May 19, 1942. E. C. CORK ET AL 2,283,793

HIGH FREQUENCY MODULATED RADIO SIGNAL TRANSMITTER

Filed Feb. 9, 1940 2 Sheets-Sheet 1

Fig. 1

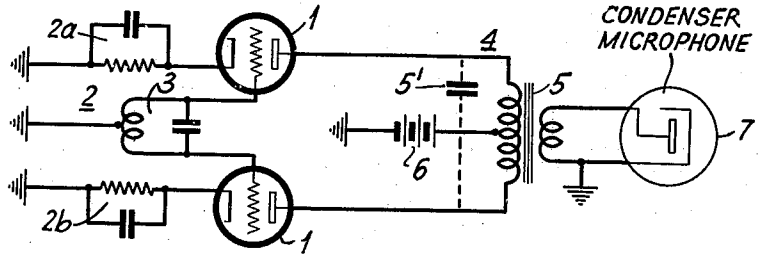


Fig. 2

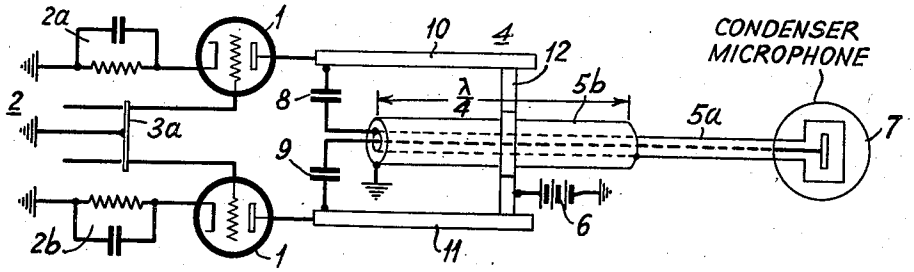
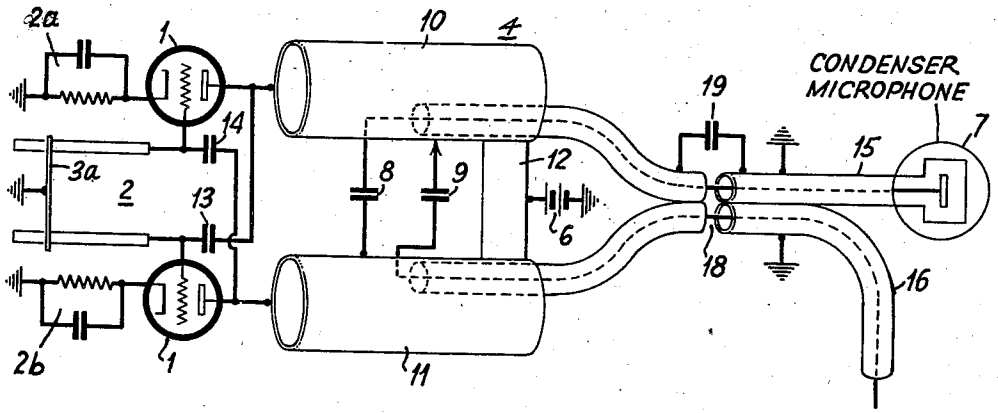


Fig. 3



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Filed Feb. 9, 1940 2 Sheets-Sheet 2

Fig. 3a

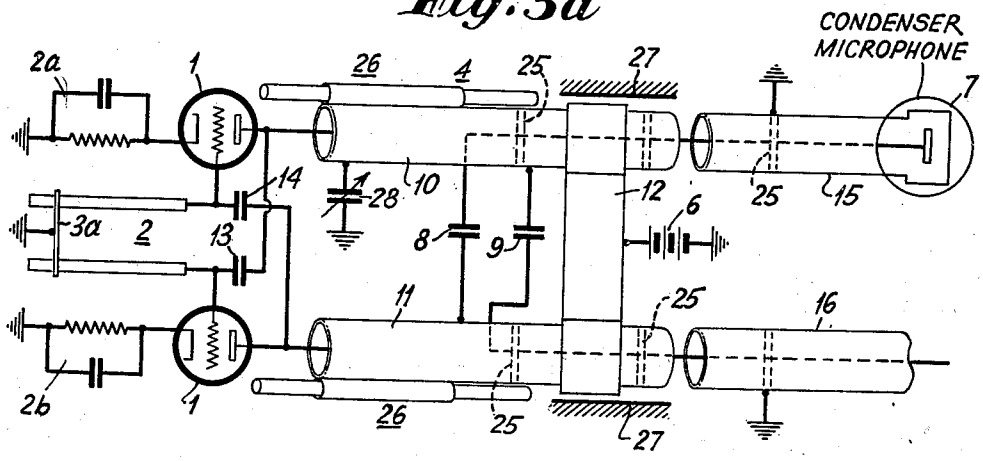
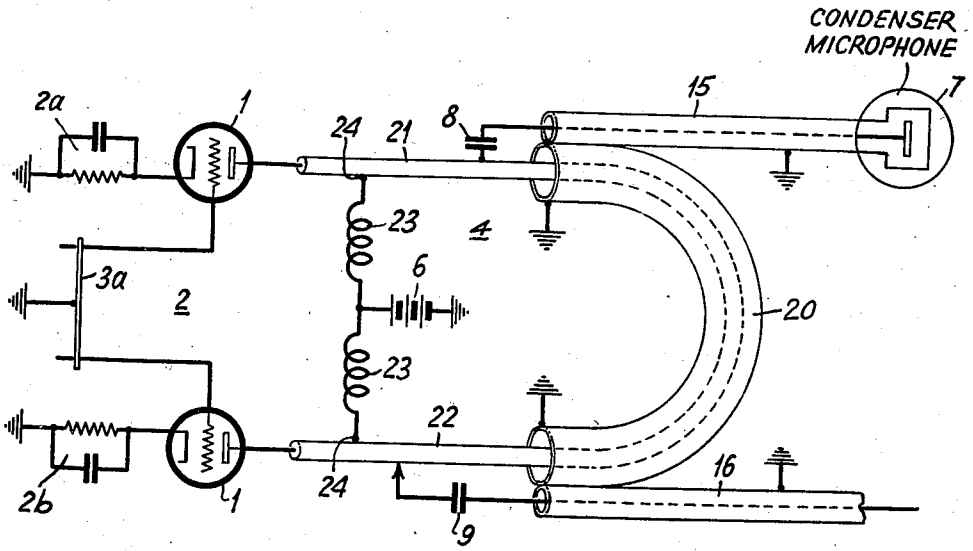


Fig. 4



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Patented May 19, 1942 2,283,793

UNITED STATES PATENT OFFICE

2,283,793

HIGH FREQUENCY MODULATED RADIO SIGNAL TRANSMITTER

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Application February 9, 1940, Serial No. 318,044
In Great Britain June 7, 1939

10 Claims. (Cl. 179—171.5)

The present invention relates to frequency modulated radio signal transmitters in which modulation of the output of the transmitter is effected by operation of a transmitting device as a capacity microphone, reed or like device, of which the capacity varies in response to the signals to be transmitted, and has particular but not exclusive reference to transmitters operating at the so-called ultra-short wave frequencies, above about 50 mc. sec.

In order to obtain adequate output it is desirable to use in a transmitter of the kind set forth an oscillator including a balanced pair or pairs of electron discharge valves. In this case the frequency controlling circuit, usually the anode circuit, of the oscillator, is a balanced circuit and the transmitter device is required to operate to produce balanced capacity variations in the control circuit. Thus, in cases where the transmitter device is connected directly in the frequency control circuit both plates of the device must, in most cases, be subjected to high frequency and high tension voltages, which is a disadvantage.

The object of the present invention is to provide an arrangement in which an unbalanced condenser microphone or reed device can be used as the transmitting instrument for a radio transmitter having a balanced oscillator.

In accordance with the present invention a frequency modulated radio signal transmitter comprises an oscillator including a balanced tuned circuit and an unbalanced condenser microphone or other signal responsive capacity varying device coupled with said tuned circuit by means of a transformer device in such manner that the balance of said tuned circuit is substantially undisturbed and the frequency of the oscillator can be modulated by actuation of said microphone in accordance with the signals to be transmitted. Preferably said tuned circuit is a balanced line circuit and is excited by a pair of valves connected in push-pull relation. The microphone or other signal responsive device is preferably connected in the tuned circuit by means of a concentric line arrangement which is such that balanced capacity variations are developed in the tuned circuit in response to variations in the capacity of the signal responsive device. Conveniently an unbalanced output from the transmitter may be derived from one side of the balanced line arrangement on the other side of which the signal responsive device is connected.

The nature of the invention will be fully understood from the following description with reference by way of example to the accompanying drawings of which the various figures show circuit diagrams of suitable oscillator arrangements for use in transmitters according to the invention. Like reference numerals in different figures of the drawings indicate like parts.

In the drawings Figs. 1 to 3, 3*a* and 4, inclusive, each illustrate a wave generator of the balanced type, a modulating means of the unbalanced type with circuits and means for coupling the modulating means to the balanced generator without upsetting the balance thereof. In Fig. 1, the generator is of the push-pull tuned circuit type with the microphone coupled thereto by a transformer. In Fig. 2, the tuned circuits of the generator comprise lines shunted by tuning straps and the modulator is coupled to the generator by concentric lines. In Figs. 3, 3*a* and 4, the generators are in general as in Fig. 2. In the latter figures, however, the modulating means is coupled by concentric lines to one side of the generating circuits and the effect thereof is counteracted by additional means connected to the other side of the generating circuit.

Figure 1 of the drawings shows a simple form of the invention. In this case the arrangement includes a pair of valves 1 connected in push-pull relation, the valves having a tuned grid circuit 2 including the inductance capacity combination 3 and an output circuit 4 including the secondary winding of transformer 5 to the mid-point of which the positive pole of the high tension source 6 is connected in the usual way. The cathode circuit includes suitable biasing arrangements for valves 1, these arrangements being indicated conventionally at 2*a* and 2*b* of the grid circuit. The output circuit 4 may be tuned by the stray capacity of the circuit indicated by the condenser 5', shown dotted and the inductance of the secondary winding of transformer 5 and the regenerative coupling between circuits 4 and 2 is effected due to the stray capacity between the grid and anode of the valves 1. The primary winding of transformer 5 is connected in an unbalanced circuit associated with the condenser microphone 7.

With this arrangement capacity variations of the microphone in response to signals are transformed and appear as balanced variations of capacity in the anode circuit of valves 1 and accordingly the frequency of the oscillator is varied in accordance with the signals to be transmitted. Thus, the desired frequency modulated carrier wave signals are produced. The output of the transmitter is connected to the output circuit 4 in any suitable manner.

The arrangement illustrated in Figure 1 is not suitable for ultra short wave operation, for example at frequencies above about 50 mc./sec., as in this case the stray capacities of the circuits render satisfactory operation very difficult. It is thus preferred to adopt, for ultra short wave working, arrangements such as those shown in Figures 2, 3 and 4.

Thus, referring to Figure 2 the microphone is shown connected to a concentric line 5*a* surrounded by a further cylinder 5*b* a quarter of a wave length long extending from the end of the line 5*a* remote from microphone 7 towards the microphone and earthed at the end remote from the microphone and connected to the outer conductor of line 5*a* at the end nearest the microphone. The conductors of the line 5*a* are connected through blocking condensers 8 and 9 respectively one to each of a pair of anode conductors 10 and 11 associated one with each of the valves 1 and tuned by the shorting bar 12 to which the high tension source 6 for the anodes of valves 1 is connected.

The cylinder 5*b* serves two purposes. In the first place, it substantially eliminates unbalance in the output circuit between the plates of the tubes, and in the second place it substantially removes radio frequency currents from the surface of line 5*a* between the condenser microphone and the point where line 5*a* is connected to the cylinder 5*b*. These two functions may be explained best separately. The preservation of balance may most easily be shown by considering the outer surface of 5*a* and the inner surface of 5*b* as forming a quarter wave tank shorted at one end. It is well known that such a tank presents an extremely high impedance, the high impedance in this case occurring between ground and the point where condenser 8 is connected to line 5*a*.

The impedance between the ground and the point where condenser 9 is connected to the inner conductor of 5*a* is the sum of the impedance between the conductors of 5*a* and the very high impedance between the outer conductor of 5*a* and ground. Hence the effective impedance between condensers 8 and 9 is substantially solely the impedance between inner and outer conductors of 5*a* and the system is balanced because there is no admittance to ground in the circuit between condensers 8 and 9 of appreciable magnitude.

On the other hand, to explain why the cylinder 5*b* substantially eliminates currents from the outer surface of 5*a*, it is only necessary to note that since the currents flowing on the inner and outer conductors of the quarter wave tank formed by the outer surface of 5*a* and the inner surface of 5*b*, respectively, are necessarily substantially equal, the current flowing along the outside of 5*a* from left to right is substantially neutralized at the point of contact with 5*b* by the equal and opposite current flowing from the contact point to the inside of 5*b*. Thus of the current originally assumed to be flowing along the outside of 5*a* on the left of this point of contact, there is substantially nothing remaining to the right hand side of the point of contact.

Thus the cylinder 5*b* may be considered either as a by-pass path of the effectively zero impedance for currents flowing along 5*a* or it may be considered as a neutralizing path so energized as to feed into the line 5*a* an equal and opposite current to that flowing along 5*a*. In any case, the currents on the outer surface of 5*a* are substantially eliminated and this result is important because if any current were to flow on this outside surface the capacity between the line 5*a* and other objects would enter into the determination of frequency of oscillation, and this is, of course, highly undesirable.

For ultra short wave operation, the grid circuit preferably includes the lecher wire arrangement 3*a* rather than the capacity inductance combination 3 shown in Figure 1.

A further arrangement for ultra-short wave operation is shown in Figure 3. In this case unbalanced to balanced working from the microphone 7 is obtained by the use of the concentric line 15 across one end of which the microphone 7 is connected and the other end of which extends inside the tubular anode conductor 10 connected to the upper valve 1 as shown in the drawing. A cross connection is taken from the inner conductor of line 15 through the D. C. blocking condenser 8 to some point on the outside of anode conductor 11 associated with the lower valve 1 as shown in the drawing. Also the control grid and anodes of the valves 1 may be cross-connected through condensers 13 and 14 as shown, the leads to these condensers passing through suitable apertures or slots in conductors 10 and 11. The line 15 tends to cause unbalance and loss of power, but the balance is restored by the provision of a similar concentric feeder 16 in association with the lower valve 1. The feeder 16 can be used to afford a power output feeder of the transmitter by means of the adjustable cross connection between the inner conductor of feeder 16 and the outside of conductor 10 through the blocking condenser 9. The lines 15 and 16 are preferably interrupted as shown at 18, the gap being bridged by condenser 19 which serves in conjunction with the condensers 8 and 9 to prevent high tension voltage from source 6 from being applied to either electrode of microphone 7.

In Figure 3 the feeder 15 is shown as being tapped down the anode tuned conductor 10. This arrangement is adopted in order that the losses introduced by the line 15 will have less effect, but the use of the arrangement is not restricted to the case in which the feeder is tapped down the conductor 10. In the arrangement shown in Figures 2 and 3 the frequency of the transmitter is readily adjustable by sliding the shorting bar 12 along conductors 10 and 11.

If desired, in order to improve the stability of the transmitter the anode of the valves 1 may be connected to tappings on the conductors 10 and 11 instead of to the ends of the conductors as shown.

The line 15 is preferably between a quarter and a half wave length long, such that the end of the line 15 remote from the microphone presents an open circuit.

Figure 3*a* shows a modification of the arrangement shown in Figure 3. In this case the lines 15 and 16 extend parallel to the conductors 10 and 11, the inner conductors of lines 15 and 16 extending into the conductors 10 and 11 and being supported in the associated outer conductors and in conductors 10 and 11 by means of insulating discs 25, which give a low loss arrangement.

The shorting bar 12 is adjustable to provide a coarse frequency control and a fine control of frequency is afforded by providing slidable rods 26 which are supported in sleeves on the outside of conductors 10 and 11. Rods 26 can be actuated

through a suitable device such as a rack or pinion to provide a ready means for close adjustment of the frequency.

Capacity coupling between conductors 10 and 11 and the outer conductors of lines 15 and 16 respectively is afforded by arranging an insulating sheet between the tubes 10 and 11 and the metal chassis diagrammatically represented at 27, on which the arrangement is mounted, the outer conductors of lines 15 and 16 being in direct contact with the chassis. The chassis is preferably suitably recessed under conductors 10 and 11 to accommodate the insulating sheet.

Variable condenser 28 may be connected to either line 10 or 11 as desired to balance the capacities of lines 10 and 11 to earth.

A further possible arrangement according to the invention is shown in Figure 4. In this case the transformation of the microphone output from an unbalanced to a balanced condition is effected by means of a half wave length concentric conductor 20 which is connected between two open wire sections 21 and 22 each approximately half a wave length long which are connected to the anodes of the valves 1. The high tension source 6 is connected to the said anodes through the choke 23 which are connected to voltage nodes 24 on the conductors 21 and 22. The conductors of concentric lines 15 and 16 are connected one to each end of the concentric line 20 and the inner conductors thereof are connected respectively through blocking condensers 8 and 9 to the adjacent conductors 21 and 22.

We claim:

1. In a frequency modulation system an oscillation generator including a pair of electron discharge devices each having input and output electrodes, oscillatory circuits connected with said input and output electrodes including lines symmetrically coupled with said output electrodes and balanced with respect to ground, an unsymmetrical modulating reactance, and means for coupling said unsymmetrical modulating reactance to at least one of said lines and for coupling to the other of said lines a reactance to restore the balance of said lines with respect to ground unbalanced by the coupling thereto of said unsymmetrical modulating device.

2. In a frequency modulation system an oscillation generator including a pair of electron discharge devices each having input and output electrodes, tuned oscillatory circuits comprising lines coupling corresponding electrodes in said devices in push-pull relation, said tuned circuits being balanced with respect to ground, an unsymmetrical modulating capacity, and means for coupling said unsymmetrical modulating capacity to said balanced circuits including a tubular conductor having a length approximately equal to $\lambda/4$, a concentric line including inner and outer members within said tubular conductor each member being connected to said modulating capacity at one end and coupled to said balanced circuits at the other end, and means connecting the outer member of the concentric line to said tubular conductor to prevent transmission of currents from the tuned circuits to the modulating capacity along the outer surface of the outer member of said concentric line.

3. In a frequency modulation system an oscillation generator including, a pair of electron discharge devices having electrodes connected in a high frequency tuned oscillatory circuit including lines connecting corresponding electrodes in each of said tubes in push-pull relation, said circuit being balanced with respect to ground, and means for modulating the frequency of the oscillations generated by means of an unbalanced condenser microphone without upsetting said balance of said tuned circuit including, a condenser microphone, a concentric line having its inner and outer members connected to the elements of said condenser microphone at one end, a tubular member, a connection between a point on the outer member of said concentric line and said tubular member, said point being spaced from the end of said tubular member a distance approximately equal to $\lambda/4$, and a coupling between the members of said concentric line and said first named lines.

4. In a frequency modulation system an oscillation generator including, a pair of electron discharge devices having electrodes connected in a high frequency tuned oscillatory circuit including lines connecting corresponding electrodes in each of said tubes in push-pull relation, said circuit being balanced with respect to ground, and means for modulating the frequency of the oscillations generated by means of an unbalanced condenser microphone without upsetting said balance of said tuned circuit including, a condenser microphone, a concentric line having its inner and outer members connected to the elements of said condenser microphone at one end and coupled to at least one of the lines of said oscillatory circuit at the other end, and a second concentric line coupled at least to the other of said lines of said oscillatory circuit to restore the balance of said balanced circuit.

5. In a frequency modulation system an oscillation generator comprising, a pair of electron discharge devices each having electrodes connected in a high frequency tuned oscillatory circuit including lines connecting corresponding electrodes in each of said tubes in push-pull relation, said lines being balanced with respect to ground, and means for modulating the frequency of the oscillations generated by means of an unbalanced condenser microphone without upsetting said balance of said tuned circuit including, a condenser microphone, a concentric line having its inner and outer members connected to the elements of said condenser microphone at one end and coupled to one of the lines of said oscillatory circuit at the other end, and a second concentric line coupled to the other of said lines of said oscillatory circuit to compensate for said condenser microphone and to provide an output circuit.

6. In a frequency modulation system an oscillation generator including, a pair of electron discharge devices having electrodes connected in high frequency tuned oscillatory circuits including conductors connecting corresponding electrodes in each of said tubes in push-pull relation, said circuit being balanced with respect to ground, and means for modulating the frequency of the oscillations generated by means of an unbalanced condenser microphone without upsetting said balance of said tuned circuit including, a condenser microphone, a concentric line having its inner and outer members connected to the elements of said condenser microphone at one end, means coupling the other end of the members of said concentric line to one side of said oscillatory circuit, a second concentric line coupled to the other side of said oscillatory

circuit to provide an output circuit for said system, and a means connecting the outer members of said concentric lines together and to ground at a point intermediate the ends thereof.

7. In a modulation system, a pair of electron discharge tubes having electrodes coupled in a balanced oscillation generator system including a frequency determining tank circuit, a signal controlled unbalanced reactance element, a concentric line coupling said reactance element to said oscillation generator tank circuit for modulating the oscillations generated in accordance with signals, a radio frequency voltage being impressed from the frequency determining oscillation generator tank upon the signal controlled reactance element by way of said concentric line over the surface of the outer member of which generated current may reach the reactance element, and means for maintaining balance in said oscillation generator by eliminating generated radio frequency currents from the outer surface of said line between a point on said line and said reactance element including a conductor connected to the outer member of said line at said point between said element and said tank circuit, and means to supply to said line at said point a current substantially equal and opposite to the generated current flowing at said point on said line toward said reactance element including a coupling between said conductor and said tank circuit.

8. In a balanced oscillator having two tubes with lines connecting corresponding electrodes thereof in a push-pull tank circuit, and frequency modulating means including an unbalanced reactance variable in accordance with signals coupled to the said lines by a concentric cable over the outer member of which generated voltages from said first lines may reach said signal controlled reactance, means for maintaining balance in said oscilaltor and for eliminating generated radio frequency currents from the surface of the outer member of said cable between a point on said cable and said reactance including a conductor the length of which is substantially $\lambda/4$ connected to the outer member of said cable at a point between said reactance and said tank circuit and cooperating with said outer member to supply to said cable at said point a current substantially equal and opposite to the generated current flowing at said point on said cable toward said reactance.

9. In a wave length modulation system a pair of electron discharge devices each having a plurality of electrodes including a cathode connected in a high frequency oscillatory circuit including a tank circuit coupled to corresponding electrodes in said devices and balanced with respect to said cathodes. an unbalanced reactance variable at signal frequency, and means for coupling said variable reactance to said tank circuit including, a concentric line having its inner and outer conductors coupled at one end to said variable reactance and at the other end to spaced points on said tank circuit, and means for restoring the balance of said tank circuit upset by the coupling thereto of said variable reactance by said concentric line including, an additional conductor connected to the outer conductor of said concentric line at a point intermediate its ends to form with said outer conductor a resonant line of a length equal to $\lambda/4$.

10. In a signalling system, a balanced oscillator including two tubes having anode electrodes and cathode electrodes with lines coupling said anodes in a push-pull tank circuit balanced with respect to said cathodes, and means for modulating the frequency of the generated oscillations in accordance with signals including a variable condenser, and a concentric cable coupling said variable condenser to said lines, and means for restoring the balance of said circuit upset by coupling said condenser thereto and for preventing generated currents from reaching said condenser over the surface of the outer member of said concentric cable including, a cylindrical conductor the length of which is $\lambda/4$ surrounding said concentric cable, and a low impedance connection between the end of said cylindrical conductor and a point on the outer member of said concentric cable between said element and said tank circuit, said cylindrical conductor forming with said outer member of said cable a resonant circuit the length of which is $\lambda/4$ to supply at said point a current substantially equal and opposite to the generated current flowing at said point on said line toward said reactance element.

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