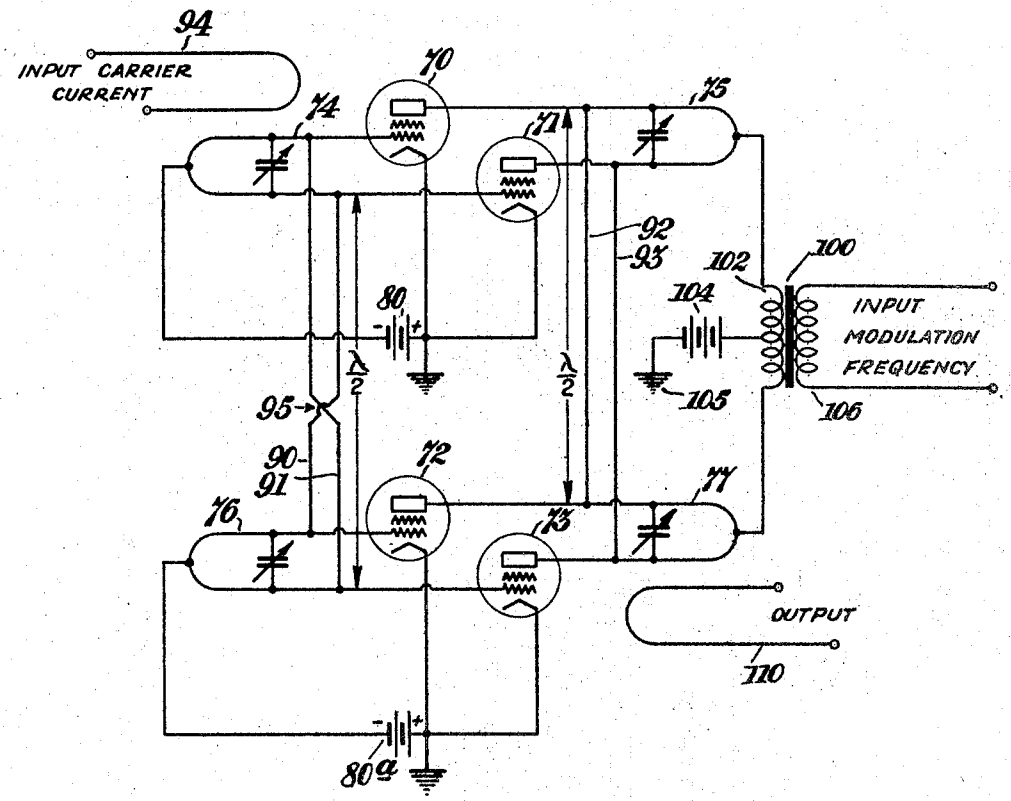
INVENTOR
CHESTER B. WATTS JR.
BY Paul R Adams
ATTORNEY

Feb. 1, 1944. C. B. WATTS, JR 2,340,352

RADIO CIRCUIT

Filed May 18, 1942 2 Sheets-Sheet 2

Fig. 2.



INVENTOR
CHESTER B. WATTS JR.
BY Paul R Adams
ATTORNEY

Patented Feb. 1, 1944 2,340,352

UNITED STATES PATENT OFFICE

2,340,352

RADIO CIRCUIT

Chester B. Watts, Jr., East Orange, N. J., assignor to Federal Telephone and Radio Corporation, a corporation of Delaware

Application May 18, 1942, Serial No. 443,391

12 Claims. (Cl. 179—171.5)

This invention relates to radio-frequency circuits and more particularly to amplifier, modulator and other circuit parts thereof having multiple vacuum tube arrangements for operation at ultra-high frequencies.

When ultra-high frequency currents are used on the existing amplifier, modulator and other circuits of the prior art having multiple tube arrangements, the operating results are not satisfactory. One of the difficulties found in using the existing multiple vacuum tube circuits of the prior art at ultra-high frequencies is that the capacitative reactance of such circuits with respect to the higher frequencies is so low that it is impossible for practical purposes to properly tune the common tank circuits. This unusually large capacitance, I discover, is largely due to the parallel arrangement of tie-lines and other connections between the terminals of the tubes. In order to avoid the occurrence of such large capacitance in multiple vacuum tube operation at ultra-high frequencies, and to otherwise improve the operation of amplifier and other radio-circuit parts having amplifying characteristics, I arrange each tube or pair of tubes as a separate amplifier having its own grid tank, plate tank and preferably with at least partially separate biasing means, by-pass condensers, and connect together these amplifiers through lengths of tie-lines equal electrically to substantially one-half of the wave length of the ultra-high frequency impressed thereon. This circuit arrangement, I find, greatly minimizes the heretofore capacitance found to occur in the existing multiple tube circuits of the prior art when operated at ultra-high frequencies.

One of the objects of this invention, therefore, is to provide a low capacitance circuit having a multiple vacuum tube arrangement suitable for operation at ultra-high frequencies.

Another object of the invention is to provide a low capacitance circuit having two or more tubes in multiple arrangement so as to obtain increased power at ultra-high frequencies.

Still another object of the invention is to provide a plural tube amplifier and modulator circuit by which the amplified ultra-high frequency current can be satisfactorily modulated.

The above objects and others ancillary thereto will become more apparent upon consideration of the following detailed description when taken in connection with the accompanying drawings, in which:

Fig. 1 is a schematic illustration of one form of amplifier circuit in accordance with the invention; and

Fig. 2 is a schematic illustration of another amplifier circuit having an input for a source of modulating frequency current by which an input ultra-high frequency carrier current can be amplified and modulated.

Referring to Fig. 1 of the drawings, the circuit shown for purposes of illustration contains three sets of vacuum tubes 10, 11; 12, 13; and 14, 15; the circuit of each set being connected as an individual push-pull amplifier. These amplifier units are connected together in parallel as hereinafter described so that the output power of a plurality of such units is equal to that of one unit multiplied by the number of units so connected, it being understood, of course, that any desired number of amplifier units may be connected together in accordance with this invention.

Referring particularly to the amplifier circuit for the tubes 10 and 11, the grids 20 and 21 thereof are connected together by a suitable tank circuit 24 having a variable condenser 25. The plates 26 and 27 are likewise connected together by a tank circuit 28 having a variable condenser 29. The filaments 30 and 31 are connected together by a wire 32, and a battery 34 is connected between the wire 32 and the tank circuit 24 to provide a suitable potential for the grids 20 and 21. A suitable potential for the plates 26 and 27 is provided by connecting the tank circuit 28 at its midpoint by a wire 38 to the wire 32 through a battery 39. The tubes may in addition be provided, if desired, with a screen grid 40 suitably connected in the circuit.

The circuits of the tubes 10 and 11 are thus arranged in push-pull relationship, the two tubes being identical and operated at the same continuous grid and plate potentials, and excited in phase opposition by an electromotive force to be amplified. The two sets of tubes 12, 13 and 14, 15 are provided with push-pull circuit arrangements similar to the arrangement described for the set of tubes 10 and 11.

The grid terminals of the tubes 10 and 11 to which the tank circuit thereof is connected are connected in parallel by tie-lines 44 and 45 with the terminals of the grids of the tubes 12 and 13, and the latter terminals are connected in parallel by tie-lines 46 and 47 to the terminals of the tubes 14 and 15. Likewise, the terminals of the plates 26 and 27 are connected by tie-lines 50 and 52 in parallel to the terminals of the plates of the tubes 12 and 13 and the plates of the tubes 12 and 13 are connected by tie-lines 54 and 55 in parallel to the plates of tubes 14 and 15. Each of these tie-lines is of a length

equal electrically to substantially one-half of the wave length of the high frequency current to be amplified. These parallel tie-line connections being chosen at substantially one half wave length greatly minimize the capacitance effect otherwise present in the prior existing circuits when operated at ultra-high frequencies. It will be understood, however, that while the circuits of my invention are particularly adapted for use at ultra-high frequencies, they may also be used satisfactorily at lower frequencies.

The electromotive force input to be amplified may be applied to any one of the grid tank circuits of the three sets of tubes. As shown in Fig. 1, the input circuit 60 is shown coupled with the grid tank circuit 24 of the tubes 10 and 11. While the output circuit may likewise be coupled with any of the plate tank circuits of the three sets of tubes, I prefer as shown to couple the output circuit 62 with the tank circuit 63 of the tubes 14 and 15 diagonally disposed with respect to the input circuit 60.

In use, each set of tubes operates as an individual push-pull amplifier and the parallel tie-line connections of the grid and plate tank circuits give parallel inputs and additive power output. The input alternating electromotive force is impressed over the parallel connections to each of the grid tank circuits and excite the grids of the two tubes of each set in phase opposition. That is to say, the grid 20 of tube 10 is positive or less negative when the grid 21 of tube 11 is at a maximum negative potential and vice versa. This results in the well-known push-pull amplification of the input electromotive force, and the units being connected in parallel, the power output is additive, the summation thereof being transmitted to the output circuit 62.

Modulated electromotive force of ultra-high frequencies may be effected by two push-pull units of my invention. Such a modulating circuit is shown in Fig. 2. The two push-pull units including the tubes 70, 71 and 72, 73 respectively may be arranged in substantially the same circuit arrangements shown in Fig. 1. The tubes 70 and 71 are provided with a grid tank circuit 74 and a plate tank circuit 75. The tubes 72 and 73 are provided with a grid tank circuit 76 and a plate tank circuit 77. The potential of the grid tank circuits 74 and 75 may, for sake of simplicity, be provided by connecting individual batteries 80 and 80a between the respective tanks and ground. The potential of the plate tanks may be provided by connecting the tanks to opposite ends of a secondary winding 102 of a transformer 100 used as an input for a source of modulation frequency, the center tap of which is connected through a battery 104 to ground 105.

The two push-pull circuits are connected together in parallel by tie-lines equal electrically in length to substantially one half of the wave length of the input carrier frequency. Two of the tie-lines 90 and 91 connect the terminals of the grid tanks of the two push-pull units and tie-lines 92 and 93 connect the terminals of the plate tanks of the two units.

In order to make the output of the two push-pull units in phase opposition, either the tie-lines 90, 91 or the tie-lines 92, 93 may be transposed. As shown in Fig. 2, the tie-lines 90 and 91 are transposed at 95 so that the grid of tube 70 is connected to the grid of tube 73, and the grid of tube 71 is connected to the grid of tube 72. By this arrangement, the carrier frequency applied to the grid tank circuits by the input-circuit 94 operates the two units in phase opposition so that the plate electromotive force of the tank circuits 75 and 77 buck each other and therefore tend to balance.

While the transformer 100 is shown to be connected across the plate tank circuits 75 and 77, it will be readily apparent to those skilled in the art that the transformer may be connected across the grid tank circuit 74 and 76 and the batteries 80 and 80a transposed to provide potential for the plate tank circuits 75 and 77.

An output circuit 110 may be coupled with either of the plate tank circuits 75 or 77. As shown, the output circuit is coupled with the plate circuit 77 diagonally opposite the input circuit 94.

In operation, the input carrier frequency which, in accordance with my invention, may be ultra-high, is applied to the grid tank circuits of the push-pull units through the input circuit 94. The grid tanks of the two push-pull units having the tie-lines therebetween transposed operate in phase opposition so that the plate frequencies of the two circuits are directly opposed and therefore tend to balance each other. The input of a modulating frequency is provided by connecting the transformer primary 106 to a suitable source of modulating frequency. This modulating input unbalances the current conditions of the plate circuits thereby resulting in a carrier output current of ultra-high frequency modulated in accordance with the input modulation frequency. The modulation is of the carrier-suppressed type giving only side bands.

The parallel connecting tie-lines 90, 91, 92 and 93 being one-half of the wave length of the carrier frequency, the heretofore high capacitance effect of the connections are avoided and ultra high frequencies are effectively amplified and modulated.

From the foregoing description, it will be readily apparent that the amplifying characteristics of the push-pull units of a circuit, such as illustrated in either of the embodiments (Fig. 1 or Fig. 2), are substantially the same; that the input power can be fed to any one of the grid tanks thereof and that the output power can be taken from any one of the plate tanks thereof; that the grid tank circuits of each embodiment act together as one and the plate tank circuits of each embodiment act together as one; and that the tuning of any grid tank operates to influence the tuning of the other grid tanks connected thereto and the tuning of any plate tank circuit operates to influence the tuning of the other plate tanks connected thereto. Each separate tank circuit should preferably be tuned correctly in order to have good power distribution. This may be done by tuning all the grid tanks with the same condenser settings and all the plate tanks with the same condenser settings.

It is recognized that many variations and changes may be made in the circuits shown and described without departing from the invention. It will be understood, therefore, that the circuits shown and described are to be regarded as illustrative of the invention only and not as restricting the appended claims.

What I claim is:

1. In a radio frequency circuit, a part thereof comprising a plurality of pairs of three-electrode vacuum tubes, a grid tank circuit for each pair

of tubes connecting together the grids thereof, a plate tank circuit for each pair of tubes connecting together the plates thereof, tie-lines connecting togethe the terminals of the grid tank circuits, and other tie-lines connecting together the terminals of the plate tank circuits.

2. In a radio frequency circuit, a part thereof comprising a plurality of pairs of three-electrode vacuum tubes, a grid tank circuit for each pair of tubes connecting together the grids thereof, a plate tank circuit for each pair of tubes connecting together the plates thereof, tie-lines connecting together the terminals of the grid tank circuits, other tie-lines connecting together the terminals of the plate tank circuits, and the lengths of the tie-lines each being equal electrically to substantially one half of the wave length of the frequency input thereto.

3. In a radio frequency circuit, a part thereof comprising a plurality of pairs of three-electrode vacuum tubes, a grid tank circuit for each pair of tubes connecting together the grids thereof, a plate tank circuit for each pair of tubes connecting together the plates thereof, tie-lines connecting together the terminals of the grid tank circuits, other tie-lines connecting together the terminals of the plate tank circuits, an input circuit electrically coupled to one of said grid tank circuits, and an output circuit electrically coupled to one of said tank plate circuits.

4. In a radio frequency circuit, a part thereof comprising a plurality of pairs of three-electrode vacuum tubes, a grid tank circuit for each pair of tubes connecting together the grids thereof, a plate tank circuit for each pair of tubes connecting together the plates thereof, tie-lines connecting together the terminals of the grid tank circuits, other tie-lines connecting together the terminals of the plate tank circuits, the grid tank circuit of the first of the pairs of tubes being electrically coupled to an input circuit carrying an electromotive force of a given frequency, and the tank plate circuit of the last of the pairs of tubes being electrically coupled to an output circuit.

5. An amplifier circuit for an electromotive force of high frequency comprising a plurality of pairs of three-electrode vacuum tubes, a grid tank circuit for each pair of tubes connecting together the grids thereof, a plate tank circuit for each pair of tubes connecting together the plates thereof, tie-lines connecting in parallel the corresponding terminals of the grid tank circuits, tie-lines connecting in parallel the corresponding terminals of the plate tank circuits, the grid tank circuit of the first of the pairs of tubes being electrically coupled to an input circuit, the tank plate circuit of the last of the pairs of tubes being electrically coupled to an output circuit and the lengths of the tie-lines each being equal electrically to substantially one half of the wave length of the input frequency.

6. A circuit for amplifying an electromotive force of high frequency comprising a plurality of push-pull amplifier units, tie-lines connecting in parallel the corresponding grid terminals of the tubes of successive units, tie-lines connecting in parallel the corresponding plate terminals of the tubes of successive units, and the lengths of the tie-lines each being equal electrically to substantially one-half of the wavelength of the input frequency.

7. A circuit for amplifying an electromotive force of high frequency and modulating the same comprising a plurality of push-pull amplifier units, tie-lines connecting the grid terminals of the tubes of successive units, tie-lines connecting the plate terminals of the tubes of successive units, the tie-lines being so connected that the plate currents tend to balance, the lengths of the tie-lines each being equal electrically to substantially one-half of the wavelength of the input frequency, and means to impose on the circuit a source of modulating frequency.

8. A circuit for amplifying an electromotive force of high frequency and modulating the same comprising a plurality of pairs of three-electrode tubes, a grid tank circuit for each pair of tubes connecting together the grids thereof, a plate tank circuit for each pair of tubes connecting together the plates thereof, a pair of tie-lines connecting the terminals of the grid tank circuits, a pair of tie-lines connecting the terminals of the plate tank circuits, one of the pairs of tie-lines being transposed so that the electromotive forces of the plate circuits of the pairs of tubes tend to balance, and means to impose on one of the tank circuits of each pair of tubes a source of modulating frequency.

9. A circuit for amplifying an electromotive force of high frequency and modulating the same comprising a plurality of pairs of three-electrode tubes, a grid tank circuit for each pair of tubes connecting together the grids thereof, a plate tank circuit for each pair of tubes connecting together the plates thereof, a pair of tie-lines connecting the terminals of the grid tank circuit, a pair of tie-lines connecting the terminals of the plate tank circuits, the tie-lines each being equal electrically to substantially one-half of the wavelength of the high frequency applied thereto, one of the pairs of tie-lines being transposed so that the plate currents of the pairs of tubes tend to balance, and means to impose on one of the tank circuits of each pair of tubes a source of modulating frequency.

10. A circuit for amplifying an electromotive force of high frequency and modulating the same comprising two pairs of three-electrode tubes, a grid tank circuit for each pair of tubes connecting together the grids thereof, a plate tank circuit for each pair of tubes connecting together the plates thereof, a pair of tie-lines connecting the terminals of the grid tank circuit, a pair of tie-lines connecting the terminals of the plate tank circuits, one of the pairs of tie-lines being transposed so that the plate currents of the two sets of tubes tend to balance, a source of potential connected between the grid tanks of each set of tubes and the ground, an input transformer connectable to a source of modulating frequency, the secondary winding of which is connected between the plate tank circuits of the two sets of tubes, and a source of potential connected between the mid-point of said secondary winding and the ground.

11. A circuit for amplifying an electromotive force of high frequency and modulating the same comprising two pairs of three-electrode tubes, a grid tank circuit for each pair of tubes connecting together the grids thereof, a plate tank circuit for each pair of tubes connecting together the plates thereof, a pair of tie-lines connecting the terminals of the grid tank circuit, a pair of tie-lines connecting the terminals of the plate tank circuits, one of the pairs of tie-lines being transposed so that the plate currents of the two sets of tubes tend to balance, the tie-lines each being equal electrically to substantially one-half of the wavelength of the high frequency applied thereto,

a source of potential connected between the grid tanks of each set of tubes and the ground, an input transformer connectable to a source of modulating frequency, the secondary winding of which is connected between the plate tank circuits of the two sets of tubes, and a source of potential connected between the mid-point of said secondary winding and the ground.

12. A circuit for amplifying an electromotive force of high frequency and modulating the same comprising two pairs of three-electrode tubes, a grid tank circuit for each pair of tubes connecting together the grids thereof, a plate tank circuit for each pair of tubes connecting together the plates thereof, a pair of tie-lines connecting the terminals of the grid tank circuits, a pair of tie-lines connecting the terminals of the plate tank circuits, the pair of tie-lines connecting the grid tank circuits being transposed so that the resulting plate currents of the two sets of tubes tend to balance, sources of potential for the grid and plate tank circuits, and means to impose on the plate tank circuits a source of modulating frequency.

CHESTER B. WATTS, JR.