Dec. 30, 1947. A. J. MADDOCK 2,433,380

AMPLIFYING ARRANGEMENT

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FIG. 1.

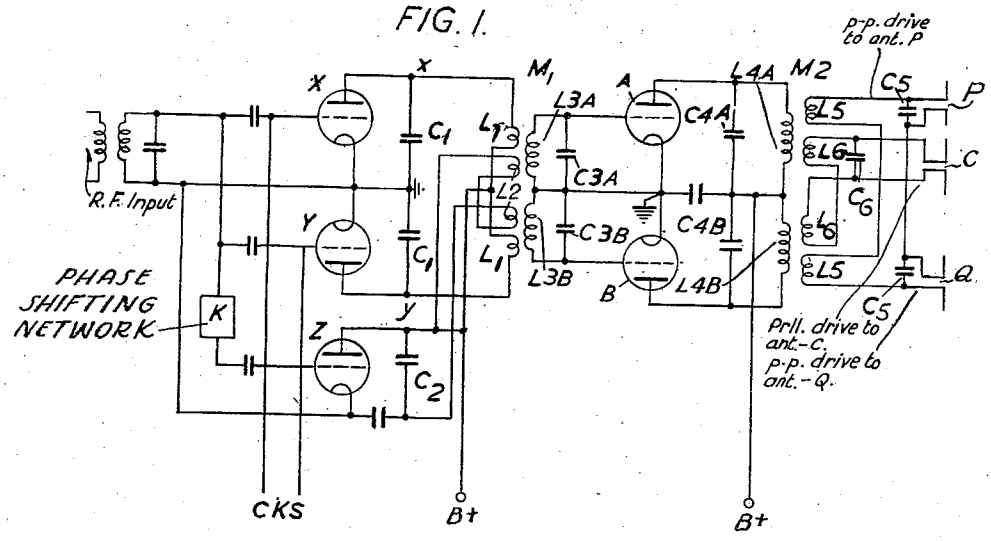
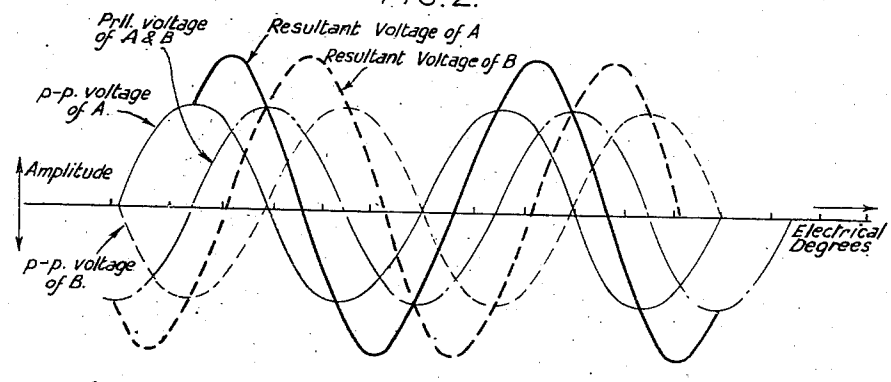


FIG. 2.



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AMPLIFYING ARRANGEMENT

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The present invention relates to amplifying arrangements and particularly to an amplifying system feeding two or more loads, such as antennae, with currents having different relative phases.

With directive antenna systems in which two or more antennae are to be fed with current of different relative phases it is usually essential that the magnitudes and phases of the currents should not vary with respect to one another due to variations in amplifier characteristics. These conditions are particularly important, for example, in systems used for guidance of aircraft, ships, etc., where two overlapping field strength patterns are used capable of being radiated in some rhythmic manner so that on each side of the line joining the intersection of the two patterns and the centre of the antenna system a different and distinctive signal is radiated whilst on the intersecting line a continuous signal is obtained; this is produced for example by radiating one pattern for the period of a dash and the other pattern for the period of a dot, the two following each other regularly.

Under such circumstances it is preferable that all antennae should be energised by the same amplifier system to obviate any difference of phase or magnitude arising between the antennae which might occur if separate amplifiers are used. In many instances it is possible to do this but for some applications heretofore it has been found necessary to use separate amplifiers with the above mentioned difficulties arising thereby. It is the purpose of this invention to provide a system whereby the antennae are energised by the same amplifier thus leading to elimination of effects arising from variations of magnification in the valves of the amplifier, variations of grid driving volts, variations of high tension anode supply, etc. The scheme will be considered with particular reference to an approach system having three driven or energised antennae, the currents in which differ in phase and magnitude and it will be shown hereinafter how characteristic changes of the radiated pattern may be effected in simple manner whilst still retaining all the above advantages.

According to the invention an electronic discharge device amplifying system arranged to feed power into two or more loads is characterised in this that it comprises two amplifying arrangements fed from the same source in push-pull and parallel modes with any desired amount of phase difference between the driving voltages of the two modes, and that the load circuits are so coupled to the output circuits of the two amplifying arrangements that the outputs due to the two modes are separated to feed the said loads as desired.

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Fig. 1 represents an amplifier system according to the present invention as applied to driving three antennae with currents of differing relative phases and amplitudes and including also means for instantaneously reversing the phases of two of the antennae by 180° whilst Fig. 2 shows the wave-forms of voltages existing in the final amplifier circuits.

Referring to Fig. 1, A and B are thermionic amplifying valves each having grid input and anode output circuits resonant to the frequency of operation, the circuits of the valves being disposed relative to each other so as to have negligible reaction between each other. (The sources of supply for cathode and grid are not shown as not being relevant to the invention and these may be arranged in any known manner.) The three valves X, Y and Z have their grid input circuits connected in parallel and excited from the common source of radio frequency as shown. The valve Z has a phase shifting network K inserted in its grid circuit so that the phase of the voltage applied to its grid relative to that applied to X or Y may be set to a desired value.

Only one of the valves X or Y is permitted to amplify at a time, the grids of these valves being connected to sources of large negative value via a keying system connected at CKS, and any suitable keying system may be employed, but a particularly suitable arrangement is disclosed in my British Patent Number 558.224 of March 20, 1944, so that keying may be effected in complementary fashion with instantaneous changeover between the two values. Thus when valve X is amplifying say for the period of a dash, Y is blocked and then Y amplifies for the period of a dot and X is blocked and so on. A push-pull circuit is connected to the outputs of valves X and Y and consists of the coils L_1 and condensers C_1, the centre point of which latter is returned to the valve cathodes and the coils L_1 are so connected as to be series aiding for the push-pull voltage, thus driving the valves A and B in push-pull through the intermediary of the coupling existing between coils L_1 and L_3. The anode tuned circuit L_1C_1 is excited from either side alternately at the points x and y by the valves X and Y, respectively, by means of the complementary keying arrangements referred to and connected at CKS, and thus a phase change of 180° may be obtained in the push-pull driving volts applied to the grids of A and B as desired by the keying rhythm.

At the same time as A and B are driven in

push-pull mode they are also driven in the parallel mode at the same frequency by the valve Z having output circuit L_2C_2, the coils L_2 being so connected and coupled to coils L_3 that the grids of A and B are driven in parallel. The phase difference between the parallel and push-pull voltages is determined by the network K. The valves A and B will thus have a resultant voltage equal to the vector sum of the push-pull and parallel voltages applied to their grids and will amplify same and develop corresponding voltages in the output circuits C_{4A}, L_{4A} and C_{4B}, L_{4B}. By connecting coils L_5—tuned by condensers C_5—in such sense as to be series aiding for the push-pull voltages in L_{4A} and L_{4B} only such voltage and hence such power will be delivered to antennae P and Q whilst coils L_6 (tuned by condenser C_6) are connected in such sense as to be series aiding for the parallel voltages in L_{4A} and L_{4B} so that only such voltage, and hence such power, is delivered to antenna C. With the arrangement as shown, the currents fed to the two antennae P and Q will differ by 180° and that fed to C will differ from that fed to one antenna of P or Q by the amount of phase shift introduced at K and by 180° minus this shift from the other of P or Q; as X and Y are keyed the phases of the two antennae P and Q will be changed by 180° as already described.

Thus with this arrangement the power fed to all antennae is supplied by the same amplifier system (viz. A and B) so that any variation of anode supply or variations in valves affect all antennae equally and hence do not cause relative changes in the radiated field patterns but only changes of magnitude which are unimportant.

The amplifiers X, Y, Z, A and B may be operated under any condition but in a preferred arrangement they would all operate as Class C amplifiers (it will be shown below that Class C operation is possible) since then variations of grid drive will not affect the output and thus even if valves X and Y did induce different voltages on the grids of A and B the output in the two cases would still be the same. For the same reason any variation in Z would not cause changes in the relative outputs. Preferably, also valves X, Y and Z would have the same source of anode tension supply so that variations are still further reduced. If the valves are operating under Class A or Class B conditions, the radio frequency input may be modulated if required or with the preferred Class C working valves A and B may be anode modulated.

Relative phase changes between P, Q and C other than those automatically obtained above may be introduced if desired by variation of length of the transmission lines feeding the antennae or by the introduction of phase shifting networks in the feed to said antennae in manner well known in the art.

In Fig. 2 in which ordinates represent amplitude and abscissae represent electrical degrees, the push-pull voltages induced in the grid circuits of A and B are shown at P—P voltage of A or of B and the parallel voltage applied to A and B simultaneously is shown at parallel voltage of A and B of amplitude equal to the push-pull voltage and differing in phase therefrom by −90° and +90° respectively. The resultant voltages applied to the grids of A and B are as shown at resultant voltage of A or B in the heavy full and dashed lines respectively and the anode voltages in the output circuits L_{4A} C_{4A}, L_{4B} C_{4B}

would be correspondingly similar and it can readily be seen that since these voltages were built up by injecting two voltages in push-pull and parallel and differing in phase as hereinbefore stated, they may be separated utilising push-pull and parallel circuits after amplification, from the output circuits of valves A and B.

It is known that if two sine waves of the same frequency and any relative amplitude and phase are combined the resulting wave is also a sine wave: if $e \sin \omega t$ represents one wave and $e_1 \sin (\omega t - \phi)$ the other where e and e_1 are the amplitudes, ω the angular frequency, t the time and ϕ the phase difference between the two waves, then it can be shown that the resultant wave is represented by

$$E = \sqrt{e^2 e_1^2 + 2ee_1 \cos \phi} \cdot \sin \left(\omega t - \tan^{-1} \frac{e_1 \sin \phi}{e_1 \cos \phi + e} \right) \quad (1)$$

which, since all factors except ωt are constant, is of sine wave form. In the special case when $e = e_1$ this reduces to

$$E_{11} = e\sqrt{2} \cdot \sqrt{1 + \cos \phi} \cdot \sin \left(\omega t - \tan^{-1} \frac{\sin \phi}{\cos \phi + 1} \right) \quad (2)$$

or

$$E_{11} = 2e \cos \phi/2 \cdot \sin (\omega t - \phi/2) \quad (3)$$

and in the further special case when $\phi = \pi/2$ (and $e = e_1$), Equation 2 or 3 reduce to

$$E_{90} = e\sqrt{2} \cdot \sin (\omega t - \pi/4) \quad (4)$$

In the arrangements of the present invention the output voltages of valves A and B must simulate those applied to their grids so that the resultants may be analysed into their components and this may readily be done if A and B work under Class A or B conditions. In Class C operation, even a distorted input voltage will give a sine wave voltage in the output so that normally this type of amplifier is not used to follow variations of grid circuit voltage. However, since, as we have shown, the grid input voltage in these arrangements is always of sine wave form we may utilise this class of operation and so obtain output voltages following the grid voltages.

With the special case considered of a phase shift being introduced at K (Fig. 1) of 90° we are able to feed an antenna system very suitable for use in guiding or approach systems wherein a centre antenna is fed with current of constant magnitude and two outer antennae are fed with currents displaced −90° and +90° with respect to the centre antenna and these outer currents can be instantaneously changed in phase by 180° to obtain the required change of field pattern. The relative magnitudes of the currents can be altered by variation of the coupling between L_5 and L_4 or between L_6 and L_4.

There is no interaction between the parallel and push-pull circuits when arranged as described, for the voltage induced in say one parallel coil (L_2 top) by the neighbouring push-pull coil (L_1 top) will be annulled by an equal voltage induced in the bottom L_2 coil due to the way in which the coils are connected and similarly interaction in the opposite sense is annulled.

The foregoing description has detailed the case of an antenna system in which instantaneous keying is required but it is clear that the system is equally applicable to systems in which constant radiation is to be emitted and it is readily evident that any number of antennae greater than one, may be fed in this manner in which

case one of the valves X or Y may be omitted. For example for two antennae one is fed by the parallel coils L_6 and the other by the push-pull coils L_5 in which case the condenser C_5 need not be split. For three antennae the scheme already described may be employed if two of the antennae are to differ in phase by 180° or as mentioned subsequent phasing networks or lines may be inserted. Four antennae may be similarly driven arranged for example in pairs, the coils L_5 driving one pair and coils L_6 another pair. And so on, variations in the arrangements described being readily apparent to those skilled in the art and coming within the scope of the invention as defined in the appended claims.

Similar keying arrangements may be provided if desired for the parallel drive in which case a split driving circuit would be provided for this mode and two valves instead of the one Z with a similar arrangement of keying as already described for X and Y. Both the parallel and push-pull driving keyed circuits may be provided together.

Whilst the phasing network K has been shown in the grid circuit of valve Z it may equally well be inserted in the anode circuit thereof. It is an added advantage of the scheme that phasing of the antenna currents may be effected in low power circuits where control is readily possible.

Although reference has been made throughout to the power being delivered to an antenna system this is not meant to imply a limitation on the invention since any load may be employed and furthermore the invention is applicable to arrangements using other frequencies than radio frequencies.

What is claimed is:

1. An amplifying system employing electron discharge devices and adapted to feed power into a plurality of load circuits comprising a pair of valves having input and output circuits, a source of high frequency voltage, means to feed voltages from said source to the input circuits of said valves in push-pull and parallel modes with predetermined phase displacement between the voltages of said modes, a plurality of load circuits, means to couple one of said load circuits to the output circuits of said valves so as to transfer power in one mode, and means to couple another load circuit to said output circuits so as to transfer power in said other mode.

2. An amplifying system in accordance with claim 1 in which the feeding means for the input circuits of the valves includes a phase adjustment device so that the phase between the two modes may be adjusted.

3. An amplifying system in accordance with claim 1 in which separate amplifying devices are provided to feed the input circuits of the valves in the different modes.

4. An amplifying system in accordance with claim 1 in which the phase difference between the push-pull and parallel modes is substantially ninety electrical degrees.

5. An amplifying system adapted to feed power into a plurality of load circuits comprising a first pair of valves having input and output circuits, a source of high frequency voltage, a second pair of valves having input and output circuits, means to connect said second pair of valves in push-pull, means to couple the input circuits of said second pair of valves in push-pull arrangement with said first pair of valves, a source of high frequency voltage, means to feed high frequency voltage from said source to the input circuits of said first pair of valves in parallel and with the phase of said voltage displaced a predetermined amount from that fed to said second pair of valves, a plurality of load circuits, means to couple one of said load circuits to said output circuits of said first pair of valves so as to transfer power to said load circuit in the push-pull mode, and means to couple another of said load circuits to said output circuits for said first pair of valves so as to transfer power to said load circuit in the parallel mode.

6. An amplifying system in accordance with claim 5 in which means is provided to adjust the relative phase of the voltages delivered from the source of high frequency voltage to the input circuits of said first and second pair of valves.

7. An amplifying system in accordance with claim 5 in which a separate amplifier is provided between the source of high frequency voltage and the means to feed the voltage to the input circuits of the first pair of valves in the parallel mode.

8. An amplifying system in accordance with claim 5 in which a separate amplifier is provided connected between the source of high frequency voltage and the means to feed the input circuits of the first pair of valves in the parallel mode, and a phase adjusting device is included in this feeding circuit.

9. An amplifying system in accordance with claim 5 in which means is provided to block the valves of the second pair alternately at a predetermined rate.

10. An amplifying system adapted to feed power into a plurality of load circuits comprising a first pair of valves having input and output circuits, a second pair of valves having input and output circuits with said input circuits connected in push-pull arrangement with the output circuits of said first pair of valves, a source of high frequency voltage, means to connect said source to the input circuits of said first pair of valves in push-pull arrangement, a fifth valve having an input and an output circuit, means to connect the input circuit of said fifth valve to said source of high frequency voltage, means to connect the input of said fifth valve in parallel with the input circuits of said first pair of valves, means to adjust the phase of the voltage delivered in parallel to the input circuits of said first pair of valves, a plurality of load circuits, means to connect one of said load circuits to the output circuits of said first pair of valves in push-pull, and means to connect another of said load circuits to the output circuits of said first pair of valves in parallel.

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