Aug. 28, 1934. J. W. HORTON 1,971,675

ELECTROOPTICAL IMAGE PRODUCTION

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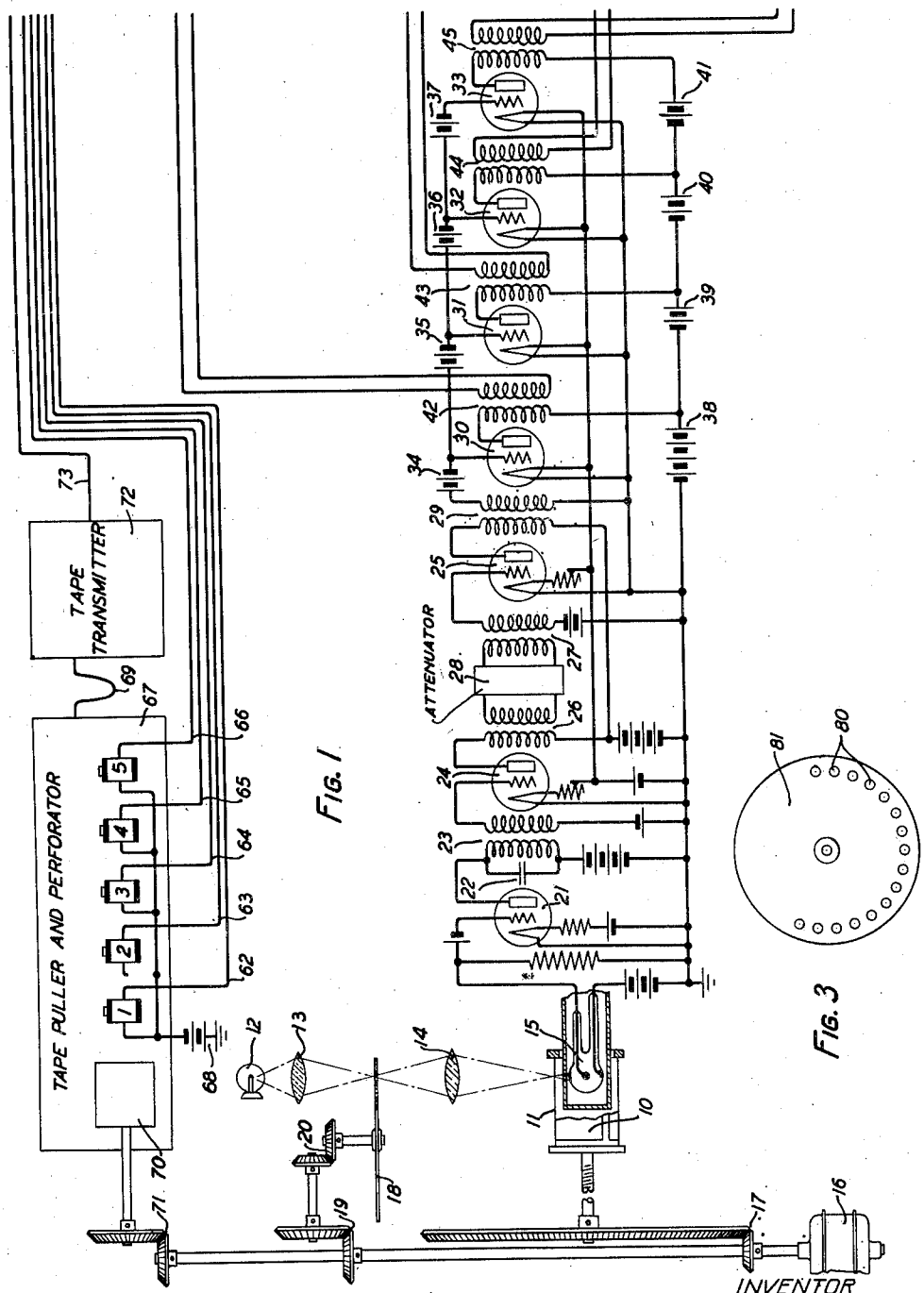

FIG. 1

FIG. 3

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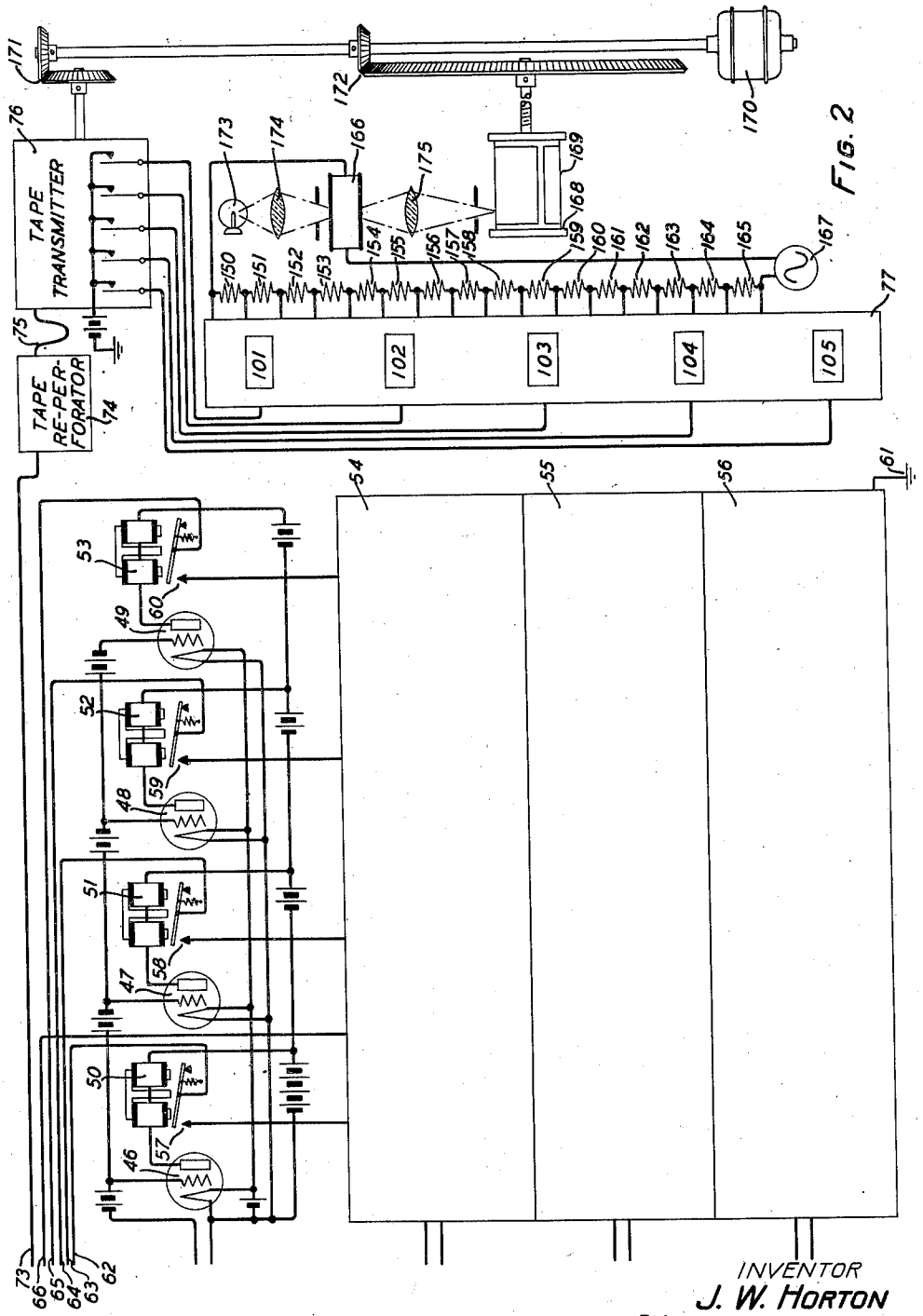

FIG. 2

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ELECTROOPTICAL IMAGE PRODUCTION

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13 Claims. (Cl. 178—5)

This invention relates to electro-optical systems and particularly to systems for reproducing pictures by the use of telegraph code signals.

The invention provides an improved system for the electrical transmission of pictures or the production of images at a distant point under control of transmitted currents corresponding to the tone values of the elemental areas of a picture or other object.

In accordance with the invention, there is produced a current having an alternating component the amplitude of which periodically changes from one value to another and the amplitude of this current is controlled in accordance with the tone values of successively scanned elemental areas of a field of view. This current is preferably produced by non-uniformly interrupting the light beam which actuates a photoelectric cell in accordance with the tone values of successively scanned elemental areas of a field of view and this current is preferably employed to control the actuation of one or more of a group of relay devices to produce a corresponding code combination of telegraph impulses which are transmitted directly or punched in the tape for subsequently controlling the production of an image. A system in which the scanning light beam is uniformly interrupted is disclosed and claimed in a copending application of J. H. Bollman Serial No. 553,098, filed July 25, 1931.

In a specific embodiment of the invention, herein shown and described for the purpose of illustration, means are provided for directing upon a light sensitive element a beam of light which is caused to vary in accordance with the tone values of the successive elemental areas of a picture or object an image of which is to be produced. There is provided a rotating disc making a single revolution in the period required for scanning a single elemental area and having apertures therein arranged along an arc of a circle for interrupting the beam of light at a high frequency so that a high frequency current modulated in accordance with the tone values of the picture or object is produced in the circuit associated with the light sensitive cell. The apertures are omitted over a portion of the circle, so that the light beam is interrupted for a comparatively long period between the scanning of successive elemental areas. This modulated high frequency current, after being amplified by an alternating current amplifier which is preferably associated with a tuned circuit to increase the amplification efficiency, is impressed through a transformer, upon a plurality of alternating current amplifier vacuum tubes connected in parallel and biased so as to operate over different ranges of impressed electromotive force, respectively. The output circuit of each of these vacuum tubes is coupled through a transformer to a plurality of rectifier vacuum tubes, which are biased so as to operate over different values of impressed electromotive force, respectively. An electromagnetic relay is connected in the output circuit of each of the rectifier vacuum tubes. After the scanning of each elemental area the scanning light beam is interrupted for a relatively long period, as pointed out above, so that all of the relays are released prior to the scanning of the succeeding elemental area. There is no need of employing relays of such accuracy that they operate or release in response to small changes of current such as are produced when scanning portions of a picture or other object, the successive elemental areas of which differ only slightly in tone value. These relays control the selection of code combinations of telegraph signals to be punched in a tape or transmitted directly, said code combinations corresponding to the tone values of the elemental areas of the picture or object.

A detail description of an illustrative embodiment of the invention follows, reference being made to the accompanying drawings in which,

Figs. 1 and 2 show diagrammatically the transmitting and receiving stations of a code telegraph picture reproducing system in accordance with the present invention;

Fig. 3 is a plan view of an apertured disc such as may be employed in the system shown in Fig. 1 for interrupting the scanning light beam.

Figs. 1 and 2 when placed side by side, Fig. 1 on the left, show a complete code telegraph picture transmission system. The picture which is to be reproduced is in the form of a negative film 10 of varying transparency mounted on the drum 11 of transparent material. A beam of light from source 12 is focussed upon a small spot on the film by means of the lenses 13 and 14 and, after passing through the film, impinges upon the photoelectric cell 15. The drum 11 on which the picture film is mounted is driven by motors 16 through gears 17 to cause it to rotate and at the same time move slowly in an axial direction. The light beam impinging upon the picture film 10 thus scans the picture along a helical path. The scanning light beam is interrupted by an apertured disc 18 driven by motor 16 through gears 19 and 20. There is thus produced in the circuit of the photoelectric cell 15 a pulsating current having an alternating component, the frequency of

which is controlled in accordance with the rate of interruption of the light beam and the picture amplitude of which varies in accordance with the tone values of the successively scanned elemental areas of the picture. The photoelectric current is amplified by the vacuum tube amplifier 21 in the anode circuit of which is a circuit comprising a condenser 22 and the primary winding of transformer 23 tuned to the frequency of the alternating component of the photoelectric current. The secondary winding of transformer 23 is connected to an alternating current amplifier comprising vacuum tubes 24 and 25, transformers 26 and 27 and an adjustable attenuator 28. The output circuit of the amplifying vacuum tube 25 is connected through transformer 29 to the input circuits of amplifying vacuum tubes 30 to 33, inclusive. These vacuum tubes have different grid biasing potentials and different anode potentials, respectively, so that the operation of different tubes, respectively, is initiated in response to different values of alternating signaling current transmitted through the transformer 29. The grid of vacuum tube 30 is biased by the electromotive force of battery 34; the grid of vacuum tube 31 is biased by the sum of the electromotive forces of batteries 34 and 35; the grid of vacuum tube 32 is biased by the sum of the electromotive forces of batteries 34, 35 and 36 and that of tube 33 is biased by the sum of the electromotive forces of batteries 34 to 37, inclusive. The vacuum tubes 30 to 33, inclusive, also have different sources of anode potential, the tube 30 having the anode potential equal to the electromotive force of battery 38, tube 31 having the sum of the electromotive forces of batteries 38 and 39, tube 32 the sum of the electromotive forces of batteries 38, 39 and 40 and tube 33 having the electromotive forces of batteries 38 to 41, inclusive. When an elemental area of the negative picture representation 10 of relatively dark tone value is being scanned, the transmitted alternating current and the corresponding alternating electromotive force impressed upon the input circuits of vacuum tubes 30 to 33, inclusive, is of low amplitude. As a result a varying current is caused to flow in the primary winding of transformer 42 and a corresponding alternating electromotive force induced in the secondary winding of this transformer. When an elemental area of somewhat lighter tone value is being scanned the alternating electromotive force impressed upon the input circuits of vacuum tubes 30 to 33 is of correspondingly greater amplitude and vacuum tubes 30 and 31 are operated to cause an electromotive force to be induced in the secondary windings of transformers 42 and 43. When the tone value of the elemental area being scanned is still lighter, vacuum tubes 30 to 32, inclusive operate and for elemental areas of very light tone value all four vacuum tubes 30 to 33 operate. When vacuum tubes 30 to 32, inclusive operate an alternating electromotive force is induced in the secondary windings of transformers 42 to 44, inclusive and when all four vacuum tubes operate an alternating electromotive force is induced in the secondary windings of all four transformers 42 to 45, inclusive. We may therefore consider the tone values of the picture as being grouped into four ranges of value, for example, very dark, dark, light and very light, and one, two, three or all four of the vacuum tubes 30 to 33 will be operated according to the group into which the tone value of the elemental area being scanned is classified. Each of these groups may be subdivided into as many groups as desired, for example, four. It is apparent that not only will one, two, three or four of the vacuum tubes 30 to 33 be operated as elemental areas falling in different groups of tone values, respectively, are being scanned, but also that the alternating electromotive forces induced in the secondary windings of transformers 42 to 45, inclusive, vary over a range of values in accordance with the variations in tone value occurring within each of the four groups of tone values.

The secondary windings of transformers 42 to 45, inclusive, are connected to the input circuits of four different groups of rectifier vacuum tubes, respectively, the first group comprising vacuum tubes 46 to 49, inclusive. Relays 50 to 53, inclusive, are connected respectively in the anode circuits of the vacuum tubes 46 to 49, inclusive. The rectangles 54 to 56, inclusive, designate groups of rectifier vacuum tubes, having electromagnetic relays connected in the anode circuits thereof, similar to the group of rectifier vacuum tubes 46 to 49, inclusive, and the electromagnetic relays 50 to 53, inclusive. One or more of the rectifier vacuum tubes 46 to 49, inclusive, will be operated whenever the amplifier vacuum tube 30 is operated, one or more of the second group 54 whenever the vacuum tube 31 is operated, one or more of the third group 55 whenever the vacuum tube 32 is operated, and one or more of the fourth group 56 whenever vacuum tube 33 is operated. The vacuum tubes of each group are provided with different grid biasing and anode potentials, respectively, similarly to the vacuum tubes 30 to 33, inclusive, so that they operate to cause the anode current to reach a predetermined amplitude in response to input signal electromotive forces of different amplitudes, respectively. Suppose, for example, that a black or very dark elemental area of the negative picture 10 is being scanned and the attenuation of the variable attenuator 28 is progressively reduced until current flows in the anode circuits of vacuum tubes 30 and 46, the current in the anode circuit of the vacuum tube 46 having sufficient amplitude to cause the operation of relay 50 and the closure of the circuit through contact 57. As elemental areas of lighter tone value are scanned, the current in the anode circuit of vacuum tube 30 will increase in amplitude until vacuum tube 47 and its associated relay 51 are operated to close contact 58, in addition to vacuum tube 46 and relay 50. As further increases in current in the anode circuit of vacuum tube 30 take place vacuum tubes 46, 47 and 48 and relays 50, 51 and 52 will be operated to close contacts 57 to 59 simultaneously and for a still further increase in current vacuum tubes 46 to 49, inclusive, and relays 50 to 53, inclusive, will operate to close contacts 57 to 60. When an elemental area of still lighter tone value is scanned current will commence to flow in the output circuit of vacuum tube 31 and in the output circuits of one or more of the vacuum tubes of the group 54. It is thus seen that we may divide the total range of picture tone values into 16 groups and the picture will be reproduced in 16 tone values, one corresponding to the range of tone values of each of the groups. When a black or very dark elemental area is scanned relay 50 will operate, when an elemental area of slightly lighter tone value is scanned relays 50 and 51 will operate simultaneously, etc. until all of the relays are operated simultaneously

in response to the scanning of a very light or white elemental area.

When one or more of the relays 50, 51, 52, etc. are operated, a circuit is completed from ground 61 through one or more of the leads 62 to 66, inclusive, through one or more of the punch magnets 1 to 5, inclusive, of the tape perforator 67, to the grounded battery 68, thus causing the operation of different combinations of punch magnets 1 to 5 in accordance with the operation of the relays 50, 51, 52, etc., and punching code combinations in tape 69 in accordance with the tone values of the successively scanned elemental areas of the picture 10. The motor 16 which drives the drum 11 and the light interrupting disc 15 also drives a cam operated punch 70 through gears 71 for punching the tape 70 with code combinations corresponding to the tone values of the successive elemental areas of the picture 10, one code combination being punched each time the light interrupting disc 18 makes a single revolution.

The tape 69 is fed into a tape transmitter 72 which transmits code telegraph signals corresponding to the code punchings in the tape, over a telegraph conductor 73 such as a submarine cable, for example. Instead of punching a tape for controlling the transmission of code signals over a line, the code combinations may be set up by means of relays taking the place of the punch magnets 1 to 5 which, together with a commutating device may control the transmission of the code signals directly without first punching a tape.

Any suitable system may be employed for reproducing a picture under control of the received code telegraph impulses. At the receiving station shown in Fig. 2, the code telegraph signals sent over line 73 are impressed upon a tape reperforator 74 for controlling the punching of code signals in a tape 75 to correspond with the punchings of tape 69 at the transmitting station. The tape 75 is fed into a tape transmitter 76 which is similar to the transmitter 72 at the transmitting station, for producing code signals which are impressed on one or more of the relays 101 to 105, inclusive, of the switching circuit 77 in accordance with the operation of the contacts of the tape transmitter 76. The combination of relays 101 to 105, inclusive, which are energized in accordance with a given code signal will correspond to the combination of punch magnets 1 to 5, inclusive, which are energized at the transmitting station for controlling the production of this code signal. One or more of the resistance elements 150 to 165, inclusive, are short-circuited in accordance with the combination of relays 101 to 105 which are energized, the number of short-circuited resistance elements corresponding to the number of relays 50, 51, 52, etc. which are energized at the transmitting station.

The number of resistance elements which are short-circuited controls the amplitude of the current from a suitable source flowing through a light valve 166 to control the size of the light aperture therein. The source of current for actuating the light valve may, for example, be a source of alternating current 167 having a period which is low compared with the time required for reproducing a single elemental area of a picture. The tape 75 is fed into the tape transmitter 76 for producing current impulses in relays 101 to 105 at a desired rate and a picture drum 168 which holds a light sensitive sheet 169 is driven at a corresponding rate under control of a driving motor 170 and the gears 171 and 172, respectively. Light from source 173 is directed upon a small spot of light sensitive sheet 169 at any particular instant by means of the lenses 174 and 175. The picture drum is caused to rotate and at the same time to move slowly in an axial direction, similarly to the drum 11 at the transmitting station, to cause the successively illuminated spots on the picture receiving surface to describe, in effect, a helical path. The intensity of the light reaching successive elemental areas of the picture receiving surface 169 is controlled in accordance with the amplitude of the current flowing through the light valve 166 which in turn is controlled in accordance with the received code signals which determine the number of resistance elements 150 to 165 which become short-circuited by the action of the relays 101 to 105. A positive picture corresponding to the negative picture 10 which is scanned at the transmitting station is therefore produced on the light sensitive surface 169. If desired, the relay circuits which control the short-circuiting of one or more of the resistance elements 150 to 165 may be rearranged so that a negative picture is produced from a negative of the original picture, or so that a positive picture is produced from a positive original. The switching circuit comprising the relays 50, 51, 52, etc. at the transmitting station and the switching circuit 77 comprising the relays 101 to 105 at the receiving station are described in greater detail in the copending application of J. H. Bollman referred to above.

A disc 18 for interrupting the scanning light beam is preferably of the type shown in Fig. 3. This disc is of opaque material and has a large number of closely spaced light apertures 80 arranged along a circular path near the periphery of the disc. The apertures are preferably omitted from a portion 81 from the disc which is large compared with the distance between adjacent apertures 80 for the purpose of interrupting the scanning light beam for a comparatively long period between the scanning periods of adjacent elemental areas of the picture. This interruption of the scanning light beam for a comparatively long period permits the relays 50, 51, 52, etc. to be restored to the unenergized condition prior to the scanning of each elemental area of the picture. The possibility of the incorrect operation or releasing of relays, as when elemental areas of only slightly different tone values are being scanned in succession is thus reduced. By the use of a light interrupting disc of this type there is produced in the circuit of the photoelectric cell 15 and in the transmission circuit connected to the cell a current having an alternating component having amplitude variations controlled in accordance with the tone values of successively scanned elemental areas of the picture 10 and other amplitude variations which are independent of the tone values of the elemental areas.

What is claimed is:

1. The method of electro-optical transmission which comprises producing a current having an alternating component having amplitude variations controlled in accordance with the tone values of successively scanned elemental areas of a field of view and other amplitude variations which are independent of the tone values of said elemental areas and which are recurrent at a predetermined fixed frequency, and utilizing both said amplitude variations to control the production of a current

of different wave form representative of said tone values only.

2. An electro-optical system comprising means for producing a current having an alternating component having amplitude variations corresponding to the tone values of successively scanned elemental areas of a field of view and other amplitude variations recurring at a predetermined fixed frequency which are independent of the tone values of said elemental areas, means controlled by both said amplitude variations for producing a different current representative of said tone values only and means responsive to said last mentioned current for controlling the production of an image of said field of view.

3. An electro-optical system comprising means for producing a current having an alternating component having amplitude variations corresponding to the tone values of successively scanned elemental areas of a field of view and other amplitude variations which are independent of the tone values of said elemental areas, means controlled by both said amplitude variations for controlling the production of code telegraph signals, and means responsive to said code telegraph signals for controlling the production of an image of said field of view.

4. An electro-optical system comprising means for producing a current having an alternating component having amplitude variations corresponding to the tone values of successively scanned elemental areas of a field of view and other amplitude variations which are independent of the tone values of said elemental areas, and means controlled by both said amplitude variations for producing a code telegraph record corresponding to the tone values of said elemental areas.

5. In an electro-optical image producing system, a source of radiant energy, means for directing radiant energy from said source upon elemental areas in succession of a field of view, an image of which is to be produced, and means for non-uniformly interrupting the radiant energy from said source directed upon said field of view during the scanning period of each elemental area.

6. In an electro-optical image producing system, a source of light, means for directing a beam of light from said source upon a field of view, an image of which is to be produced, light responsive means for receiving light from said field of view for controlling the production of image current having a characteristic determined by the tone values of elemental areas of said field of view, and means for non-uniformly interrupting the light beam from said source directed upon said field of view during the scanning period of each elemental area.

7. In a code telegraph image transmission system, means for controlling the production of an image current, said means comprising means for producing a beam of radiant energy, an electromagnetic relay the operation of which is controlled in accordance with said image current, and means for periodically interrupting said beam of radiant energy for a period of sufficient duration to cause said relay device to be rendered inoperative.

8. In a code telegraph image transmission system, means for controlling the production of an image current, said means comprising means for producing a beam of light for scanning the elemental areas of a field of view in succession, a plurality of electromagnetic relay devices which are adapted to be operated selectively in accordance with a characteristic of said image current, and means for interrupting said light beam following the scanning period of each elemental area for an interval of sufficient duration to cause said electromagnetic relays to become inoperative during said interval.

9. In a code telegraph image transmission system, means for controlling the production of discontinuous impulses of periodically varying image current, each impulse corresponding to the tone value of an elemental area of a field of view, and means under control of said impulses of varying image current for controlling the production of current impulses of substantially constant amplitude to control the production of an image.

10. In a code telegraph system, means for intermittently producing impulses of periodically varying current, each impulse corresponding to the tone value of an elemental area of a field of view, and means under control of said current impulses for producing current impulses of substantially constant amplitude for controlling telegraph apparatus.

11. In a code telegraph system, means for periodically producing impulses of periodically varying current, each impulse corresponding to the tone value of an elemental area of a field of view, and means under control of said current impulses for controlling the punching of code combinations in a tape in accordance with amplitude variations of said current impulses.

12. In a code telegraph system, means for intermittently producing impulses of alternating electromotive force, each impulse corresponding to the tone value of an elemental area of a field of view, said impulses having different amplitudes in accordance with a signal to be produced, means for producing, under control of said alternating electromotive force, code telegraph signals comprising impulses of relatively steady current.

13. An electro-optical image producing system comprising a source of light, means for directing light from said source upon elemental areas in succession of a field of view, an image of which is to be produced, means responsive to light received from said field of view for controlling the production of periodic impulses of alternating electromotive force, said impulses having different amplitudes, each impulse corresponding to the tone value of an elemental area of said field of view, means for producing code telegraph signals under control of said impulses of alternating electromotive force, and means responsive to said code signals for controlling the production of an image of said field of view.

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