Jan. 24, 1928. 1,657,396

H. F. HERBIG

METHOD OF AND APPARATUS FOR AMPLIFYING ELECTRIC SIGNAL IMPULSES

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Fig. 1.

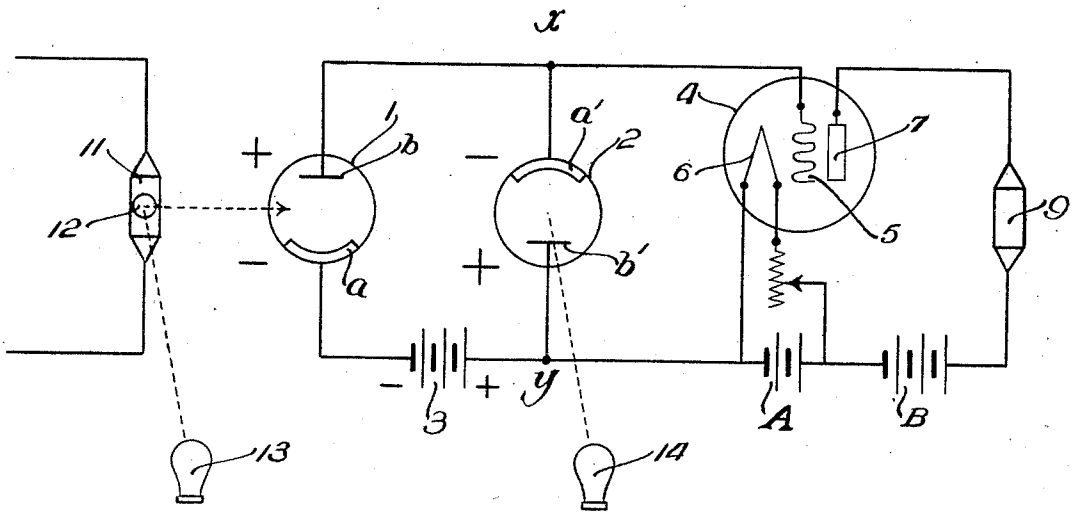
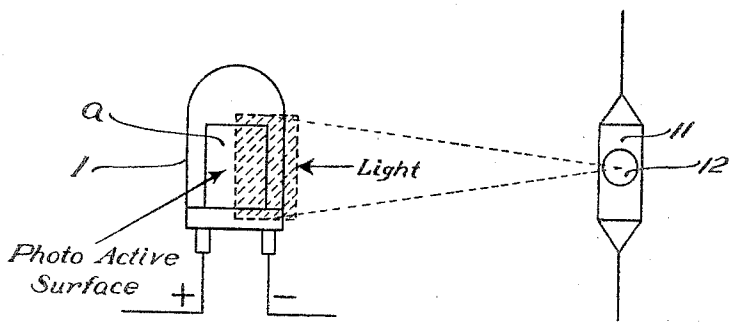


Fig. 2.



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UNITED STATES PATENT OFFICE.

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METHOD OF AND APPARATUS FOR AMPLIFYING ELECTRIC SIGNAL IMPULSES.

Application filed May 16, 1924. Serial No. 713,832.

The invention relates particularly to a method of and apparatus for amplifying electrical impulses transmitted as signals. The invention is adapted for use in amplifying signal impulses transmitted over a cable in submarine telegraphy. These signal impulses are of positive, negative or zero current value and while the invention is well adapted for use in cable telegraphy it is also well adapted for use in land line telegraph systems, and other systems of communication wherein electric impulses are transmitted.

The invention consists primarily in the use of a pair of the well known photo-electric cells in circuit with one or several vacuum tubes. The illumination of one of the photo-electric cells is substantially constant after the proper adjustment of the light, while the illumination of the other cell is varied by the receiving apparatus in response to the received signals, thereby producing variations in the plate current of the vacuum tube. A siphon recorder or other suitable receiving or relaying device is arranged in the plate circuit of the vacuum tube amplifier so that the variations in the current in said circuit will be recorded or retransmitted in the way well known in the art. Very satisfactory results have been obtained by the use of reflections from a mirror attached to a moving galvanometer coil for receiving the signal impulses, and, through its deflections, varying the amount of light on one of the photo-electric cells.

The invention further consists in so arranging the two photo-electric cells and the tube amplifier, that variations in the amount of light on one of the cells will vary the potential of the grid of the vacuum tube. By varying the potential of the grid, variations in the plate current will result, which in turn reproduce the signals in accordance with the variations of the illumination of the cell, amplified and undistorted.

In the embodiment of the invention disclosed herein, variations of the amount of light on one of the photo-electric cells cause a variation of potential across the terminals of the other cell, said second cell being connected in series with the first photo-electric cell. The variation of potential across the second cell is impressed on the grid of a thermionic amplifier which in turn reproduces signals according to the variation of the amount of light on the cell.

In the drawing, Figure 1 is a diagrammatic view of one form of circuit for carrying out the invention;

Fig. 2 is a diagrammatic view indicating the manner of illuminating the receiving photo-electric cell by means of a reflecting galvanometer.

The photo-electric cell used in carrying out the method described herein consists of a light-sensitive substance, such as barium, etc. which is the cathode, and a wire, plate or grid as the anode, usually sealed in a highly evacuated bulb with an opening for light to enter the cell. When light enters the cell it causes the light-sensitive substance (the cathode) to emit electrons. When an electromotive force is connected to the terminals of the cell, positive side of said electromotive force to the anode and negative to the cathode, the liberated electrons are drawn to the anode of the cell causing a current to flow in the electrical circuit. The photo-electric current is proportional to the amount of illumination of the light-sensitive substance of the cell.

Referring to Fig. 1 of the drawing, 1 designates a receiving photo-electric cell. This cell may be of any suitable form. The well known Case barium cell made in accordance with Patent No. 1,376,605 has been found to be satisfactory. 2 designates a photo-electric cell whose internal impedance is made substantially equal to the internal impedance of the receiving photo-electric cell, and which is in series with the receiving photo-electric cell. 3 designates a DC supply to the two cells, the negative side of which is connected to the cathode *a* of the receiving cell 1 the positive side being connected through the impedance cell 2 to the anode *b* of the cell 1. 4 designates a vacuum tube or thermionic amplifier. The grid 5 of the tube is connected to the anode *b* of the photo-electric cell 1, and the cathode *a'*, of the photo-electric cell 2. The filament 6 is provided with the usual A battery or supply, and the usual variable resistance. The plate 7 is in circuit with the B battery or supply

and in said circuit is arranged a galvanometer coil 9 which serves as a signal recording instrument. A signal receiving device 11, which is illustrated in the form of a reflecting galvanometer coil, is arranged in the receiving circuit to receive the incoming signal impulses. This coil carries a reflecting mirror 12 which is so arranged as to vary the illumination of the cell 1 when the coil is deflected by the received signals. A lamp 13 is arranged to throw a beam of light to the mirror 12. The receiving coil is so arranged that with no current through the coil, that is to say, with the current at zero, part of the cathode *a* of the cell is illuminated. With this arrangement a positive current impulse or signal will move the coil in one direction and increase the illumination of the cell while a negative current impulse or signal will move the coil in the opposite direction and decrease the illumination of the cell. The recording coil 9 may be biased by any suitable means to neutralize the normal plate current and to hold said recording coil in zero position with no current through the receiving galvanometer coil 11.

A lamp 14 is arranged to illuminate the cathode *a'* of the cell 2. This light is of substantially constant value or amount after proper adjustment has been made. The anode *b'* of the cell 2 is connected to the + side of the supply 3; and the cathode *a'* of the cell 2 is connected to the grid 5 of the tube 4, and to the anode *b* of the receiving cell 1.

When the cathode is illuminated and a suitable E. M. F. applied properly to its terminals, there is a flow of electrons from the cathode to the anode. This flow of electrons causes a flow of an electric current. In the circuit, as illustrated in Fig. 1, the flow of current through the cell 1 is from the anode *b* to the cathode *a*, the electrons flowing in the opposite direction. In the cell 2 the flow of electric current is from the anode *b'* to the cathode *a'* while the flow of electrons is from *a'* to *b'*. The electronic current flow of the cell 2 is substantially constant due to the substantially constant illumination of the cathode *a'*. The electronic current flow of the cell 1 is variable due to the variations in the amount of light on the cathode *a*. The internal impedance of the cells 1 and 2 is adjusted to the desired normal by regulating the lamps 13 and 14 in any suitable manner. This gives the desired normal flow of current through the circuit and causes the desired normal potential to be applied to the grid 5. By varying the amount of light on the cell 1, a varying electronic current flow results, and the potential of the grid will be increased or decreased depending upon the increase or decrease of the amount of light on the cell 1. The variation in the potential across the terminals of the cell 2 is dependent upon the flow of current through cell 1, and this flow of current is dependent upon the variation of the amount of light on the receiving cell 1. This variation in potential is due to the substantially constant current produced by the cell 2 being modulated by the varying current produced in cell 1 by the varying amount of light on the cathode *a*.

The amount of light on cathode *a'* of the cell 2 is adjusted until the impedance of 2 is approximately equal to that of the receiving cell 1, when illuminated by the light reflected from the mirror 12 with the coil 11 in normal or zero position with no current in the coil.

The receiving photo-electric cell 1 is partially illuminated when the receiving galvanometer coil is at zero position, as illustrated in Fig. 2, and this results in a steady current in the plate circuit of the vacuum tube, this steady current representing the zero line of the signals. When a signal impulse is received in the galvanometer coil it deflects the coil with the mirror attached, either to the left or to the right depending upon the direction of current flowing through the coil. Assuming that a deflection to the left causes an increase in the amount of light on the light sensitive surface area of the cell 1 and thereby causes less plate current to flow than that current representing the zero line, then a deflection to the right will cause a decrease in the amount of light on cell 1 and an increase in the plate current above that representing the zero line. By this means alternating and zero signals may be obtained. When the amount of light on the cell 1 is increased, a decrease in the plate current of the vacuum tube results. The grid of the vacuum tube, under this condition, becomes more −, as the current through the two cells that are in series, is increased and the potential of *x* lowered with respect to that of *y* (see Fig. 1). When the coil is deflected in the opposite direction the grid becomes more +, causing the plate current to increase, as the current through the two cells is decreased, and the potential of *x* is increased with respect to that of *y*. In this manner + and − signals are obtained, the recording coil responding to the variations in the plate current which result from the variations in the potential of the grid.

By increasing the amount of light on the cell 1, the flow of current through the cells in series is increased thereby causing a variation of potential across the terminals of the cell 2. When the amount of light is varied on photo-electric cell 1, a variation of current through the photo-electric cell 2 is produced, due to the effect of the light on 1 and the E. M. F. supplied by the generator 3. The varying current flowing through the

photo-electric cell 2 causes a variation of potential across the terminals of 2, which is impressed across the grid circuit of a thermionic amplifier. By adjusting the amount of light from the lamp 14 on 2, the grid potential may be made more or less negative for controlling the shape of the wave output of the signal. The output current of the plate circuit may be either positive or negative with respect to the normal plate current, depending upon the position of light on the photo-electric cell 1. The variation of the potential across cell 2 is impressed on the grid and this in turn results in a variation in the current of the plate circuit. The recording galvanometer responds to these variations in the plate circuit. The variations in the current of the plate circuit above and below the normal current of said circuit result in deflections of the recording coil 9, so that the recording instrument, which may be a siphon recorder or other suitable device, will be moved away from the zero line in response to changes of polarity in received signals and will return to zero position in response to the zero position of the receiving galvanometer coil 11.

In Fig. 2 is shown only one method of using the photo-electric cell. The light may be made to vary over the surfaces of two or more cells in any manner whatever.

Various modifications and changes may be made in the circuits within the scope of the invention and it is to be understood that I am not to be limited to the circuits shown and described. It will, of course, be understood that the amplitude of the signals recorded by the coil 9 may be increased if desired by adding another stage of amplification.

What I claim is:

1. An apparatus for receiving and amplifying and reproducing electric impulses, comprising an impulse receiving means, two electron discharge cells sensitive to light connected in series with a source of electric current, an impulse amplifying and reproducing means having a normal zero position and electrically connected to one terminal of one of said cells the other terminal of said cell being connected to the current source, said impulse reproducing means being adapted to respond to variations in the potential of the cell terminal to which it is connected, means for producing a substantially constant normal current flow through the two cells to hold the reproducing means in its zero position, and means operated by the impulse receiving means for varying the current flow through the said cells to thereby vary the potential of the cell terminal connected to the impulse reproducing means to cause the reproducing means to move away from and back to its zero position.

2. An apparatus for receiving and amplifying and reproducing electric impulses, comprising an impulse receiving means, two electron discharge cells sensitive to light connected in series with a source of electric current, an impulse amplifying and reproducing means electrically connected to one terminal of one of said cells the other terminal of said cell being connected to the current source, said impulse reproducing means being adapted to respond to variations in the potential of the cell terminal to which it is connected, means for producing a substantially constant normal current flow through the two cells, and means operated by the impulse receiving means for varying the illumination of one of said cells to thereby vary the current flow through said cells to thereby produce changes in the potential of the cell terminal connected to the impulse reproducing means.

3. An apparatus for receiving, amplifying and reproducing electric impulses, comprising an impulse receiving means, two electron discharge cells sensitive to light connected in series with a source of electric current, an impulse amplifying vacuum tube having a grid circuit and a plate circuit the grid being connected to one terminal of one of said cells the other terminal of said cell being connected to the + side of the current source, means independent of the impulse receiving means for producing a substantially constant normal current flow through the two cells, and means operated by the impulse receiving means for varying the current flow through the said cells to thereby vary the potential of the grid circuit, and an impulse reproducing means in the plate circuit of the vacuum tube.

4. An apparatus for receiving, amplifying and reproducing electric impulses, comprising an impulse receiving means, two electron discharge cells sensitive to light connected in series with a source of electric current, an impulse amplifying vacuum tube having a grid circuit and a plate circuit the grid being connected to one terminal of one of said cells the other terminal of said cell being connected to the + side of the current source, means for producing a substantially constant normal current flow through the two cells, and means operated by the impulse receiving means for varying the illumination of one only of said cells to thereby vary the current flow through said cells to produce changes in the potential of the grid circuit, and an impulse reproducing means in the plate circuit of the vacuum tube.

5. An apparatus for receiving and amplifying and reproducing electric impulses, comprising an impulse receiving means, two electron discharge cells sensitive to light connected in series with a source of electric current, an impulse amplifying and repro-

ducing means electrically connected to one terminal of one of said cells the other terminal of said cell being connected to the current source, said impulse reproducing means being adapted to respond to variations in the potential of the cell terminals to which it is connected, means for illuminating both of said cells to produce a substantially constant normal current flow through the two cells, and means operated by the impulse receiving means for varying the illumination of one only of said cells to thereby vary the current flow through said cells to thereby produce changes in the potential of the cell terminal connected to the impulse reproducing means.

6. An apparatus for receiving, amplifying and reproducing electric impulses, comprising an impulse receiving means, two electron discharge cells sensitive to light connected in series with a source of electric current, an impulse amplifying vacuum tube having a grid circuit and a plate circuit the grid being connected to one terminal of one of said cells the other terminal of said cell being connected to the + side of the current source, means for illuminating both of said cells to produce a substantially constant normal current flow through the two cells, and means operated by the impulse receiving means for varying the illumination of one only of said cells to thereby vary the current flow through said cells to produce changes in the potential of the grid circuit, and an impulse reproducing means in the plate circuit of the vacuum tube.

7. An apparatus for receiving, amplifying and reproducing electric impulses comprising two electron discharge cells sensitive to light and connected in series with a source of electric current, a signal impulse receiving means having a normal zero position and adapted to be moved in one direction by positive current impulses and in the opposite direction by negative current impulses, means whereby in its zero position it will partly illuminate the light sensitive substance of one only of the said electron discharge cells, the movement of said signal receiving means in response to the positive and negative current impulses increasing and decreasing the said illumination of said cell to increase and decrease the flow of electrons in said cell, means for constantly illuminating the light sensitive substance of the second electron discharge cell only to produce a substantially constant normal current flow through the second cell with the signal receiving means in its zero position, an impulse reproducing and amplifying means electrically connected to the two electron discharge cells, means for causing a substantially uniform normal flow of current through said amplifying means, and means responsive to the variations in the current flow through the electron discharge cells to vary the flow of current through the amplifying means to thereby reproduce and amplify the impulses which operate the signal receiving means.

8. An apparatus for receiving, amplifying and reproducing electric impulses comprising two electron discharge cells sensitive to light and connected in series with a source of electric current, a signal impulse receiving means having a normal zero position and adapted to be moved by current impulses, means whereby in its zero position it will partly illuminate the light sensitive substance of one only of the said electron discharge cells, the movement of said signal receiving means in response to the current impulses increasing and decreasing the said illumination of said single cell to increase and decrease the flow of electrons in said cell, means for constantly illuminating the light sensitive substance of the second electron discharge cell to produce a substantially constant normal current flow through the second cell with the signal receiving means in its zero position, an impulse reproducing and amplifying vacuum tube electrically connected to the two electron discharge cells, means for causing a substantially uniform normal flow of current through said vacuum tube, and means responsive to the variations in the current flow through the electron discharge cells, to vary the flow of current through the amplifying vacuum tube to thereby reproduce and amplify the impulses which operated the signal receiving means.

9. An apparatus for receiving and amplifying electric current impulses comprising a normally closed electric circuit including two electron discharge cells responsive to light connected in series in said circuit, means to illuminate said cells for producing a substantially constant normal current flow through said cells, means responsive to the received signals for varying the illumination of one only of said cells to thereby vary the current flow through the said two cells and produce changes in the potential across the terminals of one of said cells, and an impulse amplifying and reproducing means responsive to the said variations of potential.

10. The method of receiving and amplifying electric impulses consisting in producing a substantially constant normal flow of electrons in two light sensitive electron discharge devices by illuminating one only of said devices by means of a substantially constant amount of light, causing a variation in said electron flow by varying the illumination of one only of said discharge devices by means operated by the received impulses and then utilizing the variations in the said electron flow to control means to reproduce and amplify impulses corresponding to the impulses received.

11. The method of receiving and amplifying electric impulses consisting in producing a substantially constant normal flow of electrons and a substantially normal flow of electric current in two light sensitive electron discharge devices by illuminating one only of said devices by means of a substantially constant amount of light and arranging said two devices in series in a closed electric circuit, causing a variation in said electron flow and in said current flow by varying the illumination of one only of said discharge devices by means operated by the received impulses, and then utilizing the variations in the said electric current flow to control means to reproduce and amplify impulses corresponding to the impulses received.

12. The method of receiving and amplifying electric impulses of positive, negative and zero current values consisting in producing a substantially constant normal flow of electrons and a substantially normal flow of electric current in two light sensitive electron discharge devices by illuminating said devices by means of a substantially constant amount of light and arranging said two devices in series in a closed electric circuit, causing a variation in the electron flow and in said current flow through one of said devices by varying the illumination of said discharge device by means operated by the received impulses to thereby produce changes in potential in a part of the circuit connecting the said two electron discharge devices, and then utilizing the said changes in potential to control means to reproduce and amplify impulses corresponding to the positive or negative current impulses received.

13. The method of receiving and reproducing electric current impulses by means of two substantially balanced impedances arranged in series in a closed circuit with an electric current supply consisting in electrically connecting an impulse reproducing means with the terminal of one of said impedances opposite the connection of said impedance to the current supply, producing a substantially constant normal current flow through the two impedances, and providing means responsive to the received signals for varying the current flow through one of said impedances to thereby vary the potential of the terminal connected to the impulse reproducing means whereby said impulse reproducing means will respond to the variations in the potential of said connected terminal.

14. An apparatus for receiving and amplifying and reproducing electric impulses, comprising a galvanometer coil to receive the incoming signal impulses and adapted to be moved in one direction by a positive impulse and in the opposite direction by a negative impulse, two photo-electric cells connected in series with a source of electric current, a three-electrode vacuum tube having a grid circuit and a plate circuit, the grid being electrically connected to one terminal of one of said cells the other terminal of said cell being connected to the current source and to the other side of the grid circuit, means for producing a substantially constant normal current flow through the two cells, means operated by the movement of the galvanometer coil in response to the incoming signal impulses for varying the current flow through the said cells to thereby vary the potential of the grid circuit, and a signal reproducing means normally at zero position and operated by the plate circuit and adapted to be moved in one direction from zero in response to a positive current impulse in the receiving galvanometer coil and in the opposite direction from zero in response to a negative current impulse in the receiving galvanometer coil.

15. An apparatus for receiving and amplifying and reproducing electric impulses, comprising a galvanometer coil to receive the incoming signal impulses and adapted to be moved in one direction by a positive impulse and in the opposite direction by a negative impulse, two photo-electric cells connected in series with a source of electric current, a three electrode vacuum tube having a grid circuit and a plate circuit, the grid being electrically connected to one terminal of one of said cells the other terminal of said cell being connected to the current source and to the other side of the grid circuit, means for producing a substantially constant normal current flow through the two cells, means operated by the movement of the galvanometer coil in response to the signal impulses for varying the illumination of one only of said cells to thereby vary the current flow through said cells to thereby produce changes in the potential of the grid circuit, and a signal reproducing means normally at zero position and operated by the plate circuit and adapted to be moved in one direction from zero in response to a positive current impulse in the receiving galvanometer coil and in the opposite direction from zero in response to a negative current impulse in the receiving galvanometer coil.

In testimony whereof I hereunto affix my signature.

HENRY F. HERBIG.

CERTIFICATE OF CORRECTION.

Patent No. 1,657,396. Granted January 24, 1928, to

HENRY F. HERBIG.

It is hereby certified that the above numbered patent was erroneously issued to "The Commercial Cable Company of New York, a Corporation of New York" as assignee of the entire interest in said invention, whereas said Letters Patent should have been issued to the inventor, said "Herbig and The Commercial Cable Company, of New York, a Corporation of New York", said Corporation being assignee of one-half interest only in said invention, as shown by the records of assignments in this office; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 6th day of March, A. D. 1928.

M. J. Moore,
Acting Commissioner of Patents.

Seal.

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Acting Commissioner of Patents.