A. WEAVER

SYSTEM OF MODULATING CARRIER CURRENTS

Filed March 7, 1925 2 Sheets-Sheet 1

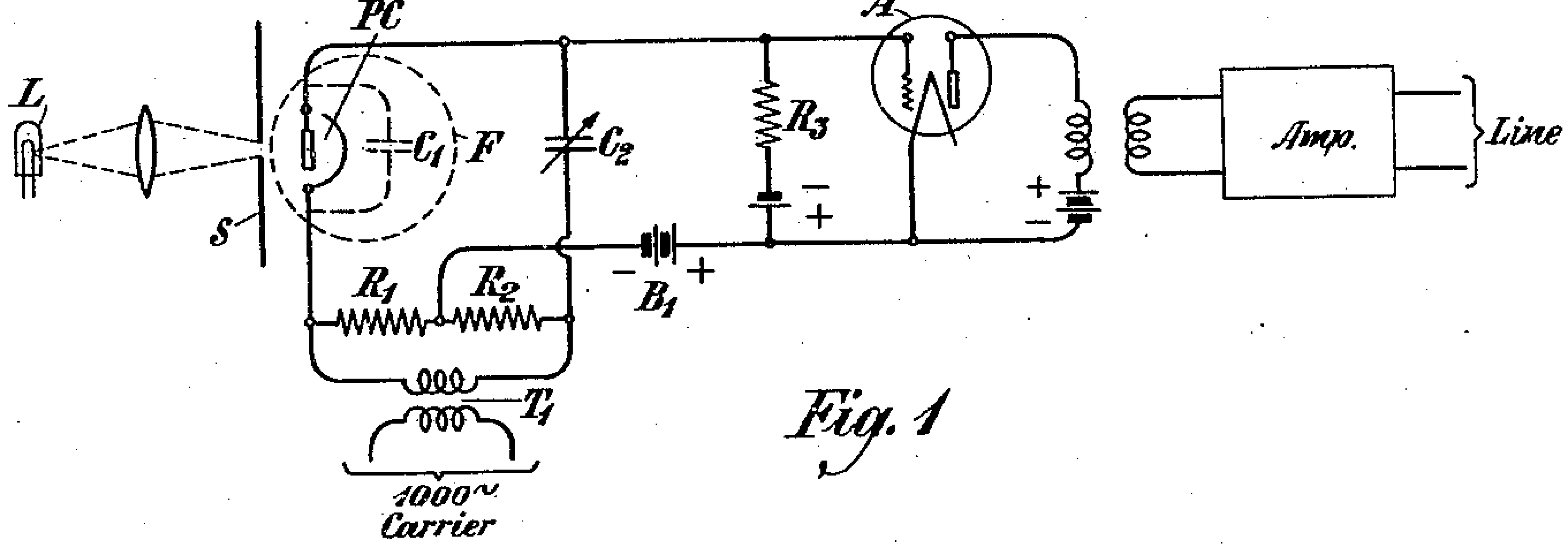

Fig. 1

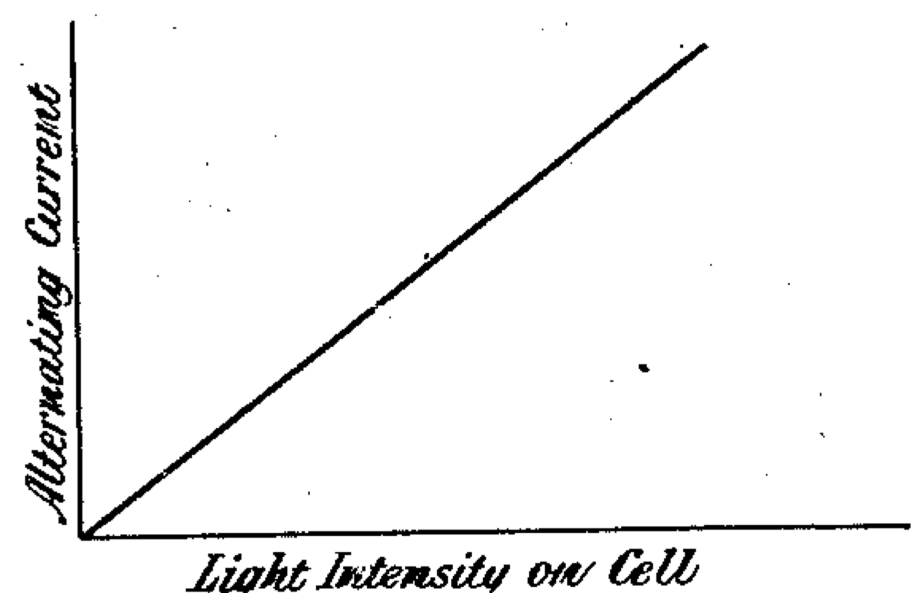

Fig. 2

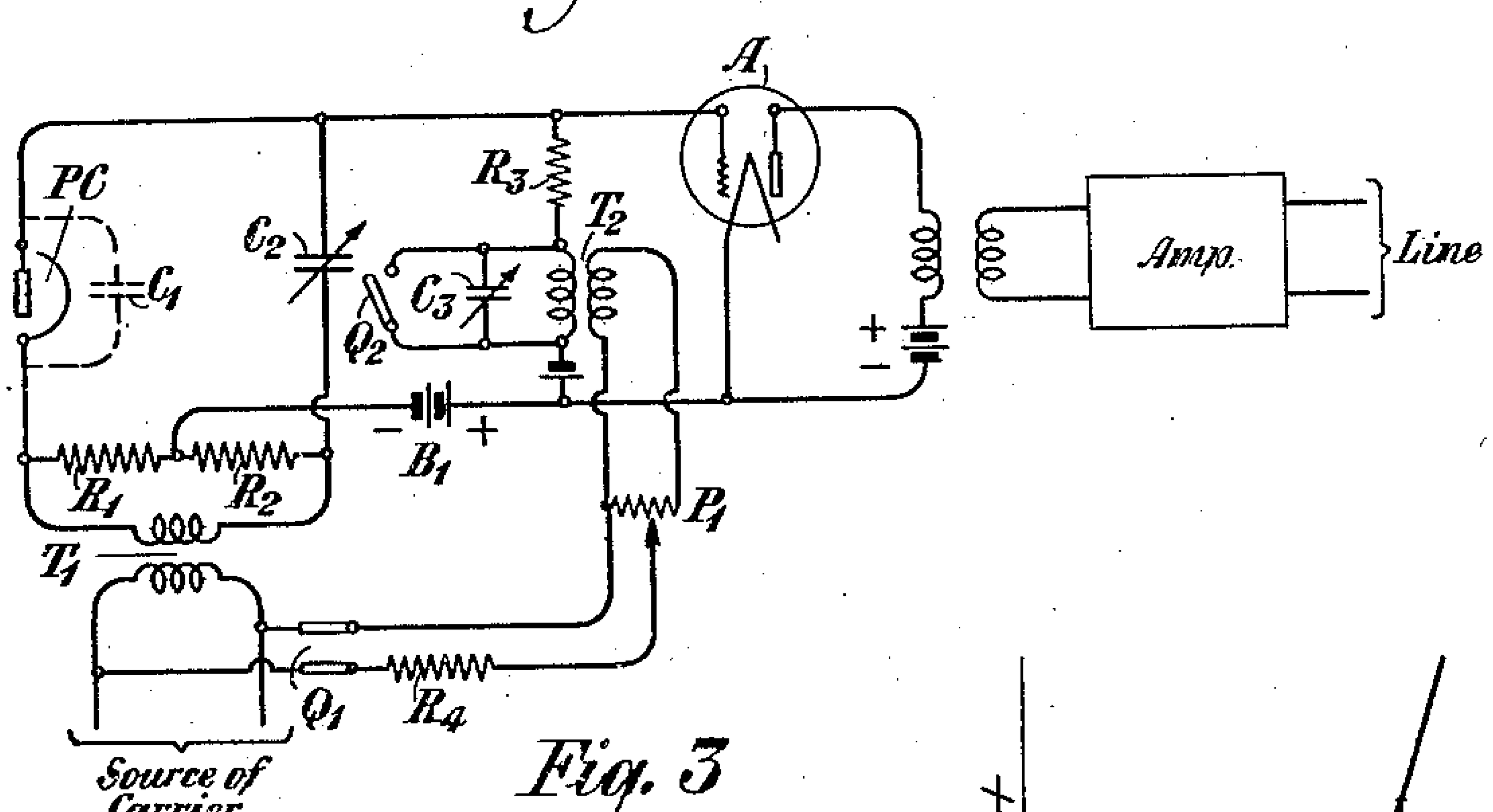

Fig. 3

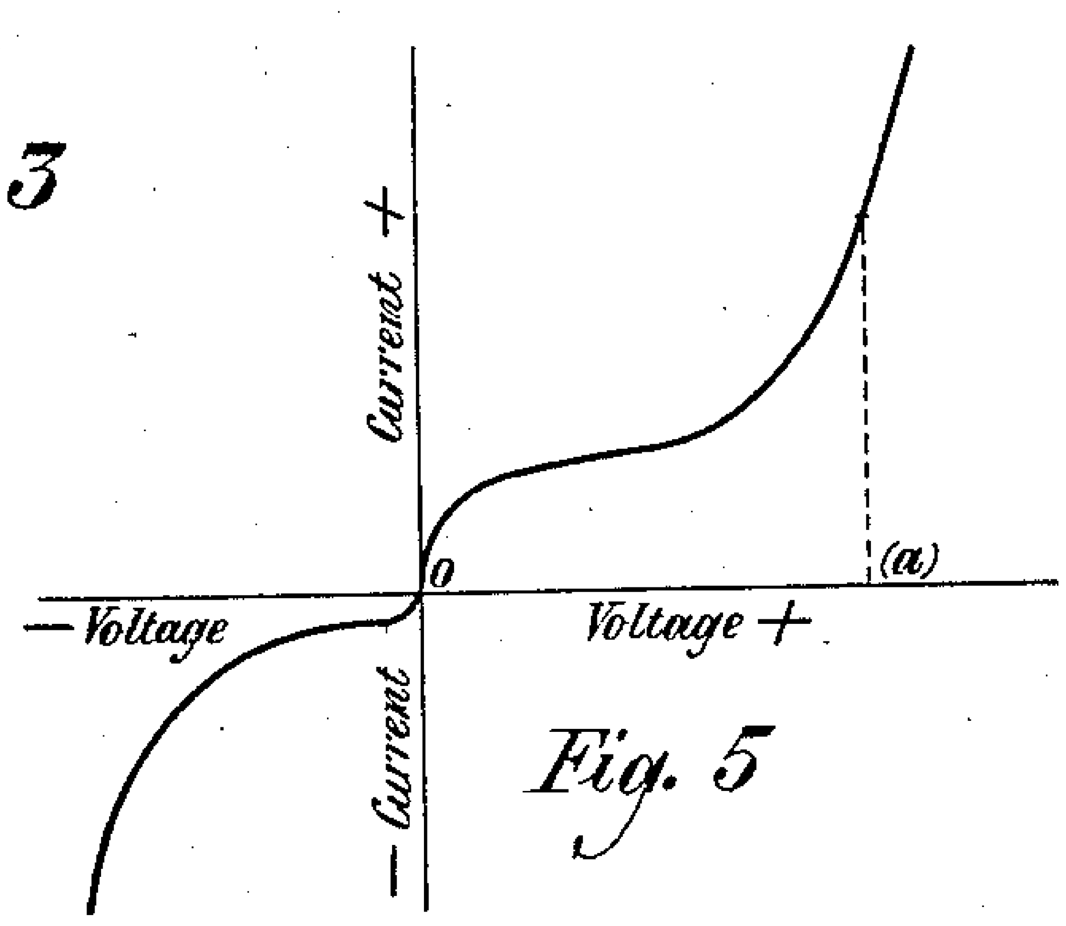

Fig. 5

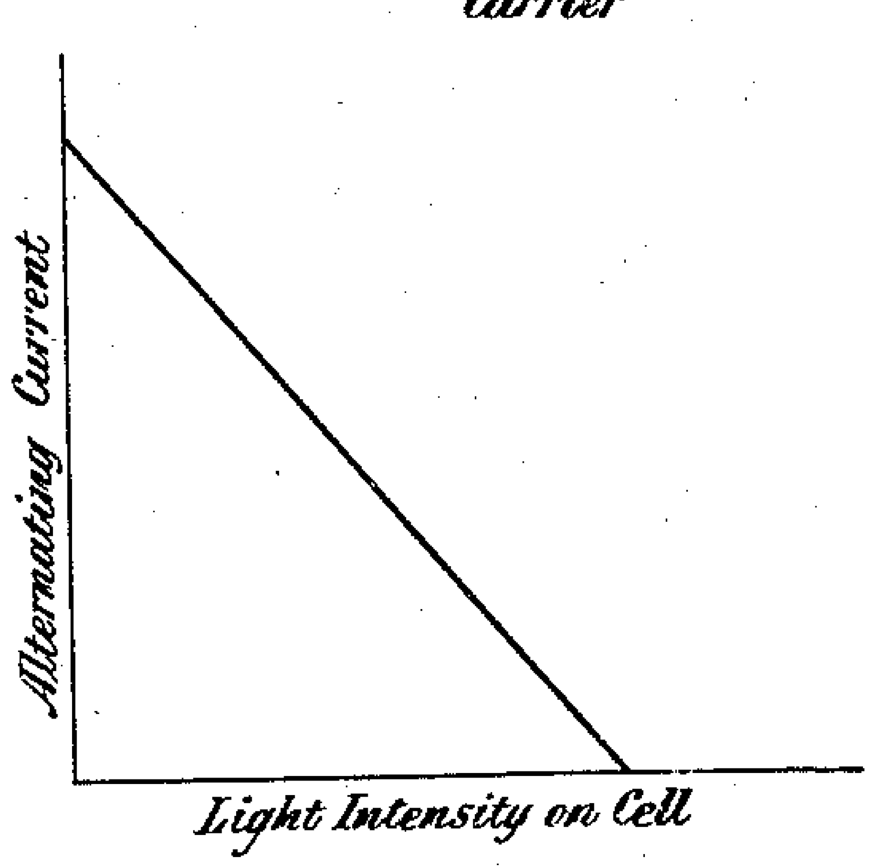

Fig. 4

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1,688,292

A. WEAVER

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2 Sheets-Sheet 2

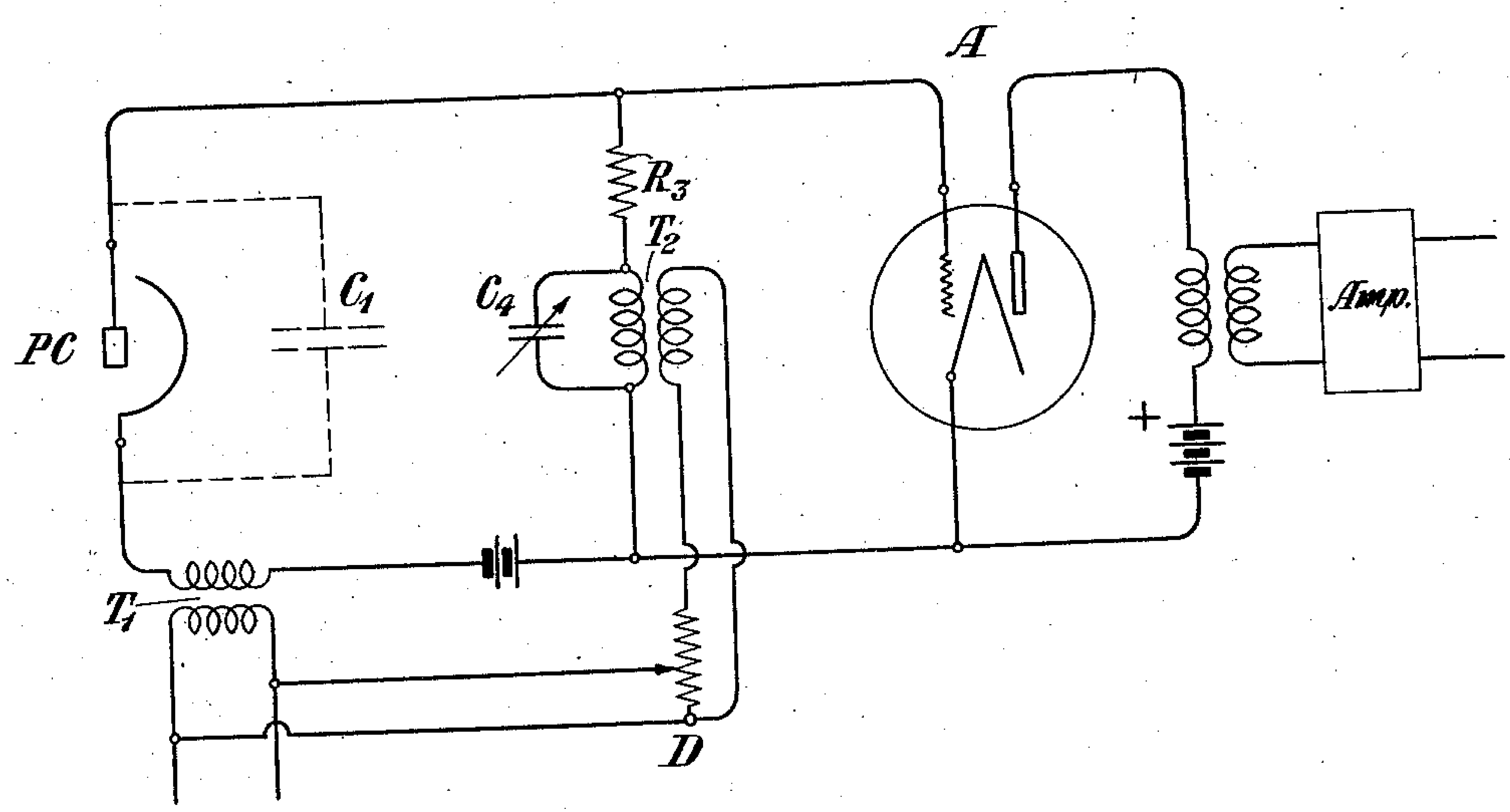

Fig. 6

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UNITED STATES PATENT OFFICE.

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SYSTEM OF MODULATING CARRIER CURRENTS.

Application filed March 7, 1925. Serial No. 13,925.

An object of my invention is to provide for the neutralization or balancing out of the effect of the capacity of a light controlled photoelectric cell, or other light sensitive device, introduced into the circuit of the cell by the cell itself. This object of my invention and others will become readily apparent on consideration of a limited number of specific embodiments of the invention which I have chosen to illustrate in the accompanying drawings, and which I now proceed to describe. It will be understood that this description refers to these particular examples of the invention and that the invention will be defined in the appended claims.

Referring to the drawings, Figure 1 is a diagram showing one embodiment of my invention; Fig. 2 is a characteristic curve for the relation of output current to light intensity; Fig. 3 is a diagram of a modification as compared with Fig. 1; Fig. 4 is the corresponding characteristic for Fig. 3; Fig. 5 is a characteristic for a photoelectric cell to which reference will be made in explaining the adjustment of my system, and Fig. 6 is another modification of Fig. 1.

Referring to Fig. 1, light from the source L is focused by a lens on the opening in the screen S. Behind the screen S is a picture film F wrapped on a glass cylinder which is rotated on its axis and traversed relatively slowly along its axis by a screw threaded mounting for its axial shaft. Accordingly, the spot on the film F, underlying the opening in the screen S travels a helical course and covers the entire film.

The photoelectric cell PC receives the light through the opening in the screen S as determined in intensity by the degree of shade in the underlying portion of the film F.

A carrier current of say 1,000 cycles per second is applied through the transformer T_1 across the extreme terminals of the series resistance R_1 and R_2. These resistances constitute two of the four arms of a Wheatstone bridge; the adjustable capacity C_2 is in a third arm and the photoelectric cell PC is in the fourth arm and its electrostatic capacity is represented as C_1.

When the relation

$$\frac{R_1}{R_2}=\frac{C_2}{C_1}$$

obtains, the system constitutes a balanced Wheatstone bridge and the carrier current source will put no electromotive force across the terminals of the resistance R_3, assuming that no light is falling on the photoelectric cell PC so that it corresponds accurately to a condenser of capacity C_1.

But when light falls from the source L on the cell PC a current is established with the result that the effective impedance of the cell is changed and the bridge is unbalanced and an effective carrier electromotive force is applied across the terminals of the resistance R_3, its magnitude corresponding to the intensity of the light falling on the cell PC. Thus a periodic electromotive force of the carrier frequency and of amplitude corresponding to the degree of illumination of the cell PC is applied to the grid of the three-electrode vacuum tube amplifier A. The output from this tube is further amplified and is put on the line for transmission.

The importance of neutralizing the capacity in the photoelectric cell will be appreciated from the following rough computation of an assumed example. A reasonable value to assume for the capacity of the cell may be about 3×10^{-12} microfarads at 1,000 cycles per second. This corresponds to an impedance of about 50 megohms or an admittance of about $\frac{K}{50}$. Under normal operating conditions the maximum steady current usually obtained from the cell due to light falling upon it, corresponds to an impedance through the cell of about 300 megohms (or even greater), or an admittance of about $\frac{K}{300}$ (or less). Accordingly, it will be seen that the alternating current admittance without light on the cell, namely $\frac{K}{50}$, is varied by the incidence of light only within the range

$$\frac{K}{50} \pm \frac{K}{300}$$

From this it is seen that the impedance, or reciprocally, the admittance of the cell is not greatly changed relatively by the light falling upon it, consequently the carrier current would not be as effectively modulated as when the capacity of the cell is neutralized.

The battery B_1 in Fig. 1 is employed to bring the operating point on the most favorable portion of the characteristic, which will be its steepest part. This is illustrated in Fig. 5, which shows a typical characteristic curve of a photoelectric cell. A good adjustment for the battery B_1 will be to the value represented by the abscissa *oa*.

Fig. 2 gives a characteristic of output alternating current as a function of light intensity on the cell. This characteristic starts at zero current (when the bridge is in balance) for zero light and increases approximately linearly as the light on the cell is increased.

Referring to Fig. 3, this shows a system arranged to give a negatively sloped characteristic (that is the output decreases as the light increases) as shown in Fig. 4. If the receiving apparatus to go with Fig. 1 produces a positive, then that same receiving apparatus without adjustment, when associated to receive from Fig. 3, will produce a negative, and vice versa. It will be seen that in Fig. 3 the carrier current is applied as in Fig. 1, and also by a branch circuit through the potentiometer P_1 and the transformer T_2 the carrier voltage is applied in phase opposition to the output from the bridge. Accordingly, when the electromotive force applied through the potentiometer P_1 and through the output from the bridge are equal, the input on the amplifier A will be zero, whereas, without the auxiliary voltage through the potentiometer P_1 the output at this time would be a maximum. By throwing the switches Q_1 and Q_2 the apparatus can be changed; with one adjustment it is practicable to send from positive to positive or negative to negative and with the other adjustment to send from negative to positive or positive to negative.

The voltage at the secondary of the transformer T_2 will not be exactly 180° out of phase with the voltage coming from the bridge, so an adjustable condenser C_3 is placed in parallel with the secondary of the transformer to adjust the phase until the opposition becomes exact.

The system of Fig. 3 should be adjusted as follows:

1. Set the potentiometer P_1 at zero, that is, so that it gives zero voltage at the primary of the transformer T_2. Adjust condenser C_2 until the output from the bridge, as indicated by a thermocouple, placed in the output of the amplifier temporarily for measuring, is zero with no light shining on the cell.

2. Allow maximum light to shine on the cell and adjust either battery B_1 or the intensity of the carrier source until an output current is obtained which is deemed to be a suitable maximum.

3. Adjust the potentiometer P_1 until the output current is reduced to a minimum.

4. Adjust the condenser C_3 until the output current is further reduced to zero. This adjustment will stand unless the frequency of the carrier is changed.

If the adjustment has been made as outlined above, the apparatus will give a characteristic of output current as a function of light intensity corresponding to Fig. 4.

It will be seen that by my invention I have provided for modulating the carrier current directly in a photoelectric cell; this may be effected by light determined by the degree of shade of successive picture elements. Accordingly, the output of the photoelectric cell is a modulated picture transmitting current which needs only to be amplified to be transmitted. An advantage of my system is that it gives a satisfactory approximation to a linear characteristic for the output current intensity as a function of the degree of light on the cell.

In Fig. 6 I have shown another way of neutralizing the electrostatic capacity of the cell. In this case a branch circuit from the carrier source goes to the transformer T_2, and adjustment is made at C_4 and D so that when no light falls on the cell PC, its capacity is neutralized and there is no electromotive force on the grid of the audion A.

I claim:

1. In combination, a photoelectric cell, means to apply a carrier current electromotive force to its terminals, means to apply to the cell a light varying in a determinate manner whereby the current through the cell is a corresponding modulated carrier current, an output circuit, and adjustable means in said output circuit to make the magnitude of the output vary directly or inversely as the light as desired.

2. In combination, a photoelectric cell, means to apply a carrier current electromotive force to its terminals, an associated output circuit, and means to apply a counter electromotive force in said output circuit whereby the output current will decrease with increased light on the said cell.

3. In combination, a photoelectric cell, means to apply a carrier current electromotive force to its terminals, means to neu-

tralize the capacity of the cell, and means to apply to the cell a light varying in a determinate manner whereby the current through the cell is a corresponding modulated carrier current.

4. In combination, a photoelectric cell, means to apply an alternating electromotive force to its terminals, an output circuit associated therewith, means to neutralize the electrostatic capacity of the cell, and means to apply to the cell a light varying in a determinate manner whereby the current in said output circuit is a corresponding modulated carrier current independent of said capacity.

5. The method of generating a picture transmitting modulated carrier current which consists in applying the carrier electromotive force to the terminals of a photoelectric cell, neutralizing the capacity of said cell, and illuminating the cell in degree according to the degree of shade of successive elements of area of the picture to be transmitted, whereby the current through the cell is a modulated carrier current suitable for transmission of the picture.

6. In combination, a photoelectric cell, means to apply a carrier current electromotive force across its terminals, means to apply light to the cell graduated according to the shade of successive elements of a picture representation, whereby the current through the cell is a modulated carrier current suitable for transmission of the picture, and adjustable means adapted at one adjustment to determine this current for sending from a positive representation to reproduce a positive or from a negative to reproduce a negative, and at another adjustment to determine the current for sending from a positive to reproduce a negative or from a negative to reproduce a positive.

7. In combination, a Wheatstone bridge comprising a source of carrier current, a photoelectric cell in one arm, a condenser in another arm and impedance elements in the remaining arms whereby the electrostatic capacity of the cell is neutralized and the bridge is in balance with no light falling on the cell, and means to apply light varying in a determinate manner to the cell so that the unbalance current from the bridge will be a modulated carrier current.

8. In an electro-optical image producing system, a light sensitive device, means for producing an alternating current in a circuit including said light sensitive device, means for actuating said light sensitive device in accordance with the shades of successive elemental areas of a picture or object an image of which is to be produced, thereby modulating said alternating current in accordance with the shades of said elemental areas, and means for neutralizing that component of the impedance of said light sensitive device which remains substantially constant when the intensity of the light impressed thereon is varied, thereby increasing the effectiveness of the modulating produced by said light sensitive device.

9. In an electro-optical image producing system, a light sensitive device, means for producing an alterntaing current in a circuit including said light sensitive device, means for actuating said light sensitive device in accordance with the shades of successive elemental areas of a picture or object an image of which is to be produced, thereby modulating said alternating current in accordance with the shades of said elemental areas, and means for neutralizing the capacity of said light sensitive device to increase the effectiveness of the modulating produced thereby.

10. In an electro-optical image producing system, a light sensitive device, means for producing an alternating current in a circuit including said light sensitive device, means for actuating said light sensitive device in accordance with the shades of successive elemental areas of a picture or object the image of which is to be produced, thereby modulating said alternating current in accordance with the shades of said elemental areas, means for neutralizing that component of the impedance of said light sensitive device which remains substantially constant when the intensity of the light impressed thereon is varied, thereby increasing the effectiveness of the modulating produced by said light sensitive device, and means for transmitting said modulated current to a distant station for controlling the production of an image of said picture or object.

11. The method of modulating a carrier current in a determinate sequence which comprises causing a carrier current to flow through a light sensitive device, varying the illumination of said light sensitive device in accordance with said determinate sequence for modulating said carrier current accordingly, and neutralizing that component of the impedance of said light sensitive device which remains substantially constant when the intensity of said illumination is varied, thereby increasing the efficiency with which said carrier current is modulated.

12. The method of modulating a carrier current in a determinate sequence which comprises causing a carrier current to flow through a light sensitive device, varying the illumination of said light sensitive device in accordance with said determinate sequence, and neutralizing the capacity of said light sensitive device to increase the modulation efficiency thereof.

In testimony whereof, I have signed my name to this specification this 6th day of March, 1925.

ALLAN WEAVER.