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SYSTEM FOR AMPLIFYING ELECTRIC CURRENT VARIATIONS.

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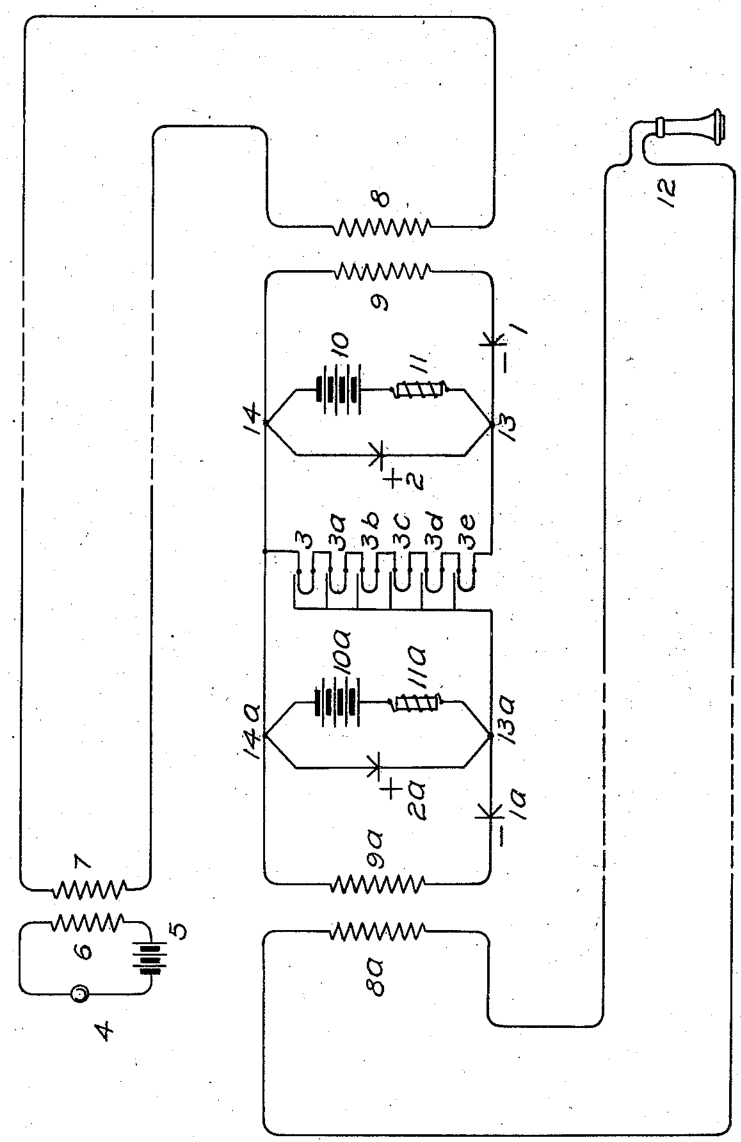

WITNESSES

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SYSTEM FOR AMPLIFYING ELECTRIC-CURRENT VARIATIONS.

1,047,956. Specification of Letters Patent. **Patented Dec. 24, 1912.**

Application filed November 17, 1911. Serial No. 660,885.

To all whom it may concern:

Be it known that I, CHARLES D. LINDRIDGE, a subject of the King of England, and a resident of Providence, county of Providence, and State of Rhode Island, have invented a new and useful Improvement in Systems for Amplifying Electric-Current Variations, of which the following is a specification.

This invention has for its object the amplification of electric current variations of moderately high frequency, such, for example, as the current variations employed in telephone transmission systems. This object is attained by the use of negative and other variable resistances.

The practical application of systems using negative resistance independently of other variable resistances for amplifying current variations, such as the system described in my patent for a telephone repeater No. 979,012 dated December 20, 1910, presents two serious difficulties. Firstly, the negative resistances which are known at the present time, and which are reliable in their operation, do not undergo sufficiently large variations in resistance for the purpose. Secondly, a negative resistance when placed in circuit, amplifies the current variations in the local circuit winding of the input coil in addition to amplifying them in the corresponding winding of the output coil with the result that the effective resistance of the input coil is very seriously lowered and consequently its efficiency is reduced.

This invention overcomes this second difficulty by balancing positive resistances against the negative resistances and an attempt is made to satisfactorily overcome the first difficulty by obtaining a part of the amplification by the operation of ionized gas resistances. By this means a certain desired degree of amplification is obtained with less sensitive negative resistances. In fact, if desired, the positive and ionized gas resistances may be relied upon to provide the greater part of the amplification.

In the drawing which accompanies and forms part of this specification the only apparatus symbolized which requires explanation are the negative resistances 1 and 1^a which automatically decrease when the current passing through them increases, the positive resistances 2 and 2^a which automatically increase when the potential of current across them increases and the ionized gas resistances 3, 3^a, 3^b, 3^c, 3^d and 3^e. The negative resistances may be of the mercury vapor tube type described in the patent of Weintraub and Latour No. 921,930 issued May 18, 1909. The positive resistances may be of the Fleming electric valve type described in *The Principles of Electric Wave Telegraphy and Telephony* by Prof. Fleming. The ionized gas resistances are of a modified Fleming electric valve type consisting of Wollaston wires and constant temperature electrodes sealed in evacuated chambers.

On page 480 of the second edition of *The Principles of Electric Wave Telegraphy and Telephony* mentioned above, the positive resistance character of the electric valve is shown graphically with the lamp filament at various temperatures. This shows that with the lamp filament maintained at a certain temperature the device permits twenty-eight milliamperes of current to pass through it when there is a potential of fifty volts across it, and that when the applied voltage is doubled, the current passing through it is reduced fifteen per cent. It will also be noted that the author uses a separate source of current to bring the lamp filament to incandescence. The same arrangement is satisfactory for amplifying current variations in this system where the device is used as a positive resistance, but in the form of the device which is used for the ionized gas resistances 3, 3^a, 3^b, 3^c, 3^d and 3^e shown on the drawing, instead of passing a steady current through the lamp filament the current variations to be amplified are passed through the filament, and owing to its small mass the filament undergoes a variation in temperature with every variation in the current passing through it. The variations in the temperature of the filament vary the current passing through the intervening space between the filament and the constant temperature electrode, the device thereby repeating the current variations from one circuit section to another. The filament consists of a portion of the platinum core of a piece of Wollaston wire which may be bared by immersing it in nitric acid, but is not necessarily so exceedingly fine as that commonly used in radiotelegraphy as the lower the frequency of the current variations to be amplified the larger in diameter may be the wire used. The constant temperature electrode may consist of a platinum wire and may encircle the filament. The resistance of the device between the electrodes is undesirably high and the resistance of the filament is undesirably low. The constant temperature electrode is therefore placed as near the filament as possible and a number of ionized gas resistances are used with the filaments connected in series and the conducting paths between the electrodes arranged in multiple as shown on the drawing.

Referring to the drawing, we may assume that the diaphragm of the telephone transmitter 4 is set in vibration resulting in variations in current being produced in the circuit 4 5 6. Alternating currents are then produced in the circuit which includes the induction coil windings 7 and 8 and these currents alternately oppose and reinforce the current passing through the circuit 10 11 1 9. A current in one direction in the circuit which includes the induction coil windings 7 and 8 has the opposite effect to a current in the other direction in this circuit and results in a current being sent on in the other direction to the receiving station 12. It will be sufficient, therefore, to follow the effect of a current in the direction such that it reinforces the current passing through the circuit 10 11 1 9. (1) The current passing from the battery 10 through the induction coil winding 9 tends to increase owing to the negative character of the resistance 1. (2) The potential of current from 13 to 14 is reduced owing to operation (1) and to the resistance and self-induction of the induction coil 11 thereby (*a*) causing more current to pass through the resistance 2 owing to its positive character, and (*b*) causing less current to flow through the Wollaston wire filaments of the ionized gas resistances 3, 3^a, 3^b, 3^c, 3^d and 3^e. (3) The temperature of the Wollaston wire filaments being reduced, less current flows from the battery 10^a through the circuit 10^a 11^a (3, 3^a, 3^b, 3^c, 3^d and 3^e). (4) The potential from 13^a to 14^a is increased owing to operation (3) and to the resistance and self-induction of the inductive resistance 11^a thereby (*a*) causing less current to pass through the resistance 2^a owing to its positive character, and (*b*) causing more current to pass through the circuit 10^a 11^a 1^a 9^a. (5) The current passing through the circuit 10^a 11^a 1^a 9^a is increased owing to the negative character of the resistance 1^a. (6) A current is induced in the circuit which includes the induction coil winding 8^a and the receiving station 11, and, owing to these several amplifications, this current is stronger than would be received at the receiving station with direct transmission from the induction coil winding 7.

It should be noted that the variable resistances 1 and 2 both intensify the variations in current which result in variations in the temperature of the Wollaston wire filaments yet they tend to have opposite effects upon the current passing through the input coil winding 9. They should be adjusted so as to have, as nearly as possible, an equal effect upon the current passing through this induction coil winding. It should also be mentioned that a single battery may be used in place of the two batteries 10 and 10^a shown on the drawing. Furthermore, although the circuit is shown as providing for one-way transmission only, it may be expected to allow transmission through it in both directions under certain conditions but with a greater degree of amplification in one direction.

The positive resistances 2 and 2^a, it should be mentioned, must be of such a nature as to be controlled by variations in the amount of energy applied to them rather than by variations in the current received or in the electromotive force impressed upon them. For if a positive resistance be of such a nature as to be controlled by variations in the current received regardless of the applied electromotive force, it could not, of course, be positive in character to a sufficient degree to be of use in this system. And if controlled by the applied electromotive force regardless of the amount of current received by it, the first slight variation in the applied electromotive force would be amplified by the positive resistance to such an extent as to cause it to pass from further control. But by being controlled by the product of the received current and the applied electromotive force an increase in potential across the resistance may cause a reduction in the amount of current passing through it and yet result in a slight increase in the amount of energy consumed and to thus admit of the resistance remaining under the control of the received current variations.

It has been assumed that the ionized gas resistances are rendered operative by causing the filaments to undergo variations in temperature. It may be noted, however, that the action of these devices may be explained by considering the temperature of the filaments to remain constant, the effect of the received current variations being merely to vary the potential across the filaments thereby varying the potential drop from what has been termed the constant temperature electrodes to the filaments. Whether the filaments are or are not made to vary in temperature, however, the apparatus should be arranged exactly as described and as shown on the drawing.

From the foregoing description it will readily be seen that the positive and negative resistances at the input coil end of the circuit are closely dependent upon each other in that if used separately they would change the effective resistance of the input coil but being used together they tend to have equal and opposite effects upon it and therefore do not affect it. The other variable resistances shown on the drawing are not so closely interdependent, or dependent upon the positive and negative resistances at the input coil end of the circuit, however, and these could possibly be dispensed with, but in this case more sensitive variable resistances would be required at the input coil end of the circuit, and the more sensitive variable resistances which are available at the present time are not sufficiently reliable in their operation for the purpose. It might be thought that instead of increasing the sensitiveness of the variable resistances there is the alternative of increasing the number of variable resistances of the same type and that where one variable resistance provides a slight amplification more of the same type can be added, as required, and placed at the same point in the circuit. Attempts to use a number of variable resistances so placed, however, have thus far been unsuccessful. It should further be noted that the amplification provided by one type of variable resistance placed at one point in a circuit which may be sufficient for use in this system, may be insufficient, by itself, to overcome the loss in the induction coils in which case no gain is affected by placing two or more of such circuits in tandem. So that lacking a sufficiently reliable variable resistance which is sufficiently sensitive to provide, by itself, all the required amplification, it is necessary to use a number of variable resistances and to distribute them throughout the amplifying circuit. The function of a variable resistance at any one part of the circuit shown on the drawing, therefore, is to provide a slight amplification so as to allow less sensitive but more reliable variable resistance to be used at other parts of the circuit. The omission of one or more of the variable resistances shown on the drawing would therefore result in a corresponding loss in amplification or reliability.

What I claim as new and desire to secure by Letters Patent of the United States is:

A system for amplifying electric current variations including main line induction coil windings and two local circuit sections, ionized gas resistances common to both of said local circuit sections, a negative resistance and an induction coil winding in each of said local circuit sections and in series with said ionized gas resistances, a source of unidirectional current and an inductive resistance in series across each local circuit section, and a positive resistance across each local circuit section adapted to amplify variations in potential across the local circuit sections and to prevent the transmission of amplified current variations back toward the transmitting station as described.

Signed by me at Providence, county of Providence and State of Rhode Island this 14th day of November, 1911.

CHARLES D. LINDRIDGE.

Witnesses:

Edwin C. Potter,
Henry W. Potter.