May 15, 1945. W. VAN B. ROBERTS 2,375,821

AMPLIFIER

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Fig. 1.

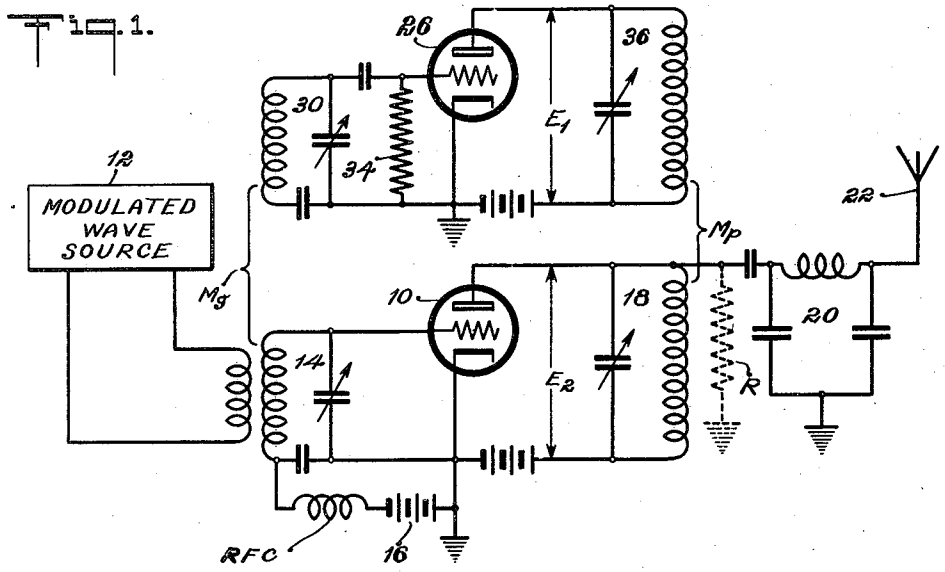
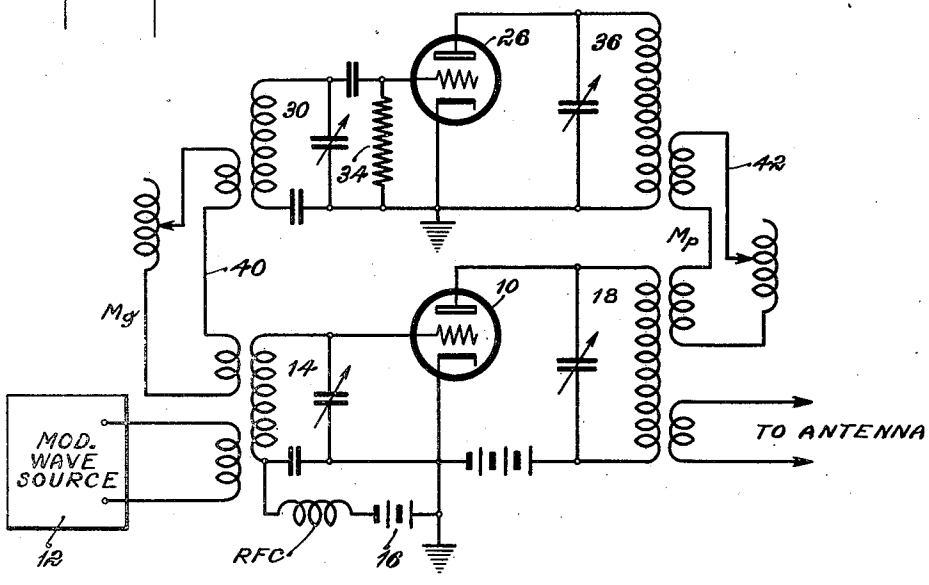


Fig. 2.



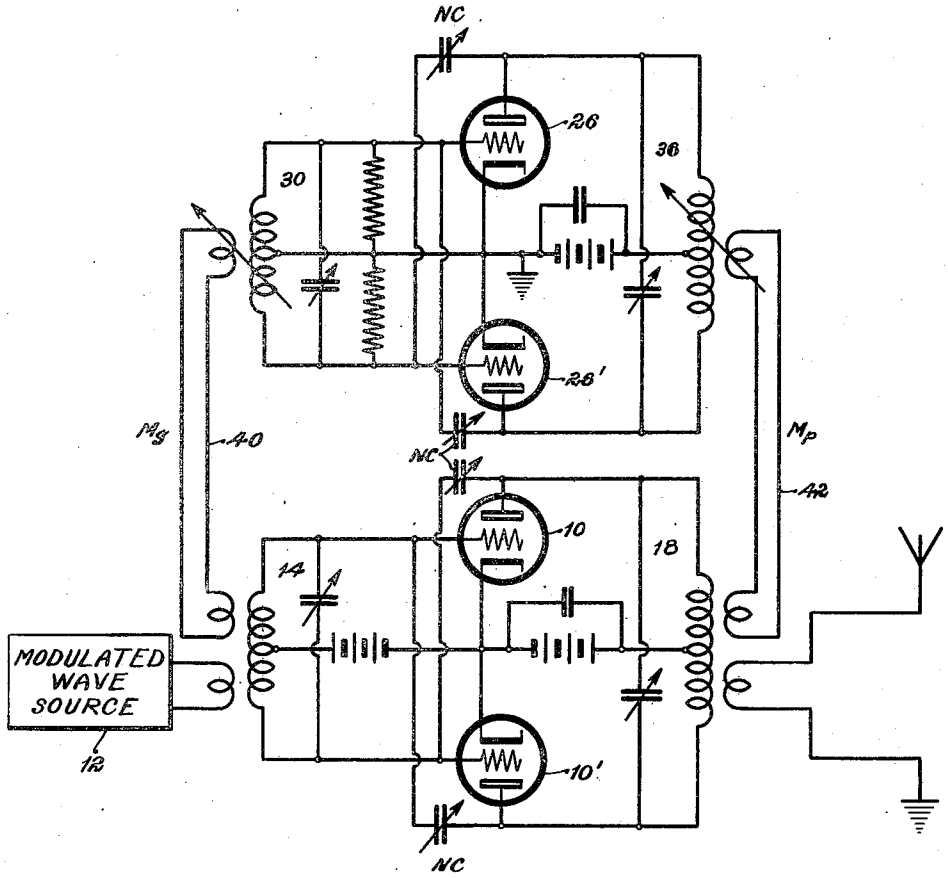
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Fig. 3.



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AMPLIFIER

Walter van B. Roberts, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application January 27, 1943, Serial No. 473,695

6 Claims. (Cl. 179—171)

This application discloses a new and improved linear and efficient amplifier which is adapted to uses in the radio and allied arts, as for example, to raise the power of amplitude varied carrier energy.

In describing my invention reference will be made to the attached drawing; wherein,

Fig. 1 illustrates schematically a circuit arrangement of an efficient linear amplifier arrangement in accordance with my invention. In this circuit features known in the art such as neutralizing connections have been omitted for the sake of simplicity. The system as illustrated comprises two stages coupled and arranged and operated in a novel manner.

Figs. 2 and 3 are modifications of the arrangement of Fig. 1.

In the Doherty system (Sept. 1936, IRE page 1163) two tube amplifier stages have their input excited in phase quadrature by alternating current and their outputs coupled to a common load R. One stage is biased to operate at carrier and above (i. e., cut off at carrier) while the other stage operates at carrier and below and has an impedance inverting network in its output coupling to the load. The network feeds into a load or terminating impedance R but is given a surge impedance 2R. At carrier condition, that is when said one tube is cut off, the input impedance of the network is therefore equal to 4R.

The last mentioned other tube stage supplies the carrier power efficiently and feeds through the network into the load resistance R which also is the terminating impedance of the network and remains constant and equal to R so that tube works into a network input of constant impedance and E1 the tube stage output voltage varies linearly with the applied grid voltage. On peaks of applied voltage which exceed carrier amplitude the said one tube stage (biased to cut off for carrier amplitude) feeds power to the load R thus raising the effective terminating impedance of the network thereby lowering the input impedance of the network into which the said other mentioned tube works. This other stage as a consequence delivers more power although its output voltage E1 remains constant. At the peaks or say full modulation, conditions are such that the said one tube stage delivers half of the total power thus raising the effective network termination impedance from R to 2R ohms and lowering the network input impedance into which the said one tube works from 4R to 2R. The said one tube then delivers twice carrier power as does the said other tube giving a total power of four times the carrier power.

The object of my invention is to improve and simplify amplifiers of the nature described in the preceding paragraph.

The simplified circuit of Fig. 1 illustrates my improved system. In the interest of simplicity refinements such as neutralizing circuits, etc., have been omitted.

The stage tube 10 has its input electrodes coupled to a source of alternating current 12 by way of a tuned circuit 14. The grid of this tube is biased about to cutoff at carrier amplitude by source 16. The output electrodes are connected in tuned output circuit 18 and the power is fed by a filter 20 to any load such as an antenna 22. The stage tube 26 has its input electrodes connected to a tuned circuit 30 coupled to tuned circuit 14. This tube is biased to operate for impressed voltage by, for example, resistance 34. The output electrodes of tube 26 are connected to a tuned circuit 36 which is coupled to circuit 18. Circuits 14, 18, 30 and 36 are tuned to the same frequency, i. e., the frequency of the alternating current from source 12.

Assume circuit 14 is excited by alternating current of carrier amplitude, or less. The bias in this stage tube 10 is not overcome so that it does not supply plate current to circuit 18 or total load R. The mutual between circuits 14 and 30, however, is made such that the input electrodes of stage tube 26 are excited equally with the excitation on the input electrodes of tube 10. Moreover, this method of coupling causes the excitation voltage on the input electrodes of tube 26 to be shifted 90° with respect to that on the input electrodes of tube 10. This phase shift has been shown by measurement.

The tube 26 now feeds into circuit 36 and thence into circuit 18 and to the load impedance which I take as R ohms. Remembering that the tube 10 is inactive the effect of the mutual inductance M_p is to throw a resistance proportional to 1/R across tank circuit 36, i. e., across the plate of tube 26. This is made high enough to make tube 26 work at high efficiency for all voltages of amplitude less than carrier amplitude. Under these conditions tube 26 operates into a constant impedance with its plate voltage E following its grid excitation voltage and we can assume that this impedance into which tube 26 works is adjusted by means of M_p to be 4R.

Now as the modulation increases the tube 10 cutoff bias is overcome and tube 10 supplies power to the load thus increasing the total effective im-

pedance R. This decreases the load reflected across the circuit 36 and thereby lowers the impedance into which tube 26 is working and the tube 26 feeds more power into circuit 36 and thence to the load R.

When peak modulation is reached, i. e., twice carrier excitation, the arrangement is such that the impedance into which tube 26 works is reduced by about ½ and is 2R and tube 26 supplies to the load R twice as much power as at carrier excitation. The arrangement is also such that tube 10 is then supplying about half the total power to the load.

As to the inverting action between 18 and 36, it can be shown that the effective load conductance across 36 is inversely proportional to the load conductance across 18 when the Q's of said circuits are sufficiently large as is the case in practice. By a suitable adjustment of the mutual M_p therefore the resistance R may be caused to create the effect of a resistance of 4R across 36 while a resistance 2R across 18 acts like a resistance of 2R.

There is also produced a 90° phase shift which offsets the phase shift between the excitation voltages.

In practice the couplings and loading are adjusted by "cut and try" until the required operating conditions are attained such as equal power from both tubes at the peaks of the modulating cycle.

The output of the system of Fig. 1 may be supplied to any utilization means such as an antenna 22 by way of a filter circuit 20.

The modification illustrated in Fig. 2 makes use of the principle described above in detail in connection with Fig. 1. Fig. 2 differs from Fig. 1 in that a link circuit 40 couples the tuned circuits 14 and 30 and provides variable coupling between these circuits whereby equal but substantially 90° displaces excitation voltages are fed to the input electrodes of tubes 26 and 10. A second link circuit 42 couples the tuned circuits 36 and 18 and these couplings as in Figure 1 are adjusted so that when taken with the loading provide the proper amplitude proper phase excitation voltages at the input of tube 26 and the impedance inverting effect described above between circuit 18 and 36.

In the arrangement of Fig. 3 each stage comprises a pair of tubes connected in pushpull relation with the circuits neutralized. These tubes, except for the circuit connections which follow from the use of two tubes instead of one, are in principle the same as in Fig. 1 and the operation therefore, it is believed, is entirely clear from the foregoing description. In this case also, link coupling may be used between input circuits and/or between output circuits.

The advantages of my system are:

1. It requires no additional elements for phase shifting and impedance inversion as these functions are accomplished by the usual tuned circuits in the two stages.

2. It is equally well adapted to a pair of push-pull stages.

I claim:

1. A first amplifier stage having a tuned input circuit and a tuned output circuit, a second amplifier stage having a tuned input circuit and a tuned output circuit, there being effective mutual coupling between said input circuits such that when one thereof is excited by modulated voltages to be amplified the other thereof is also excited by voltages of nearly equal amplitude and of phase shifted about 90°, there being effective mutual coupling between said output circuits such that the impedance across one thereof is substantially proportional to the reciprocal of the impedance across the other thereof, and means for biasing one of said amplifiers for operation at carrier output and above.

2. A system as recited in claim 1 wherein said couplings comprise a link circuit between the input circuits and a link circuit between the output circuits.

3. A system as recited in claim 1 wherein said amplifiers are each neutralized.

4. A system as recited in claim 1 wherein said amplifiers are of the push-pull type.

5. In an amplitude modulated wave amplifier system, a tube stage having input electrodes coupled by a tuned circuit to a source of alternating current and having output electrodes coupled by a second tuned circuit to a load, means for biasing said stage substantially to cut off in the presence of alternating current of carrier wave amplitude and less, a second tube stage having input and output electrodes, a tuned circuit coupled to said input electrodes, there being mutual inductance between said first named tuned circuit and said last named tuned circuit, a tuned circuit coupled with the output electrodes of said second tube, there being mutual inductance between said second tuned circuit and said last named tuned circuit and means for supplying a bias to the input electrodes of said second named tube, such that it amplifies small voltages impressed thereon.

6. In an amplitude modulated wave amplifier system, a push-pull amplifier comprising two tubes having input electrodes coupled by a tuned circuit to a source of alternating current and having output electrodes coupled by a second tuned circuit to a load, means for biasing the tubes of said stage substantially to cut off in the presence of alternating current of carrier wave amplitude and less, a second push-pull amplifier comprising two tubes having input and output electrodes, a tuned circuit coupled with said input electrodes, there being effective mutual impedance between said first named tuned circuit and said last named tuned circuit, a tuned circuit coupled with the output electrodes of said last mentioned two tubes, there being effective mutual impedance between said second tuned circuit and said last named tuned circuit and means for supplying a bias to the input electrodes of said second named two tubes, such that they amplify small voltages impressed thereon.

WALTER VAN B. ROBERTS.