July 23, 1929. R. A. HEISING 1,722,089

WAVE REPEATING AND AMPLIFYING

Original Filed April 13, 1923

Fig. 1.

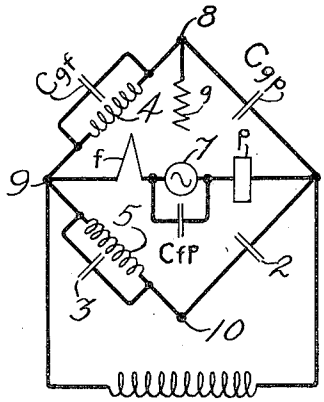


Fig. 2.

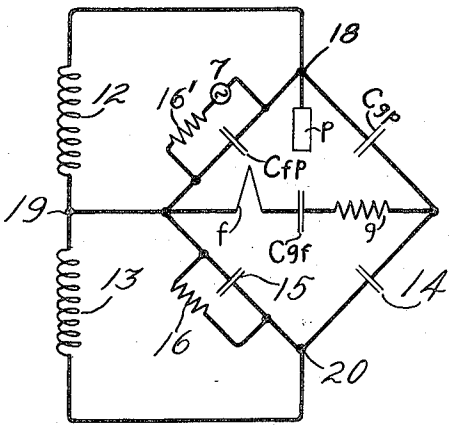
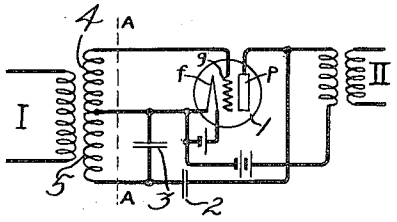


Fig. 3.



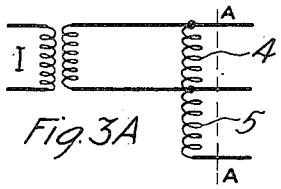
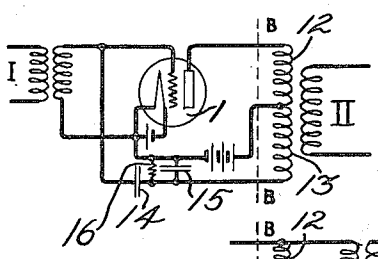


Fig. 3A

Fig. 4.



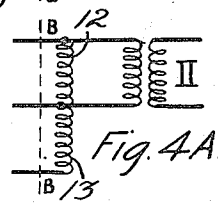
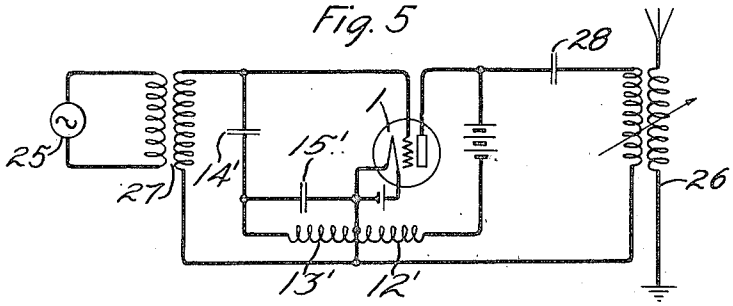


Fig. 4A.

Fig. 5



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Patented July 23, 1929. 1,722,089

UNITED STATES PATENT OFFICE.

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WAVE REPEATING AND AMPLIFYING.

Application filed April 13, 1923, Serial No. 631,814. Renewed February 12, 1929.

The present invention relates to wave repeating or wave amplification. The invention has particular application in connection with discharge tube repeaters or similar devices possessing appreciable capacity between their elements, due to which capacity there is a tendency for the waves to be shunted across the circuit or passed directly from the input side to the output side of the device, or in the reverse direction, by condenser action.

It is an object of the invention to compensate for this tendency of the waves to pass by condenser action between elements of the repeating device or circuit.

Since this tendency becomes greater at the higher frequencies, the invention has particular value in radio frequency circuits, although it is applicable in general to repeating systems or devices operating at any desired frequencies.

A further object of the invention is to compensate for the capacity effects of a discharge tube repeater in causing or aiding the production of oscillations in the circuit or circuits associated with the tube.

A further object of the invention is to compensate for the reactive effect of tuned circuits or tuning elements or reactive elements in general, associated with the output side of a discharge tube repeater upon the input circuit, or upon circuits associated with the input side of the tube, due to back coupling through the tube.

A still further object of the invention is to stabilize a radio frequency amplifying circuit so that more dependable action and greater amplification can be obtained with the circut than has heretofore been obtainable.

Briefly and specifically stated, the invention involves the balancing out or neutralizing of the potential variations present at a particular point in the repeater circuits in consequence of the undesired condenser action or capacity transfer of potentials between elements of the repeating device or circuits. This is preferably accomplished, according to the invention, by providing a condenser at such a point in the circuit that the potential variations across it are similar to the undesired potential variations set up by the capacity between elements of the repeater, and opposing the potential variations across the condenser to the undesired variations.

The above and other objects of the invention, and the various features which contribute toward the realization of the objects will be explained more fully in the following description, and by the aid of the accompanying drawings, in which: Figs. 1 and 2 show diagrams of balanced or bridged circuit arrangements which are helpful in explaining the action of the circuits according to the invention; Figs. 3, 4, and 5 are typical circuit applications of the invention; and Figs. 3A and 4A show modified arrangements.

Figs. 1 and 2 will be referred to in connection with the circuit arrangements shown in Figs. 3 and 4, respectively. Fig. 3 shows a single stage amplifying or repeating circuit embodying the invention. This repeating circuit is inserted between the incoming circuit I and the outgoing circuit II. The repeating circuit includes the electric discharge tube 1 of familiar type, together with the windings and other circuit elements shown. This tube comprises a preferably highly-evacuated envelope in which are included a heated filament or cathode f, a cold electrode or anode P commonly called the plate, and the control electrode or grid g, all suitably positioned with respect to one another. It is well known that a certain capacity exists between the grid and plate, its magnitude depending on their areas, proximity, etc., and this may be denoted by the symbol C_{gp}. Similarly a capacity C_{gf} exists between the grid and filament, and another capacity C_{pf} exists between the plate and filament. These capacities are, in the case of the usual amplifying or repeating tube, relatively small compared to the condensers commonly employed in the circuits. However, these capacities are in many cases sufficient to influence the action of the tube or device in repeating and amplifying waves, and this influence is most marked at relatively high frequencies such as radio frequencies.

One effect of these internal capacities, for example, is to cause or aid the production of self sustained oscillations, sometimes referred to as "singing." A disturbance in the plate circuit, for example, changes the potential of the plate, and due to the capacity C_{gp} the grid potential is correspondingly changed. This change of grid potential affects the current flow through the tube, which again changes the plate potential, and if the

potential variations so impressed on the grid and plate are of the proper sign and magnitude, sustained oscillations, or singing, will result. This effect is particularly troublesome in radio-frequency amplifying circuits whether for transmitting or receiving, and the tendency to sing has heretofore imposed a serious limitation on the amount of amplification obtainable in such circuits.

Another common effect of the internal capacity of a tube is to permit a reactive effect of elements in the output circuit on the input circuit. For example, in transmitting circuits an oscillator is often connected to an amplifier, which, in turn, feeds into a tuned transmission circuit such as an antenna or a selective branch to a line. Where the period of the oscillator depends upon a tuning of its circuit it has been found that a change of tuning of the antenna, for example, or a change in coupling, or any change which disturbs the adjustment of the circuit, may react through the tube to change the period of the oscillator.

The two effects above specifically pointed out are typical and may be taken as examples. These effects, and various others, are or may be present unless some balancing or compensating arrangements are employed to counteract them. Three arrangements illustrative of the principle employed in the invention will now be described.

In the arrangement of Fig. 3, waves in the incoming circuit I set up potential variations across the windings 4 and 5, the potential of the lower end of winding 5 at any instant being opposite in sign to that of the upper end of winding 4 at the same instant. The potential across winding 4 is effective in controlling the potential of the grid with respect to the cathode, and such grid potential controls in the well known manner the current in the anode circuit and hence the current in the outgoing circuit II. The winding 5 is not effective in controlling the grid potential in accordance with the waves to be repeated but its purpose will be explained below in connection with the balancing out or neutralizing of the tendency for the device 1 to transfer waves by effects other than control of the space current by the grid potential, the principal other effect being that of the capacity which the elements of the device 1 exhibit toward one another.

For the purpose of explaining the balancing action of the circuit scheme of Fig. 3, this circuit may be reduced to the bridge diagram of Fig. 1. The windings 4 and 5 are preferably very closely coupled with each other, so that any flux variation in one causes a corresponding flux change in the other. The directions of the fluxes in these windings is such that if a current impulse is set up from 8 to 9, this acts to set up a corresponding current impulse from 9 to 10. If, therefore, the impulse of current from 9 to 10 is opposed, this is equivalent to opposing the impulse of current from 8 to 9. Any change of potential in the positive direction applied to the point 8 with respect to the point 9, therefore, is neutralized if an equal positive potential change is applied to the point 10, and the same is, of course, true of negative potentials. This means that, as regards variations of potential, the grid will have, at any instant the same potential as the filament if the point 10 has the same potential as the point 8, for as stated above, any tendency for a difference of potential to arise between points 8 and 9 will under these conditions be neutralized by the equal and opposite tendency due to the potential impressed between points 10 and 9.

Consider now the effect of a change in the plate potential with respect to the filament, due to any cause. Such a change will produce a change in the potential of the grid due to the capacity C_{gp}, and if this were to produce a difference of potential of the grid with respect to the filament, the undesired phenomena such as singing and the like would be liable to occur as explained heretofore. According to the invention, however, the winding 5 is provided and the balancing condenser 2, the former serving to cooperate with the winding 4 in the manner described, and the latter being of such dimensions as to balance the capacity C_{gp}. The assumed change in plate potential, therefore, produces the same potential change at point 10 as is produced on the grid by the capacity C_{gp}, and, due to the relation between windings 4 and 5, the points 8, 9 and 10 are all maintained at the same potential so far as the influence of the plate potential variations is concerned. Since the plate potential changes are thus prevented from setting up differences of potential between the grid and filament, the undesired effects mentioned are prevented from occurring.

A more complete balance can be obtained by inserting the condenser 3 as shown, this condenser being of the proper dimensions to balance the capacity C_{gf}. This condenser is not so important, however, as the balancing elements 2 and 5, and it can in many cases be dispensed with.

When the tube 1 is employed to repeat variations of any kind, these variations occur between the filament and plate as variations in the space current, and the bridge diagram of Fig. 1 to be complete must include the fictitious alternating current generator 7 and the condenser C_{fp}, the plate impedance of the tube being assumed to be in the generator 7. The effect which these elements between the filament and plate might produce on the grid is balanced out in the same way as any other variations of plate potential.

The waves which are impressed on the coils 4 and 5 to be repeated, set up relatively

large potential differences across the points 8 and 10, but the capacities C_{gp} and 2 are ordinarily so small as to have practically no shunting effect on the impressed waves. The direct transfer of the waves from the grid to the plate through the capacity C_{gp} is prevented since condenser 2 neutralizes any potential change which the grid tends to produce on the plate.

Fig. 4 shows another balancing arrangement, the bridge scheme for this arrangement being indicated in Fig. 2. This arrangement offers more difficulties than the arrangement of Fig. 3, and requires greater accuracy of balance to secure the same results. The principal balancing elements are the condenser 14, which is so dimensioned as to balance the capacity C_{gp}, and the winding 13 which preferably has as nearly perfect mutual relation as possible, that is, as high degree of coupling as possible, with the winding 12. Windings 12 and 13 cooperate in the manner described in detail in connection with the windings 4 and 5 of Fig. 3, so that a potential difference set up between the plate and filament, that is, between 18 and 19, is accompanied by an equal potential difference between 19 and 20. The effect of potential changes on the plate is therefore to produce equal but opposite potential changes at 20, and if the capacity 14 just equals the capacity C_{gp}, the influence of these two potential variations on the potential of the grid will be nil. The potential of the grid with respect to the filament is, therefore, uninfluenced by plate potential variations.

The space current path and the plate impedance are, in this type of circuit, in one of the arms of the bridge rather than in a diagonal branch, and it is therefore necessary to balance the effects on the grid of the variations taking place between the filament and plate and representing the wave that is being repeated. In this type of circuit it is more important to maintain an accurate balance between the capacities C_{fp} and 15 than was necessary in the arrangement of Figs. 1 and 3, and it may be desirable also to provide an impedance 16 to match the impedance 16′ of the tube. However, these elements are less important than the elements 13 and 14, and may in cases involving small power be omitted or supplied with approximate values. On account of the larger currents carried by the coils 12 and 13, they should be balanced with accuracy.

The balancing circuits do not interfere in any way with repetition of waves from the circuit I to the circuit II, and such repetition may take place in the circuits described, with or without amplification, as desired, in accordance with the generally well-understood action of such devices. Either arrangement represented in Figs. 3 and 4 may be preceded or followed by other tube amplifiers, repeaters, or the like as may be desired, and may be used for transmitting or receiving or in any other situation where repeaters or discharge tubes are or may be used.

Instead of coupling the incoming circuit I in Fig. 3 or the outgoing circuit II in Fig. 4 inductively to the tube circuit windings, either circuit may be connected as shown by the fragmentary circuits of the respective Figs. 3^A and 4^A, the broken lines A—A and B—B, respectively, indicating the portions of the circuits of Figs. 3 and 4 to be replaced by the alternative circuits.

Fig. 5 illustrates a somewhat different manner of applying the principle employed in the circuit of Fig. 4. Instead of using the balancing coils 12 and 13 to couple to an outgoing circuit II as in Fig. 4, the corresponding balancing coils 12′ and 13′ of Fig. 5 are partly in shunt of the grid and plate branches through which the operating waves are transmitted and these coils are used merely for securing the necessary exchange of voltages between the tube and circuit elements to effect a balance after the manner shown in Fig. 2. By reference to Fig. 2 and with the explanation given in connection with the circuit of Fig. 4, it will be clear how the plate potential variations are balanced out on the grid.

The generator 25 represents any desired type of transmitting source, and the waves to be transmitted are impressed on the grid of the repeater or amplifier 1 through transformer 27, the repeated amplified waves passing mainly through the large condenser 28 and through the inductive coupling into the antenna 26. Changes in adjustment or in the characteristics of the antenna are prevented from disturbing the generator 25 or other circuits associated with the grid circuit of the tube. This is due to the fact that potential variations set up on the plate from the circuits associated with the plate are prevented from appearing in the grid circuit by the balancing action of condenser 14′ and windings 12′ and 13′ as described in connection with Figs. 2 and 4. Generator 25 may have a sensitive frequency adjustment and its period may, as in the case of oscillating discharge tube generators, be determined by a resonant circuit (not shown) associated with the amplifier 1. The circuit arrangement of Fig. 5 effectively prevents adjustments in the antenna circuit, for example, from reacting upon the frequency-determining circuit of such a generator to vary the frequency of the wave generated. It is obvious that the balanced circuit arrangement of Fig. 5 may be utilized in other types of circuit arrangements than that shown and that it is useful wherever it is desired to prevent the effect of back-coupling through the tube, or kindred effects.

If desired, the outgoing or load circuit may be coupled to the coils 12' and 13' instead of as shown in Fig. 5.

It has been stated that the capacities 2, 14, 3, etc., are made equal to the capacities which they are used to balance. This is preferable but is not to be construed as limiting the invention, since the only requirement of these capacities is to produce the degree of balance which any particular conditions require, and these capacities may actually differ considerably from the tube capacities, particularly where the windings 4 and 5 or 12 and 13 may be unequal or not closely coupled or where other circuit conditions might require that these capacities have a different value from exact equality with the tube capacities in order to obtain a balance. The same is true of other quantities, such as resistances and inductances.

The circuits shown are illustrative of the principle of operation of the invention, but are not to be taken as in any wise limiting the invention, the scope of which is defined in the claims.

What is claimed is:

1. In a wave repeating system a repeating device for repeating potential variations, having an input and an output electrode between which appreciable capacity exists, an output circuit for transmitting the variations repeated by said device, means for coupling said device to said output circuit, means independent of the coupling means for deriving potential variations from said output electrode substantially equal in amplitude and opposite in phase to the variations repeated, and a condenser connected between the potential-deriving means and said input electrode, said condenser having a capacity substantially equal to the capacity between said electrodes.

2. In a repeating system, a repeating device having input and output electrodes between which appreciable capacity exists, a load circuit, means for coupling said device to said load circuit, and means for neutralizing the potential variations set up on said input electrode by potential variations on said output electrode and due to the capacity between said electrodes, said means comprising a condenser connected to said input electrode and a pair of mutually related inductance windings separate from said coupling means for deriving from the output electrode and applying to said condenser, potential variations of opposite phase to the potential variations on said output electrode.

3. In a transmission system, a generator, a transmitting conductor, a discharge tube for repeating waves from said generator to the transmitting conductor, a transformer for impressing the waves from the generator on said conductor, and means external to the discharge tube and separate from and independent of said transformer for preventing changes in the characteristic of the transmitting conductor from reacting through the inherent capacity of the discharge tube upon the generator.

4. In a radio transmitter, a source of radio-frequency waves, an amplifier for said waves comprising a discharge tube having input and output electrodes between which appreciable capacity exists, an antenna, a radio frequency transformer for impressing waves from said amplifier upon said antenna, and means separate from and independent of said transformer for neutralizing the effect of the capacity of the tube to prevent the frequency of said source from changing due to a change in adjustment of the antenna.

5. In a wave repeating system, a repeating device for repeating potential variations, having an output electrode and input electrodes between which appreciable capacity exists, an output circuit for transmitting the variations repeated by said device, means for coupling said device to said output circuit, means independent of the coupling means for deriving potential variations from said output electrode substantially equal in amplitude and opposite in phase to the variations repeated, a condenser connected between the potential-deriving means and one of said input electrodes, said condenser having a capacity substantially equal to the capacity between said output electrode and said one input electrode, and a second condenser connected between said potential-deriving means and the other of said input electrodes.

6. In a transmission system, a source of waves, an amplifier for said source, comprising a space discharge device having input and output electrodes between which appreciable capacity effect exists, and having an input and an output circuit, a load circuit associated with said output circuit, means included in said input circuit for impressing waves to be repeated on said input circuit, and means independent of the nature of said load circuit for preventing variations in the waves transmitted through said device due to said natural capacity between said input and output electrodes from reaching said load circuit comprising an inductance in shunt to a portion of said input circuit, and separate and distinct from said means for impressing the waves on the input circuit, a second inductance coupled to the first mentioned inductance in shunt to a portion of said output circuit, and capacity substantially equal to the natural capacity between said input and output electrodes, connected between said input electrodes.

7. In a wave repeating system a space discharge device having a cathode an anode and a grid or control element, a source of waves to be repeated associated with the grid and cathode, said cathode having appreciable capacity with respect to said anode, and means

to neutralize the effect of said capacity comprising means for deriving from said anode a potential substantially equal and opposite at all times to the instantaneous potential of said anode with respect to said cathode, and a capacity substantially equal to the cathode-anode capacity having one terminal connected to the cathode and its other terminal connected to said means to receive therefrom said equal and opposite potential.

8. In a wave transmission system, a source of waves of varying potential, a repeating device having an input circuit and an output circuit, and having an input electrode and an output electrode between which appreciable natural capacity exists, means coupling said source of waves to said input circuit whereby potential variations are supplied to said device to be repeated, an outgoing circuit, means coupling said output circuit to said outgoing circuit whereby the variations repeated by said device are transmitted thereto, means independent of said input circuit coupling means and said output circuit coupling means for deriving potential variations from said output electrode substantially equal in amplitude and opposite in phase to the variations repeated, means for supplying the derived variations to said input electrode, and a condenser connected between the potential-deriving means and said input electrode, said condenser having a capacity substantially equal to the natural capacity between said input electrode and said output electrode.

In witness whereof, I hereunto subscribe my name this 12th day of April, A. D. 1923.

RAYMOND A. HEISING.